TEXAS DEPARTMENT OF TRANSPORTATION

The Texas Guide to Accepted Mobile Source Emission Reduction Strategies

2ND EDITION

The Texas Guide to Accepted Mobile Source Emission Reduction Strategies

Prepared by the

Texas Transportation Institute

in cooperation with the

Texas Department of Transportation

and in association with

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<u>Texas Department of Transportation</u>

- Jack Foster,
- Fred Marquez,
- Michelle Conkle, and
- Tim Juarez;

<u>Texas Transportation Institute</u>

- Todd Carlson,
- Jason Crawford,
- Edward Sepulveda, and
- Montie Wade.

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PREFACE

The United States Environmental Protection Agency (EPA) sets and enforces the National Ambient Air Quality Standard (NAAQS). In 2007, four areas in the state of Texas were considered in nonattainment for the primary ozone standard: Beaumont-Port Arthur, Dallas-Fort Worth, San Antonio, and Houston-Galveston-Brazoria.

Before the current NAAQS for ozone was adopted, additional areas of the state initiated Early Action Compacts (EACs) to address air quality issues in their region. These areas included Longview-Tyler and Austin. They have been able to plan, fund, implement, and analyze mobile source emission reduction strategies. Many of these measures are specified in the 1990 Clean Air Act Amendments (CAAA), and several others were developed in the field in the last decade.

This new edition of the guide is an updated reference for new and experienced technical staff in metropolitan areas undertaking transportation/air quality planning to better understand and utilize mobile source emission reduction strategies as they seek to achieve attainment for NAAQS. It is also intended to serve as an introduction for transportation professionals in new nonattainment areas with little or no experience in transportation/air quality issues. The guide provides an overview of the transportation/air quality relationship, along with specific details about mobile source emission reduction strategies, and serves several functions.

First, it is a tool for technical staff to assess the benefits of state implementation plan (SIP) elements, conduct transportation conformity analysis, and initiate proactive emission reduction programs to fulfill national air quality standards. Formulating plans to attain air quality standards can be a long, arduous process for staff and elected officials. Mobile source emission reduction strategies are a key part of the process, but information regarding their use and analysis is not readily available in one source. This guide is an attempt to provide the most relevant information for these mobile source emission reduction strategies in one location.

Second, the guide provides technical staff with appropriate transportation/air quality resources for SIP revision and conformity analysis. The guide provides information, but also points staff in the right direction for further information on topics that are larger than mobile source emission reduction strategies or are outside the scope of the guide. The CD-ROM provides an instant library of resources for the planner.

Third, the analysis methodologies attempt to equalize strategy analysis between regions. As a result, conformity analysis should be expedited since any questions arising from differences in analysis results will be attributed to differences in local or project-specific inputs, rather than methodology. Reviewing agencies will avoid slowing the approval process if analysis and documentation presented by nonattainment areas are based on the same methodology. This unified methodology avoids “black box syndrome” and increases the efficiency of the review process.

The intent of this guide is that the analysis methodologies contained within serve as a starting point for discussion, evaluation, validation, and improvement. Mobile source emission reduction strategy analysis has not been standardized before in the field; regions develop their own analysis methodologies and present them for documentation by review agencies. The included strategies may not be as extensive as those projects implemented by the various nonattainment areas, and these methodologies may lack some modeling characteristics of a strategy. As a result, technical staffs are strongly encouraged to assess the analysis methodologies and, if better methodologies can be developed, present them for peer review, discussion, and adoption by the Transportation/Air Quality Technical Working Group. The methodology will then replace or be added to the collection of methodologies in the guide.

Fourth, this guide seeks to standardize the terminology of emission reduction measures among technical staff. The term "mobile source emission reduction strategy" is an attempt to bring greater clarity to discussion of emission reduction measures among professionals in the state. As the field has developed, mobile source emission reduction strategies have usually been referred to as transportation control measures (TCMs) as identified in the CAAA. However, the use of the acronym "TCM" has increasingly referred to those emission reduction measures in a SIP. Many emission reduction strategies are implemented outside of a SIP, and referring to them as TCMs tends to create confusion. Mobile source emission reduction strategies denote the entire universe of emission reduction measures developed out of the original CAAA measures. It encompasses a much broader range of projects than TCM currently does. Within the guide, an emission reduction strategy is designated a TCM only as part of a SIP. In other words, a mobile source emission reduction strategy in a SIP is a TCM.

ORGANIZATION OF THE GUIDE

The second edition is divided into four main sections.

Part A provides an overview of transportation/air quality planning basics. It discusses mobile source pollutants, the national air quality standards, and mobile source emission reduction strategies. It highlights mobile source emission reduction strategy planning, implementation, analysis, and documentation for review agencies. This edition contains updates to transportation legislation such as the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and future emissions factor models. Graphics were updated throughout the document. Readers should gain a better understanding of the role of mobile source emission reduction strategies in the context of achieving air quality standards.

Part B discusses mobile source emission reduction strategies in more depth. It focuses on the specific measures, their requirements, and applicability and provides equations to document the air quality benefits of the measure. The guide contains 17 separate strategies, with a total of 56 individual project/program types. Each strategy is described, and then every program is summarized by goal, description, applicability, and methodology. Equations, developed since the first edition, are included in their respective strategy.

Part C, a new section of the guide, contains data guidance based on work conducted since the previous edition. Values or ranges are given for a selected number of the variables used in Part B. These values or ranges may be of use to analysts and organizations that lack the resources or time necessary to gather local data.

Part D contains an updated acronym list and glossary.

A companion CD-ROM is included in the guide. It contains numerous appendices, reports, and links to applicable laws and regulations on emission reduction strategies. It provides transportation planners with a quick and useful library for accepted mobile source emission reduction strategies.

1.0 THE BASICS — AIR POLLUTANTS

Section Objective

This section introduces the main pollutants involved in the relationship between air quality and transportation. The standards by which the pollutants are measured (National Ambient Air Quality Standards [NAAQS]) are outlined, along with an explanation of attainment designations.

CRITERIA POLLUTANTS

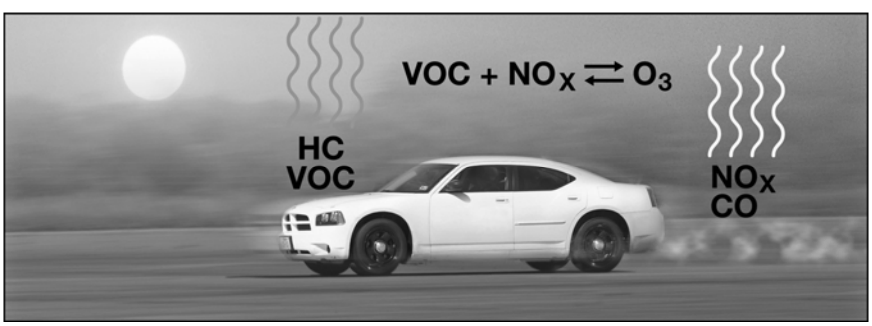
The United States Environmental Protection Agency (EPA), in response to the Clean Air Act of 1970 (CAA) and subsequent amendments, established NAAQS for several pollutants that adversely affect human health and welfare. These are termed "criteria" pollutants. The EPA, through state or local air quality agencies, monitors these pollutants against NAAQS. The six criteria pollutants are:

- Carbon monoxide (CO),
- Lead (Pb),
- Nitrogen dioxide (NO_2),
- Ozone (O_3),
- Particulate matter (PM), and
- Sulfur dioxide (SO_2).

Transportation
<u>Criteria Pollutants</u>

Ozone
Particulate matter
Carbon monoxide

The transportation field focuses on three criteria pollutants: CO, PM, and ozone. CO and PM are directly emitted from motor vehicles. Ozone is formed through a complex chemical reaction between two pollutants emitted from motor vehicles: hydrocarbons (HC) and oxides of nitrogen (NO_x). HC and NO_x are called "precursor" pollutants. Above certain standard levels (discussed in Section 3), the three criteria pollutants can cause or exacerbate health problems and even increase mortality rates.



Ozone

O_3 is formed by the reaction of NO_x and volatile organic compounds (VOCs) in the presence of sunlight. O_3 occurs naturally in the upper atmosphere, providing protection from ultraviolet radiation. O_3 at ground level, however, is a noxious pollutant. Ground-level O_3 is a major component of smog.

Ozone is a severe irritant. It can be responsible for coughing, choking, and stinging eyes associated with smog. O_3 can damage lung tissue, aggravate respiratory disease, and increase susceptibility to respiratory infections. Children are especially vulnerable, as are adults with existing health conditions. Ground-level O_3 may even affect breathing in healthy adults.

Peak concentrations of O_3 usually occur in the summertime. It should be remembered that in addition to O_3 sources in a particular region, O_3 might also travel from other areas upwind. This is called ozone regional transport.

Ozone concentrations peak in the summertime

Particulate Matter

PM includes dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO_2 and VOCs are also considered particulate matter.

Based on studies of human populations exposed to high concentrations of particles and laboratory studies of animals and humans, PM can have major effects on human health. These include effects on breathing and respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The major population groups that appear to be most sensitive to the effects of PM include individuals with chronic obstructive pulmonary or cardiovascular disease or influenza, asthmatics, the elderly, and children. PM also soils and damages materials and is a major cause of visibility impairment in the United States.

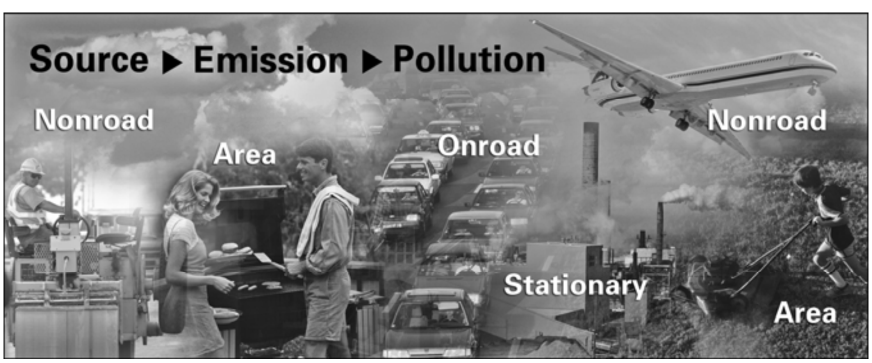
Particulate matter is often referred to as PM 2.5 and PM 10. Particles less than 2.5 microns in diameter (PM 2.5) are created from fuel combustion in motor vehicles and other sources. Coarser particles less than 10 microns in diameter (PM 10) generally consist of windblown dust and are released through materials handling, agriculture, and crushing and grinding operations. The EPA has used these designations since 1987 when research determined that these smaller-sized particles are more likely responsible for most of the adverse health effects of particulate matter. The smaller particles have a greater ability to reach the thoracic or lower regions of the respiratory tract.

Carbon Monoxide

CO is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues. The negative health effects of CO vary depending on the length and intensity of exposure and the health of the individual. Health threats are most serious for those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Exposure to elevated CO levels can cause dizziness, headaches, fatigue, and impairment of visual perception, manual dexterity, learning ability, and performance of complex tasks.

According to the EPA, 77 percent of nationwide CO emissions are from transportation sources. The largest emission contribution comes from highway motor vehicles. The focus of CO monitoring has been on traffic-oriented sites in urban areas where the main source of CO is motor vehicle exhaust. High concentrations of CO can occur along roadsides in heavy traffic and in enclosed areas. Major intersections and poorly ventilated tunnels are examples of these areas. CO concentrations typically peak in colder months, when CO vehicle emissions are greater and nighttime inversion conditions are more frequent. Other major CO sources are wood-burning stoves, incinerators, and industrial sources.

Major intersections and poorly ventilated tunnels are examples of potential high CO concentrations



Mobile Source Air Toxics

Mobile source air toxics (MSATs) are compounds, emitted from highway vehicles that are known or suspected to cause cancer and other serious health and environmental effects. Motor vehicles emit several pollutants that the EPA classifies as known or probable human carcinogens. For example, benzene is a known human carcinogen, while formaldehyde, acetaldehyde, 1, 3-butadiene, and diesel particulate matter are probable human carcinogens. The EPA estimates that MSATs account for as much as half of all cancers attributed to outdoor sources of air toxics.

MSATs are increasingly important in the air quality field

The EPA master list of MSATs is quite extensive and contains over 425 identified compounds emitted from highway vehicles. Some toxic compounds are present in gasoline and are emitted into the air when gasoline evaporates or passes through the engine as unburned fuel.

In 2002, the EPA developed a list of 21 MSATs and then refined it further, compiling a subset of six that were identified as having the greatest influence on health. This subset includes:

- Benzene,
- 1, 3-butadiene,
- Formaldehyde,
- Acrolein,
- Acetaldehyde, and
- Diesel particulate matter (DPM).

MSATs do not have NAAQS associated with them at this time.

MSATs do not have NAAQS associated with them at this time

These compounds occur naturally in petroleum and become more concentrated when petroleum is refined to produce high-octane gasoline. Benzene is a component of gasoline. Cars emit small quantities of benzene in unburned fuel, or as vapor when gasoline evaporates. A significant amount of automotive benzene comes from the incomplete combustion of compounds in gasoline.

Formaldehyde, acetaldehyde, diesel particulate matter, and 1, 3-butadiene are not present in fuel but are byproducts of incomplete combustion. Formaldehyde and acetaldehyde are also formed through a secondary process when other mobile source pollutants undergo chemical reactions in the atmosphere.

<u>Sources</u>

Air Toxics from Motor Vehicles: Environmental Fact Sheet, United States Environmental Protection Agency, August 1994.

Expanding and Updating the Master List of Compounds Emitted by Mobile Sources — Phase III: Final Report, prepared for the EPA by ENVIRON International Corporation, Novato, California, February 2006.

Fact Sheet, Final Revisions to the National Ambient Air Quality Standards for Particle Pollution (Particulate Matter), United States Environmental Protection Agency, September 21, 2006.

The Green Book, Office of Air Quality Planning and Standards, United States Environmental Protection Agency, 2007.

The Plain English Guide to the Clean Air Act, United States Environmental Protection Agency, PA-400-K-93-001, April 1993.

2.0 MOBILE SOURCE EMISSION REDUCTION STRATEGIES: LEGISLATION AND REGULATIONS

Section Objective

This section will introduce the reader to the relevant legislation and regulations in the transportation/air quality relationship over the last 30 years.

CLEAN AIR ACT, 1970

The Clean Air Act (CAA) was the initial comprehensive federal law that regulates air emissions from area, stationary, and mobile sources.

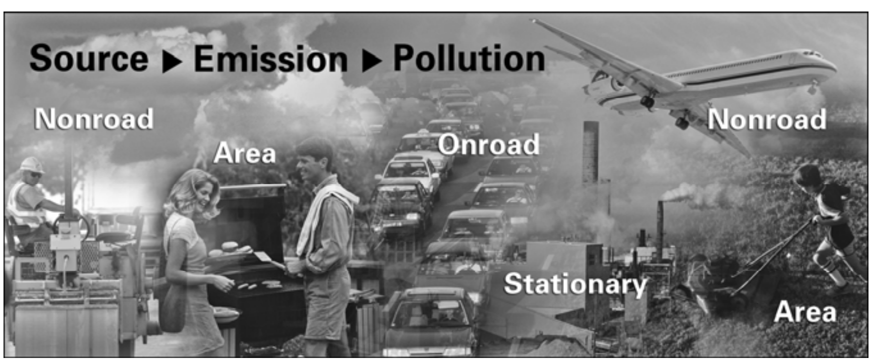
Area sources are small sources of air toxics producers such as gasoline stations and dry cleaners.

Stationary sources are places or objects that release *pollutants* and do not move around. Stationary sources include power plants, incinerators, houses, etc.

Mobile sources are moving objects that release pollution; mobile sources include cars, trucks, buses, planes, trains, motorcycles, and gasoline-powered lawn mowers. Mobile sources are divided into two groups:

Transportation/air quality deals with mobile sources

- Road vehicles, which include cars, trucks, and buses; and
- Nonroad vehicles, which include trains, planes, and lawn mowers.



Transportation by its very nature concentrates on mobile sources.

The CAA authorized the EPA to establish, maintain, and enforce NAAQS to protect public health and the environment.

The EPA establishes, maintains, and enforces NAAQS

The CAA required the EPA to set national health-based air quality standards to protect against common pollutants including ozone (smog), carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, and particulate matter. The EPA identified these six pollutants as "criteria" pollutants. State governments must devise cleanup plans to meet the established standards by a specific date. Areas with the highest levels of smog were given a longer time to meet the standards. In addition, the EPA sets national standards for major new sources of pollution such as automobiles, trucks, and electric power plants.

1970 Clean Air Act

Created the EPA, authorized to establish NAAQS

Required SIPs to meet standards

Set deadline for nonattainment areas

The goal of the CAA was to set and achieve NAAQS in every state by 1975. The setting of maximum pollutant standards was coupled with directing the states to develop state implementation plans (SIPs) applicable to appropriate industrial sources in the state.

As a response to the CAA, in 1975 the Federal Highway Administration (FHWA) and the Urban Mass Transportation Administration (UMTA), precursor to the Federal Transit Administration, issued "Joint Regulations on Urban Transportation Planning." The highlights included:

- The governor must designate a metropolitan planning organization (MPO) in each urban area as a condition for continued federal assistance.
- The MPO must develop a unified planning work program and a prospectus of the planning process.
- The metropolitan transportation plan (MTP) must consist of a long-range element and a transportation system management (TSM) element.
- The MPO must develop a transportation improvement program (TIP) and an annual element detailing the following year's projects.

CLEAN AIR ACT AMENDMENTS, 1977

The 1977 amendments to the CAA set new dates for achieving attainment of NAAQS since many areas of the country had failed to meet the original deadlines. In addition, these amendments were enacted:

- The amendments required revisions to SIPs for areas in nonattainment of NAAQS.
- SIPs were required to develop transportation control plans that included programs to reduce mobile source emissions.

- Regulations in 1981 were issued that required transportation plans, programs, and projects to conform to the approved SIPs giving priority to transportation control measures (TCMs).

CLEAN AIR ACT AMENDMENTS, 1990

The 1990 Clean Air Act Amendments (CAAA) built on the main aspects of the CAA, but also contain several new provisions. These were the most significant amendments to the CAA. The CAAA are divided into a number of titles addressing a broad range of pollution control and abatement issues. The CAAA were intended to meet inadequately addressed problems derived from the CAA such as acid rain, ground-level ozone, stratospheric ozone depletion, and air toxics.

The 11 titles in the CAAA are:

- Title I: Nonattainment. This title defines various categories of ozone (six classifications), carbon monoxide (two classifications), and particulate matter (two categories) nonattainment regions and establishes deadlines ranging from 3 to 20 years for regions to achieve specified air quality standards. Smaller pollution sources were included in heavily polluted regions to allow regulatory agencies greater freedom to address the full range of pollution sources. The amendments also supplant the 1970 provision of "reasonable further progress" with annual emission reduction goals.
- Title II: Mobile Sources. Title II specifies over 90 emissions standards for vehicle emissions including reductions of hydrocarbons (HC) and oxides of nitrogen (NO_x) by 35 percent and 60 percent, respectively, for all new cars beginning with the 1996 model year. Oil companies are required to offer alternative gasoline formulations (including mixtures of gasoline with ethanol and methanol, liquefied petroleum gas, and liquefied natural gas) that produce fewer emissions during combustion, particularly in nonattainment areas. In addition, auto manufacturers are required to produce experimental cars for sale in southern California that meet even more stringent emission standards.
- Title III: Hazardous Air Pollutants. Title III lists 189 chemicals for which the EPA is to phase in emission standards by the year 2000. These pollutants are known or reasonably suspected to be carcinogenic, mutagenic,

1990 Clean Air Act Amendments

Each state must submit a SIP to the EPA

Ozone nonattainment areas must demonstrate "reasonable further progress" toward attainment in specific milestone years

Expanded conformity to mean attainment strategies must conform to SIP purpose of reducing severity of NAAQS violations

Projected emissions of transportation projects and programs must reconcile with required emission reductions in the SIP teratogenic, or neurotoxic; to cause reproductive dysfunctions; or to be acutely toxic.

- Title IV and Title V: Acid Deposition Control and Permits. These titles establish an emissions trading program for sulfur dioxide (SO_2), the primary precursor to acid deposition.
- Title VI: Stratospheric Ozone Protection. Title VI domestically implements the Montreal Protocol on Substances That Deplete the Ozone Layer by requiring a phase-out of specific ozone-depleting chemicals such as chlorofluorocarbons (CFCs) and carbon tetrachloride.
- Title VII: Enforcement. This provision enhances EPA monitoring requirements and updates penalties to make them consistent with those in other environmental statutes.
- Title XI: Clean Air Employment Transition Assistance. Title XI authorizes the secretary of labor to establish a compensation, retraining, and relocation program to assist workers laid off because of their company's compliance with the Clean Air Act.
- The other titles (VIII, IX, and X) in the act are smaller provisions. They require EPA monitoring and study of smaller pollution sources and research into pollution and its health effects and require the EPA to utilize subcontractors owned by socially or economically disadvantaged persons.

INTERMODAL SURFACE TRANSPORTATION EFFICIENCY ACT

The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) was the most significant federal transportation legislation since the Interstate Highway System in the 1950s. It was the first major attempt to approach transportation planning and funding from a comprehensive, decentralized, multimodal perspective. This policy-making philosophy within ISTEA was reiterated with its reauthorization in 1998 through the Transportation Equity Act for the 21st Century (TEA-21).

ISTEA established CMAQ

ISTEA authorized the Congestion Mitigation and Air Quality Improvement Program (CMAQ) to provide funding for surface transportation and other related projects that contribute to air quality improvements and congestion mitigation. The CAAA and ISTEA, along with CMAQ, were intended to refocus transportation planning toward a more inclusive, environmentally sensitive, and multimodal approach to addressing transportation problems.

The main goal of CMAQ is to fund transportation projects that reduce emissions in nonattainment and maintenance areas. CMAQ is targeted at areas of the country with the most severe air quality problems. Funds must be spent in nonattainment or maintenance areas. Although the emission reductions achieved by the program are relatively small to attain the NAAQS, CMAQ funding can prove to be an asset to state departments of transportation (DOTs) and MPOs in meeting emission reduction requirements.

CMAQ emission reductions are small but still assets to MPOs and DOTs

TRANSPORTATION EQUITY ACT FOR THE 21ST CENTURY

The 1998 Transportation Equity Act for the 21st Century (TEA-21) built upon the foundation laid down by ISTEA. TEA-21 reauthorized CMAQ. It also expanded provisions to improve bicycle and pedestrian facilities.

The core ISTEA metropolitan and statewide transportation planning requirements remained intact under TEA-21. It emphasized the role of state and local officials in tailoring the planning process to meet metropolitan and state transportation needs.

TEA-21 built upon ISTEA

The legislation also ensured the establishment of a new monitoring network for the $PM_{2.5}$ standard, promulgated at the time of the act.

SAFE, ACCOUNTABLE, FLEXIBLE, EFFICIENT TRANSPORTATION EQUITY ACT: A LEGACY FOR USERS

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law in 2005. This legislation continues to build upon the framework of ISTEA and TEA-21 with some modifications to programs and procedures pertaining to emission reduction strategies, primarily requiring conformity determinations on updated transportation plans every four years.

SAFETEA-LU extends conformity cycle

CMAQ has been reauthorized. SAFETEA-LU now requires the Secretary of Transportation to evaluate and assess the effectiveness of a representative sample of CMAQ projects and to maintain a database of the various projects.

THE CONFORMITY RULE

In 1993, the EPA released the "Criteria and Procedures for Determining Conformity to Transportation Plans Rule," referred to

Conformity established interagency consultation procedures as the "conformity rule." It established interagency consultation procedures for determining transportation plan and program conformity. It outlined the criteria for conformity determination, including the following:

Latest planning assumptions

Timely implementation of TCMs

- Transportation plans, programs, and projects must be based on the latest planning assumptions and the latest emission estimation model available.
- Plans, programs, and projects must provide for the timely implementation of TCMs.
- The rule requires a TIP and conforming plan to be in place before project approval, and the project must come from them.
- Plans, programs, or projects must not cause or contribute to new pollutant violations or increase the severity of current problems.
- Plans, programs, and projects must be consistent with SIP emission targets.
- Projects must eliminate or reduce CO violations.

<u>Sources</u>

1990 Clean Air Act Amendments.

The Green Book, Office of Air Quality Planning and Standards, United States Environmental Protection Agency, 2007.

Meyer, Michael D., and Miller, Eric J., *Urban Transportation Planning*, 2nd Ed., McGraw-Hill, New York, 2001.

The Plain English Guide to the Clean Air Act, United States Environmental Protection Agency, PA-400-K-93-001, April 1993.

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users.

Transportation Equity Act for the 21st Century.

3.0 NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS)

Section Objective

This section provides a more detailed discussion of the NAAQS for each of the transportation criteria pollutants and their relation to Texas.

Under authority of the CAA and its subsequent amendments, the EPA Office of Air Quality Planning and Standards sets the NAAQS for each of the criteria pollutants. The CAAA established two types of national air quality standards:

- *Primary standards* set limits to protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly.
- *Secondary standards* set limits to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

Primary standards protect public health

Secondary standards protect public welfare

Units of measure for the standards are:

- Parts per million (ppm) by volume,
- Milligrams per cubic meter of air (mg/m^3), and
- Micrograms per cubic meter of air ($\mu g/m^3$).

DESIGNATIONS

Based on the measurements gathered from air quality monitoring in a region, an area receives a NAAQS designation of attainment, nonattainment, or unclassifiable for a criteria pollutant.

Attainment

An area that meets the national primary or secondary ambient air quality standard for the pollutant

Nonattainment

An area that does not meet (or that contributes to ambient air quality in a nearby area that does not meet) the national primary or secondary ambient air quality standard for the pollutant

Unclassifiable

An area that cannot be classified on the basis of available information as meeting or not meeting the national primary or secondary ambient air quality standard for the pollutant

OZONE STANDARDS

As discussed in Section 1, ozone (O_3) is a byproduct of the interaction of oxides of nitrogen (NO_x) and hydrocarbons in the atmosphere. Both are emitted by motor vehicles. Peak ozone concentrations typically occur during hot, dry, stagnant summertime conditions. This strong seasonality of O_3 levels makes it possible for areas to limit their O_3 monitoring to a certain portion of the year, termed the O_3 season. The length of the O_3 season varies from one area of the country to another. May through October is typical, but states in the south and southwest may monitor the entire year.

Ozone standard is 0.08 ppm

Fourth highest daily maximum eight-hour average over the course of three years

The EPA published revisions to the ozone standards in July 1997. The two primary changes to the O_3 standard were a change in averaging time and a strengthening of the standard. The current standard takes the fourth highest daily maximum eight-hour average over the course of three years. The three-year average cannot exceed 0.08 ppm. An area meets the O_3 NAAQS if the fourth highest daily maximum eight-hour average over the course of three years does not exceed the threshold. To be in attainment, an area must meet the O_3 NAAQS for three consecutive years.

Attainment requires meeting the ozone standard for three years

Ozone Classifications

The nonattainment designation for the O_3 eight-hour average is classified as to the degree of nonattainment:

- Extreme 0.187 ppm and above
- Severe 17 0.127 up to but not including 0.187 ppm
- Severe 15 0.120 up to but not including 0.127 ppm
- Serious 0.107 up to but not including 0.120 ppm
- Moderate 0.092 up to but not including 0.107 ppm
- Marginal 0.085 up to but not including 0.092 ppm

Texas Nonattainment Areas for Eight-Hour Ozone Standards

Four ozone nonattainment areas in Texas

Dallas-Fort Worth

Houston

Beaumont-Port Arthur

San Antonio

<u>Beaumont-Port Arthur (Marginal)</u>
Hardin County
Jefferson County
Orange County

<u>Dallas-Fort Worth (Moderate)</u>
Collin County
Dallas County
Denton County
Ellis County
Johnson County
Kaufman County
Parker County
Rockwall County
Tarrant County

<u>Houston-Galveston-Brazoria (Moderate)</u>
Brazoria County
Chambers County
Fort Bend County
Galveston County
Harris County
Liberty County
Montgomery County
Waller County
San Antonio (Subpart 1 Early Action Compact)
Bexar County
Comal County
Guadalupe County

Victoria County in Victoria is considered a maintenance area for ozone due to incomplete data.

MPOs in the Texas nonattainment areas include:

- Alamo Area Council of Governments (San Antonio),
- South East Texas Regional Planning Commission (Beaumont-Port Arthur),
- North Central Texas Council of Governments in the Dallas-Fort Worth Metroplex, and
- Houston-Galveston Area Council.

Early Action Compact Areas

In December of 2002, the State of Texas submitted Early Action Compacts (EACs) pledging to reduce emissions earlier than required for compliance with the new eight-hour ozone standard. The state had to meet specific criteria and certain milestones. For those counties in the EAC agreement that the EPA has designated nonattainment for the eight-hour standard, the EPA will defer the effective date of the nonattainment designation.

In Texas, EAC areas are:

Two EAC areas in Texas

<u>Austin-San Marcos</u>
Bastrop County
Caldwell County
Hays County
Travis County
Williamson County

<u>Longview-Tyler</u>
Gregg County
Harrison County
Rusk County
Smith County
Upshur County

San Antonio is an EAC area, but has not met the eight-hour standard and is included by the EPA in the nonattainment list pending EAC deadline at the end of 2007.

MPOs in the EAC areas include:

- Capital Area Metropolitan Planning Organization (Austin) and
- East Texas Council of Governments Tyler-Longview).

EACs require communities to develop and implement air pollution control strategies, including mobile source emission reduction strategies. The agreements require them to account for emissions growth and achieve and maintain the eight-hour ozone standard.

EAC areas must attain the eight-hour ozone standard no later than December 31, 2007. In areas that do not meet the EAC deadline, the nonattainment designation will become effective April 15, 2008. The EPA will withdraw that nonattainment deferral if an area misses any milestone set out in the EAC.

EAC areas must attain the eight-hour ozone standard no later than December 31, 2007

PARTICULATE MATTER STANDARDS

The air quality standards for particulate matter were revised by the EPA in 2006. The new standards tightened the 24-hour fine particle standard from 65 $\mu g/m^3$ to 35 $\mu g/m^3$, and retained the current annual fine particle standard at 15 $\mu g/m^3$. The EPA decided to retain the existing 24-hour PM 10 standard of 150 $\mu g/m^3$. The agency revoked the annual PM 10 standard because available evidence did not suggest a link between long-term exposure to PM 10 and health problems.

PM Standards

PM 10

24-hour average
150 $\mu g/m^3$
Primary and secondary

PM 2.5

Annual
15 $\mu g/m^3$
24-hour average
35 $\mu g/m^3$
Primary and secondary

To attain the PM 2.5 annual standard, the three-year average of the weighted annual mean PM 2.5 concentrations from single or multiple community-oriented monitors must not exceed 15.0 $\mu g/m^3$. To attain the 24-hour standard, the three-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 $\mu g/m^3$.

For the 24-hour PM 10 standard, attainment is met when measurement of PM 10 does not exceed the standard more than once per year on average over three years.

Nonattainment Areas for PM in Texas

El Paso County, including the City of El Paso, is in moderate nonattainment for PM 10.

CARBON MONOXIDE STANDARDS

The NAAQS for carbon monoxide (CO) is 9 ppm, measured as an eight-hour nonoverlapping average, not to be exceeded more than once per year. An area meets the carbon monoxide NAAQS if no more than one eight-hour value per year exceeds the threshold. (High values that occur within eight hours of the first one are exempted.

CO standard is 9 ppm on an eight-hour nonoverlapping average

This is known as using nonoverlapping averages.) The rounding convention in the standard specifies that values of 9.5 ppm or greater are counted as exceeding the level of the standard. To be in attainment, an area must meet the NAAQS for two consecutive years and carry out air quality monitoring during the entire time period.

The air quality CO value is estimated using EPA guidance for calculating design values published in the Laxton Memorandum issued by the EPA on June 18, 1990.

Carbon Monoxide Classifications

The nonattainment designation for the CO eight-hour average is further classified as to the degree of nonattainment:

- Serious 16.5 ppm and above
- Moderate 9.1 up to 16.4 ppm

Nonattainment Areas for CO in Texas

El Paso County is classified in moderate nonattainment (12.7 ppm) for CO. The Texas Commission on Environmental Quality (TCEQ) has recently submitted a request to the EPA for the county to be designated a maintenance area for the pollutant.

<u>Sources</u>

The Green Book, Office of Air Quality Planning and Standards, United States Environmental Protection Agency, 2007.

"Ozone and Carbon Monoxide Design Value Calculations," memorandum from W. Laxton, United States Environmental Protection Agency, June 18, 1990.

Texas Commission on Environmental Quality.

4.0 TRANSPORTATION ACTIVITY AND EMISSION REDUCTION

Section Objective

This section provides an overview of the activities in a transportation system. This perspective is then related to transportation demand management (TDM) and efforts to reduce emissions.

TRANSPORTATION SYSTEM CHARACTERISTICS

Transportation is a trip from an origin to a destination taken primarily to accomplish some purpose. At the metropolitan and regional level, transportation is the aggregate of hundreds of thousands of individual trip-making decisions. These trips (decisions) result in vehicle and passenger trips during specific time periods. A transportation system consists of the facilities and services that allow these travel movements to occur. The characteristics of these travel flows and of the facilities and services that enable them are basic to an understanding of transportation. It is the relationship among travel patterns, transportation facilities, and the economic, social, and environmental context of a region that forms the basis of transportation analysis and policy decisions.

Transportation systems consist of five main components:

- Individual traveler,
- Stakeholders
- Mode of transportation,
- Infrastructure of the system, and
- Intermodal connections.

Transportation planners devote considerable attention to the characteristics of the users of a transportation system. Understanding the motivations and influences on an individual for choosing one mode of travel over another is very important.

The mode of transportation used receives a high level of technical analysis. Planners focus on estimating the levels of usage for the various transportation modes in a system given the performance characteristics of the mode and the motivations of individual users.

Infrastructure refers to the facilities, networks, and services necessary in the system to provide mobility. This component has received the most attention in the transportation planning process. Operational performance that allows for efficient mobility and accessibility within the system is a major goal of the planning process. Increasingly sophisticated travel demand models have been developed in the last decades to predict future performance needs of the system. As the amount of land, public support, and funding for road expansion has decreased in the last decade, more attention has been given to operations and management of the infrastructure. Planners have also begun focusing on changing demand itself within the system through various techniques, rather than on accommodating the predicted increase.

Intermodal connections consider system connectivity and the ease by which a user can travel from origin to destination at an acceptable level of performance. Transfer points, terminals, and stations are of importance to system performance.

Stakeholders are those individuals and organizations that are affected by transportation, such as employers, workers, governments, social/cultural groups, environmental groups, and neighborhood associations.

TECHNICAL ANALYSIS

The interaction of the components and characteristics of a transportation system lend themselves to high levels of technical analysis. Over the last half-century, transportation planners and researchers have refined the tools available to practitioners in order to plan a system more effectively and efficiently. There are several characteristics related to use of a transportation system that are important for understanding the technical analysis in the planning process and the types of strategies considered by decision makers. Each can be found in some form within most transportation analysis tools. They are:

Technology has improved analysis capabilities over last few decades

- Trip purpose,
- Temporal distribution of trip making,
- Spatial distribution of travel,
- Mode choice,

- Safety, and
- Cost.

Passenger trips are modeled by planners in terms of the purpose the trip serves for the user. Traditional purposes include trips for: work, shopping, recreation, business, and school. Trips are defined as one-way movements, so the category of "home" is appended to many trips, creating five classifications: home-based work, home-based shop, home-based school, home-based other, and non-home based. In recent years, planners have seen an increase in multipurpose trip making, referred to as trip chaining.

Trip purpose

Trip making in most areas of the United States evidences a distinct temporal distribution — trips that are distributed in significant ways in the course of a day. The classic example of temporal distribution is the "double peaking" of trips because of the two rush hours in a workday. On the other hand, truck traffic does not correspond temporally with rush-hour traffic. Rather, it shows a single peak in the course of work hours. All modes of travel can be distributed temporally for analysis purposes, and this distribution provides helpful data for planners in terms of infrastructure and demand management.

Distribution in time during the day

Spatial distribution of trips is directly related to land use patterns and network configuration of a system. Every trip begins and ends at a specific geographical point. As a result, planners are able to model travel flows on networks that reflect the movements of goods and services throughout a region. Modeling spatial distribution is an important element in planning since it can indicate where transportation problems are likely to occur, analyze the performance level of the existing system, and identify areas that will require action to improve system performance.

Distribution in the system related to land use and network configuration

Mode choice, or modal distribution, is the proportion of trips made in a region by different travel modes (transit, automobile, walking, etc.). Modal distribution varies from city to city and area to area due to availability, condition of the system, and environment. Mode

Some go by car, bus, or train; walk; or ride a bike selection is influenced by trip time, both actual and perceived, and mode availability, among other factors. Therefore, an understanding of this characteristic is essential to planners in a locality. With the passing of ISTEA in 1991, greater emphasis has been placed on shifting modal patterns of trip making away from single-occupant automobiles.

Safety is a high priority under SAFETEA-LU

Arriving at destinations safely is a primary goal of travelers. While transportation fatality rates have declined over the last several decades, safety projects and research remain a high priority in the transportation field.

Every trip has some form of cost but can be hard to define

Travelers incur out-of-pocket and time value costs whenever a trip is made. Travel cost is often defined and perceived differently by users, stakeholders, and system providers. Because of these differences, travel cost can be a difficult characteristic to define. Nevertheless, costs are critical to transportation investment strategies.

TRANSPORTATION IMPACTS

Transportation systems have many tremendous impacts on society; some are readily apparent, while others may be harder to perceive. Transportation impacts include noise, air quality, water quality, energy consumption, ecology, aesthetics, land use, infrastructure, employment, income, and community cohesion, among others. Impacts are created through both construction and use of the system. They can be direct and indirect.

Transportation activity has a physical impact on air quality

The impact of most interest in this guide is the physical impact of transportation activity on air quality. Transportation activity can be a major source of air pollution. It is the attempt to control the impact of transportation on air quality that has led to various legislative and regulatory efforts such as the NAAQS, the conformity rule, and amendments to the CAA.

TRAVEL DEMAND MANAGEMENT

Primary purpose of TDM is to reduce or spread the number of vehicles using the system at a given time

As noted in the discussion above, greater attention has been given in the last 20 years to altering the demand of a transportation system rather than building larger facilities. In the 1980s, urban transportation agencies began to utilize the concept of travel demand management. As we shall see, TDM strategies and programs are very similar to mobile source emission reduction strategies and incorporate many of the same concepts. TDM programs can be considered mobile source emission reduction strategies, and they, in reverse, can be considered TDM projects.

The primary purpose of TDM is to reduce or spread the number of vehicles using the road system while providing a wide variety of mobility options to those who wish to travel. To accomplish these changes, TDM programs rely on incentives or disincentives to make these shifts in behavior attractive. In terms of air quality, reductions in the number of vehicle trips reduce vehicle miles traveled (VMT), which in turn reduces emissions. Initiating a TDM program is a technique to achieve the NAAQS.

Less vehicles means less VMT

Less VMT means less emissions

The term TDM encompasses both alternatives to driving alone and the techniques or supporting strategies that encourage the use of these modes. The application of such TDM alternatives and the implementation of supporting strategies can occur at different levels under the direction of a variety of groups. One level of application found in many parts of the country is at individual employer sites or at locations where there are many employers grouped together. Another level of application is on an area-wide basis. In this type of application, the primary focus of the TDM program is to affect as many travelers as possible within an area-wide travel system.

TDM strategies include carpool/vanpools, compressed/flextime/ staggered work weeks, congestion pricing, high-occupancy vehicle (HOV) lanes, mixed-use development, and telecommuting. All of these examples can be considered mobile source emission reduction strategies.

Effective TDM employer programs usually employ a wide variety of TDM alternatives and strategies, each mutually supporting the overall objective of trip reduction.

EMISSION REDUCTION OBJECTIVES

Regional mobile source emissions are reduced one of five ways:

- Trip elimination/reductions,
- Travel distance/VMT reductions,
- Traffic flow impacts,
- Demand shifting, and
- Vehicle types.

Trip Eliminations/Reductions

Projects seeking to eliminate or reduce trip making also reduce start (cold and hot) emissions and hot-soak emissions. Starting emissions can be a significant portion of the entire trip's emissions. Projects that seek to reduce trips will provide greater benefits than other strategies.

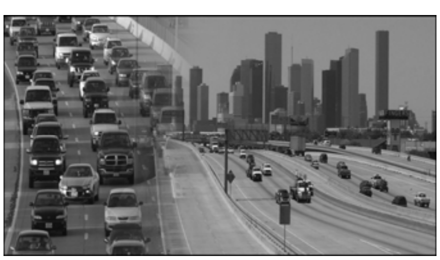
The EPA's current version of the Mobile Source Emissions Factor (MOBILE) model, its computer model for estimating motor vehicle emissions, also produces trip- and VMT-based emission factors. MOBILE6 includes the trip-based emissions (starts and soaks) in the VMT-based factors.

Travel Distance/VMT Reductions

Some TDM projects simply attempt to reduce the amount of VMT applied to the transportation system. The reduction allows the demand on the system to operate with improved performance and reduced running emissions.

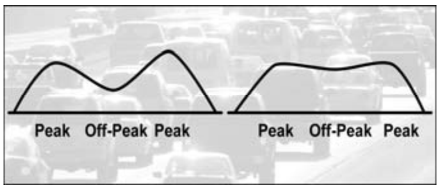
Traffic Flow Impacts

Improving traffic flow in the system to reduce delays and improve speeds reduces running emissions. Vehicles emit more pollutants (higher emission factors in grams per mile) at extremely low or high speeds or under hard acceleration. Under these conditions, emissions are greater because the engines run in a non-stoichiometric condition, meaning the engine air/fuel ratio runs either too lean or too rich. Smoothing traffic flow to maintain optimal and consistent speeds can reduce running emissions.



MOBILE emission factors, discussed in the next section, are often used for conditions that they were not originally intended, but represent the best available science for which to evaluate project impacts. The emission factors provided by MOBILE represent emissions from a typical driving cycle (accelerations, cruising, decelerations, and idling), which has an overall average speed. The emission factors for these average speeds are then commonly used for analyses with constant vehicle speeds.

Demand Shifting



Similar to the two previous objectives, shifting travel demand from peak conditions to times where recurrent and nonrecurrent congestion is less pronounced reduces running emissions. Operating speeds of vehicles shifted out of the peak period are likely to increase. Knowledge of peak and off-peak period speeds is required to estimate the emission benefits of these strategies.

Vehicle Types

Some strategies focus on improving the vehicle fleet emission factors by removing high-emitting vehicles. An example program is accelerated vehicle retirement, commonly referred to as "Cash for Clunkers." This program seeks to remove older, more polluting vehicles from the fleet, replacing them with newer, cleaner-burning vehicles. Results of this program modify the vehicle age distribution used in the emission factor models and lower emission rates.

<u>Sources</u>

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TDM Case Studies and Commuter Testimonials, Transportation Demand Management Institute of the Association for Commerce Transportation, Washington, D.C., August 1997.

5.0 EMISSIONS FACTOR MODELING

Section Objective

In this section, we introduce and discuss the emissions factor modeling process. An overview of the MOBILE model, the current emissions factor model, is given, along with its relationship to Mobile Source Emission Reduction Strategies (MOSERS). An emissions factor model is fundamental for assessing the nature and magnitude of on-road motor vehicle emissions and their impacts on ambient air quality.

AIR QUALITY MODELING

The relationship between air quality and transportation system performance is an ongoing issue for planners. It is a complex relationship requiring large amounts of data and significant time to analyze and report. Efforts to evaluate the air quality impact of on-road vehicles are by nature interdisciplinary and require the interaction of three different models and related areas of expertise: travel demand models, emissions factor models, and air quality models.

Travel demand models determine the amount of transportation activity occurring in a region based on an understanding of the daily activities of individuals and employers as well as the resources and transportation infrastructure available to households and individuals when making their activity and travel decisions.

Travel demand models provide vehicle activity

The second component is emissions factor models. These models convert information on driving conditions, vehicle and driver behavior, and environmental factors into estimates of motor vehicle emissions rates. They are based on the relationship between vehicle activities and vehicle emissions.

Emissions factor models provide pollutant rates by vehicle activity

The EPA has developed a computer model called MOBILE to estimate motor vehicle emissions. MOBILE estimates emissions rates based on vehicle type, average speed, ambient temperature, and other factors. The product of the transportation activity and the emissions rates from MOBILE results in emissions estimates for each modeled pollutant (carbon monoxide [CO], volatile organic compounds [VOCs], and oxides of nitrogen [NO_x]) for different vehicle types in three major geographic regions (low altitude, high altitude, and California). MOBILE is presented in more detail later in this section.

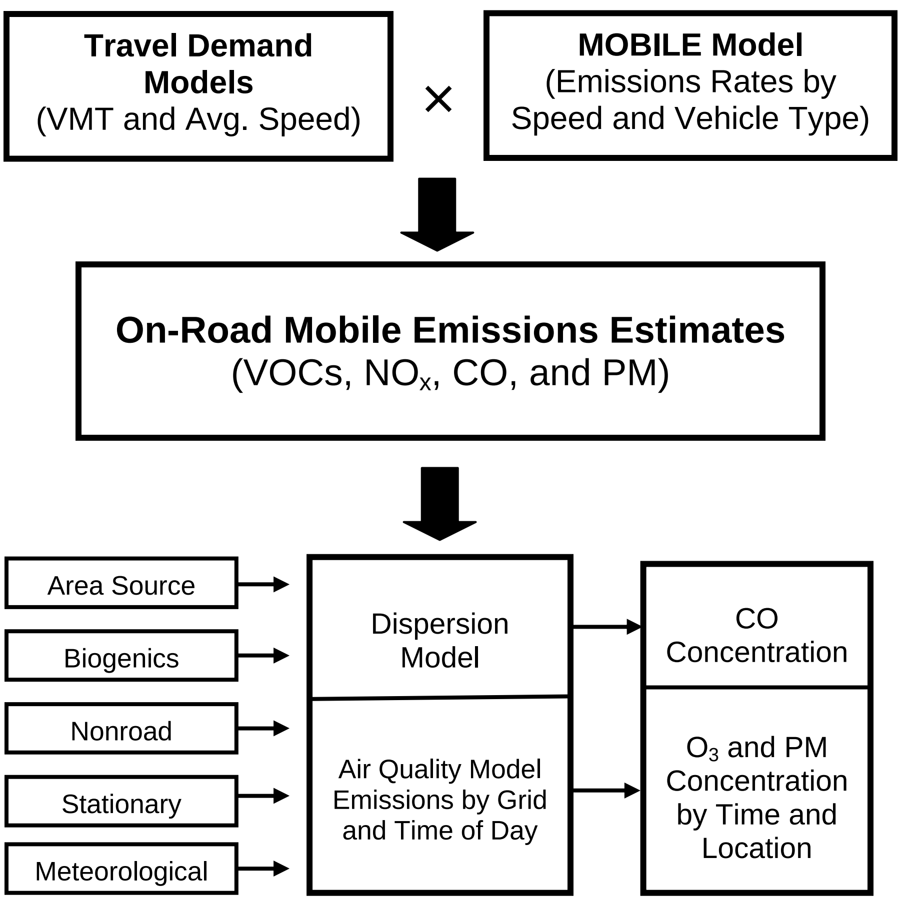
It is very important that estimates of transportation activity and emissions rates be in balance with respect to fidelity, accuracy, and precision to ensure the reasonableness of the emissions estimates. Planners should understand the different aspects of each component when considering them in their policy analysis.

Transportation activity and emissions rates must be in balance for good analysis

The third component of the modeling trilogy is the regional and microscale modeling of air quality, or dispersion models. These models translate emissions inventories into predicted ambient pollutant concentrations that carry through space and time. It uses data on emissions, meteorological conditions, and topographic characteristics to compute the dispersion of pollutants in the atmosphere. The model then predicts the concentrations of pollutants at certain locations over specified time periods. Dispersion models are much more complex than emissions models since they must account for the transport of pollutants over distance.

Microscale air quality models

These components are illustrated below.



Source: Meyer and Miller, Urban Transportation Planning

Figure 5.1 Air Quality Modeling Components

EMISSION FACTORS AND INVENTORIES

Emission factors and emission inventories have long been fundamental tools for air quality management. Emission factors are important for developing emission control strategies. The passage of the CAAA increased the need for criteria pollutant emission factors and inventories.

Ideally, data from source-specific emissions tests or continuous emissions monitors are preferred for estimating a source's emissions because these data provide the best representation of the tested source's emissions. However, test data from individual sources are not always available, and they may not reflect the variability of actual emissions over time. Therefore, emission factors are frequently the best or only method available for estimating emissions.

Emission factors are frequently the best method available for estimating emissions

An emission factor is a representative value relating the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of the pollutant divided by a unit weight, volume, travel distance, or duration of the activity emitting the pollutant. In most cases, these factors are simply averages of all available data of acceptable quality.

An emission inventory is an estimate of the total emissions in an urban area measured over time. Emission inventories can be compared with air pollutant levels in an area to determine if increased emissions decrease the air quality. Emission inventories have many purposes, including those involving ambient dispersion modeling and analysis, control strategy development, and screening sources for compliance investigations.

MOBILE

Texas uses the MOBILE model to simulate actual emissions from automobiles over varying scales of resolution (local, regional, and state). MOBILE is used in the documentation of emission reductions in SIPs, the assessment of air quality impacts of transportation projects (including the demonstration of conformity of transportation and air quality plans), and the assessment of mobile source emission reduction strategies. As the use of the model has progressed, transportation agencies and MPOs have come to rely on MOBILE in fulfilling their obligations under the CAAA and subsequent transportation legislation.

Texas uses only the MOBILE model

A primary use of MOBILE is in developing on-road mobile source emission inventories. Emissions rates developed in the model are

MOBILE develops on-road mobile source emission factors combined with average vehicle speeds and travel activity estimates to develop the inventories. The emission rates generated by MOBILE require a multitude of input assumptions. For most input assumptions, MOBILE provides national default values, or users can input locally specific values.

MOBILE was developed originally to estimate overall emissions levels, trends over time, and the effectiveness of mobile source emission control strategies. The role of MOBILE has expanded in ways that now require higher standards of accuracy that incorporate a greater degree of complexity.

The EPA first developed MOBILE in the late 1970s. Every few years, the model has had significant updates and new releases as new data become available, new regulations are promulgated, new emission standards are established, and the vehicle emissions process is better understood. Each new version of the model has become more complex in approach and has provided the user with additional options in order to customize emissions factor estimates to local conditions.

Underlying database changes in the model and changes in modeling methodology in each successive version have resulted in changes to predicted total on-road vehicle emissions. From one model version to the next, these changes can be either increases or decreases in emission factors, and the changes are not always in the same direction for each pollutant.

MOBILE6

The current generation MOBILE model, MOBILE6, is based on a tremendous amount of new vehicle emission testing data collected in the last decade. MOBILE6 also incorporates a set of modeling tools for the estimation of emissions produced by on-road and off-road mobile sources.

The design of the modeling system was guided by four broad objectives:

- All pollutants and all mobile sources at the levels of resolution needed for the diverse applications of the system should be encompassed.
- It should be developed according to principles of sound science.
- Software design of the model should be efficient and flexible.
- Implementation of the model should be in a clear and consistent manner.

MOBILE 6.2 is most recent version and is available from the EPA

Significant changes in MOBILE6 from previous versions include:

- Dramatically lower basic emissions rates after 2007,
- Separation of start and running exhaust emissions, and
- Addition of so-called off-cycle emissions (aggressive driving and air conditioning operation).

MOVES

The EPA's Office of Transportation and Air Quality (OTAQ) is developing a modeling system designated the Motor Vehicle Emission Simulator (MOVES) to keep pace with new analysis needs, modeling approaches, and data. The new system will estimate emissions for on-road and nonroad sources, cover a broad range of pollutants, and allow multiple-scale analysis, from fine-scale analysis to national inventory estimation. The new system will be a multivariate tool rather than a single software program. It will consist of software, algorithms, underlying data and guidance necessary for use in all official analyses associated with regulatory development, compliance with statutory requirements, and inventory projections. When fully implemented, MOVES will serve as the replacement for MOBILE6.

The MOVES model is the next generation modeling system for vehicle emissions

Sources

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A Sampling of Emissions Analysis Techniques for Transportation Control Measures, Cambridge Systematics, Inc., Federal Highway Administration, Washington, D.C., October 2000.

6.0 STATE IMPLEMENTATION PLAN (SIP) AND TRANSPORTATION CONFORMITY

Section Objective

This section presents an overview of the state implementation plan. It discusses the SIP process among relevant transportation agencies and includes SIP components for nonattainment areas. An overview of transportation conformity is also presented.

STATE IMPLEMENTATION PLAN

The SIP is the legal and federally enforceable plan for each state that identifies the air pollution control strategies to attain and/or maintain the primary and secondary NAAQS set forth in Section 109 of the CAA and the Code of Federal Regulations (CFR) (40 CFR 50.4 through 50.12) in each EPA–designated nonattainment or maintenance area. A SIP must be adopted by the state and approved by the EPA for each pollutant for which the state violates the NAAQS. The SIP is developed through a collaborative public process and submitted by the governor's designee to the EPA.

The contents of a typical SIP fall into three categories:

- State-adopted control measures, which consist of either rules/regulations or source-specific requirements (e.g., orders and consent decrees);
- State-submitted "nonregulatory" components (e.g., attainment plans, rate-of-progress plans, emission inventories, *transportation emission reduction measures*, statutes demonstrating legal authority, monitoring networks, etc.); and
- Additional requirements promulgated by the EPA, in the absence of a corresponding state provision, to satisfy a mandatory Part D or Section 110 CAA requirement.

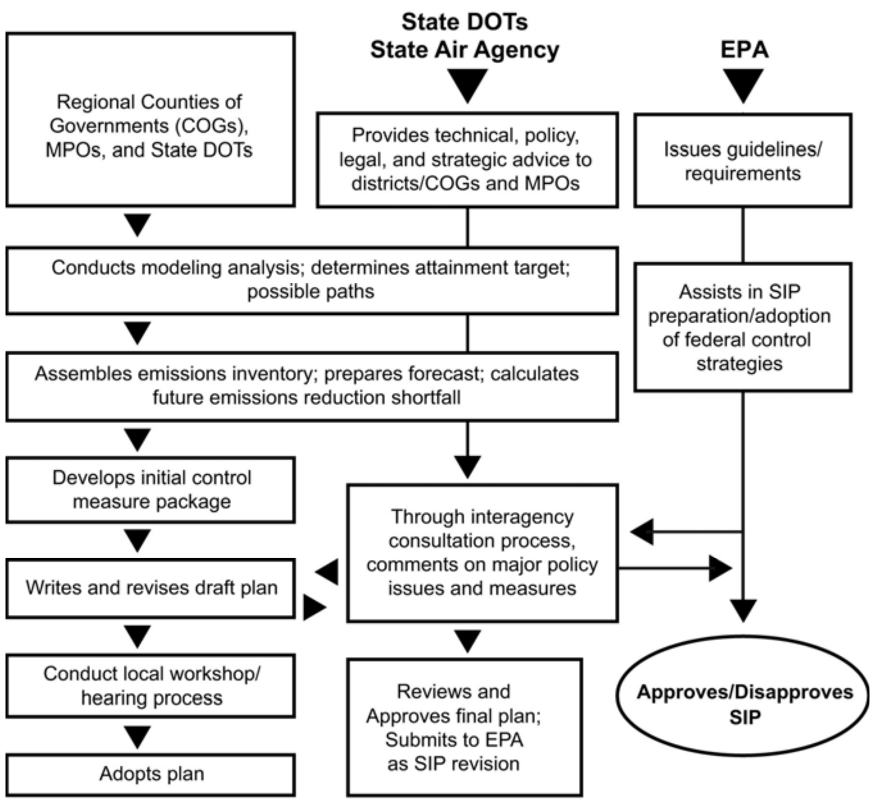
TCMs are in the category of state-submitted nonregulatory components of a SIP

Section 110 and Part D of the CAA describe the many elements of a SIP, such as emission inventories, a monitoring network, an air quality analysis, modeling results, attainment demonstrations, enforcement mechanisms, and regulations that have been adopted by the state to attain or maintain NAAQS. (Section 110 and Part D of the CAA are included in the CD-ROM companion to this guide.) The SIP also contains documents specific to each nonattainment area within the state.

Section 110 and Part D of the CAA describe SIP elements

The SIP is required and approved by the EPA pursuant to Section 110 of the CAA. Part D of the CAA mandates SIP requirements particular to nonattainment areas. Additional regulatory requirements that spell out the procedures for preparing, adopting, and submitting SIPs and their revisions are further codified in 40 CFR 51 and are included in the CD-ROM companion. All of these documents form the basis for the discussion below.

Because SIPs are continually updated, Section 110(h) of the CAA requires the EPA to periodically publish SIP compilation documents.



Source: Federal Highway Administration's Transportation Conformity Reference Guide, adapted from California Air Resources Board

Figure 6.1 Example of Roles and Responsibilities in SIP Development

SIP AND NONATTAINMENT

Areas not conforming to NAAQS within each state may be designated nonattainment and are then subject to additional planning and control requirements. Accordingly, different regulations or programs in the SIP will apply to different areas.

The following components are typically included for each nonattainment area.

Monitoring Network

By measuring the ambient concentrations of the criteria pollutants, the Texas Commission on Environmental Quality (TCEQ) can learn where and by how much any one of these pollutants exceeds its air quality standard. At the same time, the TCEQ collects meteorological information at each monitoring site. TCEQ monitors a number of representative sites for each area studied.

Nonattainment areas must have a monitoring system to measure criteria pollutants

Emissions Inventory

An emissions inventory of the pollutants or their known precursors from point, area, and mobile sources in the nonattainment area is compiled. The emission inventory also includes a biogenic (natural) emissions category.

Emissions inventories of area, point, and mobile sources must be compiled

All O_3 nonattainment areas, classified as marginal and above, and carbon monoxide (CO) areas must conduct these inventories and submit them to the EPA every three years until attainment. This provision is important because it means that SIPs need to be periodically updated when new emission factors are approved by the EPA, or when other changes in the overall level of emissions over earlier estimates are anticipated.

Emissions reductions needed to achieve the NAAQS are determined based on the emissions inventory.

Data Analysis

Air quality data and meteorological information are studied to find the appropriate relationship between emissions and air quality. This knowledge is then combined with the emissions inventory to determine what reductions are needed to attain the NAAQS within deadlines identified in the CAA.

Future Emissions Estimates

Emissions are projected to target attainment years by the use of growth factors such as population increases and also are adjusted for the impacts of adopted emission control strategies, such as the federal motor vehicle control program or cleaner fuels used statewide. Both modeling and actual inventories are used to make estimates.

Computer Modeling and Simulation

Sophisticated modeling programs analyze the effectiveness of strategies proposed to control air pollution. It is then determined whether selected controls will enable the area to comply with the standard by the mandated date.

Pollution Control Identification

The specific emissions controls to be applied to pollution sources are identified and then demonstrated that they will achieve the desired goals. The SIP is revised:

- As new control strategies are adopted,
- When the attainment status of an area changes,
- As the result of new or improved emissions data, or
- In response to new federal mandates.

The first SIP in Texas was submitted in response to CAA requirements in 1972.

Emissions Budgets

Motor vehicle emissions budget is a limit on mobile sources of pollutants

TCEQ allocates emissions reduction budgets to individual pollution sources (i.e., mobile, point, and area). The SIP then assigns specific emissions reduction levels to each source category. For the on-road mobile source category of emissions, the emissions reduction level is further refined into a regulatory limit on emissions, referred to as a *motor vehicle emissions budget* (MVEB) for on-road mobile sources.

Motor vehicle emissions are estimated based upon the number of vehicles in the region, their age, the rate of fleet turnover to newer and cleaner vehicles, seasonal temperatures in the region, vehicle miles traveled (VMT), population growth, and other factors. A motor vehicle emissions budget is the portion of the total allowable emissions for any criteria pollutant or its precursors defined in the SIP revision for a certain date for the purpose of meeting reasonable further progress milestones or demonstrating attainment or maintenance of the NAAQS.

INTERAGENCY COOPERATION IN SIP DEVELOPMENT

Interagency cooperation is essential to SIP development

Transportation and air quality agencies need to develop SIPs cooperatively in order to achieve the needed levels of emissions reductions. Different pollution control strategies will require approval at different levels of government. MPOs, Councils of Government (COGs), transit agencies, Texas Department of Transportation (TxDOT), or TCEQ cannot individually create, develop, or implement the measures required in the SIP. For example, some control strategies, like controls on automobiles and aircraft, are usually adopted by the federal government. Other strategies, like controls on fuels, inspection and maintenance programs, or market measures, can be adopted and effectively implemented and enforced at the state level. Control measures such as transit investments or HOV lanes must be implemented at the local or regional level; however, these control measures may require state legislation or approval. Therefore, by its very nature, the SIP is a collaborative process.

FEDERAL APPROVAL PROCESS

EPA approves SIPs after a formal public process

The federal approval process for SIPs resides solely with the EPA. Once the state formally adopts the regulations and control strategies through a public notice, public hearing, public comment period, and a formal adoption by a state-authorized rulemaking body, the state plan is ready for submittal to the EPA.

States send the adopted state rules, regulations, or control strategies to the EPA for inclusion in the federally enforceable SIP. The EPA begins its review as soon as possible, provides public notice, and requests additional public comment on the plan. The EPA must consider any adverse comments from the public comment period before a final action. Until the EPA approves a SIP, the submitted regulations are state enforceable only. This may result in state-enforceable SIPs differing from federally enforceable SIPs.

After its final approval actions, the EPA incorporates all state regulations, supporting information, and effective dates, sent under Section 110 of the CAA, into the federally approved SIP. The EPA maintains records of such SIP actions through "incorporation by reference" (IBR) in 40 CFR 52. This means that the specific state regulations are cited in the CFR and are therefore considered a part of the CFR just as if the text were fully printed in the CFR. Because of this action, the federal government does not reproduce the text of the federally approved state regulations in the CFR.

The IBR format allows both the EPA and the public to know which measures are contained in a given SIP and ensure that the state is enforcing the regulations. The format also allows both the EPA and the public to take enforcement action, should a state not enforce its SIP-approved regulations.

EPA Preliminary Review

States are able to gain preliminary EPA comments on draft documents intended to be SIP revisions. States seek EPA preliminary review before official notice of public hearings, incorporating EPA comments early in the process. For the state to be successful at incorporating these comments, the EPA must return comments on the draft SIP revisions soon after receipt of the draft. It should be noted that these comments reflect only the official EPA regional position. Depending on regional office procedures, EPA regional counsel concurrence and/or high-level signoff may be required.

State Notice of a SIP Public Hearing

If the state does not seek preliminary review from the EPA before notification of a public hearing, the EPA prepares comments that are included in the public record. The EPA prepares written comments and will either testify at the hearing and submit written comments, or submit written comments during the public comment period.

SUBMITTAL OF A SIP REVISION

The SIP is considered an evolving document. It can be revised by the state as necessary to address unique air pollution problems, as in nonattainment. As a result, the EPA occasionally must take action on SIP revisions submitted by states that may contain new and/or revised regulations.

A SIP is an evolving document

When a state formally submits a SIP revision request, the EPA regional office begins a formal review process following procedures prescribed in the CAA and various provisions of 40 CFR. The EPA reviews the SIP for conformance with federal policies and regulations in 40 CFR 52, entitled *Approval and Promulgation of Implementation Plans*, thereby making the state regulations federally enforceable. They perform the conformance review by first announcing their intent in the Federal Register through a Notice of Proposed Rulemaking (NPR), with an appropriate public comment period, and then publishing a Federal Register Notice (FRN) that codifies the SIP regulation. Once these control measures are approved following the process above, they are incorporated into the SIP and are identified in 40 CFR 52 as described above.

40 CFR 52 is the federal regulation for SIPs

Transportation Conformity

Transportation conformity is a method to ensure that federal funding and approval are given to those transportation plans, programs, and projects that are consistent with air quality goals. It ensures that these transportation activities do not worsen air quality or interfere with the purpose of the SIP, which is to meet the NAAQS. According to the CAA, transportation plans, programs, and projects cannot:

Conformity ensures transportation planning is consistent with air quality goals

- Create new NAAQS violations,
- Increase the frequency or severity of existing NAAQS violations, or
- Delay attainment of the NAAQS.

The concept of coordinating the transportation and air quality planning processes and ensuring that transportation plans are consistent with SIPs began with the Clean Air Act Amendments of 1977. The most recent update to these requirements was included in the Clean Air Act Amendments of 1990. ISTEA, TEA-21, and SAFETEA-LU have reinforced the need for coordinated transportation and air quality planning through the metropolitan planning provisions. The CAA conformity provisions are interpreted through regulations that set out the procedures and criteria for compliance. The regulations governing implementation requirements are included in the EPA transportation conformity rule and ISTEA's metropolitan planning regulations.

The state must make conformity determinations at least every four years, or as changes are made to plans, transportation improvement plans (TIPs), or projects. SIP revisions that establish or revise a transportation-related emissions budget, or add or delete TCMs, may also trigger new conformity determinations.

Conformity determinations must be made every four years

Conformity in Nonattainment Areas

In order to receive transportation funding or approvals from the FHWA/Federal Transit Administration (FTA), state and local transportation agencies in nonattainment or maintenance areas must demonstrate that they meet the transportation conformity requirements of the CAA as set forth in the transportation conformity rule. To meet these requirements, MPOs must explicitly show that the anticipated emissions resulting from implementation of transportation plans, programs, and projects are consistent with and conform to the purpose of the SIP for air quality. As stated in CAA 176(c)(1):

No department, agency, or instrumentality of the Federal Government shall engage in, support in any way or provide financial assistance for, license or permit, or approve, any activity which does not conform to an implementation plan after it has been approved or promulgated under CAA section 110.

No metropolitan planning organization designated under section 134 of title 23, United States Code, shall give its approval to any project, program, or plan which does not conform to an implementation plan approved or promulgated under section 110. The assurance of conformity to such an implementation plan shall be an affirmative responsibility of the head of such department, agency, or instrumentality.

The key components of the conformity determination include regional emissions analysis, project-level analysis, and, if TCMs are part of the attainment demonstration, an assurance that TCMs are being implemented on schedule.

Conformity must show that TCMs are on schedule

The foundation upon which a conformity determination is based is the MVEB in an approved SIP or a SIP budget that was found adequate by the EPA. This budget establishes the maximum aggregate emissions allowed by the transportation plan and TIP. The regional analysis must comply with specific modeling requirements included in the regulation.

Because of the strict nature of the conformity rules, when a region fails to demonstrate conformity with the SIP, federal transportation funding is then not made available, and those projects funded in full or part by federal funds can only complete their current project phase. New projects cannot begin, and current ones cannot enter the next phase of development, unless they are included as a TCM in the SIP. This is called a conformity lapse. Some projects are exempt from a lapse, but they focus mainly on safety-related improvements. Given the possible consequences of a conformity lapse, elected officials and decision makers need to be prepared to make difficult choices should they be faced with this situation.

Failure to demonstrate conformity leads to severe limits on federal funds

Sources

30 TAC §114.260, Transportation Conformity.

40 CFR 51, Requirements for Preparation, Adoption, and Submittal of Implementation Plans.

40 CFR 52, Approval and Promulgation of Implementation Plans.

1990 Clean Air Act Amendments.

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users.

Transportation Conformity Reference Guide, Federal Highway Administration, May 2000.

7.0 MOBILE SOURCE EMISSION REDUCTION STRATEGIES

Section Objective

In this section, we look at mobile source emission reduction strategies in greater detail.

DEFINITIONS AND ACRONYMS

For planning and engineering professionals entering the transportation/air quality field, the acronym "TCM" is used interchangeably in several different documents and funding programs but with one common element: they are projects that are *not* typical capacity improvements through construction of additional general purpose lanes.

Transportation control measures (TCMs) are defined in the transportation conformity rule as any measure that is specifically identified and committed to in the applicable SIP that is either one of the types listed in §108 of the CAA, or any other measure for the purpose of reducing emissions or concentrations of air pollutants from transportation sources by reducing vehicle use or changing traffic flow or congested conditions. Vehicle technology-based, fuel-based, and maintenance-based measures that control the emissions from vehicles under fixed traffic conditions are not TCMs.

The term "TCM" encompasses elements of both transportation supply management (TSM) and transportation demand management (TDM). TSM generally refers to the use of low capital-intensive transportation improvements to increase the operational efficiency of transportation facilities and services. These can include traffic flow improvements and high-occupancy vehicle lanes. TDM generally refers to policies, programs, and actions that are directed toward decreasing the use of single-occupant vehicles, including carpool and vanpool programs, parking management, and park-and-ride lots. TDMs also can include activities to encourage shifting or spreading peak travel periods. In practice, there is considerable overlap among these concepts, and TCM, TSM, and TDM are often used interchangeably.

TCM, TSM, and TDM are often used interchangeably

Section 108 of the CAAA lists 16 TCMs as:

(i) Programs for improved public transit;

(ii) Restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high-occupancy vehicles (HOV);
(iii) Employer-based transportation management plans, including incentives;
(iv) Trip-reduction ordinances;
(v) Traffic flow improvement programs that achieve emission reductions;
(vi) Fringe and transportation corridor parking facilities serving multiple-occupancy vehicle programs or transit service;
(vii) Programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use;
(viii) Programs for the provision of all forms of high-occupancy, shared-ride services;
(ix) Programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of nonmotorized vehicles or pedestrian use, both as to time and place;
(x) Programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;
(xi) Programs to control extended idling of vehicles;
(xii) Programs to reduce motor vehicle emissions, consistent with Title II, which are caused by extreme cold start conditions;
(xiii) Employer-sponsored programs to permit flexible work schedules;
(xiv) Programs and ordinances to facilitate nonautomobile travel, provide and utilize mass transit, and generally reduce the need for single-occupant vehicle (SOV) travel, as part of transportation planning and development efforts of a locality, including programs and ordinances applicable to new shopping centers, special events, and other centers of vehicle activity;
(xv) Programs for new construction and major reconstructions of paths, tracks, or areas solely for the use of pedestrian or other nonmotorized means of transportation when economically feasible and in the public interest (For purposes of this clause, the Administrator shall also consult with the Secretary of the Interior.); and
(xvi) Programs to encourage the voluntary removal from use and the marketplace of pre-1980 model year light-duty vehicles and pre-1980 model light-duty trucks.

CAACA TCMs

(Consolidated)

Improved Public Transit
Improved HOV Facilities
Employer-Based Transportation Management Programs
Trip Reduction Ordinances
Traffic Flow Improvements
Park-And-Ride/Fringe Parking
Vehicle Use Limitations/Restrictions
Area-Wide Rideshare Incentives
Bicycle And Pedestrian Programs (ix, x, xv)
Extended Vehicle Idling
Extreme Low-Temperature Cold Starts
Work Schedule Changes
Activity Centers

CMAQ allocates funds to states to implement programs often referred to as TCMs that help areas meet the NAAQS for ozone, CO, and PM. These CMAQ project types are generally the following:

- Transit improvements,
- Shared-ride services,
- Traffic flow improvements,
- Demand management strategies,
- Pedestrian and bicycle programs,
- Inspection and maintenance (I/M) programs,
- Diesel retrofits,
- Public-private partnerships,
- Education and outreach projects, and
- Experimental pilot projects.

Many other projects not listed in the SIP or funded through CMAQ are used for emission budget credit during the conformity determination process. Some of them may be referred to as TCMs.

Beginning in 1998, the EPA allowed projects under the Voluntary Mobile Source Emissions Reduction Program (VMEP) to be used for SIP emission reduction credit. These are small-scale projects, some of which are very similar to TCMs.

MOSERS — mobile source emission reduction strategies

To minimize confusion over the use of TCM in different contexts, this guide introduces a new term to encompass all of these measures. Mobile source emission reduction strategies are a set of project types known to reduce mobile source emissions and assist nonattainment areas in meeting the NAAQS. Mobile source emission reduction strategies help to reduce on-road mobile source emissions from transportation sources by reducing VMT, reducing the number or length of vehicle trips, or changing traffic flow. They may include types listed in Section 108 of the CAAA. Measures that reduce emissions by improving vehicle technologies, fuels, or maintenance practices are not mobile source emission reduction strategies.

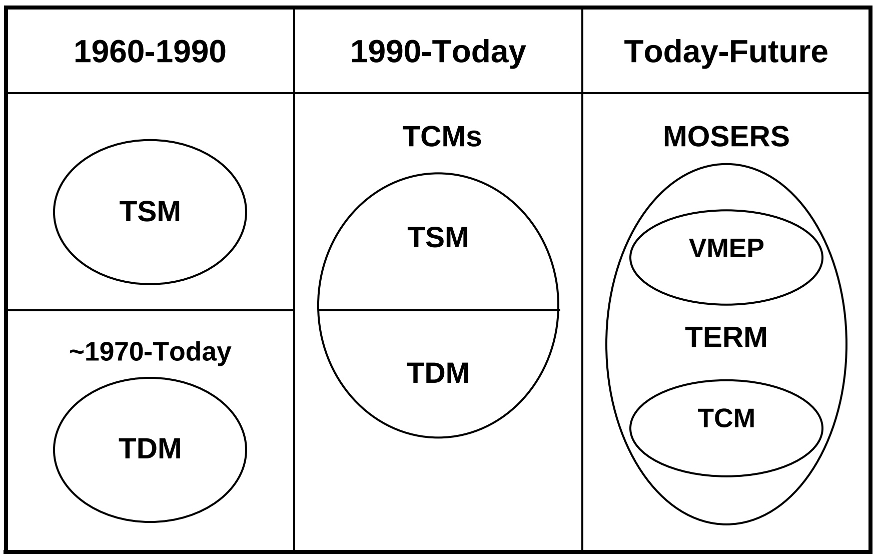


Figure 7.1 Historical Context of Technical Terminology

14 CAAA MOBILE SOURCE EMISSION REDUCTION STRATEGIES

The 14 consolidated CAAA mobile source emission reduction strategy categories are described below in greater detail.

1. Improved Public Transit

The goal of improved public transit is to provide incentives for single-occupancy vehicle commuters to utilize public transit and forego driving. This mobile source emission reduction strategy is comprised mainly of three components:

- System/service expansion projects that attempt to increase ridership by providing new rail system services and expanding bus services,
- System/service operational improvements that focus on improved geographic coverage and scheduling changes that make mass transit a more attractive option, and

- Inducements to travelers to increase ridership that include improvements in fare structures and policies, marketing programs, and passenger amenities.

2. Improved HOV Facilities

HOV lanes are intended to maximize the person-carrying capacity of the roadway by altering the design and/or operation of the facility to provide priority treatment for vehicles with two or more occupants. HOV facilities encourage travelers to shift from low-occupancy vehicles traveling in congested general purpose lanes to HOV use by providing two important incentives: reduced travel time and improved trip time reliability. These facilities should reduce vehicle trips, VMT, congestion, and associated emissions from these activities.

HOV facilities have been implemented throughout the United States, the city of Houston being a primary Texas example. HOV lanes are typically open to buses and other vehicles with a minimum of two or three occupants, although some are designated bus only.

Many types of HOV facilities exist. Some examples include:

- Separate roadways exclusive to HOV use;
- Bypass lanes at metered freeway entrance ramps;
- Lanes constructed within the freeway right-of-way but physically separated from the general purpose freeway lanes and for HOV use only;
- Concurrent flow lanes moving in the same direction of travel that is not physically separated from the general purpose traffic lanes; and
- Contraflow lanes in the off-peak direction of travel, typically the innermost lane, designated for exclusive use by eligible vehicles traveling in the peak direction.

Other HOV facilities include queue bypass, bus streets, and bus tunnels. The most common forms of HOV facilities are concurrent flow HOV lanes followed by exclusive HOV lanes in freeway rights-of-way.

3. Employer-Based Transportation Management Programs

Employers can play an important role in many mobile source emission reduction strategies because of their influence over employee travel behavior, work schedule, parking, compensation, and benefit policies and practices. Strategies often developed or promoted by employers include the following:

- Improved commute alternatives (i.e., carpooling, vanpooling, and increased use of transit);
- Facility improvements to encourage the use of these alternatives; and
- On-site support services to ensure an efficient, supportive program.

Alternatives to single occupancy vehicles (SOV) commutes serve to reduce VMT and congestion. Although these opportunities exist to provide commute alternatives to the SOV, incentives are often necessary to overcome the cost or convenience advantages of SOVs and to level the economic competition between the SOV and other transportation modes. Incentives are especially needed to promote commute alternatives in suburban areas, where employment destinations are widely scattered and the employer generally provides on-site parking at no charge. These incentives can include direct subsidies for transit use or ridesharing, parking pricing systems that favor HOVs, and guaranteed ride home programs. The most effective employer programs frequently use a variety of commute alternatives, at the same time offering incentives to increase their use.

4. Trip-Reduction Ordinances

Trip-reduction ordinances (TROs) differ from many other mobile source emission reduction strategies in that they do not directly control transportation in a specific way. TROs are regulatory mechanisms that require or provide incentives or disincentives to promote the use of various other mobile source emission reduction strategies. A TRO is a municipal, county, regional, or state regulation that usually involves the participation of developers and/or employers in trip demand management. These regulations attempt to mitigate social and environmental impacts of personal travel decisions through incentive and disincentive programs. A TRO may affect various groups, including employers, employees, and developers.

5. Traffic Flow Improvements

Traffic flow improvements are a range of measures that enhance the capacity and efficiency of a roadway system without adding extra lanes or new roads. The logic behind this mobile source emission reduction strategy is that improved operations efficiency decreases congestion and congestion-related emissions. However, once traffic congestion is reduced, motorists may feel encouraged to make more vehicle trips, leading to increased VMT and an increase in the associated emissions. Strategies to improve traffic flow can be grouped into three main types:

- Traffic signalization,
- Traffic operations, and
- Enforcement and management.

Traffic signalization represents the most common traffic management technique applied in the United States. Traffic signal improvements can include the following:

- Updating traffic signals to utilize more modern hardware, allowing for more sophisticated traffic flow strategies to be planned;
- Timing traffic signals to correspond to current traffic flows and patterns, reducing unnecessary delays;
- Coordinating and interconnecting signals to better interface pre-timed and traffic actuated signals, actively managed timing plans, and master controllers to minimize the number and frequency of stops necessary at intersections; and
- Removing signals at intersections no longer requiring signalized stop control to reduce vehicle delays and unwarranted stops.

Traffic operations describe several types of roadway improvement projects, including:

- Converting two-way streets to one-way operation to improve corridor travel times and increase roadway capacity;
- Restricting left turns on two-way streets as a means of eliminating conflicts with left turn movements, thereby reducing congestion and delay;
- Separating turning vehicles from through traffic with channelized turn lanes and raised medians;
- "Channelizing" roadways and intersections (i.e., clearly marking travel lanes and paths with striping and signage to reduce motorist confusion and uncertainty by channeling

traffic into the proper position on the street) to improve vehicular flow and capacity; and
- Widening and reconstructing roadways and intersections to reduce bottlenecks along sections where traffic capacity is below that of the adjacent street (e.g., traffic islands, turning lanes, and signage).

Several types of programs fall under enforcement and management:

- Incident management systems, consisting of roving tow or service vehicles, motorist aid call boxes, incident teams, roadway detectors to monitor traffic volumes, signage systems, traffic operations centers, contingency planning, and improved information availability to consumers through radio and television;
- Ramp metering, a technique to improve traffic flow on freeways by using signals to regulate traffic entering the highway so that it enters only at pre-timed intervals or at times determined by traffic volumes on the ramp or on the highway; and
- All other enforcement of traffic and parking program regulations necessary when individuals are required to change or adhere to a particular travel and parking behavior.

6. Park-and-Ride/Fringe Parking

Park-and-ride lots are generally located in outlying areas and serve as a central transfer point between SOVs, ridesharing, and transit services. In most cases, parking at the lot is free. Park-and-ride lots enhance the convenience of an alternative commute trip. This mobile source emission reduction strategy may entail construction of new facilities such as park-and-ride lots, direct connector ramps between park-and-ride lots and freeways, and retail and family essential services at or near park-and-ride lots. Another example is shared-use parking whereby the same parking lot may be used for park-and-ride and local business. Park-and-ride lot operators may also provide preferential parking to HOVs and transit/shuttle service from the lot.

7. Vehicle Use Limitations/Restrictions

Limiting or restricting vehicle use attempts to reduce emissions by control of time, location, and speed of vehicles in particular areas under certain circumstances. Diversion of routes may be utilized through delivery truck restrictions, turn restrictions, parking controls, and exclusive bus lanes. Drivers of designated vehicles, usually according to license plate, are encouraged or are restricted to not drive on specific days. Truck movements can be limited in certain areas of central business districts or congested areas.

8. Area-Wide Rideshare Incentives

State, regional, and local rideshare incentives have been developed in some areas to encourage commuters to use alternatives to driving alone to work and to encourage employers to provide in-house programs that promote ridesharing among employees. There are three main types of area-wide rideshare incentives or programs:

- Area-wide commute management organizations provide carpool and vanpool matching services, shared-ride taxis, and other commute trip elimination strategies.
- Transportation management associations or organizations (TMAs/TMOs) are generally business partnerships that provide similar services as commute management organizations directly to members or provide a channel for organized private sector involvement in public sector planning.
- State and local tax incentives and subsidy programs facilitate new vanpools, transit ridership, or carpooling by offering tax incentives for participating in a ridesharing program and by providing regulatory exemptions for vehicles participating in shared-ride arrangements.

9. Bicycle and Pedestrian Programs

Bicycle and pedestrian program mobile source emission reduction strategies can be used to reduce emissions associated with transportation. Since the early 1970s, bicycling has received increased attention, not only as an attractive recreational activity, but also as a viable commute alternative. Many communities have developed bicycle plans and built facilities. Similar to bicycling, the idea of walking as a means of transportation has been recognized as an alternative to using an automobile and is becoming more popular. Planners are beginning to incorporate criteria for pedestrian circulation and bicycle travel into the requirements for developing new activity centers. Traffic congestion and air quality objectives benefit from any shifting of low-occupancy vehicle trips of any purpose to bicycling and walking.

10. Extended Vehicle Idling

Science generally shows that vehicles emit the greatest amount of pollutants at low speeds and very high speeds. Mobile source emission reduction strategies that attempt to minimize the extent of vehicles idling at low speeds reduce overall emissions in the area. It may entail limitations on or prohibition of drive-through facilities in congested areas or limitations on the amount of time construction or heavy-duty vehicles may idle. Modifications can be mandated to vehicle engines, shutting them off after a set amount of idling time.

11. Extreme Low-Temperature Cold Starts

The initial vehicle start at very low temperatures creates a higher amount of emissions than at warmer temperatures. Mobile source emission reduction strategies in this category attempt to minimize this effect by encouraging or requiring preliminary warming of engines with electrical devices. Although northern parts of Texas do experience cold winter weather, Texas does not consider this mobile source emission reduction strategy relevant to state emission reduction efforts.

12. Work Schedule Changes

Changes in work schedule can effectively reduce congestion and improve air quality. Employers are the key players in making this work because they set work hour policies. Work schedule changes may improve air quality and reduce congestion. There will be fewer VMT across the work week, and employees will be arriving and departing during non-peak periods, thus reducing concentrations of ozone precursors. Three implementation options are discussed below. All three measures are similar in cost, benefit, and implementation, and so are grouped as one mobile source emission reduction strategy.

- Staggered work hours allow employees to begin work in intervals across the morning. Start times may be 15 minutes apart throughout the morning, and employees are required to work for eight hours from their start time. The goal of this strategy is to spread a given amount of traffic over a longer period of time around peak periods, which reduces concentrations of ozone precursors.
- Flextime arrangements allow employees to select their arrival and departure times. These have much the same impact as more structured staggered work hours. More flexibility in scheduling may allow some employees to rideshare who would be unable to otherwise. The fact that fewer people are arriving at the same time may discourage some ridesharing as well.
- Compressed work weeks allow employees to work more hours in fewer days than the usual 8-hour-per-day schedule. The “4/10” work week is a common option in which

employees work 10 hours per day over 4 days. Another common approach is the "9/80" work week. Employees work 80 hours over nine workdays with the tenth workday off.

13. Activity Centers

This mobile source emission reduction strategy requires attention to the transportation/land use relationship. It attempts to reduce localized areas of high congestion and emissions through land use regulations. Strategies in this category can include design guidelines that require facilities that encourage non-SOV travel to the activity center and parking regulations at the center. Requirements for mixed-use development through zoning and other land use ordinances may be used. Local government will play a key role in the utilization of this mobile source emission reduction strategy.

14. Accelerated Vehicle Retirement

Accelerated vehicle retirement, or scrappage, programs reduce emissions by removing older, high-emissions vehicles from the road before they would normally be retired. Scrappage programs typically focus on older vehicles because emission inventory estimates indicate that older vehicles, which make up a small portion of the overall vehicle population, account for a disproportionately large amount of the mobile source emissions. This imbalance is primarily because older vehicles have emission standards that are less stringent than standards for newer vehicles, and average emissions tend to increase with a vehicle's age and mileage because of wear on both the vehicle and its emission control technology.

OTHER MOBILE SOURCE EMISSION REDUCTION STRATEGIES

These mobile source emission reduction strategies are non-CAAA measures used by organizations. Parking management programs are the most common of the three presented below.

Congestion Pricing

Congestion pricing is a relatively new mobile source emission reduction strategy that is often referred to as "value pricing." This mobile source emission reduction strategy, which is still in the pilot program stage of development in the United States, operates in one of two ways. It either provides a disincentive to driving on highly used roadways by imposing fees in congested areas that vary depending on location, time, or vehicle occupancy, or it offers a priced alternative to a congestion roadway that enables the motorist to reach his or her destination more quickly. These fees are intended to reduce congestion and improve air quality by encouraging people to change their travel patterns by shifting to off-peak periods, less congested travel routes, HOVs, or a different mode of transport. There are several congestion pricing measures that may be implemented:

- Variable tolls,
- HOV lane permits,
- VMT fees, and
- Parking fees.

Parking Management

Parking management is a mobile source emission reduction strategy that administers the supply of available parking spaces. Parts of this mobile source emission reduction strategy are found in several other mobile source emission reduction strategies, but it is listed here as a separate mobile source emission reduction strategy program to be utilized as a response to nonattainment. The goal is to limit and allocate the overall number of vehicle parking spaces in a particular area that will in turn encourage SOV users to switch to other means of travel. Common forms of parking management include:

- Limiting total available parking,
- Providing preferential parking for desired travel modes such as commuters or vanpools,
- Setting minimum or maximum parking space ratios in zoning ordinances, and
- Implementing time limits on existing vehicle parking spaces.

Vehicle Purchases and Repowering

Vehicle emission rates can be reduced through the purchase of motor vehicles certified to pollute less than typical new vehicles. As an alternative to vehicle purchase, complete engine replacements may be done on older vehicles to reduce their emissions.

<u>Sources</u>

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8.0 MOBILE SOURCE EMISSION REDUCTION STRATEGY UTILIZATION

Section Objective

In this section, we will outline the responsibilities of the MPO and implementing agencies regarding MOSERS. A discussion of the use of MOSERS in the SIP is included along with issues surrounding implementation of the MOSERS. Finally, the question of MOSERS credit is presented.

PROGRAM DEVELOPMENT VERSUS INDIVIDUAL IMPLEMENTATION

By selecting mutually supportive actions, possible synergy between the individual actions may be gained. However, if strategies are not coordinated, they may conflict with one another and actually reduce the amount of emission credit gained in the region. The interaction between mobile source emission reduction strategy projects falls into one of four categories:

MOSERS need to be coordinated to gain their full effect emissions benefit

- *Directly additive* — Projects are unrelated and affect different portions or markets in the transportation system.
- *Sequentially additive* — Projects generally affect the same portion or market in the transportation system but are neither coordinated nor supporting measures. The effect of these project pairs is less than directly additive.
- *Synergistic* — Projects generally affect the same portion or market in the transportation system and act in supporting roles. The effect of these project pairs is greater than directly additive.
- *Conflicting* — Conflicting incentives reduce individual project effectiveness.

No guidance is currently available to assess the magnitude or nature of synergistic reactions to program implementation. Some resources are available in the CD-ROM companion that better define some of the interactions between typical mobile source emission reduction strategy projects.

The CD-ROM included with this guide contains helpful resources

Documentation of mobile source emission reduction strategy programs within SIP and conformity documents requires that states report and document each individual project independently. This can pose a challenge to MPO staff in taking synergistic credits of mobile source emission reduction strategy projects. Proper documentation including justification of assumptions is required to demonstrate proper analysis for synergistic measures.

EPA CRITERIA FOR MOBILE SOURCE EMISSION REDUCTION STRATEGIES TO BE INCLUDED IN SIPS

Mobile source emission reduction strategies must satisfy the following eight criteria before EPA will consider them for approval in a SIP:

- A complete description of the measure and its estimated emissions reduction benefits;
- Evidence that the measure was properly adopted by a jurisdiction with legal authority to commit to and execute the measure;
- Evidence that funding has been (or will be) obligated to implement the measure;
- Evidence that all necessary approvals have been obtained from all appropriate government agencies (including MPOs and state transportation departments, if applicable);
- Evidence that a complete schedule to plan, implement, and enforce the measure has been adopted by the implementing agency or agencies;
- A description of the monitoring program to assess the measures' effectiveness and to allow for necessary in-place corrections or alterations;
- Governor's approval of the SIP; and
- Public hearing (as part of the SIP approval process).

SUBMITTING TCMS

Nonattainment and maintenance areas can include mobile source emission reduction strategies in SIPs as control measures to support the SIP demonstration or as contingency measures. If mobile source emission reduction strategies are included as control measures in the SIP, they must be implemented, and timely implementation must be demonstrated as part of the conformity determination.

> If included in a SIP, a mobile source emission reduction strategy is referred to as a transportation control measure (TCM).

The *Revisions to the State Implementation Plan for the Control of Ozone Air Pollution*, released by TCEQ on May 30, 2000, outlines the process for submitting TCMs in the SIP in the state of Texas. Title 30 TAC 114.270 of the Texas Administrative Code (TAC) was adopted by the TCEQ to require MPOs to submit specific TCM commitments and to ensure adequate funding, implementation, and emissions reductions through the TIP and MTP process. MPOs have an opportunity to revise the TIP and MTP to provide additional TCMs as necessary to achieve fully anticipated emission reductions.

The TCM rule (30 TAC 114.270) is the enforcement mechanism for mobile source emission reduction strategies in the state of Texas. TCEQ first adopted the TCM rule in October of 1993 and revised it in July of 1994. Problems in the rule became evident regarding quantification of the emissions benefits of a mobile source emission reduction strategy, documentation requirements, and TCM substitution. Complaints were raised with both the EPA and local MPOs. The TCM rule was ultimately revised again in 2000 to address these concerns.

The state TCM rule is the enforcement mechanism for MOSERS.

The 2000 rule and SIP revision applies to MPOs and agencies that implement TCMs in designated nonattainment or maintenance areas, as defined in 30 TAC 101.1. The purpose of the rule is to implement requirements relating to TCMs, address the roles and responsibilities of the MPOs and implementing transportation agencies in nonattainment and maintenance areas, and provide a method for the substitution of mobile source emission reduction strategies without a SIP revision. The rule requires TCM project-specific descriptions and estimated emissions reductions to be included in the SIP.

MPO AND IMPLEMENTING AGENCY RESPONSIBILITIES

The TAC defines the responsibilities for both the MPO and implementing agencies (the full section of the code is provided in the CD-ROM companion) on matters for TCM reporting (the TAC language uses TCM and is reflected here). These reports cover annual estimates of emissions credits, a five-year rolling inventory, and assurances that funding is committed to these projects.

As stated in the TAC, the MPO shall:

- Ensure that all responsibilities required by an annual estimate of the emission reductions achieved from implementation of the TCM and a comparison of the actual and projected reductions are fulfilled.

- Maintain, on a rolling basis, complete and accurate records of all TCMs for at least five years. TCM records shall be sufficient to accurately reflect the effectiveness of the TCM program and shall include the following:

    - The annual status of the implementation of the TCM, including quantification of progress;
    - An annual estimate of the funding and other resources expended toward implementing the TCM and a comparison of the actual and projected expenditures;
    - An annual estimate of the emission reductions achieved from implementation of the TCM and a comparison of the actual and projected reductions; and
    - Any modifications to the TCM since the last annual report and/or projected modifications for the next reporting period to compensate for a shortfall in the implementation of the TCM or in the associated emissions reductions.

- Make such records available to representatives of the TCEQ, EPA, FHWA, FTA, TxDOT, local air pollution agencies having jurisdiction in the area, and the public, upon request.

According to the TAC, the implementing agency shall have the responsibility to:

- Ensure that all responsibilities required by providing evidence that funding has been, or will be, obligated to implement the TCMs are fulfilled.
- Provide to the MPO upon request:

    - A complete description of the TCMs and their associated estimated emission reduction benefits;
    - Evidence that the TCMs were properly adopted by a jurisdiction with legal authority to commit to and execute the program;
    - Evidence that funding has been, or will be, obligated to implement the TCMs; and
    - A description of the monitoring program to assess the TCM effectiveness.

Timely Implementation of TCMs in SIPs

TCMs must be implemented in a timely manner

Those mobile source emission reduction strategies that are included in an EPA-approved SIP and that are eligible for federal funding are designated TCMs and are subject to the timely implementation requirement. TCMs included within the SIP must have funding priority consistent with the SIP schedule for implementation in a timely manner. Because the MPO or state is required to ensure timely implementation of TCMs, it ensures that they are not postponed due to lack of a funding commitment.

Transportation projects with demonstrated air quality benefits are to receive priority allocation of funds regardless of funding source. Therefore, TCMs included in the SIP must receive maximum priority for approval, funding, and timely implementation.

Transportation planners should be aware of the relationship between timely implementation of TCMs and conformity determinations and TIPs. It is clear from the criteria below that funding and implementation of TCMs in an approved SIP receive high priority. Transportation projects used to attain NAAQS in a nonattainment area that are lacking in funding or implementation will negatively affect conformity determinations and TIPs in the area.

The FHWA's *Transportation Conformity Guide* provides the relevant sections below regarding timely implementation of mobile source emission reduction strategies, both as TCMs within SIPs and those adopted that are not in the implementation plan.

CAA §176(c)(2)(B), 42 U.S.C. §7502(c)(2)(B):

> *No metropolitan planning organization or other recipient of funds under title 23, United States Code, or the Urban Mass Transportation Act shall adopt or approve a transportation improvement program of projects until it determined that such program provides for timely implementation of transportation control measures consistent with schedule included in the application implementation plan (SIP).*

58 FR 62197, November 24, 1993:

> *EPA believes that the determination of "timely implementation" should focus on the prospective schedule for TCM implementation, and all past delays should be irrelevant. Therefore, it is permissible for the plan/TIP to project completion of a TCM implementation milestone which is later than the SIP schedule if the lateness is due to delays which have already occurred, or due to the time reasonably required to complete remaining essential steps (such as preparation of a NEPA document, design, work right-of-way acquisition, Federal permits, construction, etc.). It is also permissible to allow time for obtaining State or local permits if the project has not yet advanced to the point where a permit could have been applied.*
>
> *However, where implementation milestones have been missed or are projected to be missed, agencies must demonstrate that maximum priority*

is being given to TCM implementation. All possible actions must be taken to shorten the time periods necessary to complete essential steps in TCM implementation — for example, by increasing the funding rate — even though the timing of other projects may be affected. It is not permissible to have prospective discrepancies with the SIP's TCM implementation schedule due to lack of programming funding in the TIP, lack of commitment to the project by sponsoring agency, unreasonably long periods to complete future work due to lack of staff or other agency resources, lack of approval or consent by local government bodies, or failure to have applied for a permit where necessary work preliminary to such application has been completed.

However, where statewide and metropolitan funding resources and planning and management capabilities are fully consumed with responding to damage from natural disasters, civil unrest, or terrorist acts, TCM implementation can be determined to be timely without regard to the above, provided reasonable efforts are being made. The burden of proof will be on the agencies making conformity determinations to demonstrate that the amount of time to complete remaining implementation steps will not exceed that specified in the SIP without good cause, and that where possible, steps will be completed more rapidly than assumed in the SIP in order to make up lost time.

As part of the interagency consultation process when TCMs included in an approved SIP have been delayed in the past or are currently behind schedule, a determination must be made that all obstacles to implementation have been identified and are being overcome. In addition, the United States Department of Transportation (USDOT) must, in approving a conformity determination, find that priority is being given to TCMs included in approved SIPs.

Criteria for Demonstrating Timely Implementation of TCMs in TIPs

To demonstrate timely implementation of TCMs for TIPs, states must meet the following criteria:

Code of Federal Regulations (CFR), 40 CFR §93.113(c)(1-3), as amended by 62 FR 43780, 43809-10, August 15, 1997:

(1) An examination of the specific steps and funding source(s) needed to fully implement each TCM indicates that TCMs which are eligible for funding under title 23 U.S.C. or the Federal Transit Laws are on or ahead of the schedule established in the applicable implementation plan, or if such TCMs are behind the schedule established in the applicable implementation plan, the MPO and DOT have determined that past obstacles to implementation of the TCMs have been identified and have

been or are being overcome, and that all State and local agencies with influence over approvals or funding for TCMs are giving maximum priority to approval or funding of TCMs over other projects within their control, including projects in locations outside the nonattainment or maintenance area.

(2) If TCMs in the applicable implementation plan have previously been programmed for Federal funding but the funds have not been obligated and the TCMs are behind the schedule in the implementation plan, then the TIP cannot be found to conform if the funds intended for those TCMs are reallocated to projects in the TIP other than TCMs, or if there are no other TCMs in the TIP, if the funds are reallocated to projects in the TIP other than projects which are eligible for Federal funding intended for air quality improvement projects, e.g. the Congestion Mitigation and Air Quality Improvement Program.

(3) Nothing in the TIP may interfere with the implementation of any TCM in the applicable implementation plan.

TCM Substitution Process

SAFETEA-LU streamlined the TCM substitution process. SAFETEA-LU amends the CAA to provide a process for replacing TCMs in approved SIPs with alternate TCMs or for adding TCMs to approved SIPs.

SAFETEA-LU streamlined the TCM substitution process; the state rule aligns with the federal rule

SAFETEA-LU provides that substitute TCMs can replace or be added to existing TCMs in approved SIPs if:

- The substitute TCM achieves equal or greater emissions reductions;
- The schedule is consistent with the existing TCM or, if the implementation date has passed, as soon as practicable but no later than the date reductions are needed;
- Adequate personnel, funding, and enforcement are demonstrated; and
- The substitute TCM is developed through a collaborative process that includes public comment and concurrence by the MPO, the air agency, and the EPA.

No substitution mechanism in the SIP is needed, and substitution does not require a new conformity determination or SIP revision.

TAKING EMISSION CREDIT

If mobile source emission reduction strategy implementation has been assured or the measure has been partially implemented and it can be demonstrated that it is providing quantifiable emissions reduction benefits for the part of the measure that has been implemented, then it should be included in an emissions analysis. If the mobile source emission reduction strategy has been delayed beyond the scheduled implementation date(s) in the approved SIP, then it should not be included in the emissions analysis.

Where Credits Can Be Taken: SIP or Conformity

Mobile source emission reduction strategy credits can be taken in either the SIP or conformity documents. Taking credit in each document has advantages and disadvantages. Because of this, there is no professional consensus as to the best location to record these credits. Local decisions will prevail according to the level of commitment and certainty/uncertainty that the projects will be implemented as planned, according to both scope and time.

Local decisions will determine where credits are to be taken

We list the advantages and disadvantages for each document below.

State Implementation Plan

Advantages

- Regions can take credits toward attainment.
- TCMs that are included in approved SIPs may proceed during a conformity lapse.
- Including mobile source emission reduction strategies in the SIP may be an ultimate effort to prevent federal sanctions.
- Inclusion in the SIP demonstrates good faith toward attainment goals.
- Project descriptions are more specific.
- Projects are incorporated into the CFR.

Disadvantages

- SIP proposals are legally binding and enforceable.
- Implementation is required by the date indicated.
- Regions will face possible federal sanctions if mobile source emission reduction strategies are not implemented.
- It is a difficult process to modify the scope or implementation date of the project and requires public hearings for changes.
- Regions may feel that the projects are "micromanaged."
- It reduces the available motor vehicle emissions budget for conformity determinations.

- If all reductions are listed as SIP mobile source emission reduction strategies, there may be no additional credits available to pass conformity.

Conformity Determination

Advantages

- It can help make up for inadequate reductions.
- A lesser degree of commitment is required from the implementing agency.
- There is more flexibility so that projects might be moved from one year to the next or the scope expanded or contracted.
- The detail of documentation is less than required for the SIP.

Disadvantages

- Projects listed in these documents do not advance during conformity sanctions.
- If projects are not implemented in time, conformity cannot be demonstrated.

CREDIT DURATIONS

No clear guidance exists at this time regarding mobile source emission reduction strategy project life, but it does vary between project types. Project life may be defined by annual funding commitments or use of available capacity or other means. Until more definitive conclusions are developed on the emissions project life of a strategy, professional judgment will continue to be necessary.

The Transportation Research Board has provided some guidance for mobile source emission reduction strategy project lives. The life effectiveness for various strategies includes:

Project lifetimes are not definitive; use realistic, conservative assumptions when estimating lifetimes

- One to two years for existing transit service improvements, TDM programs, ridesharing and vanpool programs, and pricing and fare strategies;
- Two to four years for intersection improvements;
- Three years for signalization improvements;
- Four to five years for telecommunications/telework programs;
- 10 to 12 years for intelligent transportation systems (ITS), new buses or alternative fuel buses, bicycle/pedestrian facilities, and park-and-ride lots;

- 20 years for roadway improvements including HOV; and
- 30 to 35 years for rail transit systems, parking structures, and pavements.

For some mobile source emission reduction strategies, the amount of emission reductions declines over time. For example, intersection signal retiming may show immediate benefits, but these benefits are eroded as additional demand is attracted to the intersection, resulting in a decreased level of service. The declining emission benefit is assumed to decrease in a linear manner each year until the project life is expended. For these project types, one-half of the initial emissions benefit is taken for each year of the project's life. This is equivalent to annualizing the emission benefit.

Does the emissions benefit of a project erode over time?

The EPA allows areas to implement and claim SIP credit for the Voluntary Mobile Source Emissions Reduction Program (VMEP). VMEPs encompass many mobile source control measures, some of which are mobile source emission reduction strategies. However, the EPA's guidance establishes a cap on the SIP credit allowed for VMEPs to 3 percent of the total projected future year emissions reductions required to attain the NAAQS. The EPA notes that the emissions reduction potential of VMEPs is generally a fraction of one ton per day.

<u>Sources</u>

30 TAC 101.A, General Air Quality Rules.

30 TAC §114.270, Transportation Control Measures.

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9.0 DATA SOURCES FOR MOBILE SOURCE EMISSION REDUCTION STRATEGIES

Section Objective

This section provides the reader with potential data sources for MOSERS analysis. Three collection methods are discussed: use of existing data, field collection, and professional judgment. The need for good quality, local data is emphasized.

Data collection is a time-consuming but important step in mobile source emission reduction strategy analysis. Part of the reason is the lengthy implementation period of some mobile source emission reduction strategies, but it is also caused by the need for data collection from various sources. There is no one data source for mobile source emission reduction strategy analysis. Instead, a variety of data sources for different individual mobile source emission reduction strategies must be used. Some data are fairly easy to access and gather, while some information must be inferred from several different sources.

The primary goal of data collection for mobile source emission reduction strategy analysis is to gather high-quality, locally valid transportation and emissions data in order to document the impact of the mobile source emission reduction strategy. Data quality affects the results more than any other factor. The availability of local data is crucial for calculating reliable results. Section 2 of Part B lists all the variables required to document the emissions impact of individual mobile source emission reduction strategies using the equations given. To determine these variables, the analyst must attempt to provide good data.

Good Data = Good Analysis = Good Documentation

There are three primary methods of accumulating data in order to analyze mobile source emission reduction strategies:

- **Current available data** — the information can be compiled from "on-hand" sources.
- **Field data collection by the agency** — in order to fill gaps in the current data or to acquire information that is simply not available to the professional, personnel from the organization must go out to the field and collect it.
- **Professional judgment** — when no data are available or the agency is unable to collect it, agency personnel can rely on their experience and personal knowledge base to make an educated estimate of the needed data or use data from other similar regions.

It is suggested that data be collected both before and after implementation of the measures to confirm inputs and improve the analysis process. This process may require several years because of the time required to implement some mobile source emission reduction strategies.

LOCAL DATA ARE CRUCIAL!

Data types and requirements vary from mobile source emission reduction strategy to mobile source emission reduction strategy. Variables relevant to one mobile source emission reduction strategy (i.e., average vehicle speed near an intersection before mobile source emission reduction strategy implementation) are not required for other measures, such as bicycle lanes.

Different MOSERS require different data inputs

Transportation professionals should be aware of the spatial scale of an individual mobile source emission reduction strategy when evaluating its effectiveness. The mobile source emission reduction strategy may have impacts on local, corridor, or regional areas.

The smaller the intended effect of a mobile source emission reduction strategy, the larger the number of ambient air quality observations that must be collected before and after implementation in order to show any measurable effect with an acceptable level of confidence.

CURRENT AVAILABLE DATA

There are many sources of data available for mobile source emission reduction strategy analysis.

Evaluation of the impact of on-road motor vehicles requires the interaction of travel demand models and emission factor models. Both models can be sources of data to analyze the effects of mobile source emission reduction strategies in a region, if they are available. They are discussed in detail in other sections of Part A, but in this section the data that can be derived from them are highlighted.

Travel demand models and emission factor models are excellent sources of data

Travel demand models determine the amount of transportation activity occurring in a region based on an understanding of individual trip behavior within the transportation system. While mobile source emission reduction strategies are considered "off model," components of a regional travel demand model can be used as data sources for analyzing individual mobile source emission reduction strategies. The five basic components of a travel demand model are:

- Demographic data,
- Trip generation,
- Trip distribution,
- Mode choice, and
- Route choice.

All five of these components can be utilized in mobile source emission reduction strategy analysis. They can aid in the pre-implementation analysis of a proposed mobile source emission reduction strategy and provide the planner with a baseline from which to gauge the impact of a mobile source emission reduction strategy on the transportation network.

If a transportation demand model is not available for the nonattainment area, then the data collection process may be more difficult because the needed data may need to be collected from multiple sources.

MOBILE6 is the emission factor model used in Texas

Emission factor models estimate emission rates based on vehicle type, average speed, ambient temperature, fuel, maintenance, and vehicle age. In Texas, MOBILE6 is the model used. It is described in greater detail in Section 5.0. Inputs used in the model that can be of importance to mobile source emission reduction strategy analysis are:

- Average vehicle speeds by vehicle class,
- VMT by vehicle class,
- Vehicle age distributions, and
- Ambient temperature.

Existing air monitoring data can be used to assess mobile source emission reduction strategy effectiveness; however, *aspects of the monitoring system make it difficult to separate out the effects of any single* mobile source emission reduction strategy. Planners should strive to isolate the effect of the mobile source emission reduction strategy to the fullest extent possible, regardless of the difficulty of doing so.

In order to obtain the most accurate estimate of mobile source emission reduction strategy effectiveness for a specific region, data specific to that region must be used. Variables such as regional VMT, trips per person, and regional trips by mode will vary based upon the characteristics of the region itself. This includes the availability of differing transit modes, land use patterns and geographic characteristics of the area, and socio-economic characteristics. Mobile source emission reduction strategy–related travel, VMT, and mobile source emissions changes will vary according to these characteristics. If local data are not used, then the reviewing agencies may require justification of the utilized data.

Texas Department of Transportation (TxDOT)

TxDOT, through district offices and the Transportation Planning and Programming Division (TPP) in Austin, can provide most of the available data on the regional roadway system. Engineers and professionals in these offices can provide the expertise regarding any aspect of the system in a nonattainment area. TxDOT performs a regular program of traffic counts and highway performance in all districts within the state. The most recent data from these analyses are an excellent place to start gathering needed data.

TxDOT is a rich source of transportation data for an area

TPP performs annual statewide system traffic counts, urban area saturation counts on a five-year cycle for all 25 urban areas, vehicle classifications, and automated traffic recordings (ATRs) used for annual, seasonal, daily, and hourly traffic analysis.

Urban area travel surveys are conducted including individual surveys for households, workplaces, special traffic generators, external traffic, travel times, vehicle operating characteristics, and onboard transit. Travel demand models are calibrated, validated, and applied for each of 25 urban study areas to provide traffic assignment data for alternative transportation system scenarios and long-range plan updates. Special studies are conducted for HOV projects, TIP and long-range plan (LRP) air quality conformity analysis, and on-road mobile source emissions analysis used for Urban Airshed Modeling.

MPOs in a near or new nonattainment area should already have an established relationship with TPP through efforts on the TIP and LRP development.

Texas Commission on Environmental Quality (TCEQ)

Environmental data that are not confidential are available from TCEQ databases. TCEQ is responsible for developing the SIP, defining air quality modeling parameters, and developing control strategies to reduce air pollution.

TCEQ conducts air monitoring to facilitate meeting federal and state mandates. Using data collected at monitoring sites, the agency determines whether areas in Texas meet federal air quality standards for the criteria pollutants. Air monitoring data are available on the TCEQ website.

The TCEQ Monitoring Operations Division collects information around the state on meteorological conditions and levels of ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, respirable particulate matter, lead, hydrogen sulfide, and volatile organic compounds (VOCs). These data are available electronically and in hard copy through the Data Management Section. The most current information available is on the TCEQ website.

UNITED STATES CENSUS BUREAU

The U.S. Census Bureau can provide data on freight movement and vehicle fleet characteristics through its Census Transportation Planning Package (CTPP). It is a set of 12 CD-ROM discs with special tabulations of place-of-work and transportation data focused on the data needs of transportation officials. Census data can provide demographic information for a region.

FIELD DATA COLLECTION

If available sources cannot provide the comprehensive data required to analyze an individual mobile source emission reduction strategy, local agencies may need to collect their own locally specific data for required variables. Depending on the mobile source emission reduction strategy, this process may entail traffic surveys, field surveys, home interviews for travel behavior, local business surveys, or parking surveys.

Small-scale field data collection by an agency can be low cost and effective

For example, parking lot utilization rates in areas with implemented parking management programs may require a planner to physically observe the lot(s) before and after implementation in order to deduce utilization rates. Data from the regional travel demand model or traffic analysis by TxDOT do not provide parking data of a quality high enough for analysis of the measure. The local agency must collect it.

The cost of large-scale data collection and the resources and man-hours needed to conduct it successfully must be considered by the agency. Traffic surveys or air monitoring in corridors can be both time consuming and expensive. National Cooperative Highway Research Program (NCHRP) Project 8-33 determined that a specialized advanced monitoring program for ozone, requiring two 13-week periods of study, would cost $1.3 million.

This guide's emission calculations rely on factor variables (F_x) in the equations presented in Part B for individual mobile source emission reduction strategies to narrow the scope or effect to subsets of a group. These may require field collection to obtain the travel impact of the measure. For example, the number of commuters that have shifted to rideshare or transit as part of an employer-based program can be inferred from traffic count or transit ridership data, but concluding that the cause is the specific mobile source emission reduction strategy requires surveys by the agency of the businesses involved or individual commuters.

PROFESSIONAL JUDGMENT

If no data can be found, collected, or inferred from existing data, transportation planners may rely on their professional judgment to determine values of factors used in determining mobile source emission reduction strategy effectiveness. This method should be used only as a last resort. To receive credit for a TCM in a SIP, review agencies expect that documentation accurately reflect quantifiable benefits of the measure. The best method to achieve that is locally specific data of a high quality collected through scientific means. An individual transportation professional may be correct in his assumption as to the value assigned to a variable, but the assumption must be based on verifiable methods. This is difficult to do, even with decades of experience.

Using professional judgment is tempting when analyzing mobile source emission reduction strategies since there is no universally accepted method of analysis for the measures. Furthermore, it is very hard to gauge the effectiveness of an individual mobile source emission reduction strategy at a regional level within an emission program using several mobile source emission reduction strategies. Despite the accumulated wisdom of many transportation professionals in the field, verifiable quantitative data should be utilized whenever possible.

Sources

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10.0 ANALYSIS TOOLS AND TECHNIQUES

Section Objective

This section provides the reader with a general understanding of the basic elements for project analysis. The terms "on model" and "off model" are defined for the reader. This is followed by descriptions of general analysis steps for three broad MOSERS types. The section concludes with a discussion of available analysis tools.

Transportation projects are analyzed for engineering, economic, safety, and operational impacts, among other aspects. The method of analysis can vary widely. Understanding the inputs, assumptions, and calculations from these methods or tools is required before accepting the results given to the analyst.

While many methods have been developed, as shown below, the ability of practitioners to successfully analyze mobile source emission reduction strategies still relies heavily on the assumptions that go into the analysis. The data limitations regarding cost-effectiveness and difficulties associated with identifying the "true" costs and benefits make this process even more complex. The effectiveness of mobile source emission reduction strategy activities is often small relative to the size and complexity of a community's transportation network. It often takes a number of mobile source emission reduction strategies working in tandem to produce a synergy necessary to see the cumulative effects of such strategies. It also takes creativity in developing new approaches such as parking cash-out, carsharing, or pay at the pump insurance. Currently, there is a need for more pre- and post-analysis to determine how effective mobile source emission reduction strategies can be.

ON MODEL VERSUS OFF MODEL: AREN'T BOTH MODELED?

Transportation/air quality analysis typically refers to two types of analyses: on model and off model. *On model* refers to those projects whose travel effects can be quantified using travel demand model networks and other methods. For those projects that cannot be adequately represented within a travel demand model, *off-model* techniques are used.

MOSERS are quantified using off-model techniques while using on-model sources for data

Off-model techniques vary widely. Some techniques are as simple as "back of the envelope" calculations, whereas others are in the form of computer interfaces using a set of generalized equations.

GENERAL METHOD (UNDERSTANDING THE BIG BLOCKS)

A simplified approach to mobile source emission reduction strategy analysis does exist. Though models and equations may process inputs differently, their approach is very similar. Mobile source emission reduction strategy analysis can be broken down into several general steps, in which various relationships may define the result. The four analysis blocks are shown in Figure 10.1.

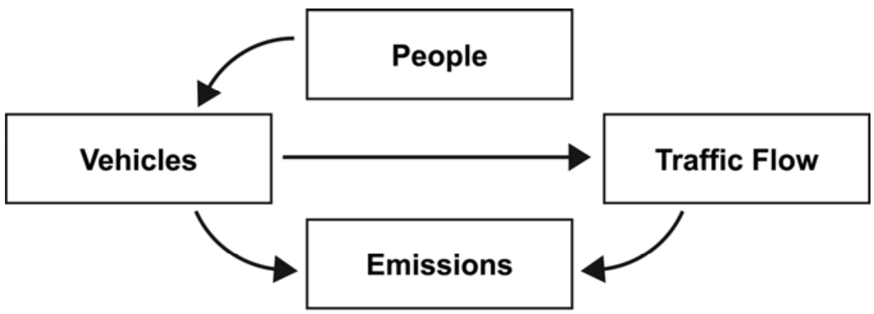

Figure 10.1 Analysis Blocks

People refers to the population that is affected by the project. This may be as small as an office building or as large as regional participation in a specific program. This analysis block can be expressed as person trips, mode share, travel time, and trip ends.

Vehicles refers to the activity people conduct with their personal mode of transportation. This can be vehicle trips, peak vehicle trips, vehicle miles traveled, and engine starts.

Traffic flow refers to how the participants' mode of travel is improved. This can be a change in overall travel speed, regional speed, or corridor speed, as well as reduced numbers of vehicle accelerations and idling times.

Finally, *emissions* refers to how pollutants from the personal mode of transportation are affected. In most cases, differences between before and after emission rates are used to determine benefits. Comprehensive emissions assessments include running, evaporative, crankcase, engine start, and diurnal emissions.

Emission factors for each component are provided by EPA's MOBILE6 emission factor model, used outside of California. California uses the EMFAC emission model. EMFAC is maintained by the California Air Resources Board (CARB).

The MPO and/or TCEQ develop emission factors. These factors reflect daily temperatures, vehicle mix and age distribution, fuel characteristics, inspection and maintenance (I/M) programs, and other factors representative for the local area.

TRIP BEHAVIOR MODIFICATION STRATEGIES

For TDM projects whose goal is to modify travel behaviors, the following generalized steps may be used.

First, the project scope (physical limits, use, and participants) must be defined. This is a critical step to the overall process. Though some TDMs will require inputs readily available, others will require some assumptions. Assumptions may be developed from survey data, experiences from other similar areas, or use of mode choice models. These assumptions should be well documented and reviewed periodically to ensure that they are reasonable. This should result in the number of person trips affected.

Second, the person trips are transformed into vehicle trips. This can be done by dividing person trips by an appropriate regional or corridor average vehicle occupancy (AVO). If employer-based strategies are used, an AVO specific to that center would be preferable to regional or corridor averages.

Third, the vehicle trips are applied over a certain length to yield changes in VMT. Again, regional or corridor average trip lengths can be used, but preference should be given to data that are as project level as possible.

Fourth, changes in speed (project level or regionally) are determined. Speed changes may be determined using elasticity.

Elasticity states how a percent change in an input variable affects a percent change in an output variable. They are developed through direct observation or from results obtained by an approved mode choice model. Elasticity is generally not valid outside the range of values developed for them, nor applicable between different regions.

The travel results are then used with emission factors derived from MOBILE6. Trip end emissions and VMT-related emissions are calculated from steps two through four.

SYSTEM IMPROVEMENT STRATEGIES

The focus of these project types is to optimize the flow within the transportation system given the current and future travel demand on it. Examples of these projects include HOV lanes, freeway ramp metering, and traffic signal coordination. These projects seek to directly affect local, corridor, or regional travel speeds by reducing delays and smoothing vehicle accelerations. Hard vehicle accelerations can increase emission rates for certain pollutants by 10 times normal running emission rates.

First, the project scope is defined by determining the number of vehicles (volume or ADT) impacted by the strategy. These data can be gathered from the field directly through observation or by consulting local or state traffic databases for current volumes.

Second, determine changes in system performance measures such as average speed or delay, a surrogate for idling time, through traffic simulation software or other sketch-planning methods. Only in rare cases should professional estimates be used to determine travel impacts. In these cases, justification of the estimate should be provided to the reviewing agencies and included in the documentation.

Third, the system performance changes are translated into emission changes using MOBILE. Before and after emission rates for corresponding before and after speeds are applied to the project scope to determine the daily emission benefits.

VEHICLE/FUEL TECHNOLOGY STRATEGIES

Projects founded in modifications to vehicles or fuels for cleaner burning engines, fuels, or systems directly affect the base emissions rate. An example of a project fitting this strategy is alternative-fuel vehicles. These projects do not seek to modify either travel behavior or system performance; instead, they seek to alter the fleet emission characteristics by lowering overall emission rates.

Vehicle or fuel technology projects simply require a scope and the change in emission rates. The scope is then applied to the difference in emission rates from before and after the project implementation.

PROJECT RANKING CRITERIA

The appropriate selection of transportation projects is always an important task. When comparing TDM-type strategies, several ranking criteria may be used. Depending on regional priorities, these criteria can be weighted to choose the most appropriate projects. Prioritization can be consolidated in major categories or composed of subcategories with unique weighting.

Consider the following examples that demonstrate the differences.

Example 1: Major Criteria-Only Project Evaluation System

	Points
Criteria 1	40
Criteria 2	30
Criteria 3	30
TOTAL	100

Example 2: Stratified Project Evaluation System

		Points	
Criteria 1			40
	Subcriteria 1-1	20	
	Subcriteria 1-2	60	
	Subcriteria 1-3	20	
	Subtotal	*100*	
Criteria 2			30
Criteria 3			30
	Subcriteria 3-1	70	
	Subcriteria 3-2	30	
	Subtotal	*100*	
TOTAL			100

Travel Impacts

Travel impacts refer to how the project changes person trips, vehicle trips, VMT, or speeds. Each of the travel impacts affects total mobile source emissions; some impacts are greater than others. If a region's goal is to significantly reduce starting emissions, then changes in person trips or vehicle trips should have higher weight assignments. If the region's goal is to minimize efforts to modify travel behavior and instead improve the transportation network performance, then changes in behavior or speeds will be more significant.

Emission Impacts

Emission impacts refer to how the project will reduce CO, VOC, NO_x or PM and whether it addresses hot spots or not (for CO only). Emphasis should be placed on pollutants of interest to regional air quality attainment. In many nonattainment areas, the focus of control plans is to manage and reduce the amounts of VOC and NO_x produced by transportation facilities. In these cases, significant weighting should be assigned to each.

Local Participation/Funding

Local participation/funding is important if local jurisdictions are willing to partially fund a project. Local participation in a proposed project demonstrates additional support and need for advancement. These projects may be less likely to be postponed to later analysis years when accommodating the accelerated funding and implementation for regionally significant projects.

Accelerated Implementation

Accelerated implementation is important for areas seeking rapid deployment of air quality strategies to reach attainment status or help to prevent reclassification to worse nonattainment status. Accelerated implementation refers to projects that will be operational within 2 years of adoption into the TIP.

Cost-Effectiveness

Cost-effectiveness can be an additional criterion by which projects are ranked and selected. This should be expressed as dollars spent (implementation and operating) per pound of pollutant reduced. California assesses cost-effectiveness for the total pollutant reduction (total organic gases [ROG] + NO_x + PM 10) as opposed to cost-effectiveness for each individual pollutant.

Project costs are amortized over the expected life of the project given a discount rate. The amortization formula yields a capital recovery factor, which, when multiplied by the funding, gives the annual funding for the project over its expected lifetime. The discount rate reflects the opportunity cost of public funds for the clean air programs. This is the level of earning that could be reasonably expected by investing public funds in various financial instruments, such as United States Treasury securities. Cost-effectiveness is calculated by dividing the annualized funds by annual emission reductions.

$$\text{Capital Recovery Factor (CRF)} = \frac{(1+i)^n\ (i)}{(1+i)^n - 1}$$

where i = discount rate
n = project life

$$\text{Cost-Effectiveness} = \frac{(\text{CRF} * \text{Funding})}{(\text{ROG} + NO_x + \text{PM } 10)}$$

SUMMARY OF PROCESS FRAMEWORK

The analytical process using three strategies is summarized graphically in Figure 10.2, excluding cost-effectiveness and project ranking.

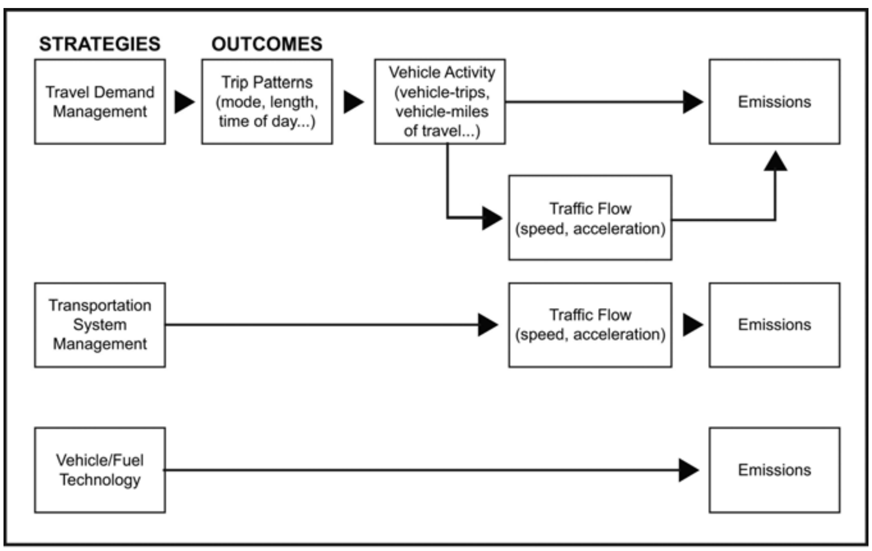

Figure 10.2 Off-Model Analysis Flow Chart

Regional Travel Demand Models

A standard tool for transportation modeling in regional transportation planning is the travel demand model. The travel demand model for a region is composed of many smaller traffic analysis zones and a transportation structure or network connecting each of the zones. Travel demand models do not provide a local street level of detail and are focused on a more homogenous area. Many factors characterize the transportation network. These factors include the monetary cost and availability (time) of travel by mode between each pair of traffic analysis zones. The model's future conditions are a function of the proposed transportation network given demands from forecasted population and employment characteristics for each traffic analysis zone. The model calculations are powered by travel survey data, which are used to predict trip generation by type in each traffic analysis zone, how these trips are distributed, which modes of travel are used, and what paths each trip takes in the network. This is also referred to as the "four-step" modeling process of trip generation, trip distribution, mode choice, and trip assignment.

Advantages

Travel demand models are good tools for estimating the impacts of large-scale projects that can be translated to the model's transportation network, but are weak for estimating small-scale projects at a local level. Because of the regional nature of the travel demand model, changes in VMT and speeds are identified across the entire transportation network.

The use of regional travel demand models may be better received by reviewing agencies. Reviewers typically have a higher confidence in the results obtained from the travel demand models because they are more familiar with its analysis concepts (four-step process). MPOs invest a great deal of staff time and data collection efforts toward the regional travel demand model. In addition, validation and calibration processes are performed on these models.

The models are also dynamic. For this reason, vehicle demand is redistributed on the transportation network as projects are evaluated. Redistribution better simulates traveler decisions made based on rate and cost (monetary and time) of travel. Redistribution may also impact other projects on the transportation network, which can then be evaluated simultaneously for any adverse impacts or lessened credits.

Table 10.1 Strategies for Representing MOSERS in Travel Demand Models

Control Measure	Strategy
Area-wide rideshare incentives	•Increase time due to meeting pool members at park-and-ride lot or other locations. •Reduce time and cost due to HOV use and ridesharing. •Reduce access time at destination to represent preferential parking. •Change auto occupancy.
Area-wide employer trip-reduction strategies	•Reduce the number of vehicle trips by traffic analysis zone (TAZ).
Improved public transit	•Reduce transit travel time and/or wait time. •Reduce transit passenger cost. •Change transit network to reflect improvements in service.
High-occupancy vehicle lanes	•Recode the network with HOV links parallel to existing links. •Reduce travel time and cost for rideshare vehicles between zones connected by HOV lanes.
Parking management	•Increase parking costs. •Increase link capacity and speeds to reflect parking restraints or reduce travel time and cost for nonscheduled road users. •Increase access (walk) time at destination to represent parking restraints.
Bicycle and pedestrian programs	•Reduce trip generation rates for shorter trips.
Vehicle use limitations/ restrictions	•Set infinitely high impedance values for specific links, or delete links from the network. •Reduce the number of vehicle trips by TAZ
Traffic flow improvements	•Adjust travel times, turn penalties, parking, and capacities for individual links and nodes.

The travel demand model generates a wealth of information. Even if the regional travel demand model is not used to evaluate benefits of mobile source emission reduction strategies, a variety of data can be mined for use in other analysis tools. For example, average trip lengths or the number of trips made in peak/off-peak periods can be derived from trip tables and network data.

The mode choice model, an integral part of the regional travel demand model, can be used independently of the travel demand model to evaluate some mobile source emission reduction strategies.

If the regional travel demand model has met approval from reviewing and oversight agencies, few problems during conformity determinations or SIP review would be expected.

Disadvantages

Travel demand models have a limited application to only a few mobile source emission reduction strategy–type projects. These models have difficultly assessing impacts from regional policies where travel is minimally affected at the zonal level, but where the aggregate benefits are measurable.

The model's scale may be too large to support mobile source emission reduction strategy evaluation in many cases. Travel demand models can study regional and corridor-level impacts of major infrastructure developments. In some cases, this geographic scale is too large to quantify the small benefits derived from projects.

Travel demand models generate speed estimates that represent the average traffic flow conditions on the links within the network. These speeds may be representative of field speeds in some cases. Because of the low confidence that speeds generated by the model are equivalent to field speeds associated with individual links, link speeds should not be used.

Travel demand models are not equipped to predict shifts in travel demand due to employer-based transportation management programs and similar programs initiated by the local government. Zonal changes are required for these types of strategies.

Use of the regional travel demand model for some mobile source emission reduction strategy projects can require a significant level of effort to develop the appropriate inputs to describe the project. Professional experience greatly reduces the time required to find or develop mobile source emission reduction strategy project inputs for use in the regional travel demand model.

Emission factors applied to model output outside the regional travel demand model use spreadsheets or other customized software. Some software programs (Post Processor for Air Quality [PPAQ] and Surface Transportation Efficiency Analysis Model [STEAM]) automate the processing of travel model outputs and emission factors.

Finally, travel demand models can produce errors of over 30 percent in link volumes and over 50 percent in link speeds. The magnitude of these errors greatly exceeds the magnitude of the travel impacts of most mobile source emission reduction strategies.

Travel Demand Model Post-Processors

These analysis tools take the information provided by the travel demand models in the form of trip tables and process the results outside of the travel demand model once the network scenario is modeled. They typically have interfaces to an emission factor model or have the emission factors coded into the program. Some tools also reconcile VMT between the regional travel demand models and the Highway Performance Monitoring System (HPMS).

Advantages

Post-processing tools can provide sound analysis methodologies directly to data generated from the regional travel demand model. Some post-processing tools can evaluate a variety of TDM projects. The capabilities of a post-processor are independent of other technologies used by other available post-processing tools.

Disadvantages

Not all post-processors estimate travel and emissions impacts. Some perform only one of the functions. The FHWA TDM Evaluation Model is an example of a post-processor which can estimate VMT impacts of TDM projects but does not have the capability to estimate emission changes from those projects. In this case, the analyst is required to use the TDM Evaluation Model results with trip-end and/or VMT-related emission factors in an additional post-processing procedure.

Use of post-processing tools requires experience with regional travel demand models. If staff members are not experienced with regional travel demand models, they should seek assistance from experienced modelers before proceeding with these tools.

Examples include:

- FHWA TDM Evaluation Model,
- FHWA STEAM,
- PAQONE, and
- PPAQ.

Traffic Simulation Models

Classified as either microscopic or macroscopic in nature, traffic simulation models are another available resource and are suited to analyze impacts of some mobile source emission reduction strategy projects. Because the model environment is physical in nature (lanes, intersections, traffic volumes, turning movements, etc.), these tools are not suited for evaluating projects influencing travel behavior. Table 10.2 shows some of the available traffic simulation models and the projects that they can be used to evaluate.

Advantages

These tools explicitly represent most traffic control devices (signals, stop signs, yield signs, etc.) without the use of surrogate measures to account for these controls. In contrast, travel demand models cannot directly evaluate improvements of signal coordination in a corridor, but use surrogates (adjustments to travel time or link capacity) to model their impacts.

When properly calibrated, microsimulation tools can provide better estimates of traffic flow than travel demand models. In addition, the travel outputs generated by these tools are comparable to actual field measurements.

Microscopic models are able to estimate the speed profile of vehicles and idling time. In addition, they can provide indications of acceleration rates. Because of this, they can evaluate the impacts from changes in acceleration and idling. These are two impacts provided by traffic signal hardware and timing improvements.

Microsimulation tools can better represent the road network than travel demand models. Their use is best for arterial streets and freeway sections. The tools can often account for vehicle interactions in merge and weaving areas, as well as along arterial streets as vehicles accelerate and decelerate.

Some microsimulation tools produce speed and acceleration results. Some models incorporate emission factors that can be used with the travel output. In these cases, traffic flow improvement projects might be better evaluated for their travel and emission projects.

Table 10.2 MOSERS Analyzed by Traffic Simulation Models

Control Measure	CORFLO	INTRAS	FREQ	NETSIM	PASSER II	PASSER III	TRANSYT-7F
Intersection Signal Improvements	No	No	No	Yes	Yes	DMD	Yes
Arterial Signal Improvements	Yes	No	No	Yes	Yes	No	Yes
Area Signal Improvements	Yes	No	No	Yes	No	No	Yes
Eliminate Unnecessary Controls	CRDR	No	No	ARTL	No	No	No
Restriping to Increase Lanes	CRDR	FWY	FWY	ARTL	ARTL	No	ARTL
One-Way Streets	Yes	No	No	Yes	Yes	No	Yes
Turn Lane Installation	CRDR	FWY	FWY	ARTL	ARTL	DMD	ARTL
Turning Movement Restrictions	Yes	No	No	Yes	Yes	DMD	Yes
Reversible Traffic Lanes	CRDR	FWY	FWY	ARTL	ARTL	No	ARTL
Intersection Widening	No	No	No	No	No	No	No
Road Widening	CRDR	FWY	FWY	ARTL	ARTL	DMD	ARTL
Improved Traffic Control Devices	CRDR	FWY	FWY	ARTL	SIG	SIG	SIG
Grade Separation	Yes	No	No	Yes	No	No	Yes
Incident Detection and Management Systems	No	Yes	No	No	No	No	No
Lane Use Restrictions by Vehicle Type	No	FWY	No	ARTL	No	No	No
Freeway Diversion and Advisory Signing	No	No	No	No	No	No	No
Ramp Metering	No	Yes	Yes	No	No	No	No
Integrated Surveillance and Control	No	No	No	No	No	No	No
Parking Restriction	Yes	No	No	Yes	Yes	No	Yes
Motorist Advisory	No	No	No	No	No	No	No
Peak-Period Pricing	No	No	No	No	No	No	No

Disadvantages

Microsimulation tools are limited to evaluating the range of traffic flow improvement projects and a limited number of market-based strategies. In addition, there is no single microsimulation tool that can evaluate all of the project types that can be evaluated by simulation tools.

Traffic simulation tools are not responsive to shifts in travel demand. They use traffic volumes supplied by the user but cannot forecast changes in demand within the network because of other network changes. These tools also lack a mode choice model and mechanisms for distributing trips on the network.

Some tools are not equipped with an emissions estimation module and require post-analysis to estimate changes in trip-end emissions, start emissions, and diurnal emissions. Even if a specific tool does provide a method for estimating emissions, a good understanding of the base emission rates and application are required to accurately interpret the results. They may not reflect the regional characteristics or VMT and vehicle fleet mixtures.

For network tools, a considerable amount of calibration is required to obtain reasonable estimates of traffic variables and thus emissions. For example, FRESIM has nearly 20 embedded parameters that the user can change to calibrate the model to local conditions. Calibration is among the more difficult tasks in any modeling effort.

Some simulation packages include vehicle emission factors. These emission factors may require adjustment to represent local conditions. A thorough review of the program's internal emission factor data is required prior to any adjustments. This ensures that analysis staff is aware of the nature of the emission factors and their use within the package before making adjustments that may not be appropriate.

Examples

Microscopic tools include:

- PASSER,
- TRANSYT,
- FREQ, and
- SYNCHRO.

Macroscopic tools include:

- CORFLO and
- NETSIM.

Off-Network Analyses or Sketch-Planning Tools

These tools entail a more formal process than use of empirical comparisons. They typically estimate travel and emission impacts from a variety of MOSERS types. They are best at estimating gross impacts of projects. In contrast to previous tools, these techniques are not validated or calibrated and are less rigorous in nature. Few regions evaluate the accuracy of these techniques through comparisons of before and after studies. These tools typically use regional travel data generated through the travel demand modeling process or other means in conjunction with the characteristics of the mobile source emission reduction strategy to estimate regional emission impacts.

Advantages

In most cases, sketch-planning tools are easy to use. They do not require a great deal of training to operate or use, in contrast to regional travel demand models. Data are supplied to the tools, and then the tools generate output.

Some sketch-planning tools attempt to segregate impacts to work and nonwork trips and by the peak and off-peak periods. Unlike the travel demand models, these tools chain trips together for defining the trip purpose. This is a more accurate representation of the true purpose of a trip, such as a work trip with one or more intermediate stops before reaching the final destination. Therefore, differences will exist between regional travel demand model trip tables and the trips used by these tools.

Once foundation data are input for use, many projects can be evaluated sequentially, or staff may experiment with project scopes to determine desired levels of effectiveness. The ability to analyze several projects in a rapid fashion allows MPO staff to quickly process many projects in a short amount of analysis time.

Disadvantages

Agency reviewers may perceive the use of these tools as a black box if sufficient documentation is not provided or if they lack experience using and judging the tools' results. Care should also be taken by

MPO staff using these tools so that they fully understand how the data are used and what the results indicate.

Some tools can require extensive data collection from the travel demand model and various other sources. This may require a majority of the total analysis effort. Data from a variety of sources including the census and regional travel demand model are required. Mining or transforming surrogate data into the proper input data can be labor intensive.

If data for these tools are not available, staff may rely on the use of assumptions to complete the analysis. If assumptions are used, they should be clearly indicated or summarized for the reviewing agency. If the assumptions are not referenced from other documents where values were used, then sufficient justification should be provided for the reviewing agency to determine if the assumption is acceptable or not.

For some mobile source emission reduction strategy projects, planning assumptions regarding the scope of the project in mobile source emission reduction strategies of vehicle trip, VMT, and speed changes must be made. These assumptions are typically made for supply management projects in lieu of simulating the effects. Again, reasonable assumptions should be made and well documented.

Examples are

- TCM Tools,
- TCM Analyst,
- DRCOG CM/AQ Evaluation Model,
- Texas Transportation Institute (TTI) CM/AQ Evaluation Model,
- FHWA Southern Resource Center Off-Model Analysis Techniques, and
- FHWA Sketch-Planning Analysis Spreadsheet model (SPASM).

Empirical Comparisons

This is one of the simplest methods for estimating the emission impacts of mobile source emission reduction strategy projects. It is also one of the least precise and least accurate methods. Planners use experiences from other similar areas to estimate the impacts in one's own area. This analysis method was suggested in *A Manual of Transportation-Air Quality Modeling for Metropolitan Planning Organizations*.

Advantages

This is the simplest approach for estimating travel and emission impacts of mobile source emission reduction strategy–type projects. Project scopes and their results might be proportionately scaled up or down to fit a region's planned project. Extreme care must be given to the appropriate application of this approach to extremely similar cases and areas so that comparable results can be expected.

The empirical data must be stringently evaluated for accuracy and reliability. Mobile source emission reduction strategy impacts are difficult or impossible to measure directly and require other ways to collect or estimate the data. A good understanding of how a project's results were calculated is required so that the results may be correctly applied to a new region.

Disadvantages

Generally, there is a lack of available before and after data to evaluate mobile source emission reduction strategy impacts. Though regions may validate their mobile source emission reduction strategy impacts, this information is difficult to find and obtain because it is not widely available through technical information services.

Considerable staff time can be invested to investigate the results of similar projects under consideration. Although information on reasons for a project's success or failure is invaluable and can be applied across geographic boundaries, the results of the projects themselves are less applicable, unless many of the characteristics between the regions are similar.

Interagency consultation partners are least likely to accept benefits from this approach. The success or failure of a mobile source emission reduction strategy is dependent on many local factors: area size, demographics, available infrastructure, and land use patterns. Therefore, rigorous approaches are more likely to be required for acceptance by federal and state reviewing agencies.

Benefits of Standardized Analysis Methods

A variety of simulation tools are required to evaluate a typical range of strategies selected for a region. As demonstrated in this section, no single analysis tool can successfully evaluate all mobile source emission reduction strategy project types. As a result, a region or state may elect to adopt a standardized set of analysis methods.

Standardization provides several benefits. First, reviewing agencies become familiar with these methods. As a result, review of off-model analyses can be expedited. Fewer questions of estimated emission benefits may be raised during review. Second, inter-regional comparisons can be made. In particular, reviewing agencies may desire to compare assumptions. In many cases, these planning assumptions significantly impact the estimated emissions benefits. Though not required during formal review, MPOs or the state could review project cost-effectiveness. Suggested projects might then be developed by maximizing the cost-effectiveness under fiscally constrained transportation plans. Finally, generalizations regarding mobile source emission reduction strategies can be made once a significant number of projects are evaluated in a like manner.

Sources

Cambridge Systematics, Inc., *A Sampling of Emissions Analysis Techniques for Transportation Control Measures,* Federal Highway Administration, Washington, D.C., October 2000.

Cambridge Systematics, Inc., *Transportation Control Measure Information Document*, Report No. 400-R-92-006, Office of Mobile Sources, United States Environmental Protection Agency, Washington, D.C., March 1992.

Eisinger, D. S., et al., *Transportation Control Measures: State Implementation Plan Guidance,* prepared for United States Environmental Protection Agency, Washington, D.C., September 1990, cited in Knapp, Keith K., Rao, K. S., Crawford, Jason A., and Krammes, Raymond A., *The Use and Evaluation of Transportation Control Measures,* Report No. FHWA/TX-94/1279-6, Texas Transportation Institute, College Station, Texas 1994.

Harvey, G., et al., *A Manual of Transportation-Air Quality Modeling for Metropolitan Planning Organizations*, developed for National Association of Regional Councils, Washington, D.C., November 1992, cited in Knapp, Keith K., Rao, K. S., Crawford, Jason A., and Krammes, Raymond A., *The Use and Evaluation of Transportation Control Measures,* Report No. FHWA/TX-94/1279-6, Texas Transportation Institute, College Station, Texas, 1994.

Knapp, Keith K., Rao, K. S., Crawford, Jason A., and Krammes, Raymond A., *The Use and Evaluation of Transportation Control Measures,* Report No. FHWA/TX-94/1279-6, Texas Transportation Institute, College Station, Texas, 1994.

Methods to Find the Cost Effectiveness of Funding Air Quality Projects: For Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation *and Air Quality Improvement (CMAQ) Projects,* California Air Resources Board and CalTrans, 1999 Ed.

TDM Case Studies and Commuter Testimonials, Transportation Demand Management Institute of the Association for Commerce Transportation, Washington, D.C., August 1997.

11.0 MOBILE SOURCE EMISSION REDUCTION STRATEGY DOCUMENTATION

Section Objective

This section provides guidance for documenting MOSERS. Features are identified that help create useful MOSERS documentation. A standard form is provided.

Good documentation of mobile source emission reduction strategies is crucial for gaining emission credit for submitted measures and conformity determination of the SIP. All off-model analysis documentation should be consistent throughout. Documentation might be provided in either electronic or hardcopy formats to the reviewing agencies. A standard documentation format should be followed to expedite the interagency consultation partner review for conformity determination.

Good documentation saves time and trouble with reviewing agencies

> The goal when creating MOSERS documentation should be to provide the same level of detail for all MOSERS with a consistent methodology used for each measure.

Planners must maintain data in such a way as to facilitate comparison of the planned and actual efficacy of the mobile source emission reduction strategies.

PROJECT DESCRIPTIONS AND BENEFITS

Good documentation of a TCM project should include:

- Project TIP ID,
- Project Name,
- Description (project limits/scope and objective);
- One small, descriptive paragraph about the project or measure and its relation to larger programs and scope, expected emissions benefits, and limitations;
- Project limits or scope;
- Specific location;
- Funding category;
- Responsible implementation agency;
- Letting date;
- Implementation date;
- Methodology used to derive the TCM project benefits;

- Analysis Tool – (description or note);
- Data sources;
- Assumptions and the basis for the assumptions;
- Documentation and references;
- Whether the methodology is nationally or locally derived;
- Detail of the equations or processes used to estimate benefits;
- Sample calculations for one inventoried like project;
- Documentation of spreadsheet (if used) equations through inclusion or hardcopy printouts;
- Procedures for obtaining and maintaining data;
- Expected benefits;
- Travel (trips removed, VMT removed/reduced, and speed improvements);
- Emissions (rate source, assumptions, trip-end emissions, and running emissions);
- Cost-effectiveness (life cycle or effective period, implementation, and operating costs);
- Major summary;
- Emission reduction;
- Total cost; and
- Annual cost per unit reduced.

SUMMARY DOCUMENTATION

There are currently no standard guidelines for summary documentation. A variety of tables can be generated to display project listings and the travel and emission benefits of those projects. A sampling of summary documentation is described below.

One area chose to summarize their TIP projects for conformity following the format in Figure 11.1.

Using this format, on-model and off-model projects are clearly separated for the reviewing agencies. Separating out how the analyses were conducted will allow the reviewing agency to check that modeled projects are ones that can actually be modeled. It also enables the reviewing agency to identify and verify that off-model analyses were performed correctly and that their benefits are accurately represented.

FY 2xxx TIP PROJECTS				
2xxx MODEL				
County	TIP#	Project/Facility	Limits	Improvement
Projects listed here				
2xxx OFF-MODEL				
County	TIP#	Project/Facility	Limits	Improvement
Projects listed here				

Figure 11.1 Sample Documentation Format

Cost-effectiveness summaries are also valuable. When used, these tables provide a broad overview of strategy benefits and costs. Many of the mobile source emission reduction strategy projects may be toward the top of the table and can vary in expense. Only a few projects will yield high emission benefits toward the bottom of the table.

Table 11.1 MOSERS Cost-Effectiveness Summary Table

Emissions Reduction	Revenue Producing	$0 – $49K per Ton	$50K – $99K per Ton	$100K – $249K per Ton	$250K – $499K per Ton	> $500 per Ton
< 0.5						
0.5 – 0.99						
1.0 – 1.49						
1.5 – 1.99						
2.0 – 2.49						
2.5 – 2.99						
3.0 – 3.49						
3.5 – 3.99						
4.0 – 4.49						
4.5 – 4.99						
5.0 – 5.49						
5.5 – 5.99						
≥ 6.0						

CONSISTENT LEVEL OF DETAIL

A complete, accurate description of units is required to avoid confusion during review. Review of off-model analysis documentation has revealed that slight mistakes in designating units are sometimes made. For example, when calculating annual VMT reductions from a project, one document identified the result as "annual miles." This prompted closer inspection of the analysis method to understand what the units actually meant and how the figure was derived.

Perform dimensional analysis checks on analysis steps as part of continued quality control. This quality control step can save valuable reviewing time and ensure that benefit estimates are accurate and calculated correctly. In rare cases, this is found to be a problem, but efforts should be made during the preparation of each document to minimize the effects of improper analysis.

The MPO should ensure consistency between the emissions evaluated in the travel demand model and off-model analyses. This is of concern for hydrocarbon emissions as precursors to ozone. Hydrocarbons can be reported several ways according to the type of interest. The most common usages are:

- Volatile organic compounds (VOCs),
- Hydrocarbons (HC),
- Total organic gases (TOG), and
- Reactive organic gases (ROG).

Some analysis tools may report hydrocarbon emission credits in one of these forms. There is no consistent method for reporting these types of emissions in analysis tools because there is no consistency among the states. In Texas, standard practice is to use VOC emissions.

In Texas, VOC is used to report hydrocarbons

The use of conservative assumptions is recommended. Including conservative assumptions during analysis will prevent a region from over-committing and failing to reach project goals. If the assumptions are applicable to other project types, then the assumption should be used. If the assumption varies, justification or proper referencing should be provided to the reviewing agency.

Conservative assumptions for project benefits are highly recommended

All factors used in the TCM analysis should be well documented. Proper and complete documentation will prevent any omissions that might confuse reviewing agencies. Omissions and lack of references are important keys used by reviewing agencies to request additional information, resulting in delays.

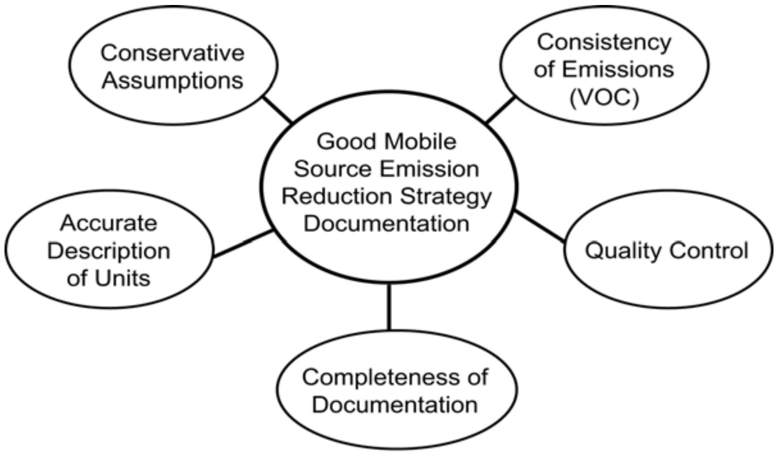

Figure 11.2 Components of Good Documentation

EXAMPLES OF DOCUMENTATION

TCM documentation is not consistent between nonattainment areas or states. There are several examples of good documentation practices found, and there are equally as many examples of poor documentation practices. Two examples are provided below to demonstrate differences in documentation practices. Both examples provide evidence of good and poor documentation. Deficiencies and comments on the documentation are highlighted in the examples by numbered notes on the side of the example

The first example shows all inputs and assumptions and makes good use of data and the equations used. It states the analysis calculations; however, no sources for data or calculations are provided. There is also a discrepancy between 250 days of use and the 365 days used to calculate the emissions reduction. The funding for the measure is provided since TCMs must have funding sources secured to be included in a SIP, although the funding source is not included. Operations and maintenance (O&M) costs are not included in the cost-effectiveness calculation. Finally, no dates for the project are given.

In example 2, no funding levels or cost-benefit analyses are provided. The documentation is not well organized, making it difficult to find key data. The calculations are difficult to follow.

Example 1: Off-Model Documentation

Traffic Signal Coordination ❶

The city's master traffic signal controller was replaced with a new controller with expanded capacity. This allowed 26 more intersections to be coordinated.

Inputs to Calculate Cost-Effectiveness:

Funding dollars (funding): $90,000 ❷
Effectiveness period (life): 5 years
Days of use/year (D): 250
Length of congested roadway segment (L): 8.07 miles
Traffic volume during congested period (congested traffic): 88,643 trips per day

Before speed: 28 mph ❸
After speed: 33 mph

Emissions Factor Inputs (from Table 4):

	Before Speed Factor	After Speed Factor
ROG Factor	0.51 grams per mile	0.43 grams per mile
NO_x Factor	1.14	1.13
PM 10 Factor	0	0

Calculations: ❹

Annual Project VMT (VMT) = (D) * (L) * (Congested Traffic)
=250 * 8.07 * 88,643 =
178,837,253 annual miles

Annual Emission Reductions (ROG, NO_x, and PM 10) in lb. per year

= [(0.50) * (VMT) * (Bef Speed Fctr – Aft Speed Fctr)]/454 grams per lb.

Note: Initial speed improvements decline to zero improvement by the end of the effectiveness period. In order to account for this, the emission reduction equation reduces initial emission reduction benefits by one half.

ROG: [(0.50) * (178,837,253) * (0.51 – 0.43)]/454 = **15,757 lb. per year**
NO_x: [(0.50) * (178,837,253) * (1.14 – 1.13)]/454 = **1,970 lb. per year**
PM 10: [(0.50) * (178,837,253) * (0 – 0)]/454 = **0 lb. per year**

Capital Recovery Factor (CRF)

= [$(1 + i)^n$ (i)] / [$(1 + i)^n$] – 1 = 0.23,
where n = project life (5 years) and i = discount rate (5 percent)

Cost-Effectiveness of Funding Dollars ❺

= (CRF * Funding)/(ROG + NO_x + PM 10) =
[0.23 * 90,000] / 17,727 **=**
$1 per lb.

FOR CMAQ PROJECTS ONLY:

Once emissions reductions have been calculated, add them together (15,727 + 1,970 = 17,727) and convert emissions reductions to kg/day:
= lb. reduced per year / (2.2 lb./kg * 365 days/year)
= 17,727 / (2.2 * 365)
= **22 kg/day**

❶ No dates

❷ No funding category

❸ No sources for volume or speed

❹ Good use of equations and data below

❺ O&M costs not included

Example 2: Off-Model Documentation

DESCRIPTION: 41 intersections with fiber optic cable installed. ❶

❷

Project will reduce the travel time for trips within the district and also help reduce delays during diversion route strategies. This project is for arterials in the city of Birmingham. Emissions reductions for air quality includes project (5) City Center Congestion Management Plan.

Vehicle miles traveled along those routes are 415.340 vehicle miles per day.

❸

Average delay reductions per mile are 46 seconds/vehicle for en route drive information, respectively, during peak hour periods.
(Source: Phase I report, Congestion Management System/IVHS Program Study for Birmingham, Alabama, by Parsons Brinkerhoff Quade and Douglas, Inc., April 1995)

❹

Idling emission rate for delay is based on Mobile 5.0 in year 1998.

HC & NO_x Worksheet for (12):

❺

Criteria & Assumptions* ❻

Description	Assumption	Note
Total vehicle miles in locations	415,340	No
Peak hours period	2.0	hours
Avg. delay reductions per veh.-mile for en route drive inform.	46.0	seconds/veh.
HC idling emission rate	62.81	grams/hour (1998)
NO_x idling emission rate at	11.26	grams/hour (1998)

Methodology ❼

E = D × VMT × Eri where

E = HC or NO_x emissions reductions in grams per day
VMT = VT × L
D = delay reductions per vehicle mile during peak hours
ERi = idling emissions rate

Result

Item	Reduction	Note
HC reduction = Delay × ERi = (46)/3600 × 415340 × (0,1x2) × 62.814	66,672	grams
NO_x reduction = (E by Bike) + (E by Ped) =(46)/3600 × 415340 × (0.1x2) × 11.26	10,393	grams/d
VMT Reductions =	0	vehicle miles/year

❶ No dates

❷ Good description, but no funding given

❸ No source

❹ Good source

❺ No project life

❻ No days/year

❼ Lack of proper unit conversion

FIELD EVALUATIONS FOR VALIDATION

It is extremely important that strong consideration be given to documenting the actual impacts of mobile source emission reduction strategy projects. For many TDM programs, data are limited on the actual changes to travel impacts, given costs of the programs. For evaluation methods to become more accurate, data of this nature are required so that refinements to the analysis techniques may be made.

Careful planning should be directed at validating mobile source emission reduction strategy inputs. Doing so ensures that project scope and other planning assumptions, from which emission credits are derived, are verified for the given credit applied to emission budgets.

STANDARD MOBILE SOURCE EMISSION REDUCTION STRATEGY DOCUMENTATION FORM

On the next page, a sample mobile source emission reduction strategy documentation form is provided. The form allows for adequate description, quantification, and documentation of mobile source emission reduction strategy projects. The space used for each section can be expanded as needed. By standardizing documentation, interagency consultation will be more efficient and SIP and conformity decisions expedited.

Expected MOSERS Documentation Elements

Mobile Source Emission Reduction Strategy Documentation

Project TIP ID:

Project name:

Description (objective):____
____

Project limits or scope (specific location or locations):___________________

Funding Category:

Implementation agency: ______________________
Letting date: ________________________________
Implementation date: ________________________

Project Benefits Methodology:

Analysis tool:

Is the methodology national or locally derived?

Inputs and sources/assumptions and their basis:

Procedures for obtaining and maintaining data (brief description):

Equations or processes used to estimate benefits (travel, emissions):

Sample calculations for one inventoried like project:

Other documentation and references (include or attach documentation of spreadsheet equations, if used):

Expected Benefits:

Travel (vehicle trips removed, VMT removed/reduced, speed improvements, delay reduction):
Emissions (rate source, assumptions, trip end emissions, running emissions):
Cost-effectiveness (life cycle or effective period, implementation and operating costs):

Major Summary:

Emission reduction (lb./day or tons/day) (kg/day — CMAQ):
Total cost:
Annual cost per unit reduced ($/ton):

1.0 INTRODUCTION

Part A of the guide introduced accepted mobile source emission reduction strategies. They were placed in historical context and beside current transportation/air quality policy and issues. The reader should now have a firm, basic knowledge of mobile source emission reduction strategies and their place within air quality planning.

This part of the guide describes the individual mobile source emission reduction strategies (MOSERS) in greater detail. All 16 1990 Clean Air Act Amendments (CAAA) emission reduction measures (eligible transportation control measures [TCMs]) are included along with three other categories of mobile source emission reduction strategies. Three CAAA measures that refer to bicycle and pedestrian programs are combined, as described in Part A. Each category of mobile source emission reduction strategies is introduced as a section and then subdivided into individual measures. The individual measures are described along with potential applications. An equation is then provided to derive the daily emission reduction of the strategy for analysis and reporting. Finally, the last sections consolidate the variables and individual equations for quick review or reference.

Each MOSERS is described and given potential applications

An equation is given for analysis of each strategy

The critical issue with mobile source emission reduction strategies stated earlier is the inability to evaluate their impacts using the traditional travel demand modeling process. Travel demand models, the primary tool of transportation planning, cannot assess specifics of small-scale projects such as intersection and signal improvements. Therefore, mobile source emission reduction strategies are evaluated "off model" and do not benefit from the many internal travel model features affecting volumes and speeds region-wide.

Part A of the guide discussed synergy between individual mobile source emission reduction strategies in a package of measures. Several measures within Part B are recommended for implementation in combination with others. This combining of measures makes it difficult to separate out the impacts of any single trip-reduction measure since the measures are not strictly additive due to their complementary nature.

Because federal and state agencies have not adopted one set of methodologies, each region has developed its own approach to evaluating mobile source emission reduction strategies priorities. These variations cause evaluation inconsistencies between regions and states. Evaluation of mobile source emission reduction strategies projects has been enhanced by post-processing software packages that estimate several measures and assess the likely effects of a particular project. Such models are designed to link directly to the traditional travel demand modeling process through trip tables. Unfortunately, software packages to estimate effects on travel activity or air quality do not exist for all mobile source emission reduction strategies, and regions must devise their own methods to evaluate these measures.

This section is an attempt to standardize mobile source emission reduction strategies analysis for transportation practitioners. Although there are software programs available to analyze mobile source emission reduction strategies, one of the purposes of this guide is to gain consensus with respect to mobile source emission reduction strategy documentation. Different software programs make different assumptions regarding the measures; emissions reductions in one program may not coincide with reductions in another. This guide does not recommend any TCM analysis software packages because they are considered to be cumbersome for the interagency review process during state implementation plan (SIP) revision. Therefore, sketch-planning techniques are used. They are the easiest to apply and provide a foundation on which to build more in-depth analysis of individual measures.

Part B is an attempt to standardize MOSERS analysis

Sketch planning technique is used for the equations

The equations presented for each measure in the guide should be considered only a beginning. They serve as a basis for conversations and discussions between the interagency review partners and the nonattainment areas regarding mobile source emission reduction strategy use. Also, the equations provide a starting point for near-nonattainment areas to utilize mobile source emission reduction strategies when formulating their emission reduction programs as part of a regionally coordinated prevention initiative.

2.0 SOURCES FOR INDIVIDUAL VARIABLES FOR MOSERS METHODOLOGIES

Many inputs are necessary to analyze and document the emissions benefits of MOSERS. Listed below are the input variables required to compute the emissions reduction benefit for the individual mobile source emission reduction strategies presented in this part of the guide.

Emphasized again, locally specific data should be the first preferred source for analysis. The most reliable results for estimating emission reduction benefits are derived from data that are specific to a nonattainment area. Section 9 of Part A discussed the various methods of data collection for estimating benefits. It is noted that locally specific data are not always available, but the initial intent of practitioners should be to seek out and/or gather data from their region before borrowing and applying data from other regions.

Local data are crucial for analysis and should be the first source searched

The primary goal of implementing the various strategies is to help attain the National Ambient Air Quality Standards (NAAQS) for the area. Practitioners will desire every emission reduction benefit that can be counted toward attainment. No one individual mobile source emission reduction strategy will solve a region's air quality problem. It is a combination of strategies that will work best in the situation. There is only so much benefit to be derived from a single strategy. Practitioners should not attribute through the individual variables more benefit than can realistically be derived. Unrealistic assumptions for the benefits of an individual strategy will, in all likelihood, be discovered by the review agencies. Therefore, conservative estimates should be used for the variables in the methodologies.

Use conservative, realistic assumptions

The input variables are listed below in alphabetical order by category. A description of potential sources for the variables is given within each category.

SCOPING INPUTS

Length and numbers are fairly easy to acquire although some variables such as number of participants in a strategy may require surveys of commuters or local businesses.

$\mathbf{HH}_{AREA}$ Number of households in strategy area

L Length of affected roadway (miles)

L_i	Length of each freeway affected by intelligent transportation systems (ITS) (miles)
N	Number of affected corridors
N_{BW}	Number of participants in bike/pedestrian programs
$N_{BW, SOV}$	Number of participants in bike/pedestrianPrograms who previously used single-occupancy vehicles (SOVs)
N_D	Number of days in the program
N_{DUi}	Number of development units by type
N_{HBO}	Average number of home-based other trips
N_{ND}	Number of people using the park-and-ride lot but not driving to it
N_{NW}	Average number of nonwork trips
N_{OPH}	Number of off-peak hours
N_P	Number of participants
N_{PH}	Number of peak hours (AM and/or PM)
N_{PK}	Number of spaces in parking lot
$N_{PK, A}$	Number of parking spaces allowed after implementation of control
$N_{PK, B}$	Number of parking spaces allowed before implementation of control
N_{PPK}	Number of preferential spaces in parking lot
$N_{PR, HOV}$	Number of high-occupancy vehicle (HOV) parking spaces at the park-and-ride facility
N_{RS}	Number of participants in rideshare programs
N_{RSt}	Average number of times the vehicle is restarted
N_T	Number of participants using transit facilities
N_{TR}	Number of new transit ridership
N_V	Number of vehicles
$N_{V, PRI}$	Number of HOVs using prioritized lane
N_{VA}	Number of vehicles after implementation
N_{VB}	Number of vehicles before implementation

Time can be easily computed and estimated from available data and field collection.

t_A	Time after implementation of strategy (hours)
t_B	Time before implementation of strategy (hours)
t_q	Average time spent in queue waiting to enter freeway (hours)

Fees for use of road facilities can be easily obtained.

FEE_A	Price for facility use after implementation of measure (decimal)
FEE_B	Price for facility use before implementation of measure (decimal)

Parking fee structure changes will require field collection through surveys of parking lots in affected areas.

$\Delta \mathbf{P}_{fee}$	Percentage change in parking fee structure (decimal)

TRAFFIC

Average daily traffic (ADT) in areas affected by an implemented emission reduction strategy can be derived from local traffic counts conducted by the Texas Department of Transportation (TxDOT) or other local sources. For specific HOV facilities related to individual strategies, some data may need to be field collected by the local agency. Conservative estimates should be given for ADT after implementation of strategies (lower instead of higher).

AADT	Annual average daily traffic in corridor (vehicles/day)
$\mathbf{ADT}_{A}$	Average daily traffic on facility after implementation (vehicles/day)
$\mathbf{ADT}_{A, ALT}$	Average daily traffic on alternate route(s) after implementation (vehicles/day)
$\mathbf{ADT}_{B}$	Average daily traffic on facility before implementation (vehicles/day)
$\mathbf{ADT}_{B, ALT}$	Average daily traffic on alternate route(s) before implementation (vehicles/day)
$\mathbf{ADT}_{i}$	Average daily traffic for each affected link
$\mathbf{ADT}_{T}$	Total average daily traffic for affected system (vehicles/day)

Delay and delay reduction can be estimated from the regional travel demand model, stopped delay studies, and average speeds derived from TxDOT traffic analysis.

$\mathbf{D}_{A}$	Average vehicle delay at intersection after implementation (hours)
$\mathbf{D}_{B}$	Average vehicle delay at intersection before implementation (hours)
$\mathbf{DR}_{OP}$	Estimated delay reduction during off-peak period (seconds)
$\mathbf{DR}_{P}$	Estimated delay reduction during peak period (seconds)

Idling may be inferred from stopped delay studies.

$\mathbf{I}_{OP}$	Off-peak hour reduction in idling emissions (hours)
$\mathbf{I}_{P}$	Peak hour reduction in idling emissions (hours)

Vehicle occupancy can be derived from occupancy surveys, transit ridership data, and business or commuter surveys. Metropolitan planning organizations (MPOs), rideshare agencies, and local transit agencies are potential sources of these data.

$\mathbf{AVO}_{RS}$	Average vehicle occupancy of rideshare (persons/vehicle)
OCC	Average vehicle occupancy (persons/vehicle)

The percentage of drivers shifting to bike or pedestrian mode can be estimated through surveys in the area affected by the strategy.

PMS	Percentage mode shift from driving to bike/pedestrian (decimal)

Trip length variables can be acquired from the regional travel demand model, census data, or local travel surveys. MPOs, TxDOT, and rideshare agencies may be able to provide these data. Trip length varies by purpose; pick the one that is most appropriate to the strategy.

$\mathbf{TL}_{A}$	Average auto trip length after implementation (miles)
$\mathbf{TL}_{B}$	Average auto trip length before implementation (miles)
$\mathbf{TL}_{B, BW}$	Average length of participants' trip before participating in the bike/pedestrian program (miles)
$\mathbf{TL}_{HBO}$	Average trip length of home-based other
$\mathbf{TL}_{NW}$	Average nonwork trip length (miles)
$\mathbf{TL}_{PR}$	Average auto trip length to the park-and-ride lot (miles)
$\mathbf{TL}_{PURi}$	Average trip length by trip purpose (miles)
$\mathbf{TL}_{RS}$	Average auto trip length to rideshare location (miles)
$\mathbf{TL}_{TC}$	Average auto trip length to the telecommuting center (miles)
$\mathbf{TL}_{W}$	Average auto trip length (miles)
$\mathbf{TR}_{DUi}$	Daily trip rate by development unit type

Utilization rate of a parking lot may require field observation but can also be derived through business surveys.

$\mathbf{U}_{P}$	Parking lot utilization rate (estimate)
$\mathbf{U}_{P, A}$	Utilization rate of parking lot after implementation (decimal)
$\mathbf{U}_{P, B}$	Utilization rate of parking lot before implementation (decimal)
$\mathbf{U}_{P, HOV}$	Utilization rate of parking spaces by HOVs (decimal)

$\mathbf{U}_{PPK}$ Utilization rate of preferential parking spaces (decimal)

Traffic volume can be computed through traffic counts, both automated and manual.

$\mathbf{V}_{A}$	Average traffic volume per operating period on main lanes after implementing ramp metering
$\mathbf{V}_{B}$	Average traffic volume per operating period on main lanes before implementing ramp metering
$\mathbf{V}_{D, OP}$	Average daily volume for the corridor during off-peak hours
$\mathbf{V}_{D, P}$	Average daily volume for the corridor during peak hours
$\mathbf{V}_{GP, A}$	Average hourly volumes on general purpose lanes during peak hours after implementation of HOV facility
$\mathbf{V}_{GP, B}$	Average hourly volumes on general purpose lanes during peak hours before implementation of HOV facility
$\mathbf{V}_{H, A}$	Average hourly volumes on HOV lanes during peak hours
$\mathbf{V}_{H, OP}$	Number of vehicles that pass through the intersection per hour during the off-peak period
$\mathbf{V}_{H, P}$	Number of vehicles that pass through the intersection per hour during the peak period

Vehicle miles traveled (VMT) can be derived from the regional travel demand model or calculation of products of trip lengths and volumes. TxDOT, census data, travel surveys, and local MPOs are sources for these data.

$\mathbf{VMT}_{Auto, A}$	Vehicle miles traveled by auto after implementation
$\mathbf{VMT}_{Auto, B}$	Vehicle miles traveled by auto before implementation
$\mathbf{VMT}_{BUS}$	Vehicle miles traveled by transit vehicle
$\mathbf{VMT}_{Bus, A}$	Vehicle miles traveled by transit vehicle after implementation (estimate)
$\mathbf{VMT}_{Bus, B}$	Vehicle miles traveled by transit vehicle before implementation
$\mathbf{VMT}_{GP, A}$	Vehicle miles traveled on general purpose lanes after implementation (estimate)
$\mathbf{VMT}_{GP, B}$	Vehicle miles traveled on general purpose lanes before implementation
$\mathbf{VMT}_{H, A}$	Vehicle miles traveled on HOV lane after implementation (estimate)
$\mathbf{VMT}_{H, B}$	Vehicle miles traveled on HOV lane before implementation of strategy
$\mathbf{VMT}_{OP}$	Off-peak hour reduction in speed emissions

VMT_{P}	Vehicle miles traveled by fleet composite
VMT_{PH}	Peak hour reduction in speed emissions
VMT_{R}	Reduction in daily automobile vehicle miles traveled
$VMT_{R, BW}$	Reduction in daily auto vehicle miles traveled by bike/pedestrian mode
$VMT_{R, OP}$	Reduction in regional off-peak period VMT after no-drive days implemented
$VMT_{R, P}$	Reduction in regional peak period VMT after no-drive days implemented
$VMT_{R, RS}$	Reduction in daily auto vehicle miles traveled by rideshare mode
$VMT_{R, T}$	Reduction in daily auto vehicle miles traveled by transit mode
VMT_{REP}	VMT of the vehicle to be replaced

Vehicle trips can be derived from traffic data from local MPOs and TxDOT, supplemented by local surveys or counts if determined to be feasible and required.

BASE	Number of daily trips generated by nonregulated residential and commercial uses (trips)
HH_{TRIPS}	Average number of trips per household in strategy area
VT_{A}	Average daily vehicle trips after implementation
VT_{ALT}	Vehicle trips on alternate facility
VT_{B}	Average daily vehicle trips before implementation
VT_{BUS}	Daily vehicle trips by bus or other transit vehicle
VT_{NC}	Vehicle trips remaining on facility after implementation
VT_{R}	Reduction in number of daily automobile vehicle trips
$VT_{R, BW}$	Reduction in number of daily vehicle trips by bike/pedestrian mode
$VT_{R, OP}$	Reduction in regional number of off-peak period vehicle trips after no-drive days implemented
$VT_{R, P}$	Reduction in regional number of peak period vehicle trips after no-drive days implemented
$VT_{R, RS}$	Reduction in number of daily vehicle trips by rideshare mode
$VT_{R, T}$	Reduction in number of daily vehicle trips by transit mode
VT_{S}	Vehicle trips on facility shifted to no cost or lower cost time period

VT_{R} is the total number of trip changes of four types: work peak trips, work off-peak trips, nonwork peak trips, and nonwork off-peak trips.

EMISSIONS

A variety of vehicle emission sources can be used during analysis. The most used sources are running exhaust, start exhaust, and evaporative hot soak. Running exhaust emissions are influenced by vehicle operating speeds. Start exhaust and evaporative hot soak emissions are influenced by engine on/off activity. Most of the emission variables can be derived directly using the Mobile Source Emissions Factor (MOBILE) model and its output. In some cases, additional processing may be required to aggregate to the level specified by the variable. Where speed emission factor is used in this guide, this refers to the speed-dependent running exhaust emission factor output by MOBILE.

$\mathbf{E}_{OP}$	Emissions generated by congestion on affected roadway system during the off-peak period for each pollutant (oxides of nitrogen [NO_x], volatile organic compound [VOC], or carbon monoxide [CO]) (grams)
$\mathbf{E}_{P}$	Emissions generated by congestion on affected roadway system during the peak period for each pollutant (NO_x, VOC, or CO) (grams)
$\mathbf{E}_{REG}$	Regional freeway emissions (grams)
$\mathbf{EF}_{A}$	Speed-based running exhaust emission factor after implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{A,\,ALT}$	Speed-based running exhaust emission factor on alternate route after implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{A,\,i}$	Speed-based running exhaust emission factor for fleet composite (including trucks) (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{A,\,OP}$	Speed-based running exhaust emission factor during off-peak hours in affected corridor after implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{A,\,P}$	Speed-based running exhaust emission factor during peak hours in affected corridor after implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{B}$	Speed-based running exhaust emission factor for affected roadway before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{B,\,ALT}$	Speed-based running exhaust emission factor on alternate route before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{B,\,i}$	Speed-based running exhaust emission factor for defined fleet composite (excluding trucks) (NO_x, VOC, or CO) (grams/mile)

$\mathbf{EF}_{B, OP}$	Speed-based running exhaust emission factor during off-peak hours in affected corridor after before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{B, P}$	Speed-based running exhaust emission factor during peak hours in affected corridor before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{BUS}$	Speed-based running exhaust emission factor for transit vehicle (grams/mile)
$\mathbf{EF}_{GP, A}$	Speed-based running exhaust emission factor on general purpose lanes after implementation (NO_x, VOCs, or CO) (grams/mile)
$\mathbf{EF}_{GP, B}$	Speed-based running exhaust emissions factor on general purpose lanes before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{H, A}$	Speed-based running exhaust emission factor on HOV lane after implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{H, B}$	Speed-based running exhaust emissions factor on HOV lane before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{I}$	Emission factor for idling (NO_x, VOC, or CO) (grams/hour)
$\mathbf{EF}_{N}$	Replacement vehicle speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{O}$	Retired vehicle speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)
$\mathbf{EF}_{PURi}$	Speed-based running exhaust emission factor by trip purpose (NO_x, VOC, or CO) (grams/mile)

This guide uses trip end factors to represent all associated vehicle engine start/stop emissions (includes start emissions at a minimum and may include hot soak emissions) of a vehicle trip measured in grams per trip. This factor can be calculated by using information from MOBILE6 database output.

$\mathbf{TEF}_{AUTO}$	Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)
$\mathbf{TEF}_{BUS}$	Bus (or other transit vehicle) trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
$\mathbf{TEF}_{TRK}$	Truck trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

In applying trip emission factors (**TEF**) in these methodologies, the user will build the **TEF** based on the characteristics of the individual measure and the underlying regional characteristics. Work trips may have a minimum of two cold starts and two hot soaks, or may be characterized with an offsite lunch trip leading to four cold starts and four hot soaks (trips to work, to lunch, to work, and to home). In reality, there may be a typical local combination that also accounts for errands along a primary trip (trip chaining, as demonstrated in Figure 2.1), such as stops at the cleaners and grocery store on the way home from the work site.

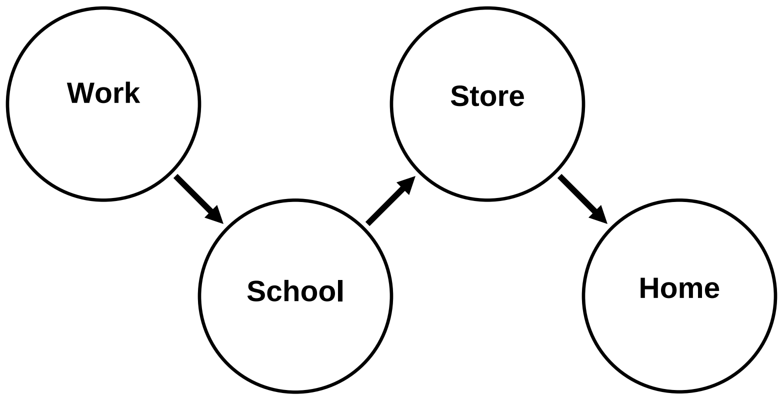

Figure 2.1 Trip Chaining

TEF can be derived from MOBILE6 with regional data using the following process:

1. MOBILE6 can calculate the factor in grams per trip by taking GM_DAY or GM_HOUR outputs (grams per day or hour) and dividing it by the value in the STARTS column (number of starts for the unit of time).
2. Exhaust start and evaporative hot soak emission estimates from MOBILE are directly influenced by a set of MOBILE6 commands. MOBILE6 includes default values for engine starts per day (STARTS PER DAY command), the distribution of starts by hour of the day (START DIST command), the distribution of hot soak length by hour of the day (SOAK DISTRIBUTION command), and the distribution of hot soak duration by time period (HOT SOAK ACTIVITY command). If the MOBILE default values are not used and customized or locally collected data are desired instead, the local dataset should be consistent with other highway-related planning assumptions and should receive approval from the interagency consultation partners (United States Environmental Protection Agency [EPA], Federal Highway Administration [FHWA], Federal Transit Administration [FTA], Texas Commission on Environmental Quality [TCEQ], TxDOT, MPO, and local transit agencies). Statistically valid instrumented vehicle studies are recommended to develop these datasets for local conditions; the EPA should be consulted before implementing the instrumented vehicle study.

3. One procedure to derive a grams per start emission rate is to use the DAILY OUTPUT command option to obtain daily engine start results in the database output. The grams for engine starts field (GM_DAY) from this output is divided by the engine starts per day field (STARTS) for each record. The registration distribution field can be used to generate a weighted start emission factor for each vehicle type over all model years. Hot and cold start emission factors can be calculated by modifying the SOAK DISTRIBUTION input to represent only cold or hot start soak periods. The soak time affects exhaust start and exhaust running emissions. Prior to the development and application of hot and cold start emission factors, the EPA and other interagency consultation partners should review the proposed plan.
4. Similarly, a hot soak emission factor can be derived by dividing the grams for hot soaks field (GM_DAY) by the engine offs per day (ENDS) for each record. The registration distribution field can be used to generate a weighted start emission factor for each vehicle type over all model years.
5. After the start emission factors are calculated, emission changes due to trip reductions are determined by multiplying the trip changes ($\mathbf{VT_R}$) by the start emission factors for each of the three pollutants and the appropriate vehicle classes.
6. Hot soak emission changes can be calculated by multiplying the change in total trips by the evaporative hot soak emission factor generated by MOBILE for each applicable vehicle class.

FACTORS

The various factor variables (**F**) can be derived from multiple sources: travel demand models, emissions inventories, fleet inventories, rideshare agencies, and local surveys conducted by agency staff.

$\mathbf{F}_{AT}$	Percentage of participants who previously drove SOVs (decimal)
$\mathbf{F}_{BW, SOV}$	Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)
$\mathbf{F}_{C}$	Compliance factor (decimal)
$\mathbf{F}_{CND}$	Percent compliance of the no-drive days program (decimal)
$\mathbf{F}_{ECP}$	Percentage of existing carpools (decimal)
$\mathbf{F}_{Eff}$	Project effectiveness factor for each affected freeway

$\mathbf{F}_{EN, OP}$	Percent of nonrecurrent congestion eliminated on roadways with ITS deployment, off-peak period (decimal)
$\mathbf{F}_{EN, P}$	Percent of nonrecurrent congestion eliminated on roadways with ITS deployment, peak period (decimal)
$\mathbf{F}_{ER, OP}$	Percent of recurrent congestion eliminated on roadways with ITS deployment, off-peak period (decimal)
$\mathbf{F}_{ER, P}$	Percent of recurrent congestion eliminated on roadways with ITS deployment, peak period (decimal)
$\mathbf{F}_{ITS}$	Percent of roadway system coverage with ITS deployment (decimal)
$\mathbf{F}_{NR}$	Nonrecurring emissions (decimal)
$\mathbf{F}_{NR, OP}$	Percent of roadway system emissions caused by nonrecurring congestion in the off-peak period (decimal)
$\mathbf{F}_{NR, P}$	Percent of roadway system emissions caused by nonrecurring congestion in the peak period (decimal)
$\mathbf{F}_{OPH}$	Percent of off-peak hours/emissions affected by ITS deployment (decimal)
$\mathbf{F}_{PARK}$	Percent of vehicles that park instead of using the drive-through facility due to imposed control (decimal)
$\mathbf{F}_{PURi}$	Percentage of trips saved by trip purpose (decimal)
$\mathbf{F}_{RS}$	Percentage of people attracted to the HOV facility using rideshare (decimal)
$\mathbf{F}_{RS, SOV}$	Percentage of people attracted to the HOV facility using rideshare that previously used an SOV (decimal)
$\mathbf{F}_{SOV}$	Percentage of those people continuing to use an SOV for their full commute (decimal)
$\mathbf{F}_{T}$	Percentage of people attracted to the HOV facility using a transit vehicle (decimal)
$\mathbf{F}_{T, SOV}$	Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)
$\mathbf{F}_{USE}$	Percentage of park-and-ride users that utilize the facilities (decimal)
$\mathbf{F}_{W}$	Percentage of participating vehicles commuting to work (decimal)

Design guidelines and mixed-use developments will require an estimate of vehicle trips saved as a result of the design and/or regulation.

CAP	Internal capture rate of regulated development (decimal)

The elasticity variable can be determined from data from TxDOT or local MPOs. Regional travel demand models rely on these elasticities in the mode choice module.

ϵ	Price elasticity for mode and time shift or facility charge
ϵ_{fee}	Price elasticity for mode shift

3.0 IMPROVED PUBLIC TRANSIT

Programs for improved public transit
Section 108 (i), CAAA

Improving public transit involves implementation of new or expanded public transit services or facilities. The improvements may be accomplished for all transit modes such as buses, light and heavy rail, and paratransit.

EPA identifies three main components of improved public transit:

- *System/service expansion projects* attempt to increase ridership by providing new rail system services and/or expanding bus services. For buses, the number of routes can be increased, higher service frequencies can be implemented, or routes can be extended to reflect new development. Express bus services can be an alternative to SOVs by providing faster routes between suburban communities and downtown areas. In some cities, bus lanes on main highways enable people to save both time and money in their commute to work. In the rail system category, there are four major types of transit services:

  - Heavy rail rapid transit is characterized by high speeds (more than 70 mph) and high capacity (between 20,000 and 34,000 passengers per hour), and is considered to be most efficient when serving areas with more than 50 million square feet of nonresidential development.
  - Light rail transit systems are designed for medium capacity (ranging from 2000 to 20,000 passengers per hour) and less developed urban areas.
  - Commuter rail is characterized by high-speed, station-to-station service and is designed to transport people from suburbs to downtown areas.
  - Fully automated rail systems circulate within urban areas and allow people easier access to congested facilities such as downtown areas or airports.

- *System/service operational improvements* focus on geographic coverage and scheduling changes that make mass transit a more attractive option to residents and commuters. Improved transfer procedures between transportation modes such as car/transit, pedestrian/transit, and bicycle/transit may encourage increased ridership on public transportation. An improved fleet maintenance program increases the efficiency of system operations and projects a perception of reliability to commuters.

- *Inducements* to potential transit users include:

  - Improvements in fare structures and policies that include monthly or weekly passes, fare simplification (i.e., multiple operators accepting one fare medium), and fare reductions;
  - Marketing programs that include customer service and intense marketing of transit services; and
  - Passenger amenities that include provision of transit shelters, benches, maps, visually pleasing aesthetics, and improved comfort of buses and trains.

According to the EPA, air quality benefits from improving public transit are not difficult to estimate relative to other MOSERS because the number of new passengers utilizing the improved transit system can be easier to quantify. This information provides a basis for estimates of the number of vehicles, miles traveled, and air emissions reduced.

There are several things to consider when considering improving public transit as an air emission reduction measure:

- Costs of transit projects need to be seriously evaluated. Projects may be extremely costly if they are capital intensive and rely on infrastructure changes. Many urban rail systems have cost several billion dollars to plan, design, construct, and implement. At the other end of the cost range, system operational improvements and public awareness programs are less expensive. Improving bus shelters, instituting regional fare structures, and using better signage are examples of effective improvements that cost much less than the capital-intensive examples mentioned above. It may take a long period of time before infrastructure improvements are fully operational. Planning and implementation timelines are very important because TCMs in the SIP must be funded and implemented in a timely manner. Implementing changes to mass transit systems often requires substantial up-front investment of government resources. Nonattainment areas attempting to implement major transit projects into their air quality programs without adequate political and financial support may run into problems.
- Improving transit systems is a complex process because of the extensive planning and coordination required.

    - Prior to extending rail or bus service, transportation departments need to secure adequate funding. This is often difficult because voter approval or permission from the state legislature is usually required.
    - To ensure the effectiveness of a public transit project, land use patterns in the region must be considered. For example, transit services should be designed in conjunction with urban development plans to ensure that new development is served by transit. Additional considerations should be made to provide minimal walking distances to transit corridors and adequately controlled parking. Transit expansions should be part of a larger, more complex urban design project.

- Once projects are completed, aggressive marketing strategies should be initiated to encourage public utilization of the new or improved system. However, attempting to change people's behavior and attitude toward daily transportation can be a significant obstacle to a program's success. Public outreach materials and advertisements may be helpful in increasing voluntary ridership, but employer incentives are more likely to be effective. Improved public transit may not create immediate increased ridership despite the public awareness campaigns.

3.1 System/Service Expansion

Strategy: Increase ridership by providing new rail system services and/or expanding bus services.

Description: Expansion of a transit system or service can include the addition of rail services through increased frequency or route extension. Bus or paratransit services can be expanded with new vehicles and/or route extensions.

Application: Large cities or communities with enough population density to support reasonably frequent transit service.

Variables:

EF_{B}:	Speed-based running exhaust emission factor for affected roadway before implementation (NO_x , VOC, or CO)(grams/mile)
EF_{BUS}:	Speed-based running exhaust emission factor for transit vehicle (NO_x, VOC, or CO) (grams/mile)
$F_{T, SOV}$:	Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)
N_{TR}:	New transit ridership
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)
TEF_{BUS}:	Bus (or other transit vehicle) trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TL_{W}:	Average auto trip length (miles)
VMT_{BUS}:	Vehicle miles traveled (VMT) by transit vehicle
VMT_{R}:	Reduction in daily automobile VMT
VT_{BUS}:	Daily vehicle trips by bus or other transit vehicle

VT_R: Reduction in number of daily automobile vehicle trips

Equation:

Daily Emission Reduction = A + B – C – D

$$A = VT_R * TEF_{AUTO}$$

Reduction in auto start emissions from trips reduced

$$B = VMT_R * EF_B$$

Reduction in auto running exhaust emissions from VMT reductions

$$C = VT_{BUS} * TEF_{BUS}$$

Increase in emissions from additional bus starts

$$D = VMT_{BUS} * EF_{BUS}$$

Increase in emissions from additional bus running exhaust emissions

Where

$$VT_R = N_{TR} * F_{T, SOV}$$

Number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use

$$VMT_R = VT_R * TL_W$$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

3.2 System/Service Operational Improvements

Strategy: Increase ridership on existing transit systems.

Description: Operational improvements focus on enhancing the efficiency of a transit system and providing more effective service. These improvements are intended to attract new riders and reduce the number of vehicle trips. Improvements can be made, among others, in scheduling, routes, fleet maintenance programs, geographic coverage, improved mode transfer procedures, and monitoring operations.

Application: Cities and/or corridors with existing transit systems, new land development, limited parking, and heavy or increasing congestion.

Variables:

EF_B: Speed-based running exhaust emission factor for affected roadway before implementation (NO_x, VOC, or CO) (grams/mile)

EF_{BUS}: Speed-based running exhaust emission factor for transit vehicle (NO_x, VOC, or CO) (grams/mile)

$F_{T, SOV}$: Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)

N_{TR}: New transit ridership

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TEF_{BUS}: Bus (or other transit vehicle) trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length (miles)

VMT_{BUS}: VMT by transit vehicle

VMT_R: Reduction in daily automobile VMT

VT_{BUS}: Daily vehicle trips by transit vehicle

VT_R: Reduction in number of daily automobile vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = A + B - C - D$$

$$A = VT_R * TEF_{AUTO}$$

Reduction in auto start emissions from trips reduced

$$B = VMT_R * EF_B$$

Reduction in auto running exhaust emissions from VMT reductions

$$C = VT_{BUS} * TEF_{BUS}$$

Increase in emissions from additional bus starts

$$D = VMT_{BUS} * EF_{BUS}$$

Increase in emissions from additional bus running exhaust emissions

Where

$$VT_R = N_{TR} * F_{T, SOV}$$

Number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use

$$VMT_R = VT_R * TL_W$$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

3.3 Marketing Strategies

Strategy: Increase ridership by enhancing market demand for transit services.

Description: Marketing programs attempt to increase demand for a transit system. Programs can include improvements in fare structures and policies such as monthly or weekly passes, fare simplification (i.e., multiple operators accepting one fare medium), and fare reductions. Transit operators can promote customer service programs that enhance responsiveness to passenger concerns. Operators can also add or improve passenger amenities such as provision of transit shelters, benches, maps, visually pleasing aesthetics, and improved comfort of buses and trains. This strategy excludes adding more transit vehicles as a result of ridership increase. If additional buses are needed, use the equation in 3.1.

Application: Cities with existing and proposed transit systems.

Variables:

$\mathbf{EF}_{B}$:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{F}_{T, SOV}$:	Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)
$\mathbf{N}_{TR}$:	New transit ridership
$\mathbf{TEF}_{AUTO}$:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
$\mathbf{TL}_{W}$:	Average auto trip length (miles)
$\mathbf{VMT}_{R}$:	Reduction in daily automobile VMT
$\mathbf{VT}_{R}$:	Reduction in number of daily automobile vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = \mathbf{A + B}$$

$$\mathbf{A} = \mathbf{VT}_{\boldsymbol{R}} * \mathbf{TEF}_{\boldsymbol{AUTO}}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B} = \mathbf{VMT}_{\boldsymbol{R}} * \mathbf{EF}_{\boldsymbol{B}}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{TR} * F_{T, SOV}$

Number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use

$VMT_R = VT_R * TL_W$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: CalTrans

4.0 HIGH-OCCUPANCY VEHICLE FACILITIES

Restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high-occupancy vehicles
Section 108 (ii), CAAA

According to EPA, high-occupancy vehicle (HOV) lanes are one of the most frequently implemented mobile source emission reduction measures. HOV lanes are designated exclusively for use by vehicles with multiple occupants such as carpools, vanpools, and transit vehicles. Implementing HOV facilities can involve adding entirely new capacity or reallocating existing capacity. Along with a range of physical options, HOV facilities have operative options such as full-time HOV-only use, peak time use, and reversing the travel direction of facilities during peak times. HOV lanes can increase transit use and car occupancy for work-related trips in congested urban travel corridors.

The most effective HOV lane improvements generally involve regional networks of linked lanes, with a system of supporting facilities and services. Historically, the most successful HOV applications have been along "radial" corridors into major central cities where HOV users can save at least 10 minutes of travel time compared to using mixed-traffic lanes. EPA studies show that HOV lanes are generally more effective if implemented along with transit improvements, park-and-ride lots, employer-based transportation programs, and commuter parking subsidies.

Because of substantial physical and financial requirements, state departments of transportation (DOTs) usually implement HOV lanes. Historically, the EPA has found the typical time frame for implementing HOV lanes is three to eight years for planning, design, and construction. Private or nonprofit authorities may construct and operate HOV facilities along the lines of a toll road (high-occupancy toll [HOT] lanes). Operators can use discriminatory pricing strategies such as granting toll discounts to HOVs to promote utilization.

Potential land acquisition often determines feasibility and the time required to implement the project. Also, HOV project planning and design is a political process involving various parties, including political leaders, business groups, and citizen groups. Discussions and negotiation among them, while very important, may add time to the project.

HOV projects can be very expensive, depending on such factors as right-of-way acquisition or cost of land, bridge and overpass modifications, and interchange and ramp modifications to provide access. Total costs of some HOV projects have exceeded several hundred million dollars.

HOV impacts on air quality are fairly complex, but Los Angeles, San Francisco, Washington, D.C., and Portland have documented emissions impacts from their HOV projects. Assessments of the effectiveness of HOV lane facilities in reducing system-wide emissions have generally found reductions amounting to less than 1 percent.

HOV lanes reduce air pollution emissions by reducing running and trip-end emissions. Reductions in running emissions are derived by increasing average speeds from low speeds in congested traffic to 50 mph in HOV lanes, and increasing the use of buses, vanpools, and carpools results in less VMT. If riders do not take additional trips, HOV lanes will also reduce trip-end emissions. However, if users of HOV lanes meet their pool or bus through a park-and-ride arrangement, these trip-end emissions may offset the reduced air emissions benefits. When calculating the effectiveness of HOV lanes in reducing emissions, trip-end emissions resulting from using linkages must be considered.

Two important factors in implementing a successful HOV program have been identified. Enforcement is critical. EPA studies show that early and substantial enforcement of HOV rules on a new facility is the best determinant of long-term public compliance. Also, education and marketing programs that promote the benefits and use of the HOV facilities, both during and after construction, increase the potential for users of the facility.

4.1 Freeway HOV Facilities

Strategy: Reduce emissions by decreasing VMT and increase average speeds on the lane.

Description: Separate lanes on controlled access highways are created for vehicles containing a specified minimum number of passengers. The lane may be concurrent flow, be barrier/buffer separated, or have a separate right-of-way.

Application: Highways in areas of traffic congestion with sufficient available right-of-way.

Variables:

$\mathbf{AVO}_{RS}$:	Average vehicle occupancy of rideshare (persons/vehicle)
$\mathbf{EF}_{B}$:	Speed-based running exhaust emission factor before implementation (NO_x , VOC, or CO) (grams/mile)
$\mathbf{EF}_{GP,A}$:	Speed-based running exhaust emission factor after implementation of HOV facility (general purpose lanes) (NO_x, VOC, or CO) (estimate)
$\mathbf{EF}_{H,A}$:	Speed-based running exhaust emission factor on HOV facility (NO_x, VOC, or CO) (estimate)
$\mathbf{F}_{RS}$:	Percentage of people attracted to the HOV facility using rideshare (decimal)
$\mathbf{F}_{RS,SOV}$:	Percentage of people attracted to the HOV facility using rideshare that previously were vehicle drivers (decimal)
$\mathbf{F}_{T}$:	Percentage of people attracted to the HOV facility using a transit vehicle (decimal)
$\mathbf{F}_{T,SOV}$:	Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)

L:	Length of HOV facility (miles)
$\mathbf{N}_{P}$**:**	Total number of expected people using the HOV lanes per day
$\mathbf{N}_{PH}$**:**	Number of peak hours (AM and/or PM)
$\mathbf{TEF}_{AUTO}$**:**	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
$\mathbf{TL}_{W}$**:**	Average auto trip length (miles)
$\mathbf{V}_{GP, A}$**:**	Average hourly volumes on general purpose lanes during peak hours after implementation of HOV facility
$\mathbf{V}_{GP, B}$**:**	Average hourly volumes on general purpose lanes during peak hours before implementation of HOV facility
$\mathbf{V}_{H, A}$**:**	Average hourly volumes on HOV lanes during peak hours
$\mathbf{VMT}_{R}$**:**	Reduction in daily automobile VMT
$\mathbf{VT}_{R}$**:**	Reduction in number of daily automobile vehicle trips (estimate)

Equation:

$$\textbf{Daily Emission Reduction} = A + B + C + D$$

$$A = V_{H,A} * (EF_{B} - EF_{H,A}) * N_{PH} * L$$

Change in running exhaust emissions from vehicles shifting from general purpose lanes to HOV lanes

$$B = (V_{GP,B} * EF_{B} - V_{GP,A} * EF_{GP,A}) * N_{PH} * L$$

Change in running exhaust emissions of vehicles in general purpose lanes as a result of vehicles shifted away from general purpose lanes

$$C = VT_{R} * TEF_{AUTO}$$

Reduction in auto start exhaust emissions from trip reductions

$$\mathbf{D = VMT_{\mathit{R}} * EF_{\mathit{B}}}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$VT_R = N_P * (F_T * F_{T,SOV} + F_{RS} * F_{RS,SOV}) * (1 - 1/AVO_{RS})$$

Number of HOV users multiplied by the sum of the fraction of users selecting transit multiplied by the percentage that previously drove single-occupant vehicles added by the fraction of users selecting ridesharing multiplied by the percentage that previously drove single-occupant vehicles multiplied by the percentage of ridesharers that are passengers

$$VMT_R = VT_R * TL_W$$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: CalTrans (adapted by Texas Transportation Institute)

4.2 Arterial HOV Facilities

Strategy: Reduce emissions by decreasing VMT and increasing average speeds on the lane.

Description: Separate lanes on arterials are created for vehicles containing a specified minimum number of passengers. The lane may be concurrent flow, be barrier/buffer separated, or have separate rights-of-way.

Application: Roadways in areas of traffic congestion with sufficient available right-of-way.

Variables:

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{GP, A}$: Speed-based running exhaust emission factor after implementation of HOV facility (general purpose lanes) (NO_x, VOC, or CO) (estimate)

$EF_{H, A}$: Speed-based running exhaust emission factor on HOV facility (NO_x, VOC, or CO) (estimate)

F_{RS}: Percentage of people attracted to the HOV facility using rideshare (decimal)

$F_{RS, SOV}$: Percentage of people attracted to the HOV facility using rideshare that previously were vehicle drivers (decimal)

F_T: Percentage of people attracted to the HOV facility using a transit vehicle (decimal)

$F_{T, SOV}$: Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)

L: Length of HOV facility (miles)

N_P: Number of expected person trips on the HOV lanes per day

N_{PH}: Number of peak hours for each peak period (AM and PM)

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length (miles)

$V_{GP, A}$: Average hourly volumes on general purpose lanes during peak hours after implementation of HOV facility

$V_{GP, B}$: Average hourly volumes on general purpose lanes during peak hours before implementation of HOV facility

$V_{H, A}$: Average hourly volumes on HOV lanes during peak hours

VMT_R: Reduction in daily automobile VMT

VT_R: Reduction in number of daily automobile vehicle trips (estimate)

Equation:

Daily Emission Reduction = A+ B + C + D

$$A = V_{H, A} * (EF_B - EF_{H, A}) * N_{PH} * L$$

Change in running exhaust emissions from vehicles shifting to HOV lane

$$B = (V_{GP, B} * EF_B - V_{GP, A} * EF_{GP, A}) * N_{PH} * L$$

Change in running exhaust emissions of vehicles in general purpose lanes as a result of vehicles shifted away from general purpose lanes

$$C = VT_R * TEF_{AUTO}$$

Reduction in auto start exhaust emissions from trip reductions

$D = VMT_R * EF_B$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_P * (F_T * F_{T,SOV} + F_{RS} * F_{RS,SOV}) * 2$ trips/day

Number of HOV users multiplied by the sum of the fraction of users selecting transit multiplied by the percentage that previously drove SOVs added by the fraction of users selecting ridesharing multiplied by the percentage that previously drove single-occupant vehicles multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: CalTrans (adapted by Texas Transportation Institute)

4.3 Parking Facilities at Entrances to HOV Facilities

Strategy: Reduce VMT.

Description: The transfer point between vehicle and HOV is made more efficient by constructing park-and-ride lots at entrances to HOV facilities.

Application: Cities with HOV facilities and sufficient public transit systems. Planners should be cautious to avoid double-counting of benefits. Analyze parking related to new use of the HOV facility.

Variables:

EF_B:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
N_{PK}:	Number of parking spaces
U_P:	Parking lot utilization rate (estimate)
TL_{PR}:	Average auto trip length from home to parking facility (miles)
TL_W:	Average length of affected auto trips (miles)

Equation:

$$\text{Daily Emission Reduction} = N_{PK} * U_P * (TL_W - TL_{PR}) * EF_B * 2 \text{ trips/day}$$

Reduction in running exhaust emissions from reduced VMT resulting from park-and-ride lot use

Final unit of measure: grams/day
Source: Texas Transportation Institute

4.4 SOV Utilization of HOV Lanes

Strategy: Reduce emissions by increasing average speed on the main lanes of a controlled access highway with an existing HOV facility.

Description: Areas can increase utilization of their HOV lanes by permitting SOVs to use the facility for a fee. The strategy will reduce the number of vehicles on the main lanes of the highway, leading to an increase in the average speed along the highway from the reduced congestion. SOVs may be allowed to use the HOV facility at certain times (peak hours) or throughout the day.

Application: Congested highways with existing HOV lanes operating under capacity.

Variables:

$EF_{GP,A}$: Speed-based running exhaust emissions factor on general purpose lanes after implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{GP,B}$: Speed-based running exhaust emissions factor on general purpose lanes before implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{H,A}$: Speed-based running exhaust emissions factor on HOV lane after implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{H,B}$: Speed-based running exhaust emissions factor on HOV lane before implementation (NO_x, VOC, or CO) (grams/mile)

$VMT_{GP,A}$: Vehicle miles traveled on general purpose lanes after implementation (estimate)

$VMT_{GP,B}$: Vehicle miles traveled on general purpose lanes before implementation

$VMT_{H, A}$: Vehicle miles traveled on HOV lane after implementation (estimate)

$VMT_{H, B}$: Vehicle miles traveled on HOV facility before implementation of strategy

Є: Price elasticity of volume change due to facility charge

Equation:

Daily Emission Reduction = A – B

$$\mathbf{A = VMT_{GP, B} * EF_{GP, B} + VMT_{H, B} * EF_{H, B}}$$

The running exhaust emissions of the affected highway before implementation of the strategy for both the general purpose and HOV lanes

$$\mathbf{B = VMT_{GP, A} * EF_{GP, A} + VMT_{H, A} * EF_{H, A}}$$

The running exhaust emissions of the affected highway after implementation of the strategy for both the general purpose and HOV lanes

Where

$$VMT_{GP, A} = VMT_{GP, B} - (VMT_{GP, B} * Є)$$

The expected VMT on the general purpose lane after implementation is equal to the VMT of the lanes before implementation multiplied by the price elasticity subtracted from the VMT before implementation

$$VMT_{H, A} = VMT_{H, B} - (VMT_{H, B} * Є)$$

The expected VMT on the HOV lane after implementation is equal to the VMT of the HOV lane before implementation multiplied by the price elasticity subtracted from the VMT before implementation

Final unit of measure: grams/day
Source: Houston-Galveston Area Council

5.0 EMPLOYER-BASED TRANSPORTATION MANAGEMENT PROGRAMS

Employer-based transportation management plans, including incentives
Section 108 (iii), CAAA

Employer-based transportation management programs principally serve home-to-work trips in urban areas with populations of 250,000 or more. Primarily large employers, i.e., those having more than 100 employees at a single work site, have used employer-based transportation management programs. Employers provide information and incentives for employees who pool or use alternative forms of transportation for their daily commute.

Because home-to-work trips account for only 25 to 33 percent of all peak period trips made in most urban areas, the impact of commute management on areawide VMT is limited. However, the commuter market represents the best potential for grouping riders, removing vehicle trips, and reducing VMT. Reducing commuter trips not only reduces emissions associated with VMT but also those associated with "cold starts," when commuters set out in the morning, and "hot soaks," when vehicles are parked at work and continue to produce evaporative emissions even after the engines are turned off.

The 1990 CAAA required the implementation of employer-based transportation management programs in severe and extreme ozone nonattainment areas. The programs can consist of both voluntary and mandatory measures. According to EPA, a package of various complementary measures produces the greatest impacts. For an individual employer, trip-reduction effects can be seen immediately.

In addition to improving air quality primarily by reduced automobile trips and VMT, employer-based transportation management programs can provide savings benefits in the following areas:

- Vehicle expenses,
- Road construction and operation and maintenance (O&M) costs,
- Expenditures on public services devoted to vehicle traffic, and
- Resource consumption.

Employer-based transportation management programs can be highly cost-effective. Employers incur initial costs to design the program and to develop eligibility requirements for their employees. Monitoring and accounting costs are incurred periodically. Variation in costs of programs is based on the size of the employer, the nature and complexity of programs offered, and the amount of the subsidy offered.

The EPA has identified three types of employer-based transportation management programs with their associated costs:

General travel allowance programs require considerable planning and promotional efforts before implementation, but ongoing administrative costs are relatively small. Employees can use general travel allowances for any transportation mode or for nontransportation purposes. Program monitoring costs are low, and accounting costs are negligible because the allowance is given out to all employees as a bonus. The only significant cost to the employer is the cost of the allowance itself. The cost can be at least partially offset because the reduction in the number of employees needing parking can generate savings in maintenance, monthly parking lease costs, and savings in future capital requirements.

- *Targeted or specific allowance programs*, such as transit and vanpool allowances, require ongoing administrative effort for accounting and monitoring eligibility requirements among employees.
- *Flexible use* of allowances for transportation services provided by many different operators is the largest and most complex program and may cost even more because of greater administrative, monitoring, and accounting needs.

Because employer-based transportation management programs are implemented by private entities, they do not require a substantial investment in government resources. The amount of time required to implement an incentive program is relative to the complexity of the measures offered. Some employer-based transportation management programs can be implemented almost immediately, while others require more time.

One significant concern for practitioners is the long-term sustainability of program impacts. Program effectiveness can diminish if management support or financial commitment wanes, or if employee turnover increases. The EPA has found programs that include financial incentives are more likely to have sustainable results. The following list summarizes three types of financial incentives and their goals:

- *Tax incentives* can allow employers and developers to provide facilities and equipment conducive to ridesharing. They may be in the form of investment tax credits or accelerated depreciation.

- *Subsidy programs* can help initiate a program by providing additional funding to enlist employer involvement and reduce the initial risk for employers in attempting a new program. The goal of the subsidies is for employers see the benefits of the program and then continue subsidizing on their own to satisfy employee desire for using the program and/or to comply with regional or local mandates. Some subsidy programs target commuters directly when employer involvement is unlikely or impractical. For example, vanpool subsidies tied to corridor reconstruction projects can aid in the formation of vanpools among commuters using the affected facilities, regardless of their particular job location.
- *Enabling legislation* can eliminate or minimize barriers to widespread implementation of employer-based trip-reduction programs. A legal requirement mandating employer or developer involvement is a powerful determinant of program effectiveness. Mandatory participation is essential to assuring widespread participation by enough employers to have an area-wide impact.

The EPA has several observations regarding employer-based transportation management programs:

- Employer size and location do not seem to determine program effectiveness. Although downtown settings have an obvious potential to be effective, many successful programs have been located in large suburban activity centers. One possible explanation is that less ridesharing occurs naturally in those areas, which allows the program more opportunities to shift commuters' mode of transportation.
- The costs and benefits of employer-based transportation management programs are more difficult to measure than other mobile source emission reduction strategies. The primary area of uncertainty regarding these programs is the difficulty in determining causality between areawide promotional efforts and VMT and emission impacts. It is a difficult task to separate out the impacts of these programs above and beyond those reported for employers or to speculate on the increase in VMT or emissions if these programs did not exist.
- It is difficult to separate out the impacts of any single trip-reduction strategy; and the techniques are not strictly additive due to the complementary nature of many strategies. Care must be taken not to double-count the effectiveness of employer-based transportation management programs with the benefits of area-wide rideshare incentives.

- The roles and responsibilities of the various public, nonprofit, and for-profit organizations involved in promoting ridesharing and other travel alternatives within a region need to be carefully delineated so that the various efforts are not perceived as either duplicative or conflicting by employers and individuals.

5.1 Transit/Rideshare Services

Strategy: Reduce vehicle trips and emissions through increased use of transit, carpooling, or vanpooling.

Description: Employers or groups of employers in activity centers provide transportation service to and from the work site to transit facilities and homes. The services can include subscription buses, midday and park-and-ride shuttles, and guaranteed ride home programs.

Application: Large companies or groups of cooperating businesses.

Variables:

EF_A: Speed-based running exhaust emission factor after implementation (NO_x , VOC, or CO) (grams/mile)

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

N_{VA}: Number of vehicles after implementation

N_{VB}: Number of vehicles before implementation

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_A: Average auto trip length after implementation (miles)

TL_B: Average auto trip length before implementation (miles)

VT_A: Vehicle trips after implementation

VT_B: Vehicle trips before implementation

Note: If an automobile is used instead of a van for ridesharing, replace auto emission factors for van emission factors.

Equation:

$$\textbf{Daily Emission Reduction} = (A - B) + C$$

$$A = VT_B * TL_B * EF_B$$

Auto running exhaust emissions before strategy implementation

$$B = VT_A * TL_A * EF_A$$

Auto running exhaust emissions after strategy implementation

$$C = (VT_B - VT_A) * TEF_{AUTO}$$

Reduction in start exhaust emissions from reduction in vehicle trips to/from employment center

Where

$VT_A = N_{VA} * 2$ trips/day
$VT_B = N_{VB} * 2$ trips/day

Number of vehicles before or after strategy implementation multiplied by two trips per day (round trip)

Final unit of measure: grams/day
Source: Texas Transportation Institute

5.2 Bicycle and Pedestrian Programs

Strategy: Reduce vehicle trips, VMT, and emissions through provision of bicycle and pedestrian support facilities and programs.

Description: Employers provide support facilities and/or services to encourage employees to bicycle or walk to work. The programs include credits to be used toward purchases of bicycles; bonus days off; shower and locker facilities; free reflective vest, helmet, nightlight, and mirror; reduced-cost purchase program for bicycles; onsite bicycle repair shop with mechanics and pick-up service; and forgiveness for occasional tardiness. In a Washington, D.C., area program, employers must provide at least one bicycle for every 50 employees for midday employee business and personal use.

Bicycle and pedestrian programs can be classified in three different TCMs under the 1990 CAAA. In this instance, the program is employer based and is placed in this category. This is a clear example of the overlap found amid the various mobile source emission reduction strategies.

Application: Areas with existing bicycle and/or pedestrian paths that can serve businesses or business centers.

Variables:

EF_B: Speed-based running exhaust emission factor for the average speed of participants' trip before participating in the bike/pedestrian program (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new cyclists who previously drove an SOV (decimal)

N_{BW}: Number of participants in the bike/pedestrian program

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

$TL_{B, BW}$: Average length of participants' trip before participating in the bike/pedestrian program (miles) *(The National Personal Transportation Survey estimated 1.8 miles, yet MPOs may want to use a more regionally significant estimate.)*

VMT_R: Reduction in daily auto vehicle miles traveled

VT_R: Reduction in number of daily auto vehicle trips

Equation:

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$VT_R = N_{BW} * F_{BW, SOV} * 2 \text{ trips/day}$$

Number of bike and pedestrian participants multiplied by the number of participants that previously drove SOVs multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_{B, BW}$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: CalTrans/CARB and FHWA Southern Resource Center (modified by Texas Transportation Institute)

5.3 Employee Financial Incentives

Strategy: Reduce SOVs for commuting through provision of incentives to employees to use transportation alternatives.

Description: Employers can provide direct financial incentives to employees to use alternative forms of transportation in their commute. Carpooling, transit use, and parking subsidies for HOV lane users are examples of these types of incentives.

Application: Measure can be used in conjunction with carpool/vanpool programs or matching services, in areas with adequate public transit and in areas with controlled or limited parking.

Variables:

$\mathbf{EF}_{B}$:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{F}_{BW,\ SOV}$:	Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)
$\mathbf{F}_{RS,\ SOV}$:	Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)
$\mathbf{F}_{T,\ SOV}$:	Percentage of new participants using transit facilities who previously drove SOVs (decimal)
$\mathbf{N}_{BW}$:	Number of participants in bike/pedestrian programs
$\mathbf{N}_{P}$:	Total number of participants *(estimate)*
$\mathbf{N}_{RS}$:	Number of participants in rideshare programs
$\mathbf{N}_{T}$:	Number of participants using transit facilities
$\mathbf{TEF}_{AUTO}$:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length (miles)

VMT_R: Reduction in daily auto vehicle miles traveled

VT_R: Reduction in number of daily vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = \textbf{A} + \textbf{B}$$

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.0 TRIP-REDUCTION ORDINANCES

Trip-reduction ordinances
Section 108 (iv), CAAA

Trip-reduction ordinances (TROs) consist of regulations or similar measures requiring implementation of other mobile source emission reduction strategies. TROs may specify emission reduction strategies or simply require a set reduction in VMT, trips, or other measure of reduced travel.

TROs are applied in a variety of ways, depending upon the needs of a particular locality. The focus of these ordinances has been to encourage socially beneficial travel choices rather than controlling traveler behavior. Most TROs, therefore, offer a range of travel options, but the individual traveler's choice is voluntary. The most successful programs incorporate agencies, employees, and developers into the creation of TROs.

TROs have existed for well over a decade, with most early examples appearing in California. Due to a history of congestion and air quality problems, state legislative actions, and the interaction of CAAA requirements with the nonattainment status of its major urban areas, California remains the state with the most significant experience with TROs.

TROs are applicable in large metropolitan areas and surrounding suburbs. Most measures are geared toward companies or developments of a minimum size. This size restriction reduces hardships on small companies and limits enforcement costs for the jurisdiction. The criterion often used for companies is the number of employees at a location. A TRO usually specifies that if a company has greater than the threshold number of employees (e.g., more than 50), it must begin complying with measures of the local TRO. In some jurisdictions, multiple thresholds exist. For example, a company with 50 employees might only have to provide preferred parking for carpools, while a company with 500 employees would be expected to provide a shuttle to the local subway station. Developers of residential, commercial, or mixed-use properties may be forced to adopt a series of measures, depending on the size of the facility. For example, a developer may need to provide vanpool parking if the office complex being built exceeds a certain size (e.g., 25,000 square feet) or if it will house more than a given number of workers.

Enforcement is another aspect of TROs that needs to be taken into consideration. Some TROs are purely voluntary, relying on the good will of businesses in achieving trip-reduction goals. In areas where compulsory TROs have been enacted, compliance is unavoidable for employers and developers. While some TROs specify no penalties, the majority of programs specify fines for given periods of noncompliance. Fines in one TRO study varied from $500 per month to $25,000 per day. In Sacramento County, California, noncompliance may be treated as a criminal misdemeanor. However, failing to fully implement TRO measures is rarely treated as a violation. This is especially true for first-time offenders or if the TRO has been recently implemented. Enforcement and punishment are usually reserved for organizations that display willful disregard toward the measure. The "spirit" of most TROs encourages participation rather than punishment of laggards.

Some TRO measures affect only new developments/businesses. This leads to older businesses feeling no effects from a regulation, while similar organizations that are new to a community are faced with regulatory compliance efforts. Most TRO regulations, by their nature, affect businesses equally in the community. In most cases, good-faith compliance efforts by most organizations provide the important groundwork to achieve the desired environmental and social benefits, without placing undue burden on any one segment of the economy.

6.1 Negotiated Agreements

Strategy: Achieve emission reduction goals through negotiation between local authorities and private companies or developers.

Description: Trip-reduction requirements can be used as a bargaining element in negotiations over rezonings and/or as part of a public-private development agreement. Negotiated agreements allow the trip-reduction program to be formulated to mitigate the emission impacts of the specific project under consideration, but may also lead to considerable variation among the requirements imposed on similar projects.

Application: Large companies and development projects in large metropolitan areas and suburbs.

Variables:

EF_B:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
$F_{BW, SOV}$:	Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)
$F_{RS, SOV}$:	Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)
$F_{T, SOV}$:	Percentage of new participants using transit facilities who previously drove SOVs (decimal)
N_{BW}:	Number of participants in bike/pedestrian programs
N_P:	Total number of participants
N_{RS}:	Number of participants in rideshare programs
N_T:	Number of participants using transit facilities

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length (miles)

VMT_R: Reduction in daily auto vehicle miles traveled

VT_R: Reduction in number of daily vehicle trips

Equation:

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$$

Number of program participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.2 Trip-Reduction Programs

Strategy: Achieve emission reduction goals by requiring specific reductions in the number of vehicle trips by employees of large companies.

Description: Trip-reduction programs require employers of specific-size companies to reduce the number of commute trips made by employees. Program goals can be mandatory or voluntary for employers. The program encourages use of alternative modes of travel including ridesharing, transit, walking/bicycling, and telecommuting among employees.

Application: Large companies and development projects in large metropolitan areas and suburbs.

Variables:

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}: Number of participants in bike/pedestrian programs

N_P: Total number of participants

N_{RS}: Number of participants in rideshare programs

N_T: Number of participants using transit facilities

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length (miles)

VMT_R: Reduction in daily auto vehicle miles traveled (estimate)

VT_R: Reduction in number of daily vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = \mathbf{A + B}$$

$$\mathbf{A = (VT_R * TEF_{AUTO})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (VMT_R * EF_B)}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.3 Mandated Ridesharing and Activity Programs

Strategy: Decrease the number of commute trips by employees.

Description: Mandatory ridesharing programs require employers who employ more than a certain number of employees to implement ridesharing and/or related alternative commute programs. The reduction goals can vary according to the specific emission reduction needs of the locality. Program goals can be measured in various ways including improvement in employee average vehicle ridership or a decrease in employee home-based work trips.

Application: Large companies and development projects in large metropolitan areas and suburbs.

Variables:

EF_B: Speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}: Number of participants in bike/pedestrian programs

N_P: Total number of participants

N_{RS}: Number of participants in rideshare programs

N_T: Number of participants using transit facilities

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W:	Average auto trip length (miles)
VMT_R:	Reduction in daily auto vehicle miles traveled
VT_R:	Reduction in number of daily vehicle trips

Equation:

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.4 Requirements for Adequate Public Facilities

Strategy: Provide necessary infrastructure to implement emission reduction strategies.

Description: These policies require that adequate public facilities be in place (or at least programmed and funded) before additional development can be approved. They may call for developers to implement specific types of facilities and services (e.g., park-and-ride lots at all major housing developments, sidewalks and bike paths, onsite transit pass sales, and rideshare matching) and/or may establish performance standards with the means of achieving those standards subject to negotiation.

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Application: Large companies and development projects in large metropolitan areas and suburbs.

Variables:

EF_B: Speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}: Number of participants in bike/pedestrian programs

N_P: Total number of participants

N_{RS}: Number of participants in rideshare programs

N_T: Number of participants using transit facilities

$\mathbf{TEF_{\mathit{AUTO}}}$:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
$\mathbf{TL_{\mathit{W}}}$:	Average auto trip length (miles)
$\mathbf{VMT_{\mathit{R}}}$:	Reduction in daily auto vehicle miles traveled
$\mathbf{VT_{\mathit{R}}}$:	Reduction in number of daily vehicle trips

Equation:

Daily Emission Reduction = A + B

$$\mathbf{A = (VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS,\ SOV}) + (N_T * F_{T,\ SOV}) + (N_{BW} * F_{BW,\ SOV})$$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.5 Conditions of Approval for New Construction

Strategy: Implement mandatory utilization of mobile source emission reduction strategies.

Description: Incorporation of mobile source emission reduction strategies in all new development projects over a certain size as a condition of approval. For example, a construction permit may require establishment of onsite parking spaces for high-occupancy vehicles; an occupancy permit may require an onsite transportation coordinator.

Application: Large development projects in large metropolitan areas and suburbs.

Variables:

EF_B: Speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}: Number of participants in bike/pedestrian programs

N_P: Total number of participants

N_{RS}: Number of participants in rideshare programs

N_T: Number of participants using transit facilities

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length (miles)

VMT_R: Reduction in daily auto vehicle miles traveled

VT_R: Reduction in number of daily vehicle trips

Equation:

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

7.0 TRAFFIC FLOW IMPROVEMENTS

Traffic flow improvement programs that achieve emission reductions
Section 108 (v), CAAA

Traffic flow improvements are a very wide range of measures for improving the operational efficiency of an intersection or corridor, generating small increases in capacity or delay reduction without the addition of extra lanes or new roads. The logic behind this emission reduction strategy is that reducing congestion and delays will also decrease congestion-related emissions. Traffic flow improvements have been used for decades, with projects becoming increasingly more complex as congestion on U.S. roadways has worsened.

Improvements generally provide a cost-effective method to reduce congestion although their effects on vehicular traffic can be difficult to quantify. Also, once traffic is less congested and flows more efficiently, motorists may increase vehicle trips, leading to increased VMT and increased emissions. *Planners should be aware of the difficulties in quantification of the benefits of the strategy because of the potential increases in VMT.*

Strategies to improve traffic flow can be grouped into four general types:

- Traffic signalization,
- Traffic operations,
- Enforcement and management, and
- Intelligent Transportation Systems (ITS).

Traffic signalization represents the most common traffic management technique applied in the United States. Traffic signal improvements can include the following:

- Updating traffic signal hardware to utilize more modern technology, allowing for more sophisticated traffic flow strategies to be planned;
- Timing traffic signals to correspond with current traffic flows, reducing unnecessary delays;
- Coordinating and interconnecting signals to better interface pre-timed and traffic actuated signals, actively managed timing plans, and master controllers to minimize the number and frequency of stops necessary at intersections; and
- Removing signals at intersections no longer requiring signalized stop control to reduce vehicle delays and unwarranted stops on the major street.

Traffic operations describe several types of roadway improvement projects, including:

- Converting two-way streets to one-way operation to improve corridor travel times and increase roadway capacity;
- Restricting left turns on two-way streets as a means of eliminating conflicts with left-turn movements, thereby reducing congestion and delay;
- Separating turning vehicles from through traffic with continuous median strip turn lanes;
- "Channelizing" roadways and intersections (i.e., clearly marking travel lanes and paths with striping and signage to reduce motorist confusion and uncertainty by channeling traffic into the proper position on the street) to improve vehicular flow and capacity; and
- Widening and reconstructing short sections of roadways and intersections to reduce bottlenecks along sections where traffic capacity is below that of the adjacent street (e.g., traffic islands, turning lanes, and signage).

Several types of programs fall under enforcement and management:

- Incident management systems consist of roving tow or service vehicles, motorist aid call boxes, incident teams, signage systems, contingency planning, and improved information availability to consumers through radio and television.
- Ramp metering, a technique for improving traffic flow on freeways, uses signals to regulate traffic entering the highway to pre-timed intervals or to intervals determined by traffic volumes on the ramp or the highway.
- This area also includes all other enforcement of traffic and parking program regulations necessary for individuals to adapt or adhere to particular travel and parking behaviors.

ITS applies information processing, communications technology, advanced control strategies, and electronics to improve the safety and efficiency of a transportation system. In the context of mobile source emission reduction strategies, ITS emphasizes advanced traffic control, incident management, and corridor management. This area includes the following:

- Transportation management centers (TMCs) contain closed-circuit monitors for observing traffic conditions. Cameras are placed along sections of freeways or arterials commonly congested during commute hours. These cameras enable TMC personnel to observe traffic and respond to situations in a timely manner, reducing adverse effects on the commuting traffic. TMCs serve as information and communication conduits between transportation personnel and law enforcement officials.

- The Congestion Management System (CMS), a decision support tool, provides an integrated approach to planning by assessing information on all asset inventories, including condition and operational performance. Designed to assist decision makers in choosing cost-effective strategies and actions, CMS is a systematic approach to improving the efficiency of transportation assets. CMS is a tool for data management, analysis, and deficiency identification for all state highway assets, as well as local roadways. CMS uses historic, current, and forecasted attributes to help identify current and future congested roadways. It also incorporates travel demand forecasting capabilities for urban and rural areas to assess transportation system performance, identifying areas where it is unacceptable. Performance measures with localized thresholds allow CMS to address movement of people, vehicles, and goods based on goals and objectives in specific areas.

Typically, city and county public works departments implement traffic flow improvements with financial assistance provided by state and federal funding sources. Because these actions facilitate urban driving, there is usually little public opposition, except perhaps for local residents who may object to disruptions caused by construction.

Many small jurisdictions and even some large central cities have limited traffic engineering capabilities and budgets. In those cases, traffic signal management and roadway maintenance and design are often limited to the most basic or rudimentary installation and maintenance functions.

Implementing programs of interrelated traffic flow enhancement strategies can lead to substantial reductions in travel time and delay. Combined with signalization improvements and enforcement, traffic operations can fundamentally affect circulation in a relatively large area, improving system travel speed and efficiency overall. For any improvement to be successful, good coordination must exist between state and local traffic agencies and the police department assigned enforcement responsibilities.

7.1 Traffic Signalization

Strategy: Reduce carbon monoxide (CO) and hydrocarbon (HC) emissions by decreasing vehicular stops and idling, which would in turn reduce travel times and traffic delays.

Description: Traffic signalization increases the efficiency of traffic flow at intersections by improving interconnection and coordination of signals, leading to reductions in travel times, delay, and stop-and-go driving. Traffic signalization can be as simple as updating equipment and/or software or improving the timing plan.

These projects are generally the most available tool for reducing congestion on local and arterial streets. Significant improvements in travel speed and/or time can be achieved.

Because signal improvements reduce travel times and stop-and-go driving conditions, they can measurably reduce CO and HC emissions as well as reduce fuel consumption. The effects on vehicular emissions, however, can be difficult to quantify. Although system-wide air quality benefits might be low, measurable benefits to local air quality and congestion relief are common in downtown areas and major activity sites or corridors.

Traffic signalization improvements may encourage additional traffic, increasing VMT. An increase in VMT along a roadway with improved traffic flow would offset some of the short-term air quality improvements generated by faster, more consistent travel speeds. Also, by reducing travel time on affected corridors, traffic signalization may attract additional vehicles and divert motorists from alternative modes of transportation.

The costs of a traffic signalization program will vary depending on the type of improvement and number of signals involved. Updating a signalized intersection requires a new traffic controller or traffic control software strategy. Timing plan improvements entail a labor-intensive data collection effort to determine new signal timings and subsequent re-timing of signals at each location. Signal coordination and interconnection require cable installation, as well as a series of controllers or a centralized computer-based master control system. To remove signals, a field survey must be performed to substantiate the elimination of the signals. Fieldwork is also necessary to remove the equipment.

Application: Major arterials or high-capacity roadways with uncoordinated traffic signals.

Variables:

D_A: Average vehicle delay at intersection after implementation (hours)

D_B: Average vehicle delay at intersection before implementation (hours)

$EF_{A, OP}$: Speed-based running exhaust emission factor during off-peak hours in affected corridor after implementation (NO_x , VOC, or CO) (grams/mile)

$EF_{A, P}$: Speed-based running exhaust emission factor during peak hours in affected corridor after implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{B, OP}$: Speed-based running exhaust emission factor during off-peak hours in affected corridor before implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{B, P}$: Speed-based running exhaust emission factor during peak hours in affected corridor before implementation (NO_x, VOC, or CO) (grams/mile)

EF_I: Idling emission factor (NO_x, VOC, or CO) (grams/hour)

L: Length of corridor affected by signalization project (miles)

$V_{D, OP}$: Average daily volume for the corridor during off-peak hours

$V_{D,P}$: Average daily volume for the corridor during peak hours

Equation:

For corridors:

Daily Emission Reduction (for each approach) = A + B

$$A = V_{D,P} * (EF_{B,P} - EF_{A,P}) * L$$

Change in running exhaust emissions from improved traffic flow during the peak period

$$B = V_{D,OP} * (EF_{B,OP} - EF_{A,OP}) * L$$

Change in running exhaust emissions from improved traffic flow during the off-peak period

Final unit of measure: grams/day
Source: Federal Highway Administration (FHWA) Southern Resource Center (modified by Texas Transportation Institute)

For individual intersection or grade separation:

Daily Emission Reduction = A + B

$$A = (D_B - D_A) * EF_I * V_{D,P}$$

Change in idling emissions from reduced vehicle delay times during the peak period

$$B = (D_B - D_A) * EF_I * V_{D,OP}$$

Change in idling emissions from reduced vehicle delay times during the off-peak period

Final unit of measure: grams/day
Source: Texas Transportation Institute

7.2 Traffic Operations

Strategy: Reduce congestion in corridors and intersections, improving traffic speeds and reducing idling times, leading to lower emissions and improved traffic system efficiency.

Description: Traffic operation improvements, similar to traffic signalization improvements (see Section 7.1), primarily focus on reducing congestion on local and arterial streets by improving the system's efficiency. Generally, each action will improve traffic flow and safety. Many roadway changes require only signage and pavement marking changes with little new construction and are relatively quick to implement.

While costs vary, these projects are relatively inexpensive compared to other types of traffic flow solutions. Converting streets to one-way operations or implementing left-turn restrictions at intersections involves installing new signage and possibly removing or relocating existing signs and traffic signals. Implementing a continuous left-turn median lane requires new signage and lane markings and modifications to existing signage and signals. Similarly, improving the channelization of a roadway or intersection requires pavement striping, markings, and signage.

The system-wide air quality benefits are low and difficult to predict. However, in conjunction with their known effectiveness at improving traffic bottlenecks and flow, these programs should provide measurable reductions in localized CO and HC emissions. Some EPA case studies cite reductions in CO and VOC emissions and decreasing hours of delay, along with increases in average speed and intersection capacity.

Combined with signalization improvements and enforcement, traffic operations can provide a plan that effectively improves circulation in a relatively large area, resulting in overall advancements in system travel speed and efficiency.

Application: Areas where changes in lane use are permitted, areas with sufficient right-of-way for roadway widening, and areas with adequate right-of-way at corners.

Variables:

DR_{OP}:	Estimated delay reduction during off-peak period (seconds)
DR_{P}:	Estimated delay reduction during peak period (seconds)
EF_{I}:	Idling emission factor (NO_x, VOC, or CO) (grams/hour)
$EF_{A, OP}$:	Speed-based running exhaust emission factor during the off-peak period after implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{A, P}$:	Speed-based running exhaust emission factor during the peak period after implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{B, OP}$:	Speed-based running exhaust emission factor during the off-peak period before implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{B, P}$:	Speed-based running exhaust emission factor during the peak period before implementation (NO_x, VOC, or CO) (grams/mile)
I_{OP}:	Off-peak hour reduction in idling emissions (hours)
I_{P}:	Peak hour reduction in idling emissions (hours)
L:	Length of affected roadway (miles)
N_{OPH}:	Number of off-peak hours
N_{PH}:	Number of peak hours

$V_{H, OP}$: Number of vehicles that pass through the intersection per hour during the off-peak period

$V_{H, P}$: Number of vehicles that pass through the intersection per hour during the peak period

VMT_{OP}: Off-peak hour reduction in speed emissions

VMT_{PH}: Peak hour reduction in speed emissions

Equation:

$$\textbf{Daily Emission Reduction} = A + B + C$$

$$A = (I_P + I_{OP}) * EF_I$$

Change in idling exhaust emissions from improved traffic flow during the peak and off-peak periods

$$B = (EF_{B, P} - EF_{A, P}) * VMT_{PH}$$

Change in running exhaust emissions from improved traffic flow during the peak period

$$C = (EF_{B, OP} - EF_{A, OP}) * VMT_{OP}$$

Change in running exhaust emissions from improved traffic flow during the off-peak period

Where

$I_P = (N_{PH} * V_{H, P} * DR_P)/3600$ seconds per hour
$I_{OP} = (N_{OPH} * V_{H, OP} * DR_{OP})/3600$ seconds per hour

Reduction of idling in the peak and off-peak period

$VMT_{PH} = N_{PH} * V_{H, P} * L$
$VMT_{OP} = N_{OPH} * V_{H, OP} * L$

Vehicle miles traveled affected by the strategy in the peak and off-peak periods

Final unit of measure: grams/day

Source: Texas Transportation Institute (modified from CARB and FHWA Southern Resource Center)

7.3 Enforcement and Management

Strategy: Help reduce congestion and improve travel times on local and arterial roads and highways by consistent enforcement of road facility use and effective incident detection.

Description: Enforcement and management programs provide a variety of tools that, alone or in combination with other measures such as traffic operations and signalization improvements, can provide additional means to improve traffic flow conditions, both locally and at the corridor-wide level.

Many traffic flow improvements involve some modifications of driving behavior by local residents and commuters. As a result, the programs most likely to be successful are those providing the greatest incentives or disincentives to change. Strict enforcement of traffic flow improvements such as restricted left turns and parking limitations, for example, discourages violations. If initial enforcement of the programs is pursued vigorously, it can eventually be relaxed somewhat. Overly restrictive measures should be avoided. Very high fines, for instance, may be unacceptable to most users, fostering general resentment toward the program.

Enforcement and management strategies typically involve a substantial amount of time and planning to implement when compared to signalization or operations improvement programs.

Management measures can implement on-street parking and may involve establishing new no-stopping zones at select locations for the peak period or all day; relocation and consolidation of cab stands, tour bus stops, loading zones, and handicapped parking spaces; and removal of short-term parking meters.

Incident detection programs can significantly reduce the average duration of lane blockages. Roving tow or service vehicles can respond rapidly to traffic blockages. Using a surveillance and management system can increase the percentages of highway sections that are relatively free flowing versus those that are congested. Broad application of ramp metering can significantly benefit regional mobility by increasing average highway speeds, decreasing travel times, and reducing congestion on the corridor.

Enforcement activities feature a highly visible program that includes meter readers, motorcycle police officers, and tow trucks. For example, an intense enforcement policy would reduce the number of illegal long-term parking at metered spaces, increasing curb-side parking capacity, and would also reduce incidences of double parking, improving arterial capacity and decreasing travel times.

Enforcement and management activities impose capital, operating, and maintenance costs. For example, an enforcement program at a specific facility includes the labor costs associated with traffic control officers providing patrols and surveillance of the facility during its operation. Traffic and parking enforcement programs require meter readers, uniformed police officers, and tow trucks. However, the revenue generated by fines usually exceeds costs by a factor of seven or more.

An incident management system entails costs for embedded traffic detectors, changeable message signs, closed-circuit televisions, and central computer control. Metered ramps require additional signals and signage.

Application: Controlled access highways and arterials.

Note: *Because of the high costs of enforcement and management programs, this measure is recommended for roads having a major impact on area-wide mobility.*

Note: *Ramp metering may result in long queues at particular ramps and higher localized CO concentrations. With traffic speed improvements brought on by metering, increases in traffic volume may be detected, which may increase VMT, thereby making air quality improvements difficult to predict.*

Variables for Incident Management Programs:

ADT_i: Average daily traffic for each affected link

ADT_T: Total average daily traffic for affected system (vehicles/day)

E_{REG}: Regional freeway emissions (grams)
(Variable can be difficult to infer from available data. Travel demand model can be used, using links, volumes, and average speeds along mainlines to infer regional emissions, but may require extra time and effort on the part of planners.)

F_{Eff}: Project effectiveness factor for each affected freeway
(The FHWA Southern Resource Center, August 1999, reports a 50 percent effectiveness rate for detection and response, 25 percent for motor assistance patrol, and 15 percent for surveillance.)

F_{NR}: Nonrecurring emissions (decimal)
(According to the FHWA Southern Resource Center, August 1999 report, 4.9 percent of freeway emissions are caused by nonrecurring congestion.)

Equation for Incident Management:

Daily Emission Reduction =

$$\mathbf{E}_{REG} * \mathbf{F}_{NR} * \sum_{i=1}^{n} \mathbf{F}_{Eff\ i} * \left(\frac{\mathbf{ADT}_i}{\mathbf{ADT}_T} \right)$$

The amount of regional nonrecurring congestion emissions multiplied by the sum of each link's effectiveness and proportion to the total regional average daily traffic (ADT)

Final unit of measure: grams/day
Source: Texas Transportation Institute

Variables for Ramp Metering:

EF_A: Speed-based running exhaust emission factor for mainline after implementation (NO_x, VOC, or CO) (grams/mile)

EF_B: Speed-based running exhaust emission factor for mainline before implementation (NO_x, VOC, or CO) (grams/mile)

EF_I: Idling emission factor (NO_x, VOC, or CO) (grams/hour)

L: Length of freeway corridor impacted by ramp metering (in hours) (miles)

t_q: Average time spent in queue waiting to enter freeway (hours)

N_V: Number of vehicles using metered ramps

V_A: Average traffic volume per operating period on main lanes after implementing ramp metering

V_B: Average traffic volume per operating period on main lanes before implementing ramp metering

Equation for Ramp Metering:

$$\text{Daily Emission Reduction} = A - B$$

$$A = [(V_B * EF_B) - (V_A * EF_A)] * L$$

The change in running exhaust emissions on the freeway along the metered section

$$B = N_V * t_q * EF_I$$

The increase in idling exhaust emissions from queuing at the metered ramps

Final unit of measure: grams/day
Source: Texas Transportation Institute

7.4 Intelligent Transportation Systems (ITS)

Strategy: Improve traffic speeds and reduce idling time through advanced traffic control systems and more efficient incident and corridor management.

Description: ITS combines the strengths of regional transportation planning models and traffic simulation models with overall transportation management strategies. It applies information technologies to the effective management of a traffic system and has received greater emphasis as a transportation planning concept since the Intermodal Surface Transportation Efficiency Act (ISTEA).

However, planners should be aware that some ITS methodologies require very detailed input data and complex computer models. Also, ITS entails potentially high costs to plan, implement, and utilize. Implementation of highway information management systems, from conceptual planning to the complete system, can require five to ten years.

Examples of ITS projects include transportation management centers. These centers contain closed-circuit monitors and many other data collection tools to observe traffic conditions. Cameras are placed along portions of freeways or arterials that commonly experience congestion difficulties during commute hours. These cameras enable personnel within the TMC to observe traffic and respond to situations in a timely manner, reducing the adverse effects on commuting traffic. TMCs serve as information and communication conduits between transportation personnel and law enforcement officials.

The Congestion Management System (CMS), a decision support tool, provides an integrated approach to planning by assessing information on all asset inventories, including condition and operational performance. Designed to assist decision makers in choosing cost-effective strategies and actions, CMS is a systematic approach to improving the efficiency of transportation assets. CMS is a tool for data management, analysis, and deficiency identification for all state highway assets, as well as local roadways.

CMS uses historic, current, and forecasted attributes to support identification of current and future congested roadways. It also incorporates travel demand forecasting capabilities for urban and rural areas to assess transportation system performance and identify areas with unacceptable performance. Performance measures with localized thresholds allow CMS to address movement of people, vehicles, and goods based on goals and objectives of specific areas.

In areas where ITS solutions are being considered and evaluated, researchers have found at least one out of three conditions exists:

- Cooperation and a partnership approach among all agencies involved in operating and enforcing laws on the transportation system.
- Improved communication and coordination across geographic boundaries and between agencies. ITS is a metropolitan and regional solution and requires a high level of cooperation among entities to be effective. ITS cannot be achieved by a single agency.
- Coordinated collection of data and use of information. ITS, especially TMCs, requires a larger amount of data collection, storage, and analysis than many agencies have previously amassed. Integration of the electronic systems that make up the different components is a key issue.

These conditions are considered preliminary but necessary steps that heighten awareness of the benefits of ITS solutions and allow for the consideration of ITS solutions. Without these conditions, planners should be cautious in considering ITS solutions as a MOSERS project in their area.

Application: Controlled-access highways and arterials.

Note: *Because of the high costs of ITS programs, this measure is recommended for high-volume roads having major impact on area-wide mobility.*

Equation 1

Variables:

ADT_i: Average daily traffic for each affected roadway

EF_A: Speed-based running exhaust emission factor after implementation (NO_x, VOC, or CO) (grams/mile)

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

L_i: Length of each freeway affected by ITS (miles)

N: Number of affected corridors

Equation:

$$\textbf{Daily Emission Reduction} = \sum_{i=1}^{n} [\mathbf{L}_i * \mathbf{ADT}_i * (\mathbf{EF}_B - \mathbf{EF}_A)_i]$$

The sum of each ITS link's change in running exhaust emissions resulting from improved traffic flow

Peak and off-peak hours can be split in equation.

Final unit of measure: grams/day
Source: Texas Transportation Institute

Equation 2

Variables:

E_{OP}: Emissions generated by congestion on affected roadway system during the off-peak period for each pollutant (NO_x, VOC, or CO) (grams)

E_P: Emissions generated by congestion on affected roadway system during the peak period for each pollutant (NO_x, VOC, or CO) (grams)

$F_{EN, OP}$: Percent of nonrecurrent congestion eliminated on roadways with ITS deployment, off-peak period (decimal)

$F_{EN, P}$: Percent of nonrecurrent congestion eliminated on roadways with ITS deployment, peak period (decimal)

$F_{ER, OP}$: Percent of recurrent congestion eliminated on roadways with ITS deployment, off-peak period (decimal)

$F_{ER, P}$: Percent of recurrent congestion eliminated on roadways with ITS deployment, peak period (decimal)

F_{ITS}: Percent of roadway system coverage with ITS deployment (decimal)

$F_{NR, OP}$: Percent of roadway system emissions caused by nonrecurring congestion in the off-peak period (decimal)

$F_{NR, P}$: Percent of roadway system emissions caused by nonrecurring congestion in the peak period (decimal)

F_{OPH}: Percent of off-peak hours/emissions affected by ITS deployment (decimal)

Equation:

$$\text{Daily Emission Reduction} = A + B + C + D$$

$$A = E_P * F_{N, RP} * F_{ITS} * F_{EN, P}$$

Change in emissions from alleviating peak hour nonrecurrent congestion

$$B = E_{OP} * F_{OPH} * F_{NR, OP} * F_{ITS} * F_{EN, OP}$$

Change in emissions from alleviating off-peak hour nonrecurrent congestion

$$C = E_P * F_{ITS} * (1 - F_{N, RP}) * F_{ER, P}$$

Change in emissions reduced from alleviating peak hour recurrent congestion

$$D = E_{OP} * F_{OPH} * F_{ITS} * (1 - F_{NR, OP}) * F_{ER, OP}$$

Change in emissions from alleviating off-peak hour recurrent congestion

Final unit of measure: grams/day
Source: North Central Texas Council of Governments, 2006

7.5 Railroad Grade Separation

Strategy: Reduce congestion in corridors by reducing idling times and leading to lower emissions and improved traffic system efficiency.

Description: Railroad grade separations remove periodic traffic delays on major roadways by raising or lowering either the rail line or the roadway and permitting more efficient flow of traffic at major rail crossings.

This strategy can be a large-scale project and may require high costs in right-of-way (ROW) and construction. Close cooperation must be gained with the affected railroad company. The system-wide air quality benefits are low and difficult to predict. However, these programs should provide measurable reductions in localized CO and HC emissions. Delay time is eliminated at the rail grade separation.

Application: Arterials with delays caused by at-grade rail crossings.

Variables:

EF_I: Idling emission factor (NO_x, VOC, or CO) (grams/hour)

t_C: Average amount of time rail crossing is closed due to train crossing (hours/crossing)

t_H: Duration of analysis period (hours)

$t_{H,C}$: Hours per analysis period roadway is closed due to train crossing

V: Bi-directional arterial volume for analysis period

Equation:

$$\text{Daily Emission Reduction} = A * B$$

$$A = t_{H,C} / t_H * V$$

The number of vehicles affected by rail crossing delays

$$B = t_C / 2 * EF_I$$

The average idling emissions resulting from affected traffic idling at the closed crossing (assumed to be half of the average time the roadway is closed per train crossing)

Final unit of measure: grams/day
Source: TTI

8.0 PARK-AND-RIDE/FRINGE PARKING

Fringe and transportation corridor parking facilities serving multiple-occupancy vehicle programs or transit service
Section 108 (vi), CAAA

Park-and-ride/fringe parking facilitates passenger transfer to transit services, carpooling, and vanpooling. The lots are usually located at key highway interchanges or along heavily traveled corridors remote from the central business district or major activity centers. Their availability promotes the use of transit services and the implementation of rideshare programs.

The parking lots accommodate drivers who wish to use transit or join carpools or vanpools at the lots to complete their trips to the work site. This results in decreases in the number of vehicles entering congested areas and, as a result, reduces emissions. State or local transportation agencies may informally designate or formally establish these parking facilities.

The costs of this emission reduction strategy are relatively high but not as expensive as HOV facilities. Design and construction of the site and operation and maintenance after it is built are the main investments. Land acquisition costs may be significant, but many lots are built in system highway or transit right-of-way next to transit stations or centers.

Key issues in considering park-and-ride and fringe lots include:

- Consideration of local traffic conditions around potential sites should be given to avoid intensifying local traffic or air quality problems.
- Lots should have adequate pedestrian and bicycle access.
- Planners should consider the availability of personal services such as banks, cleaners, convenience stores, and daycare at or near the lot.

8.1 New Facilities

Strategy: Reduce vehicle trips and vehicle miles traveled (VMT) by enhancements of transit system and ridesharing.

Description: Construction of new park-and-ride facilities in locations remote from the central city area or major business activity centers or on the fringes of major employment centers. Lots or garages are constructed adjacent to or very near transit facilities or heavily traveled corridors. These lots are designed to be conducive to several modes of transportation including pedestrian and bicycle facilities. New facilities will require coordination with other transportation agencies, and political and citizen groups.

Application: Cities with HOV facilities or public transit systems.

Variables:

$\mathbf{EF}_B$:	Speed-based running exhaust emission factor before implementation (NO_x , VOC, or CO) (grams/mile)
$\mathbf{N}_{PK}$:	Number of parking spaces
$\mathbf{TL}_{PR}$:	Average auto trip length from home to parking facility (miles)
$\mathbf{TL}_W$:	Average auto work trip length (miles)
$\mathbf{U}_P$:	Parking lot utilization rate (estimate)

Equation:

Daily Emission Reduction =

$$N_{PK} * U_P * (TL_W - TL_{PR}) * EF_B * 2 \text{ trips/day}$$

Reduction in running exhaust emissions from reduced VMT resulting from park-and-ride lot use

Final unit of measure: grams/day
Source: Texas Transportation Institute

8.2 Improved Connections to Freeway System

Strategy: Enhance the attraction of using park-and-ride lots.

Description: A direct connector ramp between park-and-ride lots and a freeway is an enhancement of the service provided by the lot. Some emissions will be reduced as buses, vans, and carpools idle less while waiting to enter and exit the freeway. This strategy serves to enable park-and-ride lots and improves public transit.

This measure is also more expensive than others. The location of the lot relative to the freeway will determine the cost of constructing the ramp. Parking lots adjacent to highways, requiring little site preparation, should demand less funding than others in more remote locations.

Application: Urban areas with park-and-ride lots, transit service, and rideshare programs.

Variables:

EF_A: Speed-based running exhaust emission factor after implementation (NO_x, VOC, or CO) (grams/mile)

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

F_{AT}: Percentage of participants who previously drove single-occupancy vehicles (SOVs) (decimal)

N_P: Number of new park-and-ride participants

TL_{PR}: Average trip length to park-and-ride facility (miles)

TL_W: Average auto trip length (miles)

$VMT_{Auto, A}$: Vehicle miles traveled by auto after implementation

$VMT_{Auto, B}$: Vehicle miles traveled by auto before implementation

$VMT_{Bus\ A}$: Vehicle miles traveled by transit vehicle after implementation

$VMT_{Bus\ B}$: Vehicle miles traveled by transit vehicle before implementation

Equation:

Daily Emission Reduction = A + B

$$A = (VMT_{Bus,\ B} * EF_B - VMT_{Bus,\ A} * EF_A) + (VMT_{Auto,\ B} * EF_B - VMT_{Auto,\ A} * EF_A)$$

Reduction in vehicle running exhaust emissions from improved travel time from park-and-ride lot to freeway entrance

$$B = N_P * F_{AT} * TL_{PR} * EF_B * 2\ \text{trips/day}$$

Reduction in auto running exhaust emissions from a reduction in commute trip length multiplied by two trips per day (round trip)

Final unit of measure: grams/day
Source: Texas Transportation Institute

8.3 Onsite Support Services

Strategy: Reduce VMT through clustering of personal services at park-and-ride/fringe parking lots.

Description: Park-and-ride/fringe parking lots that provide personal support services enhance passenger use of the lot. Riders are able to conduct personal business in one place, which reduces VMT.

Some services and amenities provided at park-and-ride/fringe parking lots include convenience stores, financial services, child-care centers, postal services, laundry/dry cleaning, and food services.

Application: Urban areas with existing park-and-ride/fringe parking lots.

Variables:

EF_B:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
F_{AT}:	Percentage of participants who previously drove SOVs (decimal)
F_{USE}:	Percentage of park-and-ride users that utilize the facilities
N_{HBO}:	Average number of home-based other trips
N_P:	Number of new participants using onsite services at the park-and-ride/ fringe parking lots
N_{PK}:	Number of parking spaces
TL_{HBO}:	Average trip length of home-based other
TL_{PR}:	Average trip length to facility (miles)
TL_W:	Average auto trip length (miles)
U_P:	Parking lot utilization rate (estimate)

Equation:

$$\textbf{Daily Emission Reduction} = A + B + C$$

$$A = (N_{PK} * U_{P} * F_{USE}) * N_{HBO} * TL_{HBO} * EF_{B}$$

Reduction in auto running exhaust emissions from a reduction in home-based other trips

$$B = (N_{PK} * U_{P} * F_{USE}) * N_{HBO} * TEF_{AUTO}$$

Reduction in auto start exhaust emissions from a reduction in home-based other trips

$$C = N_{P} * F_{AT} * TL_{PR} * EF_{B} * 2 \text{ trips/day}$$

Reduction in auto running exhaust emissions from a reduction in commute trip length multiplied by two trips per day (round trip)

Final unit of measure: grams/day
Source: Texas Transportation Institute

8.4 Shared-Use Parking

Strategy: Enhance park-and-ride services and subsequent reduced VMT and vehicle trips.

Description: In some urban locations, it may be more cost-efficient for a city to establish park-and-ride service at an existing parking lot. Joint use of lots at shopping malls, theaters, churches, or stadiums can be negotiated with property owners or management companies.

Application: Cities with transit service.

Variables:

- $\mathbf{EF_B}$: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
- $\mathbf{N_{PK}}$: Number of parking spaces
- $\mathbf{TL_{PR}}$: Average auto trip length from home to parking facility (miles)
- $\mathbf{TL_W}$: Average auto work trip length (miles)
- $\mathbf{U_P}$: Parking lot utilization rate (estimate)

Equation:

$$\textbf{Daily Emission Reduction} = N_{PK} * U_P * (TL_W - TL_{PR}) * EF_B * 2 \text{ trips/day}$$

Reduction in running exhaust emissions from reduced VMT resulting from park-and-ride lot use

Final unit of measure: grams/day
Source: Texas Transportation Institute

9.0 VEHICLE USE LIMITATIONS AND RESTRICTIONS

Programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use
Section 108 (vii), CAAA

Vehicle use limitations/restrictions are techniques for restricting the use of certain types of vehicles in a given geographic area or specified time period. There are three major categories of vehicle use restrictions:

- Route diversion,
- No-drive days, and
- Control of truck movements.

Although pedestrian and transit malls have been created in many downtown areas in the United States and auto-restricted zones have been used in Europe and Asia, vehicle use limitations and restrictions are still a potentially debatable technique for a local government or agency to implement. All these program types should accommodate the needs of commercial interests requiring accessibility by customers/clients for goods delivery in designated areas. Clear and careful consideration of an area's economic strengths and weaknesses should be made before restricting vehicle use. Regardless of the final policy, alternative means of providing access to, and circulation within, the area affected by the program should be developed.

9.1 No-Drive Days

Strategy: Reduce vehicle trips and vehicle miles traveled (VMT).

Description: No-drive days request or require identified individuals to not operate their vehicles on designated days, reducing the number of vehicles on roads. A particular letter or number on their license plates usually identifies the individuals. The program can be mandatory or voluntary. In the United States, no-drive days are currently all voluntary.

Alternative transportation on no-drive days must be available to drivers and coordinated with the program. This measure may be difficult to initiate without an existing transit system, rideshare, or employer-based programs.

No-drive day programs require significant marketing efforts and cooperation of local media.

Application: Cities or areas that are well served by transit or where alternate transportation is available.

Variables:

$EF_{B, OP}$: Speed-based running exhaust emission factor on roadway during off-peak period before no-drive days implemented (NO_x , VOC, or CO) (grams/mile)

$EF_{B, P}$: Speed-based running exhaust emission factor on roadway during peak period before no-drive days implemented (NO_x,, VOC, or CO) (grams/mile)

F_{CND}: Percent compliance of the no-drive days program (decimal)

F_W: Percentage of participating vehicles commuting to work (decimal)

N_{NW}: Average number of nonwork trips

N_V: Number of vehicles participating

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_{NW}: Average nonwork trip length (miles)

TL_W: Average work trip length (miles)

$VMT_{R, OP}$: Reduction in regional off-peak period VMT after no-drive days implemented

$VMT_{R, P}$: Reduction in regional peak period VMT after no-drive days implemented

$VT_{R, OP}$: Reduction in regional number of off-peak period vehicle trips after no-drive days implemented

$VT_{R, P}$: Reduction in regional number of peak period vehicle trips after no-drive days implemented

Equation:

Daily Emission Reduction = A + B + C

$$A = VMT_{R, P} * EF_{B, P}$$

Reduction in auto running exhaust emissions resulting from reduced peak period VMT multiplied by the average peak period running exhaust emission factor

$$B = VMT_{R, OP} * EF_{B, OP}$$

Reduction in auto running exhaust emissions resulting from reduced off-peak period VMT multiplied by the average off-peak period running exhaust emission factor

$$C = (VT_{R, P} + VT_{R, OP}) * TEF_{AUTO}$$

Reduction in auto start emissions from trip reductions

Where

$VT_{R, P} = N_V * F_{CND} * F_W * 2$ trips/day

The number of vehicles affected by the program multiplied by the compliance rate with the program multiplied by the fraction of *vehicle use for commute trips multiplied by two trips per day (round trip)*

$$VT_{R,\,OP} = N_{V} * F_{CND} * (1 - F_{W}) * N_{NW}$$

The number of vehicles affected by the program multiplied by the compliance rate with the program multiplied by the fraction of vehicle use for noncommute trips multiplied by the average number of noncommute auto trips per day

$$VMT_{R,\,P} = VT_{R,\,P} * TL_{W}$$
$$VMT_{R,\,OP} = VT_{R,\,OP} * TL_{NW}$$

The vehicle trips reduced multiplied by the average auto commute or noncommute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

9.2 Control of Truck Movement

Strategy: Reduce congestion along corridors and reduce idling. Reduce ozone formation through an offset in emission times.

Description: Cities can regulate the movement of trucks within some areas at certain times. Historically, these programs have involved restricting trucks on local streets in certain areas of the central business district during peak hours, designating specific loading zones, delivery schedules, and truck routes, as well as multiple business delivery consolidation. However, controlling truck movements requires various legal restrictions that practitioners should definitely consider when proposing such measures. The cooperation and support of the trucking industry are crucial to program success.

Implementation of controls must involve consideration of time periods and routes currently being used for movements, direct costs to businesses for the controls, and indirect costs to the economy for changing truck movement patterns. Therefore, local traffic and economic data are essential to planning controls.

Application: Downtown areas or major business activity centers with alternate freeway and arterial routes available.

Variables:

$EF_{A,i}$: Speed-based running exhaust emission factor for fleet composite (including trucks) (NO_x, VOC, or CO) (grams/mile)

$EF_{B,i}$: Speed-based running exhaust emission factor for defined fleet composite (excluding trucks) (NO_x, VOC, or CO) (grams/mile)

i: Time period

L: Length of roadway(s) in strategy area (miles)

VMT_P: Vehicle miles traveled by fleet composite

Equation:

$$\textbf{Daily Emission Reduction} = \sum [VMT_P * EF_{B,i} - VMT_P * EF_{A,i}]_i$$

The running exhaust emissions on the affected links before control subtracted by the running exhaust emissions on the affected links after control

Final unit of measure: grams/day
Source: Texas Transportation Institute

10.0 AREA-WIDE RIDESHARE INCENTIVES

Programs for the provision of all forms high-occupancy, shared-ride services
Section 108 (viii), CAAA

Area-wide rideshare incentives promote and assist state, regional, and local efforts aimed at encouraging commuters to use alternatives to SOVs in traveling to work and encourage employers to provide in-house programs that promote ridesharing, transit, bicycling, and walking among employees. This strategy facilitates most employer-based transportation management programs and provides another example of the overlap between individual emission reduction strategies. The EPA has found that these programs are effective in enhancing the emission reduction efforts of small- and medium-sized businesses in an area.

The three main categories of area-wide rideshare incentives include the following:

- *Commute management organizations* are third-party ridesharing agencies that provide rideshare matching or alternative commute organization or incentive programs. The programs focus largely on employers, given their influence over employee commute and working patterns.
- *Transportation management associations* (TMAs) provide a structure for developers, property managers, employers, and public officials to cooperatively promote programs that mitigate traffic congestion, assist commuters, and encourage particular modes of travel in specific areas. TMAs can also provide government and private industry with a forum for discussion of current and future roadway and transit needs in an area.
- *State and local tax incentive and subsidy programs* provide incentives and disincentives for employers and employees to consider and utilize alternative modes of transportation to commute instead of SOVs.

The costs and benefits of area-wide rideshare incentive programs are difficult to measure. The EPA has found it difficult to establish causality between area-wide incentives and reduced vehicle miles traveled (VMT) and emissions. Commute management organizations, TMAs, and state and local tax incentives and subsidies are supportive of in-house employer programs, but the agency has concluded that there appears to be no evaluation that has estimated the impact of these programs above and beyond that attributable to the employer programs. The programs do improve the effectiveness of employer-based ridesharing programs, produce results among unaffiliated commuters, and serve to maintain existing levels of shared ride modes. It is a difficult task to separate the impacts of these programs above and beyond those reported for employers or to speculate on the increase in VMT or emissions if these programs did not exist.

As noted in Section 4 (employer-based transportation management programs), care must be taken not to double-count the effectiveness of area-wide rideshare incentives with the benefits of employer-based transportation management programs. The roles and responsibilities of various public, nonprofit, and for-profit organizations involved in promoting ridesharing and other travel alternatives within a region must be carefully delineated so their various efforts are not perceived as either duplicative or conflicting by employers and individuals.

10.1 Commute Management Organizations

Strategy: Facilitate and promote ridesharing activities to reduce vehicle trips and VMT.

Description: Commute management organizations are third-party ridesharing agencies that provide rideshare matching or alternative commute organization or incentive programs. The programs focus largely on employers, given their influence over employee commute and working patterns. Organization services can include computerized carpool matching, vanpool managing, and providing vanpool vehicles, marketing, and technical assistance to employers.

Application: Urban areas with populations of 50,000 or more where taxes or other public funding can be obtained for transportation/air quality purposes.

Variables:

AVO_{RS}: Average vehicle occupancy of rideshare (persons/vehicle)

EF_{B}: Speed-based running exhaust emission factor before implementation (NO_x , VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}: Number of participants in bicycle/pedestrian programs

N_{RS}: Number of participants in rideshare

N_{T}: Number of participants using transit facilities

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)

TL_{RS}: Average auto trip length to rideshare facility (miles)

TL_{T}: Average auto trip length to transit facility (miles)

TL_{W}: Average auto trip length to work (miles)

VMT_{R}: Reduction in daily auto vehicle miles traveled

$VMT_{R, BW}$: Reduction in daily auto vehicle miles traveled by bike/pedestrian mode

$VMT_{R, RS}$: Reduction in daily auto vehicle miles traveled by rideshare mode

$VMT_{R, T}$: Reduction in daily auto vehicle miles traveled by transit mode

VT_{R}: Reduction in number of daily vehicle trips

$VT_{R, BW}$: Reduction in number of daily vehicle trips by bike/pedestrian mode

$VT_{R, RS}$: Reduction in number of daily vehicle trips by rideshare mode

$VT_{R, T}$: Reduction in number of daily vehicle trips by transit mode

Equation:

$$\text{Daily Emission Reduction} = A + B$$

$$A = (\Sigma VT_{R} * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_{R} * EF_{B})$$

Reduction in auto running exhaust emissions from trip reductions

Where

$1 = F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$

The fractions of strategy participants that shift to other modes from single-occupant vehicles

$VT_{R, T} = N_T * F_{T, SOV} * 2$ trips/day
$VT_{R, RS} = N_{RS} * (1 - 1 / AVO_{RS}) * F_{RS, SOV} * 2$ trips/day
$VT_{R, BW} = N_{BW} * F_{BW, SOV} * 2$ trips/day

The number of participants multiplied by the fraction of SOV drivers that switch to another mode multiplied by two trips per day (round trip)

$VMT_{R, T} = VT_{R, T} * (TL_W - TL_T)$
$VMT_{R, RS} = VT_{R, RS} * (TL_W - TL_{RS})$
$VMT_{R, BW} = VT_{R, BW} * TL_W$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by Texas Transportation Institute)

10.2 Transportation Management Associations

Strategy: Facilitate efforts by private industry and government to effectively manage local, metropolitan, and county transportation issues.

Description: Transportation management associations are private organizations that provide a structure for developers, property managers, employers, and public officials to cooperatively promote programs that mitigate traffic congestion, assist commuters, and encourage particular modes of travel in specific areas. TMAs can also provide government and private industry with a forum for discussion of current and future roadway and transit needs in an area. TMAs are implemented by private entities and therefore do not require a substantial investment from government resources. California has the largest number of TMAs in the nation.

According to the EPA, TMA development activities can be very time consuming, often requiring one to two years before the TMA is fully operational.

Application: Urban areas with large groups of individual employers.

Variables:

AVO_{RS}: Average vehicle occupancy of rideshare (persons/vehicle)

EF_{B}: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}:	Number of participants in bicycle/pedestrian programs
N_{RS}:	Number of participants in rideshare
N_T:	Number of participants using transit facilities
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)
TL_{RS}:	Average auto trip length to rideshare facility (miles)
TL_T:	Average auto trip length to transit facility (miles)
TL_W:	Average auto trip length to work (miles)
VMT_R:	Reduction in daily auto vehicle miles traveled
$VMT_{R, BW}$:	Reduction in daily auto vehicle miles traveled by bike/pedestrian mode
$VMT_{R, RS}$:	Reduction in daily auto vehicle miles traveled by rideshare mode
$VMT_{R, T}$:	Reduction in daily auto vehicle miles traveled by transit mode
VT_R:	Reduction in number of daily vehicle trips
$VT_{R, BW}$:	Reduction in number of daily vehicle trips by bike/pedestrian mode
$VT_{R, RS}$:	Reduction in number of daily vehicle trips by rideshare mode
$VT_{R, T}$:	Reduction in number of daily vehicle trips by transit mode

Equation:

$$\textbf{Daily Emission Reduction} = \mathbf{A + B}$$

$$\mathbf{A = (\Sigma VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{T,\ SOV} + F_{RS,\ SOV} + F_{BW,\ SOV}$$

The fractions of strategy participants that shift to other modes from single-occupant vehicles

$$VT_{R,\ T} = N_T * F_{T,\ SOV} * 2 \text{ trips/day}$$
$$VT_{R,\ RS} = N_{RS} * (1 - 1/AVO_{RS}) * F_{RS,\ SOV} * 2 \text{ trips/day}$$
$$VT_{R,\ BW} = N_{BW} * F_{BW,\ SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of SOV drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R,\ T} = VT_{R,\ T} * (TL_W - TL_T)$$
$$VMT_{R,\ RS} = VT_{R,\ RS} * (TL_W - TL_{RS})$$
$$VMT_{R,\ BW} = VT_{R,\ BW} * TL_W$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by Texas Transportation Institute)

10.3 Tax Incentives and Subsidy Programs

Strategy: Use taxes and subsidies to provide disincentives to SOVs and incentives to alternative commute modes, thereby reducing vehicle trips and VMT.

Description: State and local tax incentive and subsidy programs provide incentives and/or disincentives for employers and employees to consider and utilize alternative modes of transportation to commute instead of SOVs.

Three types of financial incentives and their goals are summarized below:

- *Tax incentives* can allow employers and developers to provide facilities and equipment conducive to ridesharing. They may be in the form of investment tax credits or accelerated depreciation of facilities.
- *Subsidy programs* can help initiate a program by providing additional funding to enlist employer involvement and improve the preliminary risk to employers attempting a new program. The goal of the subsidies is for employers to see the benefits of the program and then continue the subsidies on their own to satisfy employee desire and/or to comply with regional or local mandates. Some subsidy programs target commuters directly, when employer involvement is unlikely or impractical. For example, vanpool subsidies tied to corridor reconstruction projects can aid in the formation of vanpools among commuters using the affected facilities regardless of their particular job location.
- *Enabling legislation* can eliminate or minimize barriers to widespread implementation of employer-based trip-reduction programs. A legal requirement mandating employer or developer involvement is a powerful determinant of program effectiveness. Mandatory participation is key to assuring widespread participation by enough employers to have an area-wide impact.

Application: Areas where taxes and public funding can be obtained for this purpose.

Variables:

AVO_{RS}: Average vehicle occupancy of rideshare (persons/vehicle)

EF_{B}: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{BW}: Number of participants in bicycle/pedestrian programs

N_{RS}: Number of participants in rideshare

N_{T}: Number of participants using transit facilities

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)

TL_{RS}: Average auto trip length to rideshare facility (miles)

TL_{T}: Average auto trip length to transit facility (miles)

TL_{W}: Average auto trip length to work (miles)

VMT_{R}: Reduction in daily auto vehicle miles traveled

$VMT_{R, BW}$: Reduction in daily auto vehicle miles traveled by bike/pedestrian mode

$VMT_{R, RS}$: Reduction in daily auto vehicle miles traveled by rideshare mode

$VMT_{R, T}$: Reduction in daily auto vehicle miles traveled by transit mode

VT_{R}: Reduction in number of daily vehicle trips

$VT_{R, BW}$: Reduction in number of daily vehicle trips by bike/pedestrian mode

$VT_{R, RS}$: Reduction in number of daily vehicle trips by rideshare mode

$VT_{R, T}$: Reduction in number of daily vehicle trips by transit mode

Equation:

Daily Emission Reduction = A + B

$$A = (\Sigma VT_{R} * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_{R} * EF_{B})$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$$

The fractions of strategy participants that shift to other modes from single-occupant vehicles

$$VT_{R, T} = N_{T} * F_{T, SOV} * 2 \text{ trips/day}$$
$$VT_{R, RS} = N_{RS} * (1 - 1/AVO_{RS}) * F_{RS, SOV} * 2 \text{ trips/day}$$
$$VT_{R, BW} = N_{BW} * F_{BW, SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of SOV drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R, T} = VT_{R, T} * (TL_{W} - TL_{T})$$
$$VMT_{R, RS} = VT_{R, RS} * (TL_{W} - TL_{RS})$$

$$VMT_{R,\,BW} = VT_{R,\,BW} * TL_{W}$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by Texas Transportation Institute)

11.0 BICYCLE AND PEDESTRIAN PROGRAMS

Programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of nonmotorized vehicles or pedestrian use, both as to time and place
Section 108 (ix),

Programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas
Section 108 (x), CAAA

Programs for new construction and major reconstructions of paths, tracks, or areas solely for the use by pedestrian or other nonmotorized means of transportation when economically feasible and in the public interest. For purposes of this clause, the Administrator shall also consult with the Secretary of the Interior
Section 108 (xv), CAAA

Bicycling and walking represent viable alternatives to most SOV trips. Every trip shifted from an SOV to a bicycle or walking results in a 100 percent reduction in vehicle emissions for that trip.

Bicycle and pedestrian programs can be adapted to a community's characteristics (e.g., topography, population, and existing infrastructure) and the budget of the administering agency. Common types of bicycle and pedestrian facilities include the following:

- Routes, lanes, and paths;
- Sidewalks and walkways;
- Plans and maps;
- Bicycle coordinators;
- Racks and other storage facilities;
- Shower facilities and clothing lockers;
- Connections with transit;
- Ordinances for bicycle parking;
- Education, media, and promotions;
- Sidewalk furniture; and
- Pedestrian safety modifications.

According to The EPA studies, bicycling and walking can substitute for short trips, 5 miles or less in length for bicycle trips and less than one-half mile for walking trips. The amount of VMT reduced may be small, but the air emissions benefits can be much greater because cold-start and hot-soak emissions comprise a large portion of the total emissions per vehicle trip.

Bicycle and pedestrian programs are often packaged with other strategies. The EPA notes that many employers provide bike and pedestrian facilities as part of their employer-based transportation management program. Many public transit improvement plans also support bicycle and pedestrian programs by incorporating elements to improve access to transit facilities. Municipal and regional trip-reduction ordinances can mandate these types of programs. Traffic flow improvements may indirectly support bicycle and pedestrian programs by improving signal intersections and increasing safety for bicyclists and pedestrians.

Costs for developing, maintaining, and operating a bicycle or pedestrian program may include the following:

- Salary and benefits for a program coordinator and staff,
- Land acquisition,
- Bike lane construction,
- Bike path construction,
- Bicycle lockers and racks,
- Publications,
- Signage striping,
- Maintenance,
- Enforcement, and
- Educational materials.

Except for equipment, direct cost to travelers is minimal.

Three main factors affect the viability of bicycling and walking as alternative transportation:

- Trip distance, defined above as 5 miles or less for bicycles and less than one-half mile for pedestrians;
- Safety, both along the path or lane and at the destination site; and
- Weather conditions, since inclement weather is not conducive to either mode.

The EPA reports that the following local factors help to ensure a successful program:

- Short travel distances between residential areas and key trip attractions;
- High concentrations of people under age 40;

- Compatible infrastructure that can be modified into appropriate facilities;
- Areas with localized congestion or crowded parking facilities; and
- Marketing and education efforts including maps and plans, safety training, promotions, and media events.

Factors that negatively affect bicycle and pedestrian programs are:

- Missing links in the network of lanes and trails,
- Lack of safe routes to work destinations,
- Conflicts with traffic laws that give preference to autos, and
- Lack of facilities to accommodate activities.

11.1 Bicycle and Pedestrian Lanes or Paths

Strategy: Replace vehicle trips and VMT with bicycle and pedestrian travel.

Description: A large number of bicycle and pedestrian projects are available to practitioners for implementation in air quality mitigation efforts. With ISTEA, the Transportation Equity Act for the 21st Century (TEA-21), and the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), funding for these types of programs has increased dramatically in the last decade. They include:

- Reallocation of right-of-way to accommodate bicycles and pedestrians;
- Traffic calming programs;
- Median refuges at key minor street crossings and bike-friendly signals;
- Independent bicycle/pedestrian structures or those in conjunction with other existing or planned transportation facilities;
- New trails, connecting existing trail segments, and encouraging developers to include trails in their developments;
- Improved connections between residential areas and transit stops, providing secure bicycle parking at stops and providing for carrying bicycles on the system;
- On bridges, reallocation of bridge deck width by shifting lane lines, modifying surface for better bicycle stability, modifying ramps to discourage high-speed turning movements, and, as a last resort, developing bicycle connections independent of the bridge in question;
- Safety upgrades at intersections;
- Bicycle-sensitive loop detectors in new installations and existing installations retrofitted where needed;
- Replacing bad drain grate standards with bicycle-safe models, replacing or modifying existing installations, and, as a routine

practice, considering bicyclists when locating new utilities;

- Providing smooth paved shoulders on all new construction and reconstruction; and
- Increasing bike parking regularly.

Application: Areas where travel distances (residential/work or retail sites, for example) are short enough for bicycle/pedestrian travel to be practical.

Equation 1

Variables:

AADT: Average annual daily traffic in corridor (vehicles/day)

EF_B: Speed-based running exhaust emission factor for participants' trip before participating in the bike/pedestrian program (NO_x, VOC, or CO) (grams/mile)

HH_{AREA}: Number of households in strategy area

HH_{TRIPS}: Average number of trips per household in strategy area

L: Length of facility (miles)

PMS: Percentage mode shift from driving to bike/pedestrian (decimal)

TL_B: Average auto trip length before implementation (miles)

Equation:

For a facility parallel to an existing roadway:

$$\text{Daily Emission Reduction} = AADT * PMS * L * EF_B$$

The average annual daily traffic of the corridor multiplied by the percentage of drivers shifting to bike/pedestrian multiplied by the length of the project facility multiplied by the speed-based running exhaust emission factor for participants' trip before participating in the bike/pedestrian program

Final unit of measure: grams/day
Source: Capitol Area MPO (CAMPO)

For a facility without a parallel roadway:

$$\textbf{Daily Emission Reduction} = HH_{AREA} * HH_{TRIPS} * PMS * TL_B * EF_B$$

The number of households in the area affected by the strategy multiplied by the average number of household trips in the strategy area by the percentage of drivers shifting to bike/pedestrian multiplied by the length of the project facility multiplied by the speed-based running exhaust emission factor for participants' trip before participating in the bike/pedestrian program

Final unit of measure: grams/day
Source: El Paso MPO

<u>Equation 2</u>

Variables:

EF_B:	Speed-based running exhaust emission factor for participants' trip before participating in the bike/pedestrian program (NO_x, VOC, or CO) (grams/mile)
N_{BW}:	Number of new participants on the bike/pedestrian facility
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TL_B:	Average auto trip length before implementation (miles)

Equation:

$$\textbf{Daily Emissions Reduction} = A + B$$

$$A = (N_{BW} * TL_B * EF_B)$$

The number of new bicycle/pedestrian facility users multiplied by the bicycle and/or pedestrian trip length multiplied by the speed-based running exhaust emission factor for participants' trip before participating in the bicycle/pedestrian program

$$B = (N_{BW} * TEF_{AUTO})$$

The number of new bicycle/pedestrian facility users multiplied by the trip-end emission factor

Note: *For this equation,* $\mathbf{TEF}_{AUTO}$ *is computed for cold-start emissions only.*

Final unit of measure: grams/day
Source: North Central Texas Council of Governments, 2006

11.2 Bicycle and Pedestrian Support Facilities and Programs

Strategy: Enhance replacement of vehicle trips and VMT through provision of facilities for bicycle and pedestrian travel.

Description: Many support facilities are provided as part of employer-based transportation management programs and improving transit. They can include sidewalks, intersection improvements, sidewalk furniture, bicycle racks on buses, lockers and shower facilities, education, and promotions.

Application: Areas where travel distances (residential/work or retail sites, for example) are short enough for bicycle/pedestrian travel to be practical.

Variables:

EF_B:	Speed-based running exhaust emission factor for the average speed of participants' trip before participating in the bike/pedestrian program (NO_x, VOC, or CO) (grams/mile)
$F_{BW, SOV}$:	Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)
N_{BW}:	Number of new participants in the bike/pedestrian programs
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TL_W:	Average auto trip length to work (miles)
VMT_R:	Reduction in daily auto vehicle miles traveled
VT_R:	Reduction in number of daily auto vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = \mathbf{A + B}$$

$$\mathbf{A = (VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{BW} * F_{BW, SOV} * 2$ trips/day

The number of bicycle and pedestrian program participants multiplied by the fraction of participants that shifted from single-occupant vehicle use multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length.

Final unit of measure: grams/day
Source: CalTrans/CARB

12.0 EXTENDED VEHICLE IDLING

Programs to control extended idling of vehicles
Section 108 (xi), CAAA

This mobile source emission reduction strategy attempts to reduce the amount of time that vehicles spend in idle mode as part of their overall operation. Idling restrictions primarily lower CO emissions from both gasoline-powered and diesel-powered motor vehicles in affected areas. The restrictions do provide for some NO_x emission reductions.

Examples of idling restrictions include:

- Controls on the construction and operation of drive-through facilities, such as banks, fast food restaurants, and pharmacies; and
- Controls on extended idling during layover time, particularly of diesel engines used by transit vehicles and delivery trucks.

Exemptions are usually provided for emergency vehicles or idling required by traffic delays, for refrigerated cargo, and for driver sleep breaks.

The time threshold for requiring idling restriction varies across programs and urban contexts. Some programs set the limit at 30 minutes for combustion engines in cars and trucks. In Houston, vehicles over 14,000 pounds are limited to five minutes of idling when operating in the nonattainment area.

Implementation of these types of controls on vehicle operations should be conducted at the regional or state level, except for restrictions on drive-through facilities, which are a local responsibility enforced through the zoning code. Individual attempts at restrictions could result in a confusing patchwork of regulations in a nonattainment area and may not provide an effective reduction measure.

In California, negative experience with idling restrictions at rail crossings suggested that an enforcement mechanism is required for these programs but did not specify the types of penalties needed.

Public education campaigns regarding the need for controls on idling emissions should be considered when implementing idling restriction measures.

12.1 Controls on Drive-Through Facilities

Strategy: Reduce vehicle emissions.

Description: This measure involves limitations on the operation of drive-through facilities at businesses that provide drive-through service. Examples of these types of businesses are fast food restaurants, banks, and dry cleaners. Limitations may be placed on the operating hours of the facility, usually at peak traffic hours or peak restaurant hours. Prohibitions on construction of new facilities may also be implemented.

Application: Large urban areas.

Variables:

$\mathbf{EF}_{I}$:	Idling emission factor (NO_x, VOC, or CO) (grams/hour)
$\mathbf{F}_{PARK}$:	Percent of vehicles that park instead of using the drive-through facility due to imposed control (decimal)
$\mathbf{N}_{V}$:	Average number of vehicles using the drive-through facility
$\mathbf{t}_{A}$:	Time spent in queue after implementation of control (hours)
$\mathbf{t}_{B}$:	Time spent in queue before implementation of control (hours)
$\mathbf{TEF}_{AUTO}$:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

Equation:

$$\text{Daily Emission Reduction} = A - B + C$$

$$A = N_V * t_B * EF_I$$

The amount of idling exhaust emissions generated before the control

$$B = (1 - F_{PARK}) * N_V * t_A * EF_I$$

The idling exhaust emissions after the control is in place

$$C = F_{PARK} * N_V * (TEF_{AUTO})$$

The increase in start exhaust emissions resulting from consumers now parking their vehicle in lieu of idling their vehicle

Final unit of measure: grams/day
Source: Texas Transportation Institute

12.2 Controls on Heavy-Duty Vehicles

Strategy: Reduce vehicle emissions.

Description: This measure places restrictions on idling time for trucks, buses, locomotives, construction, and other heavy-duty on-road vehicles in the nonattainment area. The restriction may be automatic or manually implemented. Automatic restrictions would require a modification to a vehicle engine design that shuts off an idling vehicle engine after a set time limit. Manual restrictions would require the operator of the vehicle to shut off the engine.

The primary attraction of this measure to the regulated community is that it provides emission reduction benefits while also providing a cost savings through reduction in motor fuel consumption.

Application: Medium-sized and large urban areas with significant fleets of heavy-duty vehicles, including bus transit systems.

Variables:

EF_I: Idling emission factor for trucks (NO_x, VOC, or CO) (gram/hours)

F_C: Compliance factor (decimal)

N_{RSt}: Average number of times vehicle is restarted

N_V: Number of vehicles with restricted idling time

t_A: Time per truck heavy-duty vehicles are allowed to spend idling after restriction (hours)

t_B: Average time per truck heavy-duty vehicles spend idling before restriction (hours)

TEF_{TRK}: Truck trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

Equation:

$$\textbf{Daily Emission Reduction} = A * (B - C)$$

$$A = N_V * F_C$$

The number of vehicles with restricted idling time multiplied by the percentage of vehicles in compliance with the strategy

$$B = EF_I * (t_B - t_A)$$

The reduction in idling exhaust emissions from reduced time spent in idling

$$C = N_{RSt} * TEF_{TRK}$$

The increase in start exhaust emissions resulting from engine restarts

Final unit of measure: grams/day
Source: Texas Transportation Institute

B.12.6

13.0 EXTREME LOW TEMPERATURE COLD STARTS

Programs to reduce motor vehicle emissions which are caused by extreme cold-start conditions

Section 108 (xii), CAAA

This emission reduction strategy consists of actions that can be taken by states and local areas over and above the federal cold temperature CO standard and that are applicable under extremely cold conditions, e.g., temperatures in the range of 0° F to –20° F, or even colder. These measures normally are directed at reducing vehicle startup emissions during these extremely cold temperature episodes.

Since the required climactic conditions occur very rarely in southern states, this strategy is not recommended for consideration in the state of Texas.

14.0 WORK SCHEDULE CHANGES

Employer-sponsored programs to permit flexible work schedules
Section 108 (xiii), CAAA

The goal of implementing work schedule changes is to reduce the volume of commute traffic during peak traveling times by spreading or moving those trips to other times of day. The programs may be voluntary, mandatory, or used by employers to satisfy trip-reduction ordinances or air quality regulations. The EPA Office of Mobile Sources has found that schedule change programs achieve greater success and gain employee approval if employers adopt the changes voluntarily with employee input.

There are three main types of changes to work schedules:

- *Telecommuting* is work done on a regular basis from daily to once a week at an alternative work site such as the employee's home or a telecommuting center. A center is a facility that provides the employer, employee, and customers with all requirements to perform work and services without traveling to the employee's main work site and may be operated by a single or consortium of businesses.
- *Flextime* allows employees to set arrival and/or departure times with the approval of the employer in order to avoid traveling at peak traffic times, but all employees are present for some core period of the workday.
- *Compressed work weeks* are work scheduling programs that condense a standard number of work hours into fewer than five days per week or fewer than 10 days per two-week period. For example, four days at 10 hours per day or 80 hours over nine days.

Work schedule changes are relatively easy to establish for several reasons, including the following:

- No infrastructure costs or front-end investment of government resources is required.
- These measures can be adopted voluntarily and require no approval from government agencies: there is no potentially lengthy process of obtaining funds and/or government approval.
- The measures can be easily explained to and understood by employees.

Although work schedule changes are relatively easy to administer, they require careful planning and coordination to be successful.

Transportation planners need to be aware of employer issues with implementing work schedule changes. In terms of cost, businesses planning and implementing the policies must be compared to the potential savings that employees will gain with costs to implement and maintain them. Labor hours will be required to plan and implement the changes, increased facility security may be required since some workers will stay later or arrive earlier, and there may be increased utility needs as the facility is used longer in the day. Client relations and intra-department activities within the business or agency accustomed to the previous work hours need to be considered. Businesses must also ensure that the programs are consistent with union agreements.

The EPA Office of Mobile Sources has found that several factors should be considered when attempting to use work schedule changes as a mobile emission reduction strategy:

- *Diminished benefits* as the decrease in work trip vehicle miles traveled (VMT) may be mitigated to some extent by increased nonwork travel for people working compressed work weeks. The potential exists that although employees may benefit from driving on their day off, congestion and air quality may not significantly improve overall. However, more trips are likely to be taken during off-peak congestion hours so that the time distribution of ozone precursors is widened and ozone formation is retarded.
- *Potential reduction in ridesharing and transit use by employees* may occur because of variable work hours. Businesses should coordinate the schedule changes, whenever possible, with transit and ridesharing services. Schedules for these services may need to be modified as a response to new arrival and departure times.
- *Pilot programs are recommended* for three to six months before committing to the changed hours so that the policies can be evaluated in terms of employee morale, productivity, and financial ramifications.
- *Applicability* of variable work hour strategies can be an issue for businesses. Organizations that rely heavily on process manufacturing usually need all workers to be present at the same time to work efficiently. Compressed work weeks may be a more suitable option for manufacturing plants than a flextime or staggered hours policy. Service businesses may be more able to rotate worker schedules and permit flextime policies.
- *Location* of the organization implementing a work schedule change may be a factor influencing success. Flextime policies may be more successful in areas of greater workplace density

where associated traffic is highly concentrated around peak periods.

14.1 Telecommuting

Strategy: Reduce vehicle trips and work trip VMT.

Description: Telecommuting involves employees working at home or at satellite work centers with approval of employers for one or more days per week. Satellite work centers are constructed and maintained by employers or agencies and provide the required work tools for an employee to perform his or her tasks. Telecommuting has grown with the rise and adoption of information technology in the last two decades. The use of centers does not reduce trips but can significantly decrease VMT.

Application: Organizations that do not require daily face-to-face customer or coworker interaction or that otherwise require the constant physical presence of the employee.

Variables:

$\mathbf{EF}_{B}$:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{N}_{D}$:	Number of days in program
$\mathbf{N}_{P}$:	Number of participants
$\mathbf{TEF}_{AUTO}$:	Auto trip-end emission factor (NO_x , VOC, or CO) (grams/trip)
$\mathbf{TL}_{T}$:	Average auto trip length to the telecommuting center (miles)
$\mathbf{TL}_{W}$:	Average auto trip length to work (miles)
$\mathbf{VMT}_{R}$:	Reduction in daily vehicle miles traveled
$\mathbf{VT}_{R}$:	Reduction in number of daily auto vehicle trips

Equations:

Telecommuting (Home)

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_P * N_D /5 * 2$ trips/day

Number of people working at home multiplied by the average number of days worked at home per work week multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the auto commute trip length

Telecommuting (Center)

Daily Emission Reduction = $VMT_R * EF_B$

Reduction in auto running exhaust emissions from trip reductions

Where

$VMT_R = VT_R * (TL_W - TL_{TC})$

The vehicle trips reduced multiplied by the reduced auto commute trip length

Final unit of measure: grams/day
Source: CalTrans/CARB

14.2 Flextime

Strategy: Reduce peak hour congestion.

Description: Flextime allows employees to set arrival and/or departure times with the approval of the employer in order to avoid traveling at peak traffic times, but all employees are present for some core period of the workday.

Application: Businesses or agencies that do not require specific hours of employee availability.

Variables:

EF_A: Speed-based running exhaust emission factor for participants after implementation (NO_x, VOC, or CO) (grams/mile)

EF_B: Speed-based running exhaust emission factor for participants before implementation (NO_x, VOC, or CO) (grams/mile)

N_D: Number of days in program

N_P: Number of participants

TL_W: Average auto trip length of commute to work (miles)

Equation:

$$\textbf{Daily Emission Reduction} = (N_P * TL_W) * (EF_B - EF_A) * N_D/5$$

The number of flextime participants multiplied by the average auto commute trip length multiplied by the change in auto running exhaust emission factors due to improved average travel speed multiplied by the percentage of the work week affected by the strategy

Note: *For each hour affected by implementation of the flextime program (usually peak periods)*

Final unit of measure: grams/day
Source: Texas Transportation Institute

14.3 Compressed Work Week

Strategy: Reduce work trips, VMT, and traffic volume by reducing days of travel to work site by employees and spreading trips outside the peak period.

Description: Compressed work weeks are work scheduling programs that condense a standard number of work hours into fewer than five days per week or fewer than 10 days per two-week period, e.g., four days at 10 hours per day or 80 hours over nine days.

Application: Employers who determine that productivity and services by their organization can be maintained by a compressed work schedule.

Variables:

$\mathbf{EF}_{B}$:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{N}_{D}$:	Number of work days eliminated
$\mathbf{N}_{D, PRG}$:	Number of work days in the scheduling program (five or 10 days)
$\mathbf{N}_{P}$:	Number of participants
$\mathbf{TEF}_{AUTO}$:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
$\mathbf{TL}_{W}$:	Average auto trip length of commute to work (miles)
$\mathbf{VMT}_{R}$:	Reduction in daily vehicle miles traveled
$\mathbf{VT}_{R}$:	Reduction in number of daily vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = A + B + C$$

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

$$C = N_P * TL_W * (EF_B * EF_A) * N_D / N_{D, PRG}$$

The number of participants multiplied by the average auto commute trip length multiplied by the change in auto running exhaust emission factors due to improved average travel speed multiplied by the percentage of the work week affected by the strategy

Where

$$VT_R = N_P * N_D / N_{D, PRG} * 2 \text{ trips/day}$$

The number of program participants multiplied by the number of work days eliminated divided by the number of work days within the scheduling program multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: CalTrans/CARB

15.0 ACTIVITY CENTERS

Programs and ordinances to facilitate non-automobile travel, provision, and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel, as part of transportation planning and development efforts of a locality, including programs and ordinances applicable to new shopping centers, special events, and other centers of vehicle activity
Section 108 (xiv), CAAA

Programs to reduce vehicular travel in activity centers are another mobile source emission reduction strategy that enables other more specific emission reduction strategies to occur. Activity center measures involve urban design and transportation measures, guidelines, and regulations designed to reduce automobile trips and to promote nonautomobile travel associated with the use of a cohesive nexus of activity such as office parks, shopping centers, mixed-use developments, and other areas of vehicle activity.

The guidelines and regulations may take a number of forms, including:

- Transit-friendly design guidelines and ordinances,
- Vanpool and carpool considerations,
- Pedestrian and bicycle design considerations,
- Parking management,
- Mixed-use development ordinances and zones,
- Site plan review ordinances, and
- Higher density land development.

By incorporating opportunities for alternative travel modes such as transit, HOVs, bicycles, and walking into the overall design of new development, the desirability of these alternative modes is enhanced. Higher density development encourages transit and HOV use. A balanced mix of land uses in denser areas can reduce the need for certain types of vehicle trips if the need can be met in the immediate vicinity of residence or place of work.

The use of activity centers for emission reduction is a long-term strategy. The development of new or greatly modified urban design codes and regulations requires a significant amount of time and political discussion. If approved, new infrastructure and public services for the activity centers must then be designed and implemented.

15.1 Design Guidelines and Regulations

Strategy: Reduce vehicle trips and VMT.

Description: Land use design guidelines and regulations used in the context of this strategy require HOV/transit/bicycle/pedestrian access in the design of facilities within land developments. Unless similar guidelines or regulations have been adopted by a city within an area, creation and adoption of these regulations will take significant periods of time. Changes in development codes are a politically contentious issue in any municipality, requiring much discussion and debate.

The last decade has seen greater interest in transit-oriented development, sustainable development, and New Urbanism in urban planning, ranging from sites within urban areas such as Sacramento, California, or new cities such as Celebration, Florida. Their present success is indicative of an available market for these types of design guidelines.

Application: Cities with transit service or areas available for higher density development.

Variables:

BASE: Number of daily trips generated by nonregulated residential and commercial uses (trips)

CAP: Internal capture rate of regulated development (decimal)

EF_{PURi}: Speed-based running exhaust emission factor by trip purpose (NO_x , VOC, or CO) (grams/mile)

F_{PURi}: Percentage of trips saved by trip purpose

N_{DUi}: Number of development units by type

TL_{PURi}: Average trip length by trip purpose (miles)

TR_{DUi}: Daily trip rate by development unit type

Equation:

Daily Emission Reduction =

$$\sum \mathbf{BASE} * \mathbf{CAP} * \mathbf{F}_{PURi} * \mathbf{TL}_{PURi} * \mathbf{EF}_{PURi}$$

The number of trips reduced as a result of the mixed-use development multiplied by fraction of trips by purpose multiplied by the associated average trip length and speed-based emission factor

Where

$$\mathrm{BASE} = \sum N_{DU} * TR_{Dui}$$

The number of daily trips generated by nonmixed residential and commercial uses equals number of units generated by a typical development times the trip rate by purpose

Final unit of measure: grams/day
Source: CAMPO

15.2 Parking Regulations and Standards

Strategy: Reduce vehicle trips and VMT.

Description: This emission reduction strategy is very similar to those found in Section 17 ("Parking Management"), and the reader is referred to that section for greater detail. In this specific case, the use of the limitations on parking is to encourage and enforce the development of high-density activity centers.

Application: Cities developing activity centers.

Variables:

$\mathbf{AVO}_{RS}$:	Average vehicle occupancy of rideshare (persons/vehicle)
$\mathbf{EF}_{B}$:	Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)
$\mathbf{F}_{BW, SOV}$:	Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)
$\mathbf{F}_{RS, SOV}$:	Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)
$\mathbf{F}_{T, SOV}$:	Percentage of new participants using transit facilities who previously drove SOVs (decimal)
$\mathbf{N}_{BW}$:	Number of participants in bicycle/pedestrian programs
$\mathbf{N}_{RS}$:	Number of participants in rideshare
$\mathbf{N}_{T}$:	Number of participants using transit facilities
$\mathbf{TEF}_{AUTO}$:	Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)
$\mathbf{TL}_{RS}$:	Average auto trip length to rideshare facility (miles)

TL_T: Average auto trip length to transit facility (miles)

TL_W: Average auto trip length to work (miles)

VMT_R: Reduction in daily auto vehicle miles traveled

$VMT_{R, BW}$: Reduction in daily auto vehicle miles traveled by bike/pedestrian mode

$VMT_{R, RS}$: Reduction in daily auto vehicle miles traveled by rideshare mode

$VMT_{R, T}$: Reduction in daily auto vehicle miles traveled by transit mode

VT_R: Reduction in number of daily vehicle trips

$VT_{R, BW}$: Reduction in number of daily vehicle trips by bike/pedestrian mode

$VT_{R, RS}$: Reduction in number of daily vehicle trips by rideshare mode

$VT_{R, T}$: Reduction in number of daily vehicle trips by transit mode

Equation:

Daily Emission Reduction = A + B

$$A = (\Sigma VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$$

The fractions of strategy participants that shift to other modes from SOVs

$$VT_{R,T} = N_T * F_{T,SOV} * 2 \text{ trips/day}$$
$$VT_{R,RS} = N_{RS} * (1 - 1/AVO_{RS}) * F_{RS,SOV} * 2 \text{ trips/day}$$
$$VT_{R,BW} = N_{BW} * F_{BW,SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of SOV drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R,T} = VT_{R,T} * (TL_W - TL_T)$$
$$VMT_{R,RS} = VT_{R,RS} * (TL_W - TL_{RS})$$
$$VMT_{R,BW} = VT_{R,BW} * TL_W$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by Texas Transportation Institute [TTI])

15.3 Mixed-Use Development

Strategy: Reduce vehicle trips and VMT through high-density development of mixed-use land developments.

Description: Mixed-use development is a broad range of land use regulations, ordinances, and guidelines that require a variety of residential, retail, and other land uses clustered together in a limited land space rather than segregated and spread in a larger area. This is a long-term strategy to be implemented in significant magnitude over a long period of time.

Mixed-use developments fulfill the following criteria:

- Three or more significant revenue-producing uses (such as office, retail, residential, hotel/motel, entertainment, cultural, recreation, etc.) that in well-planned projects are mutually supporting;
- Significant physical and functional integration of project components (and thus a relatively intensive use of land), including uninterrupted pedestrian connections; and
- Development in conformance with a coherent plan (which frequently stipulates the type and scale of uses, permitted densities, and related developmental consideration).

Many terms can be used to describe this measure such as New Urbanism, transit-oriented development, sustainable development, and cluster development. All generally require greater density requirements, smaller lots, less segregation of land use with a mix of housing, business, recreation, and retail industries. Mixed-use development is intended to provide site amenities that encourage ridesharing or transit use, thus decreasing reliance on SOV use.

Application: New developments or redevelopment in urban areas.

Variables: **BASE:** Number of daily trips generated by nonmixed residential and commercial uses

CAP:	Internal capture rate of mixed use development (decimal)
EF_{PURi}:	Speed-based running exhaust emission factor by trip purpose (NO_x, VOC, or CO) (grams/mile)
F_{PURi}:	Percentage of trips saved by trip purpose (decimal)
TL_{PURi}:	Average trip length by trip purpose (miles)

Equation:

Daily Emission Reduction =

$$\sum \mathbf{BASE} * \mathbf{CAP} * \mathbf{F}_{PURi} * \mathbf{TL}_{PURi} * \mathbf{EF}_{PURi}$$

The number of trips reduced as a result of the mixed-use development multiplied by the reduction in auto running exhaust emissions from the trips reduced

Where

$$BASE = \sum N_{DU} * TR_{Dui}$$

The number of daily trips generated by nonmixed residential and commercial uses equals number of units generated by a typical development times the trip rate by purpose

Final unit of measure: grams/day
Source: CAMPO

16.0 ACCELERATED VEHICLE RETIREMENT

Program to encourage the voluntary removal from use and the marketplace of pre-1980 model year light-duty vehicles and pre-1980 model light-duty trucks
Section 108 (xvi), CAAA

Accelerated vehicle retirement, or vehicle scrappage, involves an offer to purchase older vehicles having high emission rates to remove these vehicles from the active vehicle fleet in an area. The program operates by an organization, usually private, paying a fee to owners of older, high-emission vehicles who voluntarily turn in their vehicle. The vehicle is then scrapped, removing it from use. The fee for the vehicle, also called a bounty, is usually a fixed price per scrapped vehicle although different amounts can be offered for different model years. Individual vehicle emissions characteristics might also be used as a criterion for scrappage.

A scrappage program requires a funding source before it can be initiated. Public agencies may find this initial cost prohibitive, either in amount or difficulty obtaining approval. Private companies looking to offset emissions elsewhere in their company with the emissions reductions from the program may implement scrappage programs.

According to the EPA Office of Mobile Sources, vehicle retirement programs can be made more cost-effective by linking them to regional programs that are designed to measure the emissions of individual vehicles, such as inspection and maintenance (I/M) programs and remote sensing programs. The advantage of this linkage is that vehicles can be screened to help ensure that only vehicles that emit above the applicable standards and cannot be repaired at reasonable cost are scrapped.

The cost-effectiveness of a scrappage program is likely to decline over time as the pool of older, high-emission vehicles is reduced. Vehicle owners wishing to participate may hold onto their vehicles and scrap them at the end of a continuous or long-running program. The program is more effective if limited in duration.

The amount of the bounty is a critical variable in a scrappage program. If the bounty is too low, the program will not attract enough vehicles to have any real impact on air quality. If the bounty is too high, the program will attract vehicles that are newer and cleaner, which would limit the program's overall impact and reduce its cost-effectiveness. Also, the program would not be able to remove as many vehicles out of the fleet. For the most part, actual scrappage programs have offered somewhere between $500 and

$1000 per scrapped vehicle, with the most common bounty being $700.

Vehicle eligibility for scrappage programs must be well defined. A basic criterion is vehicle age and/or model year. The vehicle should also be operational. Requiring that it be driven to the program site ensures this criterion. Registration of the vehicle should reflect origin within the program area so that emissions reductions are actually achieved in the area.

The costs of an accelerated vehicle retirement program to the implementing agency are equal to the bounty price per vehicle, plus any administrative costs per vehicle, multiplied by the number of vehicles scrapped by the program.

16.1 Cash Payments

Strategy: Reduce fleet vehicle emissions.

Description: Cash payment, or a bounty, is offered for older, high-emission vehicles. The vehicles are then scrapped. In some instances, nonemission-related parts from the vehicles may be salvaged for use as replacement parts. Cash payment programs should include follow-up and evaluation procedures to minimize any uncertainty in emission benefits.

Application: Best when utilized in conjunction with a regional inspection and maintenance (I/M) program. Congestion Mitigation and Air Quality Improvement Program (CMAQ) funds cannot be used for this strategy.

Variables:

VMT_A: VMT) by the vehicle (estimate)

VMT_B: VMT by the vehicle to be replaced (estimate)

EF_N: Replacement vehicle speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

EF_O: Retired vehicle speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

Equation:

$$\text{Daily Emission Reduction} = VMT_B * EF_O - VMT_A * EF_N$$

The average daily VMT of vehicles removed from service multiplied by the average daily composite emission factor for vehicles removed from service subtracted by the average daily VMT of new vehicles multiplied by the average daily composite emission factor for the replacement vehicles

Final unit of measure: grams/day
Source: TTI

17.0 PARKING MANAGEMENT

The management of parking supply and demand is not a mobile source emission reduction strategy created specifically by the CAAA, but is usually implemented in conjunction with other congestion management and emission reduction measures. Most urban areas have some form of parking management.

Parking management efforts attempt to reduce vehicle trips and VMT by providing disincentives to SOV travel to an area of a city. Strategies favor carpools and vanpools. Increases in parking costs or decreases in availability encourage use of alternative modes. Air quality benefits through parking management strategies are derived when travelers choose an alternative method to SOV travel because of preferential parking for that mode or limited parking availability in an area for SOV travel.

Examples of management strategies include:

- Preferential parking pricing programs for high-occupancy vehicles (HOVs),
- Preferential parking for HOVs,
- Parking fee structures that discourage long-term parking,
- Increased parking fees,
- Limitations on new public and private spaces, and
- Zoning regulations with parking controls for new developments.

Since these strategies are implemented as one part of a larger package of measures, the actual impact of parking management measures on SOV travel is difficult to quantify. It is difficult to separate the impacts of this measure itself from the overall program.

Parking management measures may be voluntary or required by ordinance. The measure does not require a substantial amount of financial resources to implement (administration, signage, enforcement, and surveys, if needed), but it is possible that a large amount of political capital may be required to overcome possible business and employer objections to reducing or limiting available parking. Implementing mandatory parking supply reductions may be unpopular with merchants, employers, or residents and require consensus building to implement a policy that is generally accepted. The EPA Office of Mobile Sources reports that cities that already have a comprehensive parking plan for downtown or suburban areas may already have the necessary experience, personnel, and resources to effectively implement a parking supply program.

Policies that limit available parking supply have a greater chance of success if the following aspects are evident:

- Current parking is well utilized.
- Transit, bicycle and pedestrian, and ridesharing facilities and programs exist to absorb commuters that no longer drive.
- High-density central business districts or activity centers are present.
- The area has high land values and strong economic development.
- Vacant land and neighborhoods in the area do not have the capacity to absorb the parking overflow or are well controlled by parking restrictions.

17.1 Preferential Parking for HOVs

Strategy: Reduce vehicle trips and VMT by providing incentives for HOV travel.

Description: Incentives are provided to HOV travelers by providing cost-free and/or reserved HOV parking spaces in an area or specific site. The incentives can also be indirect. For example, increased parking fees at the destination for SOVs discourage SOV travel but do not directly promote HOVs.

Application: Cities and the areas within them with controlled parking.

Variables:

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

F_{ECP}: Percentage of existing carpools (decimal)

N_{PPK}: Number of preferential spaces in parking lot

OCC: Average occupancy of HOV (persons/vehicle)

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_W: Average auto trip length to work before implementation of measure (miles)

U_{PPK}: Utilization rate of preferential parking spaces (decimal)

VMT_R: Reduction in daily automobile VMT

VT_R: Reduction in number of daily vehicle trips

Equation:

$$\textbf{Daily Emission Reduction} = \textbf{A} + \textbf{B}$$

$A = (VT_R * TEF_{AUTO})$

Reduction in auto start emissions from trip reductions

$B = (VMT_R * EF_B)$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{PPK} * U_{PPK} * (1 - F_{ECP}) * (OCC - 1) * 2$
trips/day

Number of preferential parking spaces multiplied by the parking utilization rate of the preferential parking spaces multiplied by the fraction of new carpools multiplied by the average number of passengers after implementation multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trip reduction multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: TTI

17.2 Public Sector Parking Pricing

Strategy: Reduce vehicle trips and VMT through disincentives.

Description: Cities modify parking fee and time structures at municipal lots to discourage use of the lot. The measure can include increasing charges for peak hour parking, raising parking fees equivalent to commercial lots, or not having a daily maximum parking fee.

Application: Cities and areas within them with controlled parking.

Variables:

AVO_{RS}: Average vehicle occupancy of rideshare (persons/vehicle)

EF_{B}: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove SOVs (decimal)

$F_{RS, SOV}$: Percentage of new participants in the rideshare programs who previously drove SOVs (decimal)

F_{SOV}: Percentage of those people continuing to use an SOV for their full commute (decimal)

$F_{T, SOV}$: Percentage of new participants using transit facilities who previously drove SOVs (decimal)

N_{PK}: Number of spaces in parking lot

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_{RS}: Average auto trip length to rideshare location (miles)

TL_{T}: Average auto trip length to transit location (miles)

TL_W:	Average auto trip length of commute to work (miles)
U_P:	Utilization rate of parking lot
VMT_R:	Reduction in daily auto vehicle miles traveled
$VMT_{R,\,BW}$:	Reduction in daily auto vehicle miles traveled by bike/pedestrian mode
$VMT_{R,\,RS}$:	Reduction in daily auto vehicle miles traveled by rideshare mode
$VMT_{R,\,T}$:	Reduction in daily auto vehicle miles traveled by transit mode
VT_R:	Reduction in number of daily vehicle trips
ΔP_{fee}:	Percentage change in parking fee structure (decimal)
ϵ_{fee}:	Price elasticity for mode shift

Equation:

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{SOV} + F_{T,\,SOV} + F_{R,\,SOV} + F_{BW,\,SOV}$$

The fractions of affected drivers that will continue to drive SOVs and those that shift to other available modes

$$VT_R = (\Delta P_{fee} * \epsilon_{fee} * N_{PK} * U_P) * (1 - F_{SOV}) * 2 \text{ trips/day}$$

The change in parking fees multiplied by a price elasticity multiplied by the number of affected parking spaces and their utilization rate multiplied by the fraction of SOVs that make a mode switch multiplied by two trips per day (round trip)

$$VMT_{R,\,T} = VT_R * F_{T,\,SOV} * (TL_W - TL_T)$$
$$VMT_{R,\,RS} = VT_R * (1 - 1 / AVO_{RS}) * F_{RS,\,SOV} * 2 \text{ trips/day}$$
$$VMT_{R,\,BW} = VT_R * F_{BW,\,SOV} * TL_W$$

The vehicle trip reduction multiplied by the fraction of SOV drivers that switch to another mode multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: TTI

17.3 Parking Requirements in Zoning Ordinances

Strategy: Limit parking supply through land use controls.

Description: Areas can provide limits on the amount of parking available in new land development within the city or area through their zoning ordinances or other land use controls. The main technique is to establish a maximum amount of parking that a developer cannot exceed, rather than a traditional minimum parking supply for a new project. Changes to land use regulations may cause a potentially contentious political debate among citizens. Transportation planners should be aware of the possibility.

Application: New land use developments in high-density urban areas with adequate public transit access.

Variables:

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Adjustment factor for people who previously drove an SOV for their full commute and shift to rideshare (decimal)

$F_{RS, SOV}$: Adjustment factor for people who previously drove an SOV for their full commute and shift to rideshare (decimal)

F_{SOV}: Percentage of those people continuing to use an SOV for their full commute (decimal)

$F_{T, SOV}$: Adjustment factor for people who drove an SOV for their full commute and shift to transit (decimal)

N_P: Number of participants

$N_{PK, A}$: Number of parking spaces allowed after implementation of control

$N_{PK, B}$:	Number of parking spaces allowed before implementation of control
OCC:	Average occupancy (persons/vehicle)
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TL_{RS}:	Average auto trip length to rideshare location (miles)
TL_T:	Average auto trip length to transit location (miles)
TL_W:	Average auto trip length of commute to work (miles)
$U_{P, A}$:	Utilization rate of parking lot after implementation (decimal)
$U_{P, B}$:	Utilization rate of parking lot before implementation (decimal)
VMT_R:	Reduction in daily auto vehicle miles traveled
$VMT_{R, BW}$:	Reduction in daily auto vehicle miles traveled by bike/pedestrian mode
$VMT_{R, RS}$:	Reduction in daily auto vehicle miles traveled by rideshare mode
$VMT_{R, T}$:	Reduction in daily auto vehicle miles traveled by transit mode
VT_R:	Reduction in number of daily vehicle trips
$VT_{R, BW}$:	Reduction in number of daily vehicle trips by bike/pedestrian mode
$VT_{R, RS}$:	Reduction in number of daily vehicle trips by rideshare mode
$VT_{R, T}$:	Reduction in number of daily vehicle trips by transit mode

Equation:

$$\textbf{Daily Emission Reduction} = \textbf{A} + \textbf{B}$$

$$\mathbf{A} = (\Sigma \mathbf{VT}_{R} * \mathbf{TEF}_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B} = (\Sigma \mathbf{VMT}_{R} * \mathbf{EF}_{B})$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{SOV} + F_{T,\ SOV} + F_{RS,\ SOV} + F_{BW,\ SOV}$$

The fractions of affected drivers that will continue to drive single-occupant vehicles and those that shift to other available modes

$$N_P = (N_{PK,\ B} * U_{P,\ B} - N_{PK,\ A} * U_{P,\ A}) * OCC * (1 - F_{SOV})$$

The difference between the number of parking spaces affected before the control multiplied by the parking utilization rate before the control and the number of parking spaces affected after the control multiplied by the parking utilization rate after the control multiplied by the average vehicle occupancy multiplied by the fraction of single-occupant vehicles that make a mode switch multiplied by two trips per day (round trip)

$$VT_{R,\ T} = N_P * F_{T,\ SOV} * 2 \text{ trips/day}$$
$$VT_{R,\ RS} = N_P * (1 - 1 / AVO_{RS}) * F_{RS,\ SOV} * 2 \text{ trips/day}$$
$$VT_{R,\ BW} = N_P * F_{BW,\ SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of single-occupant vehicle drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R,\ T} = VT_{R,\ T} * (TL_W - TL_T)$$
$$VMT_{R,\ RS} = VT_{R,\ RS} * (TL_W - TL_{RS})$$
$$VMT_{R,\ BW} = VT_{R,\ BW} * TL_W$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: TTI

17.4 On-Street Parking Controls

Strategy: Reduce vehicle trips and VMT by providing disincentives to on-street parking in urban areas.

Description: Cities can utilize several techniques to limit on-street parking in urban areas, including increased meter fees that discourage long-term parking, curb parking restrictions, peak hour parking bans, and residential parking controls. In addition, parking times can be decreased. Enforcement of the parking regulations should be strengthened. Planners should keep in mind that this measure is more effective in high-density areas such as central business districts or activity centers with limited available parking. Applied to areas with excess parking supply or dispersed development, this measure may simply reallocate the parking and not aid in encouraging alternative modes of travel.

Application: Areas of higher density, activity centers, or congested roadways with limited parking.

Variables:

EF_B: Speed-based running exhaust emission factor before implementation (NO_x, VOC, or CO) (grams/mile)

$F_{BW, SOV}$: Adjustment factor for people who previously drove an SOV for their full commute and shift to rideshare (decimal)

$F_{RS, SOV}$: Adjustment factor for people who previously drove an SOV for their full commute and shift to rideshare (decimal)

F_{SOV}: Percentage of those people continuing to use an SOV for their full commute (decimal)

$F_{T, SOV}$: Adjustment factor for people who drove an SOV for their full commute and shift to transit (decimal)

N_P: Number of participants

N_{PK}:	Number of spaces in parking lot
$N_{PK, A}$:	Number of parking spaces allowed after implementation of control
$N_{PK, B}$:	Number of parking spaces allowed before implementation of control
OCC:	Average occupancy (persons/vehicle)
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TL_{RS}:	Average auto trip length to rideshare location (miles)
TL_T:	Average auto trip length to transit location (miles)
TL_W:	Average auto trip length of commute to work (miles)
U_P:	Utilization rate of parking lot
$U_{P, A}$:	Utilization rate of parking lot after implementation (decimal)
$U_{P, B}$:	Utilization rate of parking lot before implementation (decimal)
VMT_R:	Reduction in daily auto vehicle miles traveled
$VMT_{R, BW}$:	Reduction in daily auto vehicle miles traveled by bike/pedestrian mode
$VMT_{R, RS}$:	Reduction in daily auto vehicle miles traveled by rideshare mode
$VMT_{R, T}$:	Reduction in daily auto vehicle miles traveled by transit mode
VT_R:	Reduction in number of daily vehicle trips
$VT_{R, BW}$:	Reduction in number of daily vehicle trips by bike/pedestrian mode

$VT_{R, RS}$: Reduction in number of daily vehicle trips by rideshare mode

$VT_{R, T}$: Reduction in number of daily vehicle trips by transit mode

ΔP_{fee}: Percentage change in parking fee structure (decimal)

ϵ_{fee}: Price elasticity for mode shift

Equation:

For parking fee increases:

$$\textbf{Daily Emission Reduction} = \textbf{A} + \textbf{B}$$

$$\textbf{A} = (\textbf{VT}_R * \textbf{TEF}_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$\textbf{B} = (\Sigma \textbf{VMT}_R * \textbf{EF}_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{SOV} + F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$$

The fractions of affected drivers that will continue to drive single-occupant vehicles and those that shift to other available modes

$$VT_R = (\Delta P_{fee} * \epsilon_{fee} * N_{PK} * U_P) * (1 - F_{SOV}) * 2 \text{ trips/day}$$

The change in parking fees multiplied by a price elasticity multiplied by the number of affected parking spaces and their utilization rate multiplied by the fraction of SOVs that make a mode switch multiplied by two trips per day (round trip)

$$VMT_{R, T} = VT_R * F_{T, SOV} * (TL_W - TL_T)$$
$$VMT_{R, RS} = VT_R * (1 - 1 / AVO_{RS}) * F_{RS, SOV} * (TL_W - TL_{RS})$$
$$VMT_{R, BW} = VT_R * F_{BW, SOV} * TL_W$$

The vehicle trip reduction multiplied by the fraction of SOV drivers that switch to another mode multiplied by the change in average trip length after the mode switch

For parking controls:

Daily Emission Reduction = A + B

$$\mathbf{A = (\Sigma VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{SOV} + F_{T,\,SOV} + F_{RS,\,SOV} + F_{BW,\,SOV}$$

The fractions of affected drivers that will continue to drive single-occupant vehicles and those that shift to other available modes

$$N_P = (N_{PK,\,B} * U_{P,\,B} - N_{PK,\,A} * U_{P,\,A}) * OCC * (1 - F_{SOV})$$

The difference between the number of parking spaces affected before the control multiplied by the parking utilization rate before the control and the number of parking spaces affected after the control multiplied by the parking utilization rate after the control multiplied by the average vehicle occupancy multiplied by the fraction of single-occupant vehicles that make a mode switch multiplied by two trips per day (round trip)

$$VT_{R,\,T} = N_P * F_{T,\,SOV} * 2 \text{ trips/day}$$
$$VT_{R,\,RS} = N_P * (1 - 1 / AVO_{RS}) * F_{RS,\,SOV} * 2 \text{ trips/day}$$
$$VT_{R,\,BW} = N_P * F_{BW,\,SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of single-occupant vehicle drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R,\,T} = VT_{R,\,T} * (TL_W - TL_T)$$
$$VMT_{R,\,RS} = VT_{R,\,RS} * (TL_W - TL_{RS})$$
$$VMT_{R,\,BW} = VT_{R,\,BW} * TL_W$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: Texas Transportation Institute

18.0 VEHICLE PURCHASES AND REPOWERING

Vehicle emission rates can be reduced through the purchase of motor vehicles certified to pollute less than typical new vehicles. Programs that provide complete engine replacements that result in lower pollution may also be implemented.

This measure has received new emphasis in federal transportation legislation. It is funded primarily through CMAQ.

18.1 Clean Vehicle Program

Strategy: Reduce vehicle emissions through new vehicle technology.

Description: Public funding can be committed toward the incremental cost of vehicles with lower emissions for public fleets. The program aids in converting light-duty vehicles, buses, and heavy-duty delivery trucks to natural gas and building a fleet of lower emission vehicles. Programs are open to all public fleets, transit agencies, and private companies.

Application: Cities, agencies, and employers with a large vehicle fleet.

Variables:

EF_A: Speed-based running exhaust emission factor after replacement (NO_x , VOC, or CO) (grams/mile)

EF_B: Speed-based running exhaust emission factor before replacement (NO_x, VOC, or CO) (grams/mile)

VMT_{REP}: VMT of the vehicle to be replaced

Equation:

$$\text{Daily Emission Reduction} = VMT_{REP} * (EF_B - EF_A)$$

Average daily VMT of the replaced vehicle multiplied by the change in pre-replacement and post-replacement composite emission factors

Final unit of measure: grams/day
Source: CalTrans/CARB

19.0 CONGESTION PRICING

Congestion pricing is the imposition of fees, in differential rates varying by time of day and/or location depending on the level of congestion, on road users in congested zones or traveling on congested roadways.

Depending on the scope of the project, there are three types of congestion pricing policies:

- *Facility pricing* is levied on one or several roadways that link residential areas to downtown commercial districts. Fees may be imposed on new or existing roads, but it is usually more politically acceptable to impose fees on new facilities because people would view the policy as taking away a free service. In order for a pricing measure to be considered an application of facility pricing, the purpose of the measure must be to reduce congestion.
- *Regional network pricing* levies fees on drivers traveling on a network of similar roads (e.g., highways). Unlike facility pricing, network pricing applies fees on multiple roads going in many directions. This fee structure results in a more accurate fee for vehicle use than facility pricing because more of the trip is included within the boundary of the system. Fees may be collected from a series of tollbooths along the network or from entrance and exit ramps on controlled access facilities.
- *Cordon pricing* charges vehicles that enter high-activity areas such as central business districts. Areas of high congestion are identified and encircled with one or more cordons (lines). Vehicles may enter the area on different types of roads (e.g., arterials or highways). Fees are then collected from drivers through tollbooths at the cordon, special area permits, or parking permits. Prices may vary by time of day so that drivers may be reluctant to enter the cordoned areas during typical peak congestion periods. Although this pricing measure has been successfully implemented in such countries as Singapore, Norway, and England, it has yet to be implemented in the United States.

Congestion pricing policies are only in the pilot program stage of development in the United States, so there is little empirical evidence on the extent to which VMT and emissions are reduced. Theoretically, emissions will be reduced considerably because VMT and idling will decrease. The imposed fees will provide an incentive for people to switch from SOVs to HOVs or mass transit. Therefore, fewer total VMT will accumulate, directly eliminating emissions. Fewer VMT will occur during peak periods, which results in less idling. Moreover, the revenue generated by the pricing policy may be used for transportation improvements.

Many existing toll roads cannot be considered examples of congestion pricing policies because their purpose is largely to raise revenue. Toll roads may be viewed as congestion pricing mechanisms if the fees are structured in such a manner as to influence demand. Although implementing congestion pricing policies is not typically as expensive as other emission reduction strategies such as building rail lines, there are important cost considerations such as:

- Financial and human resources for planning phases,
- Implementing tolls and HOV fees,
- Public education and marketing campaigns, and
- Ongoing operations and maintenance.

The scope of the pricing policy greatly determines program cost. Facility pricing programs generally cost significantly less than regional network pricing and cordon pricing because as little as one roadway is affected.

Congestion pricing is relatively risky to implement because:

- Citizens will be paying for a service they had perceived to be receiving free of charge.
- The policy may be politically unpopular, especially if people are willing to endure congestion rather than pay more out-of-pocket expense to lessen it.
- Because congestion pricing is still in the pilot stage, the amount of emissions reductions from these measures cannot be projected with great certainty.

19.1 Facility Pricing

Strategy: Mitigate congestion through reduction of trips and VMT.

Description: Facility pricing is levied on one or several roadways that link residential areas to downtown commercial districts. Fees may be imposed on new or existing roads, but it is usually more politically acceptable to impose fees on new facilities because people would not view the policy as taking away a free service. In order for a pricing measure to be considered an application of facility pricing, the purpose of the measure must be to reduce congestion.

Single facility projects are best suited for a corridor connecting residential neighborhoods with downtown areas. However, there are at least two disadvantages to this option, increasing VMT and moving congestion.

Total VMT may actually increase as a consequence of imposing fees on the most direct route that people travel due to drivers diverting to nontoll alternate routes. Drivers may continue to avoid the fees by driving on the alternate routes, thereby merely shifting congestion to nonpriced areas of the city.

Among the congestion pricing measures, single facility projects are generally the easiest type of policy to enact according to the EPA Office of Mobile Sources. Some of the reasons that single facility projects are easy to implement include:

- Simplest to design and require the least up-front investment of government resources;
- Easily monitored and evaluated, especially if the facility has few entrances, exits, and alternate routes; and
- Relatively more politically acceptable because they focus on only one route. Under single facility programs, there may be alternative free routes people can choose, whereas regional network pricing projects may result in people being charged no matter which route they use.

Regional network pricing levies fees on drivers traveling on a network of similar roads (e.g., highways). Unlike facility pricing, network pricing applies fees on multiple roads going in many directions. This fee structure results in a more accurate cost for vehicle use than facility pricing because more of the trip is included within the boundary of the system. Fees may be collected from a series of tollbooths along the network or from entrance and exit ramps on controlled access facilities.

Because regional network pricing is more comprehensive than facility pricing, it has a greater potential to eliminate many free alternative routes. However, if a viable public transit system is unavailable in the area, then this measure could be difficult to implement. If drivers have a choice in choosing one mode of transit over another, regional network pricing may be very effective in reducing congestion and improving air quality because of its comprehensiveness. The measure can provide strong incentive for people to ride in carpools, use public transit, or adjust their travel time in the face of high tolls.

If the network of roads to be priced encompasses several jurisdictions, coordination among transportation officials and agencies is crucial to implementation and success of the measure.

A regional pricing strategy may be analyzed in the same way as facility pricing with the analysis conducted for each roadway affected by the strategy.

Application: Highways or controlled access facilities between residential areas and central commercial areas. This strategy should only be used for CMAQ purposes.

Variables:

EF_A: Speed-based running exhaust emission factor after implementation on affected roadway (grams/mile)

EF_B: Speed-based running exhaust emission factor on affected roadway before implementation (NO_x , VOC, or CO) (grams/mile)

FEE_A:	Price for facility use after implementation of measure (decimal)
FEE_B:	Price for facility use before implementation of measure (decimal)
TEF_{AUTO}:	Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TL_A:	Average auto trip length after implementation of measure (miles)
TL_B:	Average auto trip length before implementation of measure (miles)
VMT_R:	Reduction in daily auto vehicle miles traveled
VT_{ALT}:	Vehicle trips on alternate facility
VT_B:	Vehicle trips on facility before implementation of measure
VT_{NC}:	Vehicle trips remaining on facility after implementation
VT_R:	Reduction in number of daily automobile vehicle trips
VT_S:	Vehicle trips on facility shifted to no cost or lower cost time period
ϵ:	Price elasticity for mode and time shift

Equation:

$$\textbf{Daily Emission Reduction} = A + B + C + D$$

$$A = (VT_R * TEF_{AUTO}) + (VMT_R * EF_B)$$

Reduction in auto start emissions from trip reductions plus the reduction in auto running exhaust emissions from trip reductions

$$B = VT_S * TL_B * (EF_B - EF_A)$$

Reduction in auto running exhaust emissions from trips shifted to a no cost or lower cost time period

$$\mathbf{C = VT_{\mathit{ALT}} * (TL_{\mathit{B}} * EF_{\mathit{B}} - TL_{\mathit{A}} * EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips on an alternate facility during the same time period

$$\mathbf{D = VT_{\mathit{NC}} * TL_{\mathit{B}} * (EF_{\mathit{B}} - EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions due to a speed change for trips remaining on the facility after implementation

Where

$VMT_R = VT_R * TL_B$
$VT_R = Є * (FEE_B - FEE_A) * VT_B$
$VT_S = Є * (FEE_B - FEE_A) * VT_B$

The price elasticity for use of the facility multiplied by the difference in the fee for use of the facility before and after strategy implementation multiplied by the number of vehicle trips before implementation

$VT_B = VT_R + VT_S + VT_{ALT} + VT_{NC}$

Final unit of measure: grams/day
Source: TTI

19.2 Cordon Pricing

Strategy: Mitigate congestion.

Description: Cordon pricing charges vehicles that enter high-activity areas such as central business districts. Areas of high congestion are identified and encircled with one or more cordons (lines). Vehicles may enter the area on different types of roads (e.g., arterials or highways). Fees are then collected from drivers through tollbooths at the cordon, special area permits, or parking permits. Prices may vary by time of day so that drivers may be reluctant to enter the cordoned areas during typical peak congestion periods.

Cordon pricing has potential disadvantages:

- Although it may relieve inner-city congestion, cordon pricing policy may not reduce traffic on the region's freeway system leading into the city.
- Once vehicles pay the fee for entering the area, there is no price difference for people who drive for a longer period of time than others.
- Cordon pricing may also result in the unintended consequence of congestion moving into streets adjacent to the cordoned area. Similar to single facility pricing, congestion may simply shift from the priced roadways to other nontoll alternative routes.
- An inequitable situation for businesses within the affected district may result if people choose to avoid fees and do business elsewhere. Commercial delivery businesses and companies in the transportation industry that need access to affected areas may also be negatively affected if not exempted.

Application: Major business districts or other concentrated congested areas.

Variables: **EF_A:** Speed-based running exhaust emission factor after implementation on affected roadway (grams/mile)

EF_B: Speed-based running exhaust emission factor on affected roadway before implementation (NO_x, VOC, or CO) (grams/mile)

FEE_A: Price for facility use after implementation of measure (decimal)

FEE_B: Price for facility use before implementation of measure (decimal)

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_A: Average auto trip length after implementation of measure (miles)

TL_B: Average auto trip length before implementation of measure (miles)

VMT_R: Reduction in daily auto vehicle miles traveled

VT_{ALT}: Vehicle trips on alternate facility

VT_B: Vehicle trips on facility before implementation of measure

VT_{NC}: Vehicle trips remaining on facility after implementation

VT_R: Reduction in number of daily automobile vehicle trips

VT_S: Vehicle trips on facility shifted to no cost or lower cost time period

Є: Price elasticity for mode and time shift

Equation:

$$\textbf{Daily Emission Reduction} = A + B + C + D$$

$$A = (VT_R * TEF_{AUTO}) + (VMT_R * EF_B)$$

Reduction in auto start emissions from trip reductions plus the reduction in auto running exhaust emissions from trip reductions

$$\mathbf{B = VT_{\mathit{S}} * TL_{\mathit{B}} * (EF_{\mathit{B}} - EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips shifted to a no cost or lower cost time period

$$\mathbf{C = VT_{\mathit{ALT}} * (TL_{\mathit{B}} * EF_{\mathit{B}} - TL_{\mathit{A}} * EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips shifted to an alternate destination during the same time period

$$\mathbf{D = VT_{\mathit{NC}} * TL_{\mathit{B}} * (EF_{\mathit{B}} - EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips remaining on the same routes after implementation

Where

$VMT_R = VT_R * TL_B$
$VT_R = Є * (FEE_B - FEE_A) * VT_B$
$VT_S = Є * (FEE_B - FEE_A) * VT_B$

The price elasticity for use of the facility multiplied by the difference in the fee for use of the facility before and after strategy implementation multiplied by the number of vehicle trips before implementation

$VT_B = VT_R + VT_S + VT_{ALT} + VT_{NC}$

Final unit of measure: grams/day
Source: TTI

20.0 MOSERS EQUATIONS

This section presents a consolidated list of the MOSERS equations from the previous sections of Part B.

3.1 System/Service Expansion

Daily Emission Reduction = A + B – C – D

$$A = VT_R * TEF_{AUTO}$$

Reduction in auto start emissions from trips reduced

$$B= VMT_R * EF_B$$

Reduction in auto running exhaust emissions from VMT reductions

$$C = VT_{BUS} * TEF_{BUS}$$

Increase in emissions from additional bus starts

$$D = VMT_{BUS} * EF_{BUS}$$

Increase in emissions from additional bus running exhaust emissions

Where

$$VT_R = N_{TR} * F_{T, SOV}$$

Number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use

$$VMT_R = VT_R * TL_W$$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

3.2 System/Service Operational Improvements

Daily Emission Reduction = A + B – C – D

$$A = VT_R * TEF_{AUTO}$$

Reduction in auto start emissions from trips reduced

$$\mathbf{B = VMT_{\mathit{R}} * EF_{\mathit{B}}}$$

Reduction in auto running exhaust emissions from VMT reductions

$$\mathbf{C = VT_{\mathit{BUS}} * TEF_{\mathit{BUS}}}$$

Increase in emissions from additional bus starts

$$\mathbf{D = VMT_{\mathit{BUS}} * EF_{\mathit{BUS}}}$$

Increase in emissions from additional bus running exhaust emissions

Where

$VT_R = N_{TR} * F_{T, SOV}$

Number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use

$VMT_R = VT_R * TL_W$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

3.3 Marketing Strategies

Daily Emission Reduction = A + B

$$\mathbf{A = VT_{\mathit{R}} * TEF_{\mathit{AUTO}}}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = VMT_{\mathit{R}} * EF_{\mathit{B}}}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{TR} * F_{T, SOV}$

Number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use

$VMT_R = VT_R * TL_W$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: CalTrans

4.1 Freeway HOV Facilities

$$\textbf{Daily Emission Reduction} = \mathbf{A + B + C + D}$$

$$\mathbf{A = V_{\mathit{H,A}} * (EF_{\mathit{B}} - EF_{\mathit{H,A}}) * N_{\mathit{PH}} * L}$$

Change in running exhaust emissions from vehicles shifting from general purpose lanes to HOV lanes

$$\mathbf{B = (V_{\mathit{GP,B}} * EF_{\mathit{B}} - V_{\mathit{GP,A}} * EF_{\mathit{GP,A}}) * N_{\mathit{PH}} * L}$$

Change in running exhaust emissions of vehicles in general purpose lanes as a result of vehicles shifted away from general purpose lanes

$$\mathbf{C = VT_{\mathit{R}} * TEF_{\mathit{AUTO}}}$$

Reduction in auto start exhaust emissions from trip reductions

$$\mathbf{D = VMT_{\mathit{R}} * EF_{\mathit{B}}}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_P * (F_T * F_{T,SOV} + F_{RS} * F_{RS,SOV}) * (1 - 1/AVO_{RS})$

Number of HOV users multiplied by the sum of the fraction of users selecting transit multiplied by the percentage that previously drove SOVs added by the fraction of users selecting ridesharing multiplied by the percentage that previously drove SOVs multiplied by the percentage of ridesharers that are passengers

$VMT_R = VT_R * TL_W$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: CalTrans (adapted by TTI)

4.2 Arterial HOV Facilities

$$\textbf{Daily Emission Reduction} = A + B + C + D$$

$$A = V_{H,A} * (EF_B - EF_{H,A}) * N_{PH} * L$$

Change in running exhaust emissions from vehicles shifting to HOV lane

$$B = (V_{GP,B} * EF_B - V_{GP,A} * EF_{GP,A}) * N_{PH} * L$$

Change in running exhaust emissions of vehicles in general purpose lanes as a result of vehicles shifted away from general purpose lanes

$$C = VT_R * TEF_{AUTO}$$

Reduction in auto start exhaust emissions from trip reductions

$$D = VMT_R * EF_B$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$VT_R = N_P * (F_T * F_{T,SOV} + F_{RS} * F_{RS,SOV}) * 2 \text{ trips/day}$$

Number of HOV users multiplied by the sum of the fraction of users selecting transit multiplied by the percentage that previously drove SOVs added by the fraction of users selecting ridesharing multiplied by the percentage that previously drove SOVs multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

Number of vehicle trips reduced multiplied by the average auto trip length

Final unit of measure: grams/day
Source: CalTrans (adapted by TTI)

4.3 Parking Facilities at Entrances to HOV Facilities

$$\textbf{Daily Emission Reduction} = N_{PK} * U_P * (TL_W - TL_{PR}) * EF_B * 2 \text{ trips/day}$$

Reduction in running exhaust emissions from reduced VMT resulting from park-and-ride lot use

Final unit of measure: grams/day
Source: TTI

4.4 SOV Utilization of HOV Lanes

Daily Emission Reduction = A – B

$$A = VMT_{GP,B} * EF_{GP,B} + VMT_{H,B} * EF_{H,B}$$

The running exhaust emissions of the affected highway before implementation of the strategy for both the general purpose and HOV lanes

$$B = VMT_{GP,A} * EF_{GP,A} + VMT_{H,A} * EF_{H,A}$$

The running exhaust emissions of the affected highway after implementation of the strategy for both the general purpose and HOV lanes

Where

$$VMT_{GP,A} = VMT_{GP,B} - (VMT_{GP,B} * \epsilon)$$

The expected VMT on the general purpose lane after implementation is equal to the VMT of the lanes before implementation multiplied by the price elasticity subtracted from the VMT before implementation

$$VMT_{H,A} = VMT_{H,B} - (VMT_{H,B} * \epsilon)$$

The expected VMT on the HOV lane after implementation is equal to the VMT of the HOV lane before implementation multiplied by the price elasticity subtracted from the VMT before implementation

Final unit of measure: grams/day
Source: Houston-Galveston Area Council (HGAC)

5.1 Transit/Rideshare Services

Daily Emission Reduction = (A – B) + C

$$A = VT_B * TL_B * EF_B$$

Auto running exhaust emissions before strategy implementation

$$\mathbf{B = VT_{\mathit{A}} * TL_{\mathit{A}} * EF_{\mathit{A}}}$$

Auto running exhaust emissions after strategy implementation

$$\mathbf{C = (VT_{\mathit{B}} - VT_{\mathit{A}}) * TEF_{\mathit{AUTO}}}$$

Reduction in start exhaust emissions from reduction in vehicle trips to/from employment center

Where

$VT_A = N_{VA} * 2$ trips/day
$VT_B = N_{VB} * 2$ trips/day

Number of vehicles before or after strategy implementation multiplied by two trips per day (round trip)

Final unit of measure: grams/day
Source: TTI

5.2 Bicycle and Pedestrian Programs

Daily Emission Reduction = A + B

$$\mathbf{A = (VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{BW} * F_{BW, SOV} * 2$ trips/day

Number of bike and pedestrian participants multiplied by the number of participants that previously drove single-occupant vehicles multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_{B, BW}$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day

Source: CalTrans/CARB and FHWA Southern Resource Center
(modified by Texas Transportation Institute)

5.3 Employee Financial Incentives

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs:

$$VT_R = N_P * 2 \text{ trips/day}$$

Number of participants multiplied by two trips per day (round trip)

$$VMT_R = VT_R * TL_W$$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: TTI

6.1 Negotiated Agreements

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$

Number of program participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$VT_R = N_P * 2$ trips/day

Number of participants multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: TTI

6.2 Trip-Reduction Programs

Daily Emission Reduction = A + B

$$\mathbf{A = (VT_R * TEF_{AUTO})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_R * EF_B)}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$VT_R = N_P * 2$ trips/day

Number of participants multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: TTI

6.3 Mandated Ridesharing and Activity Programs

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$N_P = (N_{RS} * F_{RS,\ SOV}) + (N_T * F_{T,\ SOV}) + (N_{BW} * F_{BW,\ SOV})$

Number of rideshare participants previously driving SOVs added to number of transit participants previously driving SOVs added to number of bike and pedestrian participants previously driving SOVs

$VT_R = N_P * 2$ trips/day

Number of participants multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.4 Requirements for Adequate Public Facilities

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$

Number of rideshare participants previously driving single-occupant vehicle added to number of transit participants previously driving single-occupant vehicle added to number of bike and pedestrian participants previously driving single-occupant vehicle

$VT_R = N_P * 2$ trips/day

Number of participants multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

6.5 Conditions of Approval for New Construction

Daily Emission Reduction = A + B

$$\mathbf{A = (VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$N_P = (N_{RS} * F_{RS, SOV}) + (N_T * F_{T, SOV}) + (N_{BW} * F_{BW, SOV})$

Number of rideshare participants previously driving single-occupant vehicle added to number of transit participants previously driving single-occupant vehicle added to number of bike and pedestrian participants previously driving single-occupant vehicle

$VT_R = N_P * 2$ trips/day

Number of participants multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: Texas Transportation Institute

7.1 Traffic Signalization

For corridors:

Daily Emission Reduction (for each approach) = A + B

$$A = V_{D,P} * (EF_{B,P} - EF_{A,P}) * L$$

Change in running exhaust emissions from improved traffic flow during the peak period

$$B = V_{D,OP} * (EF_{B,OP} - EF_{A,OP}) * L$$

Change in running exhaust emissions from improved traffic flow during the off-peak period

Final unit of measure: grams/day
Source: FHWA Southern Resource Center (modified by TTI)

For individual intersection or grade separation:

Daily Emission Reduction = A + B

$$A = (D_B - D_A) * EF_I * V_{D,P}$$

Change in idling emissions from reduced vehicle delay times during the peak period

$$B = (D_B - D_A) * EF_I * V_{D,OP}$$

Change in idling emissions from reduced vehicle delay times during the off-peak period

Final unit of measure: grams/day
Source: TTI

7.2 Traffic Operations

Daily Emission Reduction = A + B + C

$$A = (I_P + I_{OP}) * EF_I$$

Change in idling exhaust emissions from improved traffic flow during the peak and off-peak periods

$$B = (EF_{B,\,P} - EF_{A,\,P}) * VMT_P$$

Change in running exhaust emissions from improved traffic flow during the peak period

$$C = (EF_{B,\,OP} - EF_{A,\,OP}) * VMT_{OP}$$

Change in running exhaust emissions from improved traffic flow during the off-peak period

Where

$I_P = (N_{PH} * V_{H,\,P} * DR_P)/3600$ seconds per hour
$I_{OP} = (N_{OPH} * V_{H,\,OP} * DR_{OP})/3600$ seconds per hour

Reduction of idling in the peak and off-peak period

$VMT_P = N_{PH} * V_{H,\,P} * L$
$VMT_{OP} = N_{OPH} * V_{H,\,OP} * L$

VMT affected by the strategy in the peak and off-peak periods

Final unit of measure: grams/day
Source: TTI (modified from CARB and FHWA Southern Resource Center)

7.3 Enforcement and Management

Equation for Incident Management:

Daily Emission Reduction =

$$\mathbf{E}_{REG} * \mathbf{F}_{NR} * \sum_{i=1}^{n} \mathbf{F}_{Eff\ i} * \left(\frac{\mathbf{ADT}_i}{\mathbf{ADT}_T} \right)$$

The amount of regional nonrecurring congestion emissions multiplied by the sum of each link's effectiveness and proportion to the total regional ADT.

Final unit of measure: grams/day
Source: TTI

Equation for Ramp Metering:

Daily Emission Reduction = A – B

$$\mathbf{A} = [(\mathbf{V}_B * \mathbf{EF}_B) - (\mathbf{V}_A * \mathbf{EF}_A)] * \mathbf{L}$$

The change in running exhaust emissions on the freeway along the metered section

$$\mathbf{B} = \mathbf{N}_V * \mathbf{t}_q * \mathbf{EF}_I$$

The increase in idling exhaust emissions from queuing at the metered ramps

Final unit of measure: grams/day
Source: Texas Transportation Institute

7.4 Intelligent Transportation Systems (ITS)

Equation 1

Daily Emission Reduction =

$$\sum_{i=1}^{n} [\mathbf{L}_i * \mathbf{ADT}_i * (\mathbf{EF}_B - \mathbf{EF}_A)_i]$$

The sum of each ITS link's change in running exhaust emissions resulting from improved traffic flow

Peak and off-peak hours can be split in equation.

Final unit of measure: grams/day
Source: TTI

Equation 2

Daily Emission Reduction = A + B + C + D

$$A = E_{P} * F_{N,\,RP} * F_{ITS} * F_{EN,\,P}$$

Change in emissions from alleviating peak hour nonrecurrent congestion

$$B = E_{OP} * F_{OPH} * F_{NR,\,OP} * F_{ITS} * F_{EN,\,OP}$$

Change in emissions from alleviating off-peak hour nonrecurrent congestion

$$C = E_{P} * F_{ITS} * (1 - F_{N,\,RP}) * F_{ER,\,P}$$

Change in emissions reduced from alleviating peak hour recurrent congestion

$$D = E_{OP} * F_{OPH} * F_{ITS} * (1 - F_{NR,\,OP}) * F_{ER,\,OP}$$

Change in emissions from alleviating off-peak hour recurrent congestion

Final unit of measure: grams/day
Source: North Central Texas Council of Governments, 2006

7.5 Railroad Grade Separation

Daily Emission Reduction = A * B

$$A = t_{H,\,C} / t_{H} * V$$

The number of vehicles affected by rail crossing delays

$$B = t_{C} / 2 * EF_{I}$$

The average idling emissions resulting from affected traffic idling at the closed crossing (assumed to be half of the average time the roadway is closed per train crossing)

Final unit of measure: grams/day
Source: TTI

8.1 New Facilities

Daily Emission Reduction =

$$N_{PK} * U_{P} * (TL_{W} - TL_{PR}) * EF_{B} * 2 \text{ trips/day}$$

Reduction in running exhaust emissions from reduced VMT resulting from park and ride lot use

Final unit of measure: grams/day
Source: TTI

8.2 Improved Connections to Freeway System

Daily Emission Reduction = A + B

$$A = (VMT_{Bus,\,B} * EF_B - VMT_{Bus,\,A} * EF_A) + (VMT_{Auto,\,B} * EF_B - VMT_{Auto,\,A} * EF_A)$$

Reduction in vehicle running exhaust emissions from improved travel time from park-and-ride lot to freeway entrance

$$B = N_P * F_{AT} * TL_{PR} * EF_B * 2 \text{ trips/day}$$

Reduction in auto running exhaust emissions from a reduction in commute trip length multiplied by two trips per day (round trip)

Final unit of measure: grams/day
Source: TTI

8.3 Onsite Support Services

Daily Emission Reduction = A + B + C

$$A = (N_{PK} * U_P * F_{USE}) * N_{HBO} * TL_{HBO} * EF_B$$

Reduction in auto running exhaust emissions from a reduction in home-based other trips

$$B = (N_{PK} * U_P * F_{USE}) * N_{HBO} * TEF_{AUTO}$$

Reduction in auto start exhaust emissions from a reduction in home-based other trips

$$C = N_P * F_{AT} * TL_{PR} * EF_B * 2 \text{ trips/day}$$

Reduction in auto running exhaust emissions from a reduction in commute trip length multiplied by two trips per day (round trip)

Final unit of measure: grams/day
Source: TTI

8.4 Shared-Use Parking

Daily Emission Reduction =
$$N_{PK} * U_P * (TL_W - TL_{PR}) * EF_B * 2 \text{ trips/day}$$

Reduction in running exhaust emissions from reduced VMT resulting from park-and-ride lot use

Final unit of measure: grams/day
Source: Texas Transportation Institute

9.1 No-Drive Days

Daily Emission Reduction = A + B + C

$$A = VMT_{R,\,P} * EF_{B,\,P}$$

Reduction in auto running exhaust emissions resulting from reduced peak period VMT multiplied by the average peak period running exhaust emission factor

$$B = VMT_{R,\,OP} * EF_{B,\,OP}$$

Reduction in auto running exhaust emissions resulting from reduced off-peak period VMT multiplied by the average off-peak period running exhaust emission factor

$$C = (VT_{R,\,P} + VT_{R,\,OP}) * TEF_{AUTO}$$

Reduction in auto start emissions from trip reductions

Where

$$VT_{R,\,P} = N_V * F_{CND} * F_W * 2 \text{ trips/day}$$

The number of vehicles affected by the program multiplied by the compliance rate with the program multiplied by the fraction of vehicle use for commute trips multiplied by two trips per day (round trip)

$$VT_{R,\,OP} = N_V * F_{CND} * (1 - F_W) * N_{NW}$$

The number of vehicles affected by the program multiplied by the compliance rate with the program multiplied by the fraction of vehicle use for noncommute trips multiplied by the average number of noncommute auto trips per day

$$VMT_{R,\,P} = VT_{R,\,P} * TL_W$$

$VMT_{R, OP} = VT_{R, OP} * TL_{NW}$

The vehicle trips reduced multiplied by the average auto commute or noncommute trip length

Final unit of measure: grams/day
Source: TTI

9.2 Control of Truck Movement

$$\textbf{Daily Emission Reduction} = \sum [VMT_P * EF_{B,i} - VMT_P * EF_{A,i}]_i$$

The running exhaust emissions on the affected links before control subtracted by the running exhaust emissions on the affected links after control

Final unit of measure: grams/day
Source: TTI

10.1 Commute Management Organizations

$$\textbf{Daily Emission Reduction} = A + B$$

$$A = (\Sigma VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$1 = F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$

The fractions of strategy participants that shift to other modes from single-occupant vehicles

$VT_{R, T} = N_T * F_{T, SOV} * 2$ trips/day
$VT_{R, RS} = N_{RS} * (1 - 1 / AVO_{RS}) * F_{RS, SOV} * 2$ trips/day
$VT_{R, BW} = N_{BW} * F_{BW, SOV} * 2$ trips/day

The number of participants multiplied by the fraction of single-occupant vehicle drivers that switch to another mode multiplied by two trips per day (round trip)

$VMT_{R, T} = VT_{R, T} * (TL_W - TL_T)$

$VMT_{R, RS} = VT_{R, RS} * (TL_W - TL_{RS})$
$VMT_{R, BW} = VT_{R, BW} * TL_W$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by TTI)

10.2 Transportation Management Associations

Daily Emission Reduction = A + B

$A = (\Sigma VT_R * TEF_{AUTO})$

Reduction in auto start emissions from trip reductions

$B = (\Sigma VMT_R * EF_B)$

Reduction in auto running exhaust emissions from trip reductions

Where

$1 = F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$

The fractions of strategy participants that shift to other modes from SOVs

$VT_{R, T} = N_T * F_{T, SOV} * 2$ trips/day
$VT_{R, RS} = N_{RS} * (1-1/AVO_{RS}) * F_{RS, SOV} * 2$ trips/day
$VT_{R, BW} = N_{BW} * F_{BW, SOV} * 2$ trips/day

The number of participants multiplied by the fraction of single-occupant vehicle drivers that switch to another mode multiplied by two trips per day (round trip)

$VMT_{R, T} = VT_{R, T} * (TL_W - TL_T)$
$VMT_{R, RS} = VT_{R, RS} * (TL_W - TL_{RS})$
$VMT_{R, BW} = VT_{R, BW} * TL_W$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by TTI)

10.3 Tax Incentives and Subsidy Programs

$$\textbf{Daily Emission Reduction} = \textbf{A} + \textbf{B}$$

$$\textbf{A} = (\Sigma \textbf{VT}_{R} * \textbf{TEF}_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$\textbf{B} = (\Sigma \textbf{VMT}_{R} * \textbf{EF}_{B})$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$$

The fractions of strategy participants that shift to other modes from single-occupant vehicles

$$VT_{R, T} = N_{T} * F_{T, SOV} * 2 \text{ trips/day}$$
$$VT_{R, RS} = N_{RS} * (1 - 1/AVO_{RS}) * F_{RS, SOV} * 2 \text{ trips/day}$$
$$VT_{R, BW} = N_{BW} * F_{BW, SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of single-occupant vehicle drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R, T} = VT_{R, T} * (TL_{W} - TL_{T})$$
$$VMT_{R, RS} = VT_{R, RS} * (TL_{W} - TL_{RS})$$
$$VMT_{R, BW} = VT_{R, BW} * TL_{W}$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by TTI)

11.1 Bicycle and Pedestrian Lanes or Paths

For a facility parallel to an existing roadway:

$$\textbf{Daily Emission Reduction} = \textbf{AADT} * \textbf{PMS} * \textbf{L} * \textbf{EF}_{B}$$

The average annual daily traffic of the corridor multiplied by the percentage of drivers shifting to bike/pedestrian multiplied by the length of the project facility multiplied by the speed-based running exhaust *emission factor for participants' trip before participating in the bike/pedestrian program*

Final unit of measure: grams/day
Source: CAMPO

For a facility without a parallel roadway:

Equation 1

$$\textbf{Daily Emission Reduction} = HH_{AREA} * HH_{TRIPS} * PMS * TL_B * EF_B$$

The number of households in the area affected by the strategy multiplied by the average number of household trips in the strategy area by the percentage of drivers shifting to bike/pedestrian multiplied by the length of the project facility multiplied by the speed-based running exhaust emission factor for participants' trip before participating in the bike/pedestrian program

Final unit of measure: grams/day
Source: El Paso MPO

Equation 2

$$\textbf{Daily Emissions Reduction} = A + B$$

$$A = (N_{BW} * TL_B * EF_B)$$

The number of new bicycle/pedestrian facility users multiplied by the bicycle and/or pedestrian trip length multiplied by the speed-based running exhaust emission factor for participants' trip before participating in the bicycle/pedestrian program

$$B = (N_{BW} * TEF_{AUTO})$$

The number of new bicycle/pedestrian facility users multiplied by the trip-end emission factor

Note: *For this equation,* TEF_{AUTO} *is computed for cold-start emissions only.*

Final unit of measure: grams/day
Source: North Central Texas Council of Governments, 2006

11.2 Bicycle and Pedestrian Support Facilities and Programs

$$\textbf{Daily Emission Reduction} = A + B$$

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{BW} * F_{BW, SOV} * 2$ trips/day

The number of bicycle and pedestrian program participants multiplied by the fraction of participants that shifted from single-occupant vehicle use multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: CalTrans/CARB

12.1 Controls on Drive-Through Facilities

Daily Emission Reduction = A – B + C

$$\mathbf{A = N_{\mathit{V}} * t_{\mathit{B}} * EF_{\mathit{I}}}$$

The amount of idling exhaust emissions generated before the control

$$\mathbf{B = (1 - F_{\mathit{PARK}}) * N_{\mathit{V}} * t_{\mathit{A}} * EF_{\mathit{I}}}$$

The idling exhaust emissions after the control is in place

$$\mathbf{C = F_{\mathit{PARK}} * N_{\mathit{V}} * (TEF_{\mathit{AUTO}})}$$

The increase in start exhaust emissions resulting from consumers now parking their vehicle in lieu of idling their vehicle

Final unit of measure: grams/day
Source: TTI

12.2 Heavy-Duty Vehicles

Daily Emission Reduction = A * (B – C)

$$\mathbf{A = N_{\textit{V}} * F_{\textit{C}}}$$

The number of vehicles with restricted idling time multiplied by the percentage of vehicles in compliance with the strategy

$$\mathbf{B = EF_{\textit{I}} * (t_{\textit{B}} - t_{\textit{A}})}$$

The reduction in idling exhaust emissions from reduced time spent in idling

$$\mathbf{C = N_{\textit{RSt}} * TEF_{\textit{TRK}}}$$

The increase in start exhaust emissions resulting from engine restarts

Final unit of measure: grams/day
Source: TTI

14.1 Telecommuting

<u>Telecommuting (Home)</u>

Daily Emission Reduction = A + B

$$\mathbf{A = (VT_{\textit{R}} * TEF_{\textit{AUTO}})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (VMT_{\textit{R}} * EF_{\textit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_P * N_D / 5 * 2$ trips/day

Number of people working at home multiplied by the average number of days worked at home per work week multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the auto commute trip length

__Telecommuting (Center)__

Daily Emission Reduction = $VMT_R * EF_B$

Reduction in auto running exhaust emissions from trip reductions

Where

$VMT_R = VT_R * (TL_W - TL_{TC})$

The vehicle trips reduced multiplied by the reduced auto commute trip length

Final unit of measure: grams/day
Source: CalTrans/CARB

14.2 Flextime

Daily Emission Reduction = $(N_P * TL_W) * (EF_B - EF_A) * N_D/5$

The number of flextime participants multiplied by the average auto commute trip length multiplied by the change in auto running exhaust emission factors due to improved average travel speed multiplied by the percentage of the work week affected by the strategy

Note: *For each hour affected by implementation of the flextime program (usually peak periods)*

Final unit of measure: grams/day
Source: TTI

14.3 Compressed Work Week

Daily Emission Reduction = A + B + C

$A = (VT_R * TEF_{AUTO})$

Reduction in auto start emissions from trip reductions

$B = (VMT_R * EF_B)$

Reduction in auto running exhaust emissions from trip reductions

$C = N_P * TL_W * (EF_B * EF_A) * N_D / N_{D, PRG}$

The number of participants multiplied by the average auto commute trip length multiplied by the change in auto running exhaust emission factors due to improved average travel speed multiplied by the percentage of the work week affected by the strategy

Where

$VT_R = N_P * N_D / N_{D, PRG} * 2$ trips/day

The number of program participants multiplied by the number of work days eliminated divided by the number of work days within the scheduling program multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trips reduced multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: CalTrans/CARB

15.1 Design Guidelines and Regulations

Daily Emission Reduction =
$$\sum \mathbf{BASE} * \mathbf{CAP} * \mathbf{F}_{PURi} * \mathbf{TL}_{PURi} * \mathbf{EF}_{PURi}$$

The number of trips reduced as a result of the mixed-use development multiplied by fraction of trips by purpose multiplied by the associated average trip length and speed-based emission factor

Where

$BASE = \sum N_{DU} * TR_{Dui}$

The number of daily trips generated by nonmixed residential and commercial uses equals number of units generated by a typical development times the trip rate by purpose

Final unit of measure: grams/day
Source: CAMPO

15.2 Parking Regulations and Standards

Daily Emission Reduction = A + B

$$\mathbf{A} = (\Sigma \mathbf{VT}_R * \mathbf{TEF}_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$1 = F_{T,\ SOV} + F_{RS,\ SOV} + F_{BW,\ SOV}$

The fractions of strategy participants that shift to other modes from SOVs

$VT_{R,\ T} = N_{T} * F_{T,\ SOV} * 2$ trips/day
$VT_{R,\ RS} = N_{RS} * (1-1/AVO_{RS}) * F_{RS,\ SOV} * 2$ trips/day
$VT_{R,\ BW} = N_{BW} * F_{BW,\ SOV} * 2$ trips/day

The number of participants multiplied by the fraction of SOV drivers that switch to another mode multiplied by two trips per day (round trip)

$VMT_{R,\ T} = VT_{R,\ T} * (TL_{W} - TL_{T})$
$VMT_{R,\ RS} = VT_{R,\ RS} * (TL_{W} - TL_{RS})$
$VMT_{R,\ BW} = VT_{R,\ BW} * TL_{W}$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: CalTrans/CARB (adapted by TTI)

15.3 Mixed-Use Development

Daily Emission Reduction =
$$\mathbf{\sum BASE * CAP * F_{\mathit{PURi}} * TL_{\mathit{PURi}} * EF_{\mathit{PURi}}}$$

The number of trips reduced as a result of the mixed-use development multiplied by the reduction in auto running exhaust emissions from the trips reduced

Where

$BASE = \sum N_{DU} * TR_{Dui}$

The number of daily trips generated by nonmixed residential and commercial uses equals number of units generated by a typical development times the trip rate by purpose

Final unit of measure: grams/day

Source: CAMPO

16.1 Cash Payments

Daily Emission Reduction = $VMT_B * EF_O - VMT_A * EF_N$

The average daily VMT of vehicles removed from service multiplied by the average daily composite emission factor for vehicles removed from service subtracted by the average daily VMT of new vehicles multiplied by the average daily composite emission factor for the replacement vehicles

Final unit of measure: grams/day
Source: TTI

17.1 Preferential Parking for HOVs

Daily Emission Reduction = A + B

$A = (VT_R * TEF_{AUTO})$

Reduction in auto start emissions from trip reductions

$B = (VMT_R * EF_B)$

Reduction in auto running exhaust emissions from trip reductions

Where

$VT_R = N_{PPK} * U_{PPK} * (1 - F_{ECP}) * (OCC - 1) * 2$ trips/day

Number of preferential parking spaces multiplied by the parking utilization rate of the preferential parking spaces multiplied by the fraction of new carpools multiplied by the average number of passengers after implementation multiplied by two trips per day (round trip)

$VMT_R = VT_R * TL_W$

The vehicle trip reduction multiplied by the average auto commute trip length

Final unit of measure: grams/day
Source: TTI

17.2 Public Sector Parking Pricing

Daily Emission Reduction = A + B

$$A = (VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{SOV} + F_{T,\ SOV} + F_{RS,\ SOV} + F_{BW,\ SOV}$$

The fractions of affected drivers that will continue to drive SOVs and those that shift to other available modes

$$VT_R = (\Delta P_{fee} * \epsilon_{fee} * N_{PK} * U_P) * (1 - F_{SOV}) * 2 \text{ trips/day}$$

The change in parking fees multiplied by a price elasticity multiplied by the number of affected parking spaces and their utilization rate multiplied by the fraction of SOVs that make a mode switch multiplied by two trips per day (round trip)

$$VMT_{R,\ T} = VT_R * F_{T,\ SOV} * (TL_W - TL_T)$$
$$VMT_{R,\ RS} = VT_R * (1 - 1 / AVO_{RS}) * F_{RS,\ SOV} * 2 \text{ trips/day}$$
$$VMT_{R,\ BW} = VT_R * F_{BW,\ SOV} * TL_W$$

The vehicle trip reduction multiplied by the fraction of SOV drivers that switch to another mode multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: TTI

17.3 Parking Requirements in Zoning Ordinances

Daily Emission Reduction = A + B

$$A = (\Sigma VT_R * TEF_{AUTO})$$

Reduction in auto start emissions from trip reductions

$$B = (\Sigma VMT_R * EF_B)$$

Reduction in auto running exhaust emissions from trip reductions

Where

$$1 = F_{SOV} + F_{T, SOV} + F_{RS, SOV} + F_{BW, SOV}$$

The fractions of affected drivers that will continue to drive SOVs and those that shift to other available modes

$$N_P = (N_{PK, B} * U_{P, B} - N_{PK, A} * U_{P, A}) * OCC * (1 - F_{SOV})$$

The difference between the number of parking spaces affected before the control multiplied by the parking utilization rate before the control and the number of parking spaces affected after the control multiplied by the parking utilization rate after the control multiplied by the average vehicle occupancy multiplied by the fraction of SOVs that make a mode switch multiplied by two trips per day (round trip)

$$VT_{R, T} = N_P * F_{T, SOV} * 2 \text{ trips/day}$$
$$VT_{R, RS} = N_P * (1 - 1 / AVO_{RS}) * F_{RS, SOV} * 2 \text{ trips/day}$$
$$VT_{R, BW} = N_P * F_{BW, SOV} * 2 \text{ trips/day}$$

The number of participants multiplied by the fraction of SOV drivers that switch to another mode multiplied by two trips per day (round trip)

$$VMT_{R, T} = VT_{R, T} * (TL_W - TL_T)$$
$$VMT_{R, RS} = VT_{R, RS} * (TL_W - TL_{RS})$$
$$VMT_{R, BW} = VT_{R, BW} * TL_W$$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: TTI

17.4 On-Street Parking Controls

For parking fee increases:

Daily Emission Reduction = A + B

$$\mathbf{A = (VT_R * TEF_{AUTO})}$$

Reduction in auto start emissions from trip reductions

$$\mathbf{B = (\Sigma VMT_R * EF_B)}$$

Reduction in auto running exhaust emissions from trip reductions

Where

$1 = F_{SOV} + F_{T,\, SOV} + F_{RS,\, SOV} + F_{BW,\, SOV}$

The fractions of affected drivers that will continue to drive SOVs and those that shift to other available modes

$VT_R = (\Delta P_{fee} * \epsilon_{fee} * N_{PK} * U_P) * (1 - F_{SOV}) * 2$ trips/day

The change in parking fees multiplied by a price elasticity multiplied by the number of affected parking spaces and their utilization rate multiplied by the fraction of SOVs that make a mode switch multiplied by two trips per day (round trip)

$VMT_{R,\, T} = VT_R * F_{T,\, SOV} * (TL_W - TL_T)$
$VMT_{R,\, RS} = VT_R * (1 - 1 / AVO_{RS}) * F_{RS,\, SOV} * (TL_W - TL_{RS})$
$VMT_{R,\, BW} = VT_R * F_{BW,\, SOV} * TL_W$

The vehicle trip reduction multiplied by the fraction of SOV drivers that switch to another mode multiplied by the change in average trip length after the mode switch

For parking controls:

Daily Emission Reduction = A + B

$\mathbf{A = (\Sigma VT_{\mathit{R}} * TEF_{\mathit{AUTO}})}$

Reduction in auto start emissions from trip reductions

$\mathbf{B = (\Sigma VMT_{\mathit{R}} * EF_{\mathit{B}})}$

Reduction in auto running exhaust emissions from trip reductions

Where

$1 = F_{SOV} + F_{T,\, SOV} + F_{RS,\, SOV} + F_{BW,\, SOV}$

The fractions of affected drivers that will continue to drive SOVs and those that shift to other available modes

$N_P = (N_{PK,\, B} * U_{P,\, B} - N_{PK,\, A} * U_{P,\, A}) * OCC * (1 - F_{SOV})$

The difference between the number of parking spaces affected before the control multiplied by the parking utilization rate before the control and the number of parking spaces affected after the control multiplied by the parking utilization rate after the control multiplied by the average vehicle occupancy multiplied by the fraction of single-occupant vehicles that make a mode switch multiplied by two trips per day (round trip)

$VT_{R,\,T} = N_P * F_{T,\,SOV} * 2$ trips/day
$VT_{R,\,RS} = N_P * (1 - 1 / AVO_{RS}) * F_{RS,\,SOV} * 2$ trips/day
$VT_{R,\,BW} = N_P * F_{BW,\,SOV} * 2$ trips/day

The number of participants multiplied by the fraction of single-occupant vehicle drivers that switch to another mode multiplied by two trips per day (round trip)

$VMT_{R,\,T} = VT_{R,\,T} * (TL_W - TL_T)$
$VMT_{R,\,RS} = VT_{R,\,RS} * (TL_W - TL_{RS})$
$VMT_{R,\,BW} = VT_{R,\,BW} * TL_W$

The vehicle trip reduction multiplied by the change in average trip length after the mode switch

Final unit of measure: grams/day
Source: TTI

18.1 Clean Vehicle Program

Daily Emission Reduction = $VMT_{REP} * (EF_B - EF_A)$

Average daily VMT of the replaced vehicle multiplied by the change in pre-replacement and post-replacement composite emission factors

Final unit of measure: grams/day
Source: CalTrans/CARB

19.1 Facility Pricing

Daily Emission Reduction = A + B + C + D

$A = (VT_R * TEF_{AUTO}) + (VMT_R * EF_B)$

Reduction in auto start emissions from trip reductions plus the reduction in auto running exhaust emissions from trip reductions

$B = VT_S * TL_B * (EF_B - EF_A)$

Reduction in auto running exhaust emissions from trips shifted to a no cost or lower cost time period

$$\mathbf{C = VT_{\mathit{ALT}} * (TL_{\mathit{B}} * EF_{\mathit{B}} - TL_{\mathit{A}} * EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips on an alternate facility during the same time period

$$\mathbf{D = VT_{\mathit{NC}} * TL_{\mathit{B}} * (EF_{\mathit{B}} - EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions due to a speed change for trips remaining on the facility after implementation

Where

$VMT_R = VT_R * TL_B$
$VT_R = Є * (FEE_B – FEE_A) * VT_B$
$VT_S = Є * (FEE_B – FEE_A) * VT_B$

The price elasticity for use of the facility multiplied by the difference in the fee for use of the facility before and after strategy implementation multiplied by the number of vehicle trips before implementation

$VT_B = VT_R + VT_S + VT_{ALT} + VT_{NC}$

Final unit of measure: grams/day
Source: TTI

19.2 Cordon Pricing

Daily Emission Reduction = A + B + C + D

$$\mathbf{A = (VT_{\mathit{R}} * TEF_{\mathit{AUTO}}) + (VMT_{\mathit{R}} * EF_{\mathit{B}})}$$

Reduction in auto start emissions from trip reductions plus the reduction in auto running exhaust emissions from trip reductions

$$\mathbf{B = VT_{\mathit{S}} * TL_{\mathit{B}} * (EF_{\mathit{B}} - EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips shifted to a no cost or lower cost time period

$$\mathbf{C = VT_{\mathit{ALT}} * (TL_{\mathit{B}} * EF_{\mathit{B}} - TL_{\mathit{A}} * EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips shifted to an alternate destination during the same time period

$$\mathbf{D = VT_{\mathit{NC}} * TL_{\mathit{B}} * (EF_{\mathit{B}} - EF_{\mathit{A}})}$$

Reduction in auto running exhaust emissions from trips remaining on the same routes after implementation

Where

$VMT_R = VT_R * TL_B$
$VT_R = Є * (FEE_B – FEE_A) * VT_B$
$VT_S = Є * (FEE_B – FEE_A) * VT_B$

The price elasticity for use of the facility multiplied by the difference in the fee for use of the facility before and after strategy implementation multiplied by the number of vehicle trips before implementation

$VT_B = VT_R + VT_S + VT_{ALT} + VT_{NC}$

Final unit of measure: grams/day
Source: TTI

21.0 VARIABLES

AADT: Average annual daily traffic in corridor (vehicles/day)

ADT_A: Average daily traffic on facility after implementation (vehicles/day)
$ADT_{A, ALT}$: Average daily traffic on alternate route(s) after implementation (vehicles/day)
ADT_B: Average daily traffic on facility before implementation (vehicles/day)
$ADT_{B, ALT}$: Average daily traffic on alternate route(s) before implementation (vehicles/day)
ADT_i: Average daily traffic for each affected link
ADT_T: Total average daily traffic for affected system (vehicles/day)

AVO_{RS}: Average vehicle occupancy of rideshare (persons/vehicle)

BASE: Number of daily trips generated by nonregulated residential and commercial uses (trips)

CAP: Internal capture rate of regulated development (decimal)

D_A: Average vehicle delay at intersection after implementation (hours)
D_B: Average vehicle delay at intersection before implementation (hours)

DR_{OP}: Estimated delay reduction during off-peak period (seconds)
DR_P: Estimated delay reduction during peak period (seconds)

E_{OP}: Emissions generated by congestion on affected roadway system during the off-peak period for each pollutant (NO_x, VOC, or CO) (grams)
E_P: Emissions generated by congestion on affected roadway system during the peak period for each pollutant (NO_x, VOC, or CO) (grams)
E_{REG}: Regional freeway emissions (grams)

EF_A: Speed-based running exhaust emission factor after implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{A, ALT}$: Speed-based running exhaust emission factor on alternate route after implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{A, i}$: Speed-based running exhaust emission factor for fleet composite (including trucks) (NO_x, VOC, or CO) (grams/mile)
$EF_{A, OP}$: Speed-based running exhaust emission factor during off-peak hours in affected corridor after implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{A, P}$: Speed-based running exhaust emission factor during peak hours in affected corridor after implementation (NO_x, VOC, or CO) (grams/mile)
EF_B: Speed-based running exhaust emission factor for affected roadway before implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{B, ALT}$: Speed-based running exhaust emission factor on alternate route before implementation (NO_x, VOC, or CO) (grams/mile)
$EF_{B, i}$: Speed-based running exhaust emission factor for defined fleet composite (excluding trucks) (NO_x, VOC, or CO) (grams/mile)

$EF_{B, OP}$: Speed-based running exhaust emission factor during off-peak hours in affected corridor after before implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{B, P}$: Speed-based running exhaust emission factor during peak hours in affected corridor before implementation (NO_x, VOC, or CO) (grams/mile)

EF_{BUS}: Speed-based running exhaust emission factor for transit vehicle (grams/mile)

$EF_{GP, A}$: Speed-based running exhaust emission factor on general purpose lanes after implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{GP, B}$: Speed-based running exhaust emissions factor on general purpose lanes before implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{H, A}$: Speed-based running exhaust emission factor on HOV lane after implementation (NO_x, VOC, or CO) (grams/mile)

$EF_{H, B}$: Speed-based running exhaust emissions factor on HOV lane before implementation (NO_x, VOC, or CO) (grams/mile)

EF_I: Emission factor for idling (NO_x, VOC, or CO) (grams/hour)

EF_N: Replacement vehicle speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

EF_O: Retired vehicle speed-based running exhaust emission factor (NO_x, VOC, or CO) (grams/mile)

EF_{PURi}: Speed-based running exhaust emission factor by trip purpose (NO_x, VOC, or CO) (grams/mile)

F_{AT}: Percentage of participants who previously drove single-occupancy vehicles (decimal)

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove single-occupancy vehicles (decimal)

F_C: Compliance factor (decimal)

F_{CND}: Percent compliance of the no-drive days program (decimal)

F_{ECP}: Percentage of existing carpools (decimal)

F_{Eff}: Project effectiveness factor for each affected freeway

$F_{EN, OP}$: Percent of non-recurrent congestion eliminated on roadways with ITS deployment, off-peak period (decimal)

$F_{EN,P}$: Percent of non-recurrent congestion eliminated on roadways with ITS deployment, peak period (decimal)

$F_{ER,OP}$: Percent of recurrent congestion eliminated on roadways with ITS deployment, off-peak period (decimal)

$F_{ER,P}$: Percent of recurrent congestion eliminated on roadways with ITS deployment, peak period (decimal)

F_{ITS}: Percent of roadway system coverage with ITS deployment (decimal)

F_{NR}: Nonrecurring emissions (decimal)

$F_{NR, OP}$: Percent of roadway system emissions caused by nonrecurring congestion in the off-peak period (decimal)

$F_{NR, P}$: Percent of roadway system emissions caused by nonrecurring congestion in the peak period (decimal)

F_{OPH}: Percent of off-peak hours/emissions affected by ITS deployment (decimal)

F_{PARK}: Percent of vehicles that park instead of using the drive-through facility due to imposed control (decimal)

F_{PURi}: Percentage of trips saved by trip purpose (decimal)

F_{RS}: Percentage of people attracted to the HOV facility using ride share (decimal)
$F_{RS, SOV}$: Percentage of people attracted to the HOV facility using rideshare that previously used a SOV (decimal)
F_{SOV}: Percentage of those people continuing to use a SOV for their full commute (decimal)
F_T: Percentage of people attracted to the HOV facility using a transit vehicle (decimal)
$F_{T, SOV}$: Percentage of people using a transit vehicle that previously were vehicle drivers (decimal)
F_{USE}: Percentage of park-and-ride users that utilize the facilities (decimal)
F_W: Percentage of participating vehicles commuting to work (decimal)

FEE_A: Price for facility use after implementation of measure (decimal)
FEE_B: Price for facility use before implementation of measure (decimal)

HH_{AREA}: Number of households in strategy area
HH_{TRIPS}: Average number of trips per household in strategy area

I_{OP}: Off-peak hour reduction in idling emissions (hours)
I_P: Peak hour reduction in idling emissions (hours)

L: Length of affected roadway (miles)
L_i: Length of each freeway affected by ITS (miles)

N: Number of affected corridors
N_{BW}: Number of participants in the bike/pedestrian program
$N_{BW, SOV}$: Number of participants in bike/pedestrian programs who previously drove SOVs
N_D: Number of days in program
N_{DUi}: Number of development units by type
N_{HBO}: Average number of home-based other trips
N_{ND}: Number of people using the park-and-ride lot but not driving to it
N_{NW}: Average number of nonwork trips
N_{OPH}: Number of off-peak hours
N_P: Number of participants
N_{PH}: Number of peak hours (AM and/or PM)
N_{PK}: Number of spaces in parking lot
$N_{PK, A}$: Number of parking spaces allowed after implementation of control
$N_{PK, B}$: Number of parking spaces allowed before implementation of control
N_{PPK}: Number of preferential spaces in parking lot
$N_{PR, HOV}$: Number of HOV parking spaces at the park-and-ride facility
N_{RS}: Number of participants in rideshare programs
N_{RSt}: Average number of times vehicle is restarted
N_T: Number of participants using transit facilities
N_{TR}: Number of new transit ridership
N_V: Number of vehicles
$N_{V, PRI}$: Number of high occupancy vehicles using prioritized lane
N_{VA}: Number of vehicles after implementation

N_{VB}: Number of vehicles before implementation

OCC: Average vehicle occupancy (persons/vehicle)

PMS: Percentage mode shift from driving to bike/pedestrian (decimal)

t_A: Time after implementation of strategy (hours)
t_B: Time before implementation of strategy (hours)
t_q: Average time spent in queue waiting to enter freeway (hours)

TEF_{AUTO}: Auto trip-end emission factor (NO_x, VOC, and CO) (grams/trip)
TEF_{BUS}: Bus (or other transit vehicle) trip-end emission factor (NO_x, VOC, or CO) (grams/trip)
TEF_{TRK}: Truck trip-end emission factor (NO_x, VOC, or CO) (grams/trip)

TL_A: Average auto trip length after implementation (miles)
TL_B: Average auto trip length before implementation (miles)
$TL_{B, BW}$: Average length of participants' trip before participating in the bike/pedestrian program (miles)
TL_{HBO}: Average trip length of home-based other
TL_{NW}: Average nonwork trip length (miles)
TL_{PR}: Average auto trip length to the park-and-ride lot (miles)
TL_{PURi}: Average trip length by trip purpose (miles)
TL_{RS}: Average auto trip length to rideshare location (miles)
TL_{TC}: Average auto trip length to the telecommuting center (miles)
TL_W: Average auto trip length (miles)

TR_{DUi}: Daily trip rate by development unit type

U_P: Parking lot utilization rate (estimate)
$U_{P, A}$: Utilization rate of parking lot after implementation (decimal)
$U_{P, B}$: Utilization rate of parking lot before implementation (decimal)
$U_{P, HOV}$: Utilization rate of parking spaces by HOVs (decimal)
U_{PPK}: Utilization rate of preferential parking spaces (decimal)

V_A: Average traffic volume per operating period on main lanes after implementing ramp metering
V_B: Average traffic volume per operating period on main lanes before implementing ramp metering
$V_{D, OP}$: Average daily volume for the corridor during off-peak hours
$V_{D, P}$: Average daily volume for the corridor during peak hours
$V_{GP, A}$: Average hourly volumes on general purpose lanes during peak hours after implementation of HOV facility
$V_{GP, B}$: Average hourly volumes on general purpose lanes during peak hours before implementation of HOV facility
$V_{H,A}$: Average hourly volumes on HOV lanes during peak hours
$V_{H, OP}$: Number of vehicles that pass through the intersection per hour during the off-peak period

$\mathbf{V}_{H,P}$: Number of vehicles that pass through the intersection per hour during the peak period

$\mathbf{VMT}_{Auto,A}$: Vehicle miles traveled by auto after implementation
$\mathbf{VMT}_{Auto,B}$: Vehicle miles traveled by auto before implementation
$\mathbf{VMT}_{BUS}$: Vehicle miles traveled by transit vehicle
$\mathbf{VMT}_{Bus,A}$: Vehicle miles traveled by transit vehicle after implementation (estimate)
$\mathbf{VMT}_{Bus,B}$: Vehicle miles traveled by transit vehicle before implementation
$\mathbf{VMT}_{GP,A}$: Vehicle miles traveled on general purpose lanes after implementation (estimate)
$\mathbf{VMT}_{GP,B}$: Vehicle miles traveled on general purpose lanes before implementation
$\mathbf{VMT}_{H,A}$: Vehicle miles traveled on HOV lane after implementation (estimate)
$\mathbf{VMT}_{H,B}$: Vehicle miles traveled on HOV facility before implementation of strategy
$\mathbf{VMT}_{OP}$: Off-peak hour reduction in speed emissions
$\mathbf{VMT}_{P}$: Vehicle miles traveled by fleet composite
$\mathbf{VMT}_{PH}$: Peak hour reduction in speed emissions
$\mathbf{VMT}_{R}$: Reduction in daily automobile vehicle miles traveled
$\mathbf{VMT}_{R,BW}$: Reduction in daily auto vehicle miles traveled by bike/pedestrian mode
$\mathbf{VMT}_{R,OP}$: Reduction in regional off-peak period VMT after no-drive days implemented
$\mathbf{VMT}_{R,P}$: Reduction in regional peak period VMT after no-drive days implemented
$\mathbf{VMT}_{R,RS}$: Reduction in daily auto vehicle miles traveled by rideshare mode
$\mathbf{VMT}_{R,T}$: Reduction in daily auto vehicle miles traveled by transit mode
$\mathbf{VMT}_{REP}$: Vehicle miles traveled of the vehicle to be replaced

$\mathbf{VT}_{A}$: Average daily vehicle trips after implementation
$\mathbf{VT}_{ALT}$: Vehicle trips on alternate facility
$\mathbf{VT}_{B}$: Average daily vehicle trips before implementation
$\mathbf{VT}_{BUS}$: Daily vehicle trips by bus or other transit vehicle
$\mathbf{VT}_{NC}$: Vehicle trips remaining on facility after implementation
$\mathbf{VT}_{R}$: Reduction in number of daily automobile vehicle trips
$\mathbf{VT}_{R,BW}$: Reduction in number of daily vehicle trips by bike/pedestrian mode
$\mathbf{VT}_{R,OP}$: Reduction in regional number of off-peak period vehicle trips after no-drive days implemented
$\mathbf{VT}_{R,P}$: Reduction in regional number of peak period vehicle trips after no-drive days implemented
$\mathbf{VT}_{R,RS}$: Reduction in number of daily vehicle trips by rideshare mode
$\mathbf{VT}_{R,T}$: Reduction in number of daily vehicle trips by transit mode
$\mathbf{VT}_{S}$: Vehicle trips on facility shifted to no cost or lower cost time period

$\Delta\mathbf{P}_{fee}$: Percentage change in parking fee structure (decimal)

$\boldsymbol{\epsilon}$: Price elasticity for mode and time shift or facility charge
$\boldsymbol{\epsilon}_{fee}$: Price elasticity for mode shift

PART C MOSERS ANALYSIS GUIDANCE

It is crucial to attempt to collect and use local data for mobile source emission reduction strategy (MOSERS) analysis. Sections 9.0 and 10.0 in Part A, along with Part B, emphasize the importance of locally collected, valid data. However, there are circumstances that dictate use of other sources of data for strategy analysis. Agencies performing the analysis may lack sufficient resources (i.e., funds, personnel, or time) to collect the data. This section provides values for several of the variables used in the strategy equations in Part B.

Other sources of data may be necessary for analysis

Agencies may lack time, resources, or funding for data collection

Many of the variables in Part B can be readily computed with available data in specific regions or cities. The variables below were chosen for their difficulty in deriving a value at the metropolitan planning organization (MPO) or Texas Department of Transportation (TxDOT) district level or require a review of past and current practice from other areas of the country. For all of these variables, conservative assumptions are given.

Providing a realistic value or range of values for these variables will allow transportation/air quality practitioners in nonattainment and Early Action Compact (EAC) areas in the State of Texas to more efficiently perform their emissions benefit analyses for reviewing agencies and the general public.

Variables below chosen for difficulty in getting value at MPO level

Variables

AVO_{RS}: Average vehicle occupancy of rideshare (persons/vehicle)

Equations:
4.1 Freeway High-Occupancy Vehicle (HOV) Facilities
10.1 Commute Management Organizations
10.2 Transportation Management Associations
10.3 Tax Incentives and Subsidy Programs
15.2 Parking Regulations and Standards
17.2 Public Sector Parking Pricing

Value: 2.25 persons/vehicle

The default value was derived from HOV occupancy rates found in the Dallas-Fort Worth and Houston areas and a study of carpooling in the Houston area in *Transportation Research Record (TRR) 1321* (Bullard, 1991). The Texas Transportation Institute (TTI) has collected HOV occupancy data for both metropolitan areas. Houston data are provided in *Houston Managed Lanes Case Study: The Evolution of the Houston HOV System* (Turnbull, 2003), while collected data for Dallas-Fort Worth were provided by the System Operation Management Program in the TTI-Arlington office (TTI, 2004). Houston has an HOV occupancy rate of 2.25; Dallas-Fort Worth has one of 2.20.

Equation 4.1 is an HOV strategy, and the value is considered applicable to the other equations. Research reviewed on strategies in area-wide rideshare incentives does not provide occupancy rates within programs. Activity center MOSER research is not available. Parking management projects reviewed did not reveal occupancy rates.

Many rideshare programs involve large employers or focus on specific areas in a metropolitan region. The programs may include vanpools that include several more than two or three occupants in a vehicle. A default value of 2.25 allows the agency to capture this greater activity, while remaining conservative enough to avoid attributing greater benefit than experience noted in the literature provide.

F_{AT}: Percentage of participants who previously drove single-occupancy vehicles (decimal)

Equations:
- **8.2 Improved Connections to Freeway System**
- **8.3 Onsite Support Services**

Value: 0.5 (50 percent)

Transit Cooperative Research Program (TCRP) Report 95, Chapter 3: Park-and-Ride/Pool, provides aggregated prior mode information for park-and-ride lot users based on lot surveys (Transportation Research Board, 2004). The data are aggregated from 300 lot surveys conducted throughout the country. The default value assumes that new users of a park-and-ride lot drawn by improved accessibility or onsite support services will follow a similar prior mode split.

$F_{BW, SOV}$: Percentage of new participants in the bike/pedestrian programs who previously drove single-occupancy vehicles (decimal)

Equations:
- **5.2 Bicycle and Pedestrian Programs**
- **5.3 Employee Financial Incentives**
- **6.1 Negotiated Agreements**
- **6.2 Trip-Reduction Programs**

6.3	**Mandated Ridesharing and Activity Programs**
6.4	**Requirements for Adequate Public Facilities**
10.1	**Commute Management Organizations**
10.2	**Transportation Management Associations**
10.3	**Tax Incentives and Subsidy Programs**
11.2	**Bicycle and Pedestrian Support Facilities and Programs**
15.2	**Parking Regulations and Standards**
17.2	**Public Sector Parking Pricing**
17.3	**Parking Requirements in Zoning Ordinances**
17.4	**On-Street Parking Controls**

Value: **0.009 (0.9 percent)**
(Not available [N/A] for 5.2 and 11.2, where it is a scoping variable)

All equations except 5.2 and 11.2 address the modal split between transit, rideshare, and bicycle/pedestrian upon implementation of the strategy. Equations 5.2 and 11.2 ask for a percentage of new participants for a bicycle/pedestrian program itself. The expected values for those two equations would be higher. (For example, if an employer currently has 50 workers who bike to work and construction of new bicycle support facilities at the employment site encourages 10 new, former single-occupancy vehicle (SOV) drivers to commute by bicycle, then the factor value would be 0.2. The number of current bicycle commuters at an employer or within a region can be more easily derived through surveys as can potential new riders. Therefore, no default value is given for the two equations.)

In a program that incorporates more potential new travel modes, the share of new bicycle/pedestrian travelers is much smaller. The default value for all other equations is derived from a parking pricing study along with bicycle commute to work data. The parking pricing study found that cashing out employer-paid parking at eight firms in Southern California increased bicycle commuting share by 0.2 percent. In the context of the increased carpool/vanpool and transit commute modes at the firms, bicycle commute trips constituted 1.8 percent of the total mode shift away from SOV commutes (Transportation Research Board [TRB], 1987).

Bicycle commute to work percentages for Dallas-Fort Worth and Houston are 0.14 and 0.35, respectively, based on United States Census data. The national average is 0.4 percent (Dill and Carr, 2003). Averaging the two urban areas gives us 0.21 percent, half of the national average. If it is assumed that the attraction to bicycle mode for commuting is only half that of more bicycle-friendly states such as California, Oregon, and Washington, then bicycling and pedestrian programs will provide only half of the mode shift from the Shoup study noted above (0.18 percent). Therefore, only 0.9 percent (~1 out of 100) of SOV drivers will participate in a bicycle/pedestrian program as part of area-wide rideshare incentives, trip-reduction ordinances, or parking management programs.

F_C: **Compliance factor (decimal)**

Equations: **12.2 Controls on Heavy-Duty Vehicles**

Value: **N/A**

Compliance with idling restrictions on heavy-duty vehicles was not found in the literature. Recent research was found regarding idling characteristics: Lutsey et al., 2004; Baker et al., 2004. However, no data regarding actual controls on idling and compliance were found in these sources.

F_{CND}: **Percent compliance of the no-drive days program (decimal)**

Equation: **9.1 No-Drive Days**

Value: **N/A**

Research is not available to ascertain values for this particular factor. No instances of implementation of the strategy were found. Representatives from the California Air Resources Board were interviewed regarding the strategy and were not aware of research or data regarding the factor.

F_{NR}: **Nonrecurring emissions (decimal)**

Equations: **7.3 Enforcement and Management**

Value: **Context Sensitive (0.13-0.30)**
(13 percent-30 percent)

Researchers from the University of California at Berkeley created a methodology for measuring recurrent and nonrecurrent delay on urban freeways and applied the method to two freeways in the Los

Angeles area and one in the San Francisco Bay area (Skabardonis, 2003). They concluded a range of 13 to 30 percent of total delay from nonrecurring congestion on freeways. This range of values may be used to compute the amount of nonrecurring emissions in a region if the amount of increased delay is assumed to be a surrogate for emissions.

F_{PARK}: **Percentage of vehicles that park instead of using the drive-through facility due to imposed control (decimal)**

Equations: **12.1 Controls on Drive-Through Facilities**

Value: **N/A**

Although drive-through restrictions have been attempted, no research was found to ascertain values for this particular factor. Representatives from the California Air Resources Board were interviewed regarding the strategy and were not aware of research or data regarding the factor.

F_{RS}: **Percentage of people attracted to the HOV facility using rideshare (decimal)**

Equations: **4.1 Freeway HOV Facilities**
4.2 Arterial HOV Facilities

Value: **Context Sensitive (0.63-0.87)**
(63 percent-87 percent)

TTI conducted a study of managed lanes in the Houston metropolitan area (Turnbull, 2003). TTI also collected data on HOV use in the Dallas-Fort Worth area. Based on data presented in the study and collected in the Dallas-Fort Worth area, far too great a range for this variable is given to justify a default value. In the Houston area, 63 percent of HOV users are in a form of rideshare, while in Dallas-Fort Worth 87 percent are. This range of values lies in the structure of the respective HOV programs in the two metropolitan areas. Houston's transit system utilizes the HOV lanes more so than in Dallas-Fort Worth, so a lesser percentage of the total number of vehicles using the HOV lanes will be ridesharing. Local agencies implementing an HOV system should take note of the proposed use of the system by the local transit agency to derive this value.

$F_{RS, SOV}$: **Percentage of people attracted to the HOV facility using rideshare that previously used an SOV (decimal)**

Equations:

4.1	**Freeway HOV Facilities**
4.2	**Arterial HOV Facilities**
5.3	**Employee Financial Incentives**
6.1	**Negotiated Agreements**
6.2	**Trip-Reduction Programs**
6.3	**Mandated Ridesharing and Activity Programs**
6.4	**Requirements for Adequate Public Facilities**
10.1	**Commute Management Organizations**
10.2	**Transportation Management Associations**
10.3	**Tax Incentives and Subsidy Programs**
15.2	**Parking Regulations and Standards**
17.2	**Public Sector Parking Pricing**
17.3	**Parking Requirements in Zoning Ordinances**
17.4	**On-Street Parking Controls**

Value: **0.40 (40 percent)**

The default value is based on TxDOT Research Report 484, *An Evaluation of the Impact of Permitting Carpools to Use the Katy Transitway* conducted by TTI. The research study was conducted in 1984-1987.

The TxDOT study provides figures for previous travel mode for both vanpoolers and carpoolers before implementation of HOV lanes in the Houston area. Vanpoolers who previously drove alone before joining their current vanpool ranged from 33 to 36 percent. Carpoolers who previously drove alone showed a higher range from 42 to 52 percent (TTI, 1987).

The variable in the equations does not separate vanpool and carpool participants. In the interest of using conservative estimates for variables, the default value of 0.40 is given. It allows respect for both types of travel but prevents overestimates in deriving strategy benefits.

F_{SOV}: **Percentage of those people continuing to use an SOV for their full commute (decimal)**

Equations: **17.2 Public Sector Parking Pricing**
17.3 Parking Requirements in Zoning Ordinances
17.4 On-Street Parking Controls

Value: **0.90 (with parking policies and no transit) (90 percent)**
0.80 (with parking policies and transit) (80 percent)

The default values are derived from TCRP Report 95, Chapter 13: Parking Pricing. They are based on an average of reductions in SOV travel as a response to implementation of various parking fees and restrictions in the Los Angeles and Sacramento areas. The research indicated that greater reductions in SOV trips are possible if the metropolitan area has a transit system (TRB, 2005). Since Texas nonattainment and EAC areas have transit systems, a default value is provided.

F_T: **Percentage of people attracted to the HOV facility using a transit vehicle (decimal)**

Equations: **4.1 Freeway HOV Facilities**
4.2 Arterial HOV Facilities

Value: **Context Sensitive (0.10-0.35) (10 percent-35 percent)**

The TTI studies of managed lanes in the Houston and Dallas-Fort Worth metropolitan areas indicate a fairly large range for this variable; therefore, it cannot justify a default value. In the Houston area, 35 percent of HOV use is in a form of transit (Turnbull, 2003), while in Dallas-Fort Worth 10 percent is (TTI, 2004). This range of values lies in the structure of the respective HOV programs in the two metropolitan areas. Houston's transit system utilizes the HOV lanes more so than in Dallas-Fort Worth; therefore, the percentage is higher. Local agencies implementing an HOV system should take note of the proposed use of the system by the local transit agency to derive this value.

$F_{T, SOV}$: **Percentage of people attracted to the HOV facility using a transit vehicle that previously used an SOV (decimal)**

Equations:
- **3.2 System/Service Operational Improvements**
- **3.3 Marketing Strategies**
- **4.1 Freeway HOV Facilities**
- **4.2 Arterial HOV Facilities**
- **5.3 Employee Financial Incentives**
- **6.1 Negotiated Agreements**
- **6.2 Trip-Reduction Programs**
- **6.3 Mandated Ridesharing and Activity Programs**
- **6.4 Requirements for Adequate Public Facilities**
- **10.1 Commute Management Organizations**
- **10.2 Transportation Management Associations**
- **10.3 Tax Incentives and Subsidy Programs**
- **15.2 Parking Regulations and Standards**
- **17.2 Public Sector Parking Pricing**
- **17.3 Parking Requirements in Zoning Ordinances**
- **17.4 On-Street Parking Controls**

Value: **0.35 (35 percent)**

The default value is derived from TxDOT Research Report 484, *An Evaluation of the Impact of Permitting Carpools to Use the Katy Transitway* conducted by TTI from 1984 to 1987. Transit rider surveys conducted under the auspices of the research project found that 34 to 38 percent of transitway bus users previously drove alone.

F_{USE}: **Percentage of park-and-ride users that utilize the facilities (decimal)**

Equations: **8.3 Onsite Support Services**

Value: **0.43 (43 percent)**

A study conducted by the Center for Urban Transportation Research on shared-use park-and-ride lots in Florida showed that 43 percent of drivers utilizing the lot also use the available retail facilities in or adjacent to the lots (Wambalaba, 2004). The research was based on a survey of lot users and retail owners and operators at the sites. It is the only full-fledged research project pertaining to this variable found in the literature. The research design and methodology appear valid to justify use as a default value.

F_W: **Percentage of participating vehicles commuting to work (decimal)**

Equations: **9.1 No-Drive Days**

Value: **N/A**

This factor is in an equation for no-drive days programs. No research has been performed to ascertain values for this particular factor. No instances of implementation of the strategy were found. Representatives from the California Air Resources Board were interviewed regarding the strategy and were not aware of research or data regarding the factor.

L: **Length of affected roadway (miles)**

Equations: **7.1 Traffic Signalization**
7.2 Traffic Operations

Value: **0.1 miles**

This variable is in several equations, but an attempt to derive a default value was conducted specifically for intersection improvements in 7.1 and 7.2. Although no consensus was found in the literature as to the amount of affected roadway for an intersection improvement, it is determined best to maintain the 0.1 mile length used by the North Central Texas Council of Governments given in the MOSERS guide. Major metropolitan areas can improve several hundred intersections in their regions as part of efforts to garner emission reduction benefits. In order to avoid potential overlap and to isolate the effects of a signalization, timing, or operational improvement at an individual intersection, a conservative distance of 0.1 miles is maintained.

Exceptions to this distance are possible due to the particular characteristics of an intersection. For example, improvements to high-speed intersections may encompass more distance to compute benefits. There is also a need to better understand the affected length of isolated intersections.

OCC: **Average occupancy of HOV (persons/vehicle)**

Equations: **17.1 Preferential Parking for HOVs**
17.3 Parking Requirements in Zoning Ordinances

Value: **2.2 persons/vehicle**

Based on data from TTI for both Houston and Dallas-Fort Worth HOV managed lanes, the default value is derived (Turnbull, 2003). Houston has an HOV occupancy rate of 2.25; Dallas-Fort Worth has one of 2.2 (TTI, 2004). Both numbers were computed from data on AM peak hour activity on six HOV facilities in each metropolitan area. Opting for a conservative estimate, the lower figure is used as the default value.

PMS: **Percentage mode shift from driving to bike/pedestrian (decimal)**

Equations: **11.1 Bicycle and Pedestrian Lanes or Paths**

Value: **0.01 (1 percent)**

Bicycle commute to work percentages for Dallas-Fort Worth and Houston are 0.14 and 0.35, respectively. The national average is 0.4 percent (Dill and Carr, 2003). Averaging the two urban areas gives us 0.21 percent, half of the national average. In the discussion of the default value for variable $\mathbf{F}_{BW,\,SOV}$, it was estimated that only 0.9 percent (~1 out of 100) of SOV drivers will participate in a bicycle/pedestrian program as part of area-wide rideshare incentives, trip-reduction ordinances, or parking management programs. Equation 11.1 addresses bicycle/pedestrian lanes in general, so it will capture recreational use and other nonwork-based trips. This allows for a slight increase in the default value but remains a conservative estimate.

Proximity to the lane or path increases use, so a denser, mixed-use urban area may generate greater mode shift for a particular bike/pedestrian project.

Є: **Price elasticity for facility charge**

Equations: **4.4 SOV Utilization of HOV Lanes**
19.1 Facility Pricing
19.2 Cordon Pricing

Value: **–0.35**

TCRP Report 95, Chapter 14: Road Value Pricing, provides the current definitive word on congestion road pricing. Compiling many different research studies of price elasticities, both nationally and internationally, ranges of elasticities for road pricing are derived. Including all instances analyzed of creating new and changing pre-existing toll rates, the range of elasticity is from 0.0 to –0.5 (TRB, 2003). The default value is a professional judgment based on analysis of the research found. The zero value was one instance of a toll increase on already tolled drivers and is not evidence that implementing a congestion pricing system would have no effect on driver behavior.

$Є_{fee}$: **Price elasticity for price shift**

Equations: **17.2 Public Sector Parking Pricing**
17.4 On-Street Parking Controls

Value: **–0.3**

According to TCRP Report 95, Chapter 13: Parking Pricing, "research appears to corroborate conventional wisdom that parking demand, as measured strictly by number of cars parking (parking facility entries), is inelastic with respect to price." Surveys, data collection, and modeled parking demand elasticities for changes in parking price generally range from –0.1 to –0.6, with –0.3 being the most frequently cited value. The figure of –0.3 given in the report can be used for both commute and non work-based trips (TRB, 2005).

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PART D ACRONYMS AND GLOSSARY

1.0 ACRONYMS

AADT	Annual average daily traffic
ADT	Average daily traffic
AQ	Air quality
ATR	Automatic Traffic Recorder
AVO	Average vehicle occupancy
CAA	Clean Air Act of 1970
CAAA	1990 Clean Air Act Amendments
CalTrans	California Department of Transportation
CAMPO	Capitol Area Metropolitan Planning Organization
CARB	California Air Resources Board
CFC	Chlorofluorocarbon
CFR	Code of Federal Rules
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CO	Carbon monoxide
COG	(Regional) Councils of Governments
CRF	Capital recovery factor
CTPP	Census Transportation Planning Package
DOT	State department of transportation
EAC	Early Action Compact
EMFAC	Emission factor model used in California, maintained by CARB
EPA	(United States) Environmental Protection Agency
FHWA	Federal Highway Administration
FRN	Federal Register Notice
FTA	Federal Transit Administration
HC	Hydrocarbons
HOT	High-occupancy toll (lanes)
HOV	High-occupancy vehicle
HPMS	Highway Performance Monitoring System
IBR	Incorporation by reference
I/M	Inspection and Maintenance
ITS	Intelligent Transportation System
ID	Identification
ISTEA	1991 Intermodal Surface Transportation Efficiency Act
LRP	Long Range Planning
MOBILE	EPA's computer model for estimating motor vehicle emissions
MOBILE6	Current version of model used in Texas
MOSERS	Mobile Source Emission Reduction Standards
MOVES	Motor Vehicle Emission Simulator
MPO	Metropolitan planning organization
MSAT	Mobile source air toxics
MTP	Metropolitan transportation plan
MVEB	Motor vehicle emissions budget
NAAQS	National Ambient Air Quality Standards

NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Protection Act
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
NPR	Notice of Proposed Rulemaking
O_3	Ozone
O&M	Operations and maintenance
OTAQ	Office of Transportation and Air Quality
PASSER	Traffic simulation model, microscopic tool
Pb	Lead
PM	Particulate matter
PM 10	Particles of matter under 10 microns in diameter
PM 2.5	Particles of matter under 2.5 microns in diameter
PPAQ	Post Processor for Air Quality
ppm	Parts per million by volume
ROG	Total organic gases
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SIP	State implementation plan
SO_2	Sulfur dioxide
SOV	Single-occupancy vehicle
STEAM	FHWA Surface Transportation Efficiency Analysis Model
TAC	Texas Administrative Code
TAZ	Traffic analysis zone
TCEQ	Texas Commission on Environmental Quality
TCM	Transportation control measures
TDM	Transportation demand management
TEA-21	Transportation Equity Act for the 21st Century
TERM	Transportation Emission Reduction Measure
TIP	Transportation improvement program
TMA	Traffic management association
TMO	Traffic management organization
TOG	Reactive organic gases
TRO	Trip-reduction ordinance
TSM	Transportation system management
TTI	Texas Transportation Institute
TWG	Technical Working Group (Conformity Documentation Task Group)
TxDOT	Texas Department of Transportation
UMTA	Urban Mass Transportation Administration
USC	United States Code
USDOT	United States Department of Transportation
VMEP	Voluntary mobile source emissions reduction program
VMT	Vehicle miles traveled
VOC	Volatile organic compounds

2.0 GLOSSARY

Accelerated vehicle retirement, or **vehicle scrappage**, involves an offer to purchase older vehicles, typically vehicles having high emission rates, in order to remove these vehicles from the active vehicle fleet in an area. The program operates by an organization, usually private, paying a fee to owners of older, high-emission vehicles who voluntarily turn in their vehicle. The vehicle is then scrapped, removing it from use. The fee, also called a bounty, for the vehicle is usually a fixed price per scrapped vehicle although different amounts can be offered for different model years. Individual vehicle emissions characteristics might also be used as a criterion for scrappage.

Acid deposition takes two forms, wet and dry. Wet deposition occurs when sulfur dioxide and nitrogen oxides react in the atmosphere with water vapor and return to earth as acidic water commonly referred to as "acid rain." Dry deposition occurs when sulfur dioxide and nitrogen oxides react, but not with water. It settles out of the atmosphere as particles or gases.

Alternative gasoline formulations are mixtures of gasoline with ethanol and methanol, liquefied petroleum gas, and liquefied natural gas that produce fewer emissions during combustion, particularly in nonattainment areas.

Ambient air is the encompassing atmosphere within the surrounding area.

Ambient temperature means within the range of temperatures of the surrounding area.

Area sources are small sources of air toxics producers such as gasoline stations and dry cleaners.

Attainment is the classification assigned to an area that meets the national primary or secondary ambient air quality standard (National Ambient Air Quality Standards) for a criteria pollutant.

Carbon monoxide (CO) is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels.

"Channelizing" roadways and intersections (i.e., clearly marking travel lanes and paths with striping and signage to reduce motorist confusion and uncertainty by channeling traffic into the proper position on the street) improves vehicular flow and capacity.

Clean Air Act (CAA), 1970, is the comprehensive federal law that regulates air emissions from area, stationary, and mobile sources.

Clean Air Act Amendments (CAAA), 1990, built on the main aspects of the CAA but also contain several new provisions. These were the most significant amendments to the CAA. The CAAA are divided into a number of "titles" addressing a broad range of pollution control and abatement issues. The CAAA were intended to meet inadequately addressed problems derived from the CAA such as acid rain, ground-level ozone, stratospheric ozone depletion, and air toxics.

Commute management organizations (CMO) are third-party ridesharing agencies that provide rideshare matching or alternative commute organization or incentive programs. The programs focus largely on employers, given their influence over employee commute and working patterns.

Compressed work weeks are work scheduling programs that condense a standard number of work hours into fewer than five days per week or fewer than 10 days per two-week period, e.g., four days at 10 hours per day or 80 hours over nine days.

Conflicting incentives reduce individual project effectiveness.

Conformity determination is based on the measurements gathered for air quality monitoring in a region; an area receives a designation of *attainment*, *nonattainment*, or *unclassifiable* of the National Ambient Air Quality Standards for a criteria pollutant.

Conformity lapse occurs when a region fails to demonstrate conformity with the state implementation plan. Federal transportation funding is then not made available, and those projects funded in full or part by federal funds come to a halt unless they are included as a transportation control measure in the state implementation plan. Some projects are exempt from a lapse, but they focus mainly on safety-related improvements.

Conformity rule is found in "Criteria and Procedures for Determining Conformity to Transportation Plans Rule," released in 1993 by the United States Environmental Protection Agency, establishing interagency consultation procedures for determining transportation plan and program conformity. It outlines the criteria for conformity determination.

Congestion Management Process (CMP) is a decision support tool that provides an integrated approach to planning by assessing information on all asset inventories, including condition and operational performance. Designed to assist decision makers in choosing cost-effective strategies and actions, CMP is a systematic approach to improving the efficiency of transportation assets.

Congestion Mitigation and Air Quality Improvement Program (CMAQ) was authorized by the 1991 Intermodal Surface Transportation Efficiency Act to provide funding for surface transportation and other related projects that contribute to air quality improvements and congestion mitigation. The main goal of CMAQ is to fund transportation projects that reduce emissions in nonattainment and maintenance areas.

Congestion pricing is a relatively new mobile source emission reduction strategy that is often referred to as "*value pricing*." This strategy, which is still in the pilot program stage of development in the United States, operates in one of two ways. It either provides a disincentive to driving on highly used roadways by imposing fees in congested areas that vary depending on location, time, or vehicle occupancy, or it offers a priced alternative to a congested roadway that enables the motorist to reach his or her destination more quickly. These fees are intended to reduce congestion and improve air quality by encouraging people to change their travel patterns by shifting to off-peak periods, less congested travel routes, high-occupancy vehicles, or a different mode of transport. There are several congestion pricing measures that may be implemented: variable tolls, high-occupancy vehicle lane permits, vehicle miles traveled fees, and parking fees.

Cordon pricing charges vehicles that enter high-activity areas such as central business districts. Areas of high congestion are identified and encircled with one or more cordons (lines).

Criteria pollutants are the six pollutants identified by the United States Environmental Protection Agency (EPA) as having adverse effects on human health and welfare: carbon monoxide (CO), lead (Pb), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2). The EPA, through state or local air quality agencies, monitors these pollutants within the National Ambient Air Quality Standards.

Directly additive projects are unrelated and affect different portions or markets in the transportation system.

Dispersion models model air quality on a regional scale and microscale. These models translate emissions inventories into ambient pollutant concentrations that carry though space and time. They use data on emissions, meteorological conditions, and topographic characteristics to compute the dispersion of pollutants in the atmosphere. The models then predict the concentrations of pollutants at sensitive receptor locations over specified time periods. Dispersion models are much more complex than emissions models because they must account for the transport of pollutants over distance.

Elasticity states how a percent change in an input variable affects a percent change in an output variable. They are developed through direct observation or from results obtained by an approved mode choice model. Elasticity is generally not valid outside the range of values developed for them, nor applicable between different regions.

Emission factors are representative values that attempt to relate the quantity of a pollutant released into the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant. In most cases, these factors are simply averages of all available data of acceptable quality.

Emissions are gases and particles put into the air or emitted by various sources.

Emissions inventory is an estimate of the total emissions in an urban area measured over time. They can be compared with air pollutant levels in an area to determine if increased emissions decrease the air quality. Emissions inventories have many purposes including ambient dispersion modeling and analysis, control strategy development, and screening sources for compliance investigations.

Emissions models are computerized simulation models that convert information on driving conditions, vehicle and driver behavior, and environmental factors into estimates of motor vehicle emissions. They are based on the relationship between vehicle activities and vehicle emissions.

Empirical comparison is one of the simplest methods for estimating the emission impacts of mobile source emission reduction strategies. It is also one of the least precise and accurate methods. Experiences from other similar areas are used to estimate the impacts in one's own area. This analysis method was suggested in *A Manual of Transportation-Air Quality Modeling for Metropolitan Planning Organizations*.

Enabling legislation can eliminate or minimize barriers to widespread implementation of employer-based trip-reduction programs. A legal requirement mandating employer or developer involvement is a powerful determinant of program effectiveness. Mandatory participation is crucial to assuring widespread participation by enough employers to have an area-wide impact.

Facility pricing is levied on one or several roadways that link residential areas to downtown commercial districts.

Flextime allows employees to set arrival and/or departure times with the approval of the employer in order to avoid traveling at peak traffic times, but all employees are present for some core period of the workday.

Fuel characteristics are the attributes of the fuel types used in the vehicle fleet in a region.

Hard vehicle accelerations can increase emission rates for certain pollutants by 10 times normal running emission rates.

Hot soak emissions occur when vehicles are parked at work and continue to produce evaporative emissions even after the engines are turned off.

Hydrocarbons (HC) are a precursor chemical for the creation of ozone. Hydrocarbons are a component of mobile source emissions (cars, trucks, and buses).

Intelligent transportation systems (ITS) apply information processing, communications technology, advanced control strategies, and electronics to improve the safety and efficiency of a transportation system. In the context of mobile source emission reduction strategies, ITS emphasizes advanced traffic control, incident management, and corridor management.

Interagency consultation is required for conformity determination. It requires regular contact and effective communication between practitioners with applicable agencies such as the United States Environmental Protection Agency, Texas Department of Transportation, metropolitan planning organizations, Texas Commission on Environmental Quality, and United States Department of Transportation during the state implementation plan revision and conformity determination process.

Intermodal connections consider system connectivity and the ease by which a user can travel from origin to destination at an acceptable level of performance. Transfer points, terminals, and stations are of importance to system performance.

Intermodal Surface Transportation Efficiency Act (ISTEA) was the most significant federal transportation legislation since the Interstate Highway System in the 1950s. It was the first major attempt to approach transportation planning and funding from a comprehensive, decentralized, multimodal perspective.

Maintenance area is a region that has marginal attainment for a criteria pollutant.

Metropolitan planning organizations (MPOs) develop transportation plans and programs for the metropolitan area.

MOBILE is a computerized emissions model first developed by the United States Environmental Protection Agency in the late 1970s. Every few years, the model has had significant updates and new releases as new data become available, new regulations are promulgated, new emissions standards are established, and the vehicle emissions process is better understood. Each new version of the model has become more complex in approach and has provided the user with additional options in order to customize emissions factor estimates to local conditions.

MOBILE6 is the version currently used in Texas and was released in 2002.

Mobile source is a moving object that releases pollution; mobile sources include cars, trucks, buses, planes, trains, motorcycles, and gasoline-powered lawn mowers. Mobile sources are divided into road and nonroad vehicles.

Mobile source air toxics (MSATs) are compounds emitted from highway vehicles and nonroad equipment that are known or suspected to cause cancer or other serious health and environmental effects.

Mode choice models, an integral part of the regional travel demand model, can be used independently of the travel demand model to evaluate some emission reduction strategies. If the regional travel demand model has met approval from reviewing and oversight agencies, few problems during conformity determinations or state implementation plan review would be expected.

Motor Vehicle Emission Simulator (MOVES) is a United States Environmental Protection Agency effort to develop a new set of modeling tools for the estimation of emissions produced by on-road and nonroad mobile sources. Also known as the "New Generation Model," MOVES will encompass all pollutants (including hydrocarbons [HC], carbon monoxide [CO], oxides of nitrogen [NO_x], particulate matter [PM], air toxics, and greenhouse gases) and all mobile sources at the levels of resolution needed for the diverse applications of the system.

Motor vehicle emissions budget is the mechanism the United States Environmental Protection Agency has identified for carrying out the demonstration of consistency. Transportation conformity determinations are an affirmation that this test has been met.

Multimodal refers to all transportation modes in general. It is often used as a synonym for intermodalism.

National Ambient Air Quality Standards (NAAQS) was authorized by the Clean Air Act of 1970. The United States Environmental Protection Agency was authorized to establish, maintain, and enforce national health-based air quality standards to protect against common pollutants including ozone (smog), carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, and particulate soot.

No-drive days requests or requires identified individuals to not operate their vehicles on designated days, reducing the number of vehicles on roads. A particular letter or number on their license plate usually identifies the individuals. The program can be mandatory or voluntary. In the United States, no-drive days are all currently voluntary.

Nonattainment areas do not meet (or contribute to ambient air quality in a nearby area that does not meet) the national primary or secondary ambient air quality standard for a criteria pollutant

Nonroad (or off-road) vehicles include trains, planes, and lawn mowers.

Nonstoichiometric condition is the condition under which vehicles emit more pollution because the engines' air/fuel ratio runs either too lean or too rich. Vehicles emit more pollutants (higher emission factors in grams per mile) at extremely low or high speeds or under hard acceleration.

O_3 season is a certain portion of the year, usually during hot, dry, stagnant summertime conditions, when peak ozone concentrations typically occur. This strong seasonality of O_3 levels makes it possible for areas to limit their O_3 monitoring to that season.

Off-cycle emissions include aggressive driving and air conditioning operations in vehicles.

Off-model transportation/air quality analysis techniques vary from TERM to TERM. Some techniques are as a simple as "back of the envelope" calculations, whereas others are in the form of computer interfaces using a set of generalized equations.

On-model transportation/air quality analysis refers to those projects whose travel effects can be quantified using travel demand model networks and other methods. For those projects that cannot be adequately represented within a travel demand model, off-model techniques are used.

Oxides of nitrogen (NO_x) are precursor chemicals for the creation of ozone. NO_x are a component of mobile source emissions (cars, trucks, and buses).

Ozone (O_3) is formed by the reaction of NO_x and volatile organic compounds (VOC) in the presence of sunlight. O_3 occurs naturally in the upper atmosphere providing protection from ultraviolet radiation. O_3 at ground level, however, is a noxious pollutant and a major component of smog.

Ozone regional transport means that, in addition to O_3 sources in your particular region, O_3 might also travel from other areas upwind.

Paratransit is comparable transportation required by the American Disabilities Act for individuals with disabilities who are unable to use fixed route transportation systems.

Particulate matter (PM) includes dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust. Particles formed in the atmosphere by condensation or the transformation of emitted gases such as SO_2 and volatile organic compounds are also considered particulate matter

PM 10 are coarse particles under 10 microns in diameter that consist generally of windblown dust and are released through materials handling, agriculture, and crushing and grinding operations.

PM 2.5 are particles under 2.5 microns in diameter that are created from fuel combustion in motor vehicles and other sources.

Precursor pollutants, such as hydrocarbons (HC) and oxides of nitrogen (NO_x), chemically react in the atmosphere to form ozone. Many HC and NO_x are emitted from motor vehicles.

Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly.

Regional network pricing levies fees on drivers traveling on a network of similar roads (e.g., highways). Unlike facility pricing, network pricing applies fees on multiple roads going in many directions.

Ridership is the number of passenger trips on a transit system in a given time period.

Road (or on-road) vehicles include cars, trucks, and buses.

Running emissions are those emitted by a mobile source when its engine is operating at a stabilized temperature (hot stabilized).

Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), signed on August 10, 2005, authorizes the federal surface transportation programs for highways, highway safety, and transit for the five-year period 2005-2009.

Secondary standards set limits to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

Sequentially additive projects affect generally the same portion or market in the transportation system but neither coordinate with nor support measures. The effect of these project pairs is less than directly additive.

Sketch-planning tools or off-network analyses entail a more formal process than use of empirical comparisons. They typically estimate travel and emission impacts from a variety of transportation demand management project types. They are best at estimating gross impacts of projects. In contrast to previous tools, these techniques are not validated or calibrated and are less rigorous in nature. Few regions evaluate the accuracy of these techniques through comparisons of before and after studies. These tools typically use regional travel data generated through the travel demand modeling process or other means in conjunction with the characteristics of the emission reduction strategy to estimate regional emission impacts. Examples are: TCM Tools, TCM Analyst, DRCOG CM/AQ Evaluation Model, Texas Transportation Institute CM/AQ Evaluation Model, Federal Highway Administration (FHWA) Southern Resource Center Off-Model Analysis Techniques, and FHWA Sketch Planning Analysis Spreadsheet Model (SPASM).

Stakeholders are those individuals and organizations that are affected by transportation. Employers, producers, government, and social/cultural groups are examples, as are those groups that may be negatively affected by the system, i.e., environmental groups and neighborhood associations.

Standardized analysis methods may be adopted by a state to evaluate mobile source emission reduction strategies because no single analysis tool can evaluate all strategies.

Start emissions are emitted by mobile sources at engine ignition and warm-up of the engine.

State implementation plan (SIP) is the legal and federally enforceable plan for each state that identifies the air pollution control strategies to attain and/or maintain the primary and secondary National Ambient Air Quality Standards (NAAQS) set forth in Section 109 of the Clean Air Act of 1970 and Code of Federal Rules (40 CFR 50.4 through 50.12) in each United States Environmental Protection Agency (EPA)–designated nonattainment or maintenance area. A SIP must be adopted by the state and approved by the EPA for each pollutant for which the state violates the NAAQS. The SIP is developed through a collaborative public process, formally adopted by the state, and then submitted by the governor's designee to the EPA.

Stationary sources are places or objects that release pollutants and do not move around. Stationary sources include power plants, incinerators, houses, etc.

Subsidy programs can help initiate a program by providing additional funding to enlist employer involvement and improve the preliminary risk to employers attempting a new program. The goal of the subsidies is for employers to see the benefits of the program, and then continue the subsidies on their own to satisfy employee desire and/or to comply with regional or local mandates. Some subsidy programs target commuters directly when employer involvement is unlikely or impractical. For example, vanpool subsidies tied to corridor reconstruction projects can aid in the formation of vanpools among commuters using the affected facilities regardless of their particular job location.

Synergistic projects affect generally the same portion or market in the transportation system and act in supporting roles. The effect of these project pairs is greater than directly additive.

Tax incentive can allow employers and developers to provide facilities and equipment conducive to ridesharing. It may be in the form of investment tax credits or accelerated depreciation of facilities.

Tax incentive and subsidy programs (state and local) provide incentives and disincentives for employers and employees to consider and utilize alternative modes of transportation to commute instead of single-occupancy vehicles.

Telecommuting is work done on a regular basis from daily to once a week at an alternative work site such as the employee's home or a telecommuting center. A center is a facility that provides the employer, employee, and customers with all the requirements to perform work and services without traveling to the employee's main worksite and may be operated by a single or consortium of businesses.

Traffic simulation models can be classified as either microscopic or macroscopic in nature. Traffic simulation models are another available resource and are suited to analyze impacts of mobile source emission reduction strategies. Because the model environment is physical in nature (lanes, intersections, traffic volumes, turning movements, etc.), these tools are not suited for evaluating projects influencing travel behavior. These tools explicitly represent most traffic control devices (signals, stop signs, yield signs, etc.) without the use of surrogate measures to account for these controls. When properly calibrated, microsimulation tools can provide better estimates of traffic flow than travel demand models. In addition, the travel outputs generated by these tools are comparable to actual field measurements. Microscopic tools include PASSER, TRANSYT, FREQ, and SYNCHRO; macroscopic tools include CORFLO and NETSIM.

Transitional ozone nonattainment areas, or "near-nonattainment areas," have been created in the state of Texas. These are areas that had met the previous one-hour O_3 standard but will likely not meet the new eight-hour standard.

Transportation conformity is a Clean Air Act requirement intended to ensure that new transportation investments do not jeopardize air quality in nonattainment and maintenance areas. According to the Clean Air Act, no transportation activity can be funded or supported by the federal government unless it conforms to the purpose of a state's air quality plan.

Transportation Conformity Guide, from the Federal Highway Administration, provides sections regarding timely implementation of mobile source emission reduction strategies, both within state implementation plans and those not adopted in the implementation plan.

Transportation control measures (TCMs) encompass elements of both transportation system management (TSM) and transportation demand management (TDM). Transportation system management generally refers to the use of low capital-intensive transportation improvements to increase the efficiency of transportation facilities and services. These can include carpool and vanpool programs, parking management, traffic flow improvements, high-occupancy vehicle lanes, and park-and-ride lots. Transportation demand management generally refers to policies, programs, and actions that are directed toward decreasing the use of single-occupancy vehicles. TDM also can include activities to encourage shifting or spreading peak travel periods. In practice, there is considerable overlap among these concepts, and TCM, TSM, and TDM are often used interchangeably.

Transportation Equity Act for the 21st Century (TEA-21) reiterated and reauthorized the policy-making philosophy within the Intermodal Surface Transportation Efficiency Act in 1998.

Transportation infrastructure refers to the facilities, networks, and services necessary in the system to provide mobility. This component has received the most attention in the transportation planning process.

Transportation management associations (TMAs) provide a structure for developers, property managers, employers, and public officials to cooperatively promote programs that mitigate traffic congestion, assist commuters, and encourage particular modes of travel in specific areas. TMAs can also provide government and private industry with a forum for discussion of current and future roadway and transit needs in an area.

Transportation management centers (TMCs) contain closed-circuit monitors for observing traffic conditions. TMCs serve as information and communication conduits between transportation personnel and law enforcement officials.

Transportation system management generally refers to the use of low capital-intensive transportation improvements to increase the efficiency of transportation facilities and services. These can include carpool and vanpool programs, parking management, traffic flow improvements, high-occupancy vehicle lanes, and park-and-ride lots.

Travel demand management (TDM) is a group of strategies that seek to modify the travel demand placed on the transportation system. Trip behavior is modified through trip elimination or shortening, and shifting trip times outside of peak travel times. Examples of these projects are ridesharing, telecommuting, and flexible work hours.

Travel demand model for a region is composed of many smaller traffic analysis zones and a transportation structure or network connecting each of the zones. Travel demand models are good tools for estimating the impacts of large-scale projects that can be translated to the model's transportation network, but are weak for estimating small-scale projects at a local level

Travel demand model post-processors are analysis tools that take the information provided by the travel demand models in the form of trip tables and process the results outside of the travel demand model once the network scenario is modeled. They typically have interfaces to an emission factor model or have the emission factors coded into the program. Some tools also reconcile vehicle miles traveled between the regional travel demand models and Highway Performance Monitoring System. Some examples are: Federal Highway Administration (FHWA) TDM Evaluation Model, FHWA Surface Transportation Efficiency Analysis Model (STEAM), PAQONE, and Post Processor for Air Quality (PPAQ).

Unclassifiable is an area that cannot be classified on the basis of available information as meeting or not meeting the national primary or secondary ambient air quality standard for the criteria pollutant.

Vehicle purchases and repowering can reduce vehicle emission rates through the purchase of motor vehicles certified to pollute less than typical new vehicles. As an alternative to vehicle purchase, complete engine replacements may be done on older vehicles to reduce their emissions.