Texas A&M Transportation Institute

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DRAFT FOR REVIEW

White Paper on the State-of-Practice in the Application and Quantification of Benefits of TCMs in the US

Prepared by the Texas A&M Transportation Institute

Prepared for the Texas Department of Transportation

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Introduction

Transportation activity is a major source of air pollutant emissions in nonattainment and maintenance areas of Texas. Nationally, it is estimated that on-road transportation sources are responsible for 35 percent of NOx emissions[1]. Despite the projected decreasing trends of the emissions from the transportation sector as the result of improved emission control technologies and more stringent emission standard for vehicles, transportation will continue to be a major contributor to regional air pollution for the foreseeable future.

State and local transportation agencies have a long history of implementing strategies to reduce air pollutant emissions in nonattainment and maintenance areas. There are many possible strategies that can be used to reduce mobile source. The Federal Transportation Conformity Rule defines Transportation Control Measures (TCMs) as follows:

- Emissions control measures listed in Clean Air Act (CAA) Section 108(f)(1)(a), and
- Any measure that reduces emissions by reducing vehicle use or improving traffic flow (i.e., reducing congestion).

Under the conformity rule, transportation strategies that reduce emissions through improving vehicle technologies, fuels, or maintenance practices are not considered TCMs. Only approved TCMs can be included on State Implementation Plans (SIPs).

Since 1991, the Congestion Mitigation and Air Quality Improvement (CMAQ) program has provided billions of dollars of funding to transportation agencies for projects that reduce emissions and relieve congestion. CMAQ funds can be used for transportation strategies that can be documented to have emission and congestion reduction benefits in nonattainment and maintenance areas, whether or not they are in approved SIPs. Transportation strategies can be funded or implemented directly by transportation agencies (CMAQ-eligible projects). There are other (non-transportation) strategies that are typically implemented by state air agencies or require state and local government actions. Examples of such strategies are inspection and maintenance programs (I/M), land use policies, and fuel tax rate increases.

There are currently few resources that document the actual quantified effects of CMAQ and non-CMAQ funded projects on vehicular emissions. Furthermore, there is a significant lack of documentation of the methodologies and data used to estimate these effects.

Because many regions are facing multiple air quality challenges, it is important for transportation agencies to have a good understanding of their options with regards to the effectiveness of transportation measures that can help the region to achieve its air quality goals. The purpose of this report is to help transportation practitioners consider appropriate transportation strategies for reducing transportation-related emissions of concern. This white paper report provides a compendium of transportation-related control strategies that are used by transportation agencies and are either included in SIPs or funded through the CMAQ program. For each type of strategy, a summary of the expected impact and other characteristics is provided. Finally, the document provides an overview of the methodologies used in practice to estimate the impacts of these strategies.

Background

The CAA of 1970 was the first inclusive federal law that regulated emissions from all sources including mobile sources. The CAA required the EPA to set national air quality standards for common pollutants. EPA also set national standards for recent source of pollution such as passenger cars, trucks and electric power plants. States were required to set up SIPs to meet the standards by a specific date. The goal was to achieve National Ambient Air Quality Standards (NAAQS) in all states by 1975. However, many areas failed to achieve this goal; as a result, new deadlines were set in 1977 amendments to the CAA (8) (1).

Although substantial reduction in tailpipe emissions was achieved through catalytic convertors and improvements in fuel efficiency during the 1970s and 1980s, the total emission reduction was not substantial as vehicle ownership and VMT was increased during that time. As a result, TCMs got more attention in the CAA Amendments of 1990 (2).

TCMs are listed in 16 categories in section 108 of the CAA (as listed below); however, TCMs are not limited to these 16 categories. For example, market based strategies (such as road pricing and parking pricing) and public education strategies are not in the list. TCMs might be included in SIPs if they meet all EPA criteria and are: (1)-quantifiable, (2)-surplus (not be included in other SIP measures); (3) enforceable; (4) permanent; and (5) adequately supported (adequate funds are available for implementation). The 16 categories of TCMs listed in the CAA are:

(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;

(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 non-motorized 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 subchapter II of this chapter, which are caused by extreme cold start conditions;

(xiii) Employer-sponsored programs to permit flexible work schedules;

(xiv) 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;

(xv) Programs for new construction and major reconstructions of paths, tracks or areas solely for the use by pedestrian or other non-motorized means of transportation when economically feasible and in the public interest; 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.

The term "TCM" covers elements of both "Transportation System Management" (TSM) and "Transportation Demand Management" (TDM). TSM strategies are usually those low cost transportation improvements that make transportation operate more efficiently including but not limited to traffic flow improvements, incident response plans, traffic enforcements, real time driver and transit information. TDM generally refers to strategies and policies that reduce travel demands including but not limited to carpool and vanpool programs, high occupancy vehicle (HOV) lanes, parking pricing, park-and-rides lots, flexible work hours, telecommuting. (2).

Realizing the link between transportation and air quality planning, the Intermodal Surface Transportation Efficiency Act-the ISTEA of 1991 was passed by Congress. This expanded the focus on air quality aspect of transportation. As a result, new programs such as theCMAQ program were authorized under this act. The goal of the CMAQ program is to support surface transportation projects and any action that lead to air pollution and congestion reduction (3).

The CMAQ program is aimed to fund those transportation actions and programs that will help to maintain or attain the NAAQS for ozone, carbon monoxide (CO), and particulate matter (PM). The CMAQ program provides funding for a broad range of tools and actions to meet these goals. CMAQ funds are allocated annually to each state according to the severity of its air quality problem. All TCMs included in Section 108 of the CAA except the programs that encourage removal of pre-1980 light duty vehicles are eligible for CMAQ funding (4).

It is important for practitioners to have an idea on possible impacts of each strategy on each pollutant as the impacts might be complex and hard to predict. For example, strategies that increase transit ridership might require additional transit services and not reduce total emissions from motor vehicle travel. In a report for FHWA, ICF International tried to investigate the effects of various strategies on emissions of each pollutant in terms of direction (positive or negative). Control strategies were categorized as TDM, TSM and vehicle and fuel strategies. Summary tables were developed to show the general emissions impacts of strategies in each category. Overall, the tables show that TDM strategies are more likely to reduce emissions of all types of pollutants than TSM strategies. Besides, even some vehicle and fuel strategies such as "Clean Diesel Fuels" might increase the emission of pollutants based on the type of the used fuel (5).

State of the Practice

This state of practice report provides an overview of the TCMs that have been used frequently by transportation agencies. The focus therefore is a sample of TCMs that are included in SIPs and transportation strategies that received funding from CMAQ programs in a sample of metropolitan planning areas including Bay Area and Southern California in California, New York metropolitan area, Chicago metropolitan area , Houston-Galveston-Brazoria, Dallas-Fort Worth, and El Paso in Texas.

San Francisco Bay Area

The nine counties of the San Francisco Bay area are Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano and Sonoma. These nine counties encompass 7,000 square miles and 7.15 million populations (6). The Bay area's major cities and metropolitan areas are San Francisco, Oakland and San Jose. For the Bay area, critical pollutants are ground-level ozone, carbon monoxide, and $PM_{2.5}$ (7). The Bay Area is currently in nonattainment for 8 hour ozone and $PM_{2.5}$ (8). Critical precursor pollutants for ozone are volatile organic compounds (VOC) and oxides of nitrogen (NOx), and for $PM_{2.5}$ is NOx (6). For the Bay Area, the Metropolitan Transportation Commission (MTC) prepares a conformity analysis when the Regional Transportation Plans (RTP) or Transportation Improvement Program (TIP) is updated. The purpose of conformity analysis is to make sure that total emissions from RTP or TIP is within the SIP's emission budget and that TCMs are implemented as scheduled (7).

TCMs included in the SIP

TCMs have been listed in Bay Area Air Quality Plan since 1982. These measures became part of the SIP when EPA approved the 1994 Ozone Maintenance Plan. The last TCMs that were included in Ozone Attainment Plan were added in 2001 and have been fully implemented (see Table 1) (7). All numbers in the following tables are the total impacts for all the projects in a category.

Table 1. Total Estimated Impact of TCMs included in Bay Area SIP.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day)				
				VOC	CO	NOx	PM10	PM2.5
Pedestrian/ Bicycle	Pedestrian/Bicycle	N/A	20	40	N/A	30	N/A	N/A
Transit	Purchasing New Buses	N/A*	40	200	N/A	200	N/A	N/A
	Transit Access to Airport	1	N/A	90	N/A	130	N/A	N/A
Livable Communities	Linking Transportation Projects with Community Plan	N/A	31.2	80	N/A	120	N/A	N/A
Traffic Flow Improvement	Freeway Service Patrol	N/A**	N/A	100	N/A	250	N/A	N/A

Source: (Metropolitan Transportation Commission, 2010) (9)
**94 buses were purchased*
*** 55 lane miles of roving truck coverage was added*

Transportation Strategies Funded Through CMAQ Program

Table 2 shows those Bay Area transportation strategies that were funded from the CMAQ program from 2005 to 2010. The benefits and costs of the projects are also included in the table.

Table 2. Transportation Strategies Funded Through CMAQ Program in Bay Area.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day)				
				VOC	CO	NOx	PM10	PM2.5
Transit	Bus and Transit Improvement	4	216.4	205.15	551.87	270.3	4.75	3.35
	Developing a New Transit System	1	976.2	5.79	37.17	4.96	0.32	0.23
	Station Improvement	5	65.5	137.4	82.97	212.41	0.72	0.5
	Fare Collection System	6	177.3	246.55	178.7	244.63	1.55	0.95
	Train Electrification	1	629.3	5.79	37.17	4.96	0.32	0.23
	Developing TODs	1	7.0	10.95	81.53	12.62	0.7	0.49
Shared Rides	Rideshare Programs	5	3.5	115.36	35.55	121.66	0.4	0.22
Traffic Flow Improvements	ITS	21	247.6	329.41	3043.11	998.21	26.18	13.33
	Signal timing and Coordination	7	14.8	293.41	1306.38	264.25	11.25	7.88
	Adding Lane (HOV or Mixed flow)	3	481.7	69.97	530.61	83.48	4.57	3.22
	Interchange Reconstruction	1	133.8	53.01	372.57	54.73	3.32	N/A
	Improving Connectors	1	84.8	72.39	559.28	89.33	6.31	3.39
	Ramp Metering	2	244.2	80.08	1674.94	408.7	14.41	10.17
	Streetscape Traffic Improvement	2	5.3	27.16	173.54	23.03	1.49	1.06
Pedestrian/ Bicycle	Pedestrian/Bicycle	128	299.3	1501.07	6894.9	1093.4	73.66	38.76
Demand Management	Adding HOV Lane	4	303.0	59.1	294.92	70.35	2.54	1.57
	Marketing Strategies	8	36.1	165.85	108.25	173.24	25.18	0.65
	Public Education	3	15.0	79.3	245.62	77.42	13.76	1.49
	Parking Pricing	1	46.0	32.07	205.93	27.48	1.77	1.25
	Transit Information System	1	2.0	9.9	N/A	10.22	N/A	N/A
	Comprehensive Regional Plan	1	13.8	13.94	193.06	41.88	1.66	N/A
I/M	Bus Retrofit	1	0.6	26.8	N/A	133.97	15.42	N/A
	Replacing Old Vehicles	1	57.3	9.32	69.38	10.74	0.6	0.42
	Catalytic Devices	11	5.7	562.42	N/A	955.74	N/A	N/A
Other	Construct ERC Facility	1	8.4	2.12	13.59	1.81	0.12	0.08
	Alternative Fuel Vehicle Incentives	1	0.2	12.8	N/A	10.22	N/A	N/A
	Electric Vehicle Charging Station	1	0.1	6.35	N/A	5.45	N/A	N/A

Source: (CMAQ Public Access System, 2014) (10)

Southern California

The Southern California Association of Government (SCAG) is the largest metropolitan area in the United States which encompasses 38,000 square miles, 18 million population and six counties (Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura). The region's congestion is the worst one in the nation whit an estimated wasted time of three million hours each year. SCAG region has also the most polluted air in the nation although the region is a frontrunner in reducing emissions (11). The region is currently in nonattainment for 8-hour ozone, $PM_{2.5}$ and PM_{10} (attainment status is not the same for all counties and air basins) (8). As a Metropolitan Planning Organization (MPO), SCAG develops a Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS) every four years. SCAG is required to ensure that regional transportation actions are in line with Air Quality Management Plans (AQMPs) and SIPs.

TCMs included in the SIP

In the SCAG region, only two SIPs contain TCM strategies. One is the 2007 Ozone SIP developed in South Coast Air Basin (SCAB); and the other one is the 1994 Ozone SIP developed in Ventura County of the South Central Coast Air Basin (SCCAB). However, TCM projects in Ventura County were not claimed to reduce emissions. The SCAB's 2007 Ozone SIP contains three TCMs categories as follows:

- High Occupancy Vehicle (HOV) Measures,
- Transit and System Management Measures, and
- Information-based Transportation Strategies (12).

Transportation Strategies Funded Through CMAQ Program

Table 3 shows those transportation strategies that were funded from the CMAQ program from 2005 to 2010 in Southern California.

Table 3. Transportation Strategies Funded Through CMAQ Program in Southern California.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day)				
				VOC	CO	NOx	PM10	PM2.5
Transit	Purchasing New Buses & Coaches	2	5.3	2.08	25.27	1.92	1.37	1.26
	Bus Stop Improvement	5	1.4	12.92	1.26	14.14	1.19	N/A
	Bus and Transit Improvement	11	63.3	170.67	664.17	111.88	59.8	0.07
	Developing a New Transit System	1	12.8	15.84	189.75	18.13	10.02	9.22
	Adding Parking to Transit Station	3	20.1	58.88	678.82	65	37.49	8.11
Shared Ride	HOV Lane Improvement	1	161.1	25.12	95.74	34.13	4.18	3.83
	Rideshare Programs	14	29.3	258.95	3799.9	314.43	127.6	45.3
	Parking Monitoring and Management	2	0.79	12.18	363.88	34.39	4.68	4.28
	Adding Parking to Transit Station	1	6.61	1.87	21.84	2.2	1.79	1.65
	Park and Ride Lot	5	1.9	3.52	45.73	4.55	2.75	0.91
Pedestrian/ Bicycle	Pedestrian/Bicycle	35	24.6	28.69	58.74	24.00	84.87	0.95
Demand Management	Transit Information System	1	0.34	3.24	37.05	3.31	1.94	0.48
	WIFI Installation	1	1.21	4.06	47.81	4.43	2.72	0.67
	Marketing Strategies	1	0.4	1.34	7.68	1.26	0.29	N/A
	Parking Construction	1	40.6	26.0	310	32.4	14.4	N/A
	Adding HOV Lane	9	2149	219.23	1742.4	18.76	44.1	27.68
Traffic Flow Improvements	ITS	3	15.0	144.22	493.57	282.62	28.58	13.77
	Constructing Transportation Management Center	1	11.24	55.28	396.15	5.26	2.69	2.48
	Signal Coordination	22	22.9	744.33	5849.8	770.8	114.2	104.9
	Grade Separation	3	40.0	18.39	166.72	45.54	N/A	N/A
	Interchange Reconstruction/Modification	6	98.3	67.24	510.7	133.3	14.19	10.41
	Adding Lane	4	417.0	248.74	1751.8	92.45	40.58	5.52
	Mixed Flow and HOV Lane Connector	4	558.1	170.69	1798.6	-57.88	30.24	19.32
	Intersection Signalization	1	0.16	4.6	42.7	9.8	7.1	6.53
	Intersection Improvement	2	2.4	0.42	2.34	1.64	0.1	0.01
	channelization	1	0.04	0.05	0.24	0.41	0.01	0.01
	Transit Priority System	1	0.4	0.18	3.68	0.33	0.24	0.22
Other	Road Paving	11	2.6	3.03	126.8	0.36	438.6	N/A
	Alternative Fuel Station	3	2.3	0.05	1.25	66.47	0.04	N/A
	Alternative Fuel Non-Transit Vehicle	13	1.8	94.56	2388.9	988.05	2609	N/A
	Alternative Fuel Transit Vehicle	16	170.5	0.96	15.29	221.15	0.3	N/A

Source: (CMAQ Public Access System, 2014) (10)

New York Metropolitan Area

The New York Metropolitan Area (NYMA) consists of New York State counties of Suffolk, Nassau, Richmond, New York, Kings, Queens, Bronx, Westchester and parts of Connecticut and New Jersey. In 2005, the NYMA was designated as a moderate nonattainment area for 8-hour ozone. As with other moderate nonattainment areas, attainment must be demonstrated within six years. However, New York Department of Environmental Conservation proposed to revise NYMA's SIP to demonstrate attainment by 2013 (13).

On-Road Mobile Source Measures included in the SIP

In the revised SIP the following measures are considered to reduce emissions from mobile sources (these measures are not essentially TCMs) (13):

- Low Emission Vehicles

  Description: New York adopted new motor vehicle emissions standards which are same as California's.

- NYMA I/M Programs (NYVIP and NYTEST)

  Description: In the downstate NYMA, annual enhanced I/M emission test are required. Special tests are also required for vehicles older than 25 years.

- Federal Diesel Fuel (with State Backstop)

  Description: New York Sate's regulations for motor vehicle diesel fuel program are the same as EPA regulations. These standards can only be achieved by using highly efficient catalyst exhaust emission control device or advanced technologies.

Transportation Strategies Funded Through CMAQ Program

Table 4 shows those transportation projects that received funding from the CMAQ program from 2005 to 2010 in NYMA.

Table 4. Transportation Strategies Funded Through CMAQ Program in NYMA.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day)				
				VOC	CO	NOx	PM10	PM2.5
Transit	Purchasing New Buses	1	0.36	3.63	110.16	3.82	0.05	0.07
	Replacing Old Buses	1	4.27	0.00	0.55	3.10	0.03	0.03
	Bus and Transit Improvement	1	0.12	1.83	35.25	0.99	0.40	0.01
	Developing New Transit Systems	2	23.7	528.9	1152.18	90.54	28.45	2.51
	Station Improvement	1	28.2	15.52	66.45	16.63	8.10	0.12
	Rail Freight Improvement	1	15.25	20.77	137.20	269.25	14.97	8.00
	Adding Parking to Transit Station	1	0.4	1.15	N/A	0.87	N/A	0.02
Shared Ride	Rideshare Programs	27	13.5	2233	1329.70	2257.5	2.63	21.15
	Park and Ride Lot	6	3.15	95.83	381.1	21.7	0.56	0.31
Traffic Flow Improvement	ITS Programs	15	42.2	760.9	2536.3	613.5	N/A	N/A
	Intersection Improvement	2	2.4	1.34	7.24	0.92	N/A	N/A
	Intersection Signalization	1	0.9	11.42	N/A	40.25	N/A	N/A
	Signal Timing and Coordination	4	1.6	359.6	2536.4	319.93	N/A	N/A
	Truck Rout Optimization	1	0.16	0.77	3.90	10.69	0.42	0.35
	Off Street Parking Regulation	1	0.04	3.62	55.68	3.03	0.06	1.34
	Adding Lane (HOV or Mixed Flow)	1	8.36	18.72	107.99	5.12	0.03	0.02
	Corridor Congestion Reduction Program	1	2.0	3.07	25.83	2.77	N/A	N/A
	Highway Emergency Local Patrol	2	3.9	6.0	30.02	4.34	N/A	N/A
Pedestrian/ Bicycle	Pedestrian/ Bicycle	25	49.1	108.8	918.26	90.8	17.24	0.90
Demand Management	Public Education	29	15.5	505.05	176.49	768.5	0.47	17.8
	Employee Commute Options program	9	12.7	248.8	4622.4	206.2	9.89	5.82
Other	Purchasing CNG Heavy Duty Diesel	1	3.0	0.25	1.70	0.55	0.00	0.00
	Alternative Fuel Non-Transit Vehicle	8	26.0	326.8	5446.4	355.24	14.28	4.41
	Vehicle Retrofit	1	1.4	0.07	-0.44	0.82	0.00	0.00
	Alternative Fuel Transit Vehicle	4	11.8	5.7	127.08	29.56	-2.01	-0.77
	Emission Laboratory Construction	1	2.6	467.3	7207.77	477.2	N/A	1.52
	Idle Reduction/Fuel Efficiency Program	1	0.02	28.36	500.41	23.89	1.24	0.57

Source: (CMAQ Public Access System, 2014) (10)

Chicago Metropolitan Area

Chicago Metropolitan Area (CMA) is the metropolitan area associated with the city of Chicago and its suburbs. In 2004, EPA designated portions of the CMA as moderate nonattainment for the 8-hour ozone NAAQS. The Chicago nonattainment area includes Cook, DuPage, Kane, Lake, McHenry, and Will counties, and Aux Sable and Goose Lake Townships in Grundy County, and Oswego Township in Kendall County. As required by CAA, a SIP must be developed for Chicago nonattainment areas showing attainment achievement by 2010 (14).

On-Road Mobile Source Measures included in the SIP

The following on-road mobile source measures were used and claimed to reduce emissions in Chicago area SIP (14):

- Vehicle Inspection & Maintenance Programs (I/M)

  Description: I/M are required for several areas including Chicago area by 1990 Amendments to CAA. I/M are aimed to identify and repair high emitting vehicles.

- Reformulated Gasoline (RFG)

  Description: cities with worst ozone pollution, including Chicago area, are mandated to use RFG by CAA.

- Tier 2 Motor Vehicle Emission Standards and Gasoline Sulfur Control Requirement

  Description: New standards for tailpipe emission and sulfur levels in gasoline were instituted.

- On-Highway Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur

  Description: Ultra low sulfur diesel fuel was required to sale; tighter engine emission standards were also instituted.

Transportation Strategies Funded Through CMAQ Program

Table 5 shows those measures that were funded from CMAQ program from 2005 to 2010 in Chicago Area.

Table 5 .Transportation Strategies Funded Through CMAQ Program in Chicago Area.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day)				
				VOC	CO	NOx	PM10	PM2.5
Transit	Facility and Access Improvement	4	17.7	21.6	N/A	N/A	N/A	N/A
	Bus and Bus Rout Improvement	2	5.4	3.4	N/A	N/A	N/A	N/A
	Transit Expansion	1	0.9	2.18	N/A	N/A	N/A	N/A
Shared Ride	Park and Ride Lot	1	0.08	0.32	N/A	N/A	N/A	N/A
	Rideshare Programs	3	8.1	101.74	N/A	N/A	N/A	N/A
Traffic Flow Improvement	ITS Programs	4	5.7	6.63	N/A	N/A	N/A	N/A
	Signal timing and Coordination	38	19.1	36.59	N/A	N/A	N/A	N/A
	Intersection Improvement	17	8.3	4.19	N/A	N/A	N/A	N/A
	Road Widening	4	4.4	12.5	N/A	N/A	N/A	N/A
	Continuous Turn Lanes	3	6.7	14.42	N/A	N/A	N/A	N/A
	Streetscape Improvement	3	5.3	12.5	N/A	N/A	N/A	N/A
	Constructing Roundabout	3	0.5	0.28	N/A	N/A	N/A	N/A
Pedestrian/ Bicycle	Pedestrian/Bicycle	48	23.8	14.54	N/A	N/A	N/A	N/A
Demand Management	Traffic Management	1	0.4	2.01	N/A	N/A	N/A	N/A
	Cab Connector	1	0.1	1.44	N/A	N/A	N/A	N/A
	Clean Ai Program	1	0.4	2.09	N/A	N/A	N/A	N/A
Other	Alternative Fuel Non-Transit Vehicle	1	1.5	62.01	N/A	N/A	N/A	N/A
	Bus and Locomotive Retrofit	8	20.1	207.28	N/A	N/A	N/A	N/A

Source: (CMAQ Public Access System, 2014) (10)

Dallas-Fort Worth Area

Dallas-Fort Worth area (DFW) includes twelve counties in north Texas. DFW encompasses 9,000 square miles and a population of 6.5 million. DFW is the largest land-locked and fourth-most populous metropolitan area in the United States (15). DFW failed to attain and was reclassified from a moderate to serious nonattainment for 8-hour ozone in 2010 (NOx and VOC are the precursor emissions). Nine counties including Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, and Tarrant are comprised in the DFW nonattainment area (16).

Transportation Control Measures included in the SIP

Transportation Control Measures in DFW's SIP which are committed to implementation are in the following TCM categories:

- Bicycle and Pedestrian Facilities,
- Grade Separation Projects,
- Intersection Improvement Projects,
- Park and Ride Lots,
- Transit Projects, and
- Vanpool Programs (17).

Transportation Strategies Funded Through CMAQ Program

Table 6 shows those measures that got funding from CMAQ program from 2005 to 2010 in DFW.

Table 6. Transportation Strategies Funded Through CMAQ Program in DFW Area.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day) VOC	CO	NOx	PM10	PM2.5
Shared Ride	Rideshare Programs	1	N/A	0.69	N/A	0.91	N/A	N/A
Traffic Flow Improvement	ITS Programs	3	1.5	1782.58	191.11	673.58	N/A	N/A
	Signal timing and Coordination	20	6.2	1869.38	902.87	555.05	N/A	N/A
	Intersection Improvement	33	31.8	1132.54	5556.47	488.12	N/A	N/A
	Grade Separation	3	8.5	47.35	220.74	26.74	N/A	N/A
	Continuous Turn Lanes	1	1.5	0.9	4.58	1.97	N/A	N/A
	Constructing HOV Lanes	2	3.0	73.75	469.68	152.14	N/A	N/A
Pedestrian/ Bicycle	Pedestrian/Bicycle	4	0.7	10.56	111.89	18.18	N/A	N/A
Demand Management	Commute Alternative Program	3	4.0	211.72	N/A	226.96	N/A	N/A
Other	Marketing Strategy and Public Outreach	1	2.0	0.04	N/A	82.74	N/A	N/A
	Alternative Fuel Non-Transit Vehicle	3	4.0	9.78	N/A	16.18	N/A	N/A

Source: (CMAQ Public Access System, 2014) (10)

Houston-Galveston-Brazoria

Houston-Galveston-Brazoria (HGB) nonattainment area includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. HGB area encompasses 8,800 square miles and a population of 6.1 million and is classified as a severe nonattainment area for 8-hour ozone standard. HGB must demonstrate the attainment by 2019 (18).

On-Road Mobile Source Measures included in the SIP

TCMs are not claimed to reduce on-road mobile emission and therefore are not required to demonstrate reasonable further progress or timely implementation. The federal and state on-road mobile source measures included in SIP are as following:

- Tier 1 & Tier 2 Federal Motor Vehicle Control Program,
- National Low Emission Vehicle Program,
- 2007 Heavy-Duty Diesel, Federal Reformulated Gasoline,
- Inspection & Maintenance Program, and
- Texas Low Emission Diesel Program (18).

Transportation Strategies Funded Through CMAQ Program

Table 7 shows those measures that received funding from CMAQ program from 2005 to 2010 in HGB area.

Table 7. Transportation Strategies Funded Through CMAQ Program in HGB Area.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day) VOC	CO	NOx	PM10	PM2.5
Transit	Developing a New Transit System	1	6.3	24.44	255.1	7.66	N/A	N/A
	Transit Expansion	1	6.8	1.16	4.79	1.62	N/A	N/A
Shared Ride	Park and Ride Lot	1	1.5	3.33	11.71	4.73	N/A	N/A
	Rideshare Programs	2	8.0	21.52	8.13	9.66	N/A	N/A
Traffic Flow Improvement	ITS Programs	24	34.9	680.7	1158.6	649.7	N/A	N/A
	Signal timing and Coordination	23	17.3	219.36	701.22	253.41	N/A	N/A
	Signalization	3	1.7	10.74	23.42	6.17	N/A	N/A
	Intersection Improvement	11	4.9	140.9	740.16	123.217	N/A	N/A
	Lane Widening	1	1.3	4.1	N/A	3.11	N/A	N/A
	Grade Separation	4	5.0	1.67	6.03	2.43	N/A	N/A
	Continuous Turn Lanes	2	5.9	1.8	9.7	3.94	N/A	N/A
	Constructing Managed Lanes	3	10.5	14.97	N/A	21.04	N/A	N/A
	Access Management Improvement	1	2.7	20.05	N/A	13.22	N/A	N/A
	Traffic Management Center	1	1.9	20.05	N/A	13.22	N/A	N/A
	Traffic Control Device Improvement	1	0.5	28.39	153.98	62.49	N/A	N/A
Pedestrian/ Bicycle	Pedestrian/Bicycle	18	13.1	69.3	348.55	76.99	N/A	N/A
Demand Management	Commute Alternative Program	5	6.9	196.47	518.53	243.53	N/A	N/A
	Clean Air Action Program	2	3.2	653.07	2141.23	439.14	N/A	N/A
Other	Marketing Strategy and Public Outreach	1	1.9	46.24	N/A	20.77	N/A	N/A
	Alternative Fuel Transit Vehicle	6	32.2	1215.56	3126.4	1406.34	N/A	N/A
	Alternative Fuel Non-Transit Vehicle	1	3.2	3.15	13.73	5.97	N/A	N/A

Source: (CMAQ Public Access System, 2014) (10)

El Paso County, Texas

El Paso County is the westernmost and the sixth most populous county in state of Texas which encompasses 0.8 million population and 1,000 square miles (19). In 1990, city of El Paso was classified as a moderate nonattainment area for the PM_{10} NAAQS; the attainment classification occurred in 1994. However, it is still classified as moderate nonattainment for the PM_{10} (20). El Paso County was classified as serious 1-hour ozone nonattainment area in 1999. However, in 2004, the three years of monitoring data had demonstrated the compliance with 1-hour ozone NAAQS and El Paso County is no longer classified as nonattainment area for 1-hour ozone. El Paso County has demonstrated compliance for 8-hour ozone NAAQS and has been classified as attainment for 8-hour ozone (21).

On-Road Mobile Source Measures included in the SIP

It should be noted that area sources are the most significant source of PM_{10} for El Paso. Therefore, on-road mobile source measures are not included in PM_{10} SIP (20). The maintenance plan in ozone SIP includes two one-road mobile source measures as following:

- Vehicle Inspection and Maintenance Program
- El Paso County Low Reid Vapor Pressure (RVP) Gasoline Program

Transportation Strategies Funded Through CMAQ Program

Table 8 shows those measures that got funding from CMAQ program from 2005 to 2010 in El Paso County. As the table shows, ITS strategy has the most number of project and emission benefits.

Table 8. Transportation Strategies Funded Through CMAQ Program in El Paso County.

Strategy Category	Strategy	Number of Projects	Total Cost (1,000,000$)	Expected Emissions Benefits (Kg/day)				
				VOC	CO	NOx	PM10	PM2.5
Traffic Flow Improvement	ITS Programs	14	21.3	317.01	1461.83	89.33	N/A	N/A
	Signal timing and Coordination	5	8.7	122.60	840.64	32.14	N/A	N/A
	Turnarounds	1	5.3	5.79	49.50	0.57	N/A	N/A
	Intersection Improvement	3	13.1	23.16	107.92	2.98	N/A	N/A
	Traffic Management Center	1	0.5	177.59	749.88	22.14	N/A	N/A

Source: (CMAQ Public Access System, 2014) (10)

TCM Evaluation

In most cases, the funding of TCM projects is upon the assessment and documentation of their air quality benefits. The enactment of CAAAs emphasizes largely on the accurate evaluation of the emission impacts of TCMs. Therefore, the evaluation of TCM impacts is necessary (22). In Texas, TxDOT's *The Texas Guide to Accepted Mobile Source Emission Reduction Strategies* (MOSER manual) contains standardized methods for analyzing emissions benefits of TCMs. It is discussed later in this section. These methods are used statewide to assess the emissions benefits of TCMs.

TCM Evaluation Methods

Traditionally, three types of methodologies have been used for TCM evaluation: empirical data comparison, network-based modeling, and sketch-planning tools. Empirical data comparison involves application of the observed changes in travel behavior and air quality from TCM implementation in other areas. Network-based modeling involves multifaceted simulation tool and transportation demand models. Sketch- planning methods are somewhere between the two formerly mentioned methods and include both manual and computerized approaches (23). Further information related to each method is provided in the following:

Empirical Data Comparison

This is one of the simplest ways to estimate the impacts of a TCM. However, this method due to its uncertainties is not considered as a strong TCM evaluation tool. There is always a high chance that air quality agencies do not accept a TCM evaluation based on comparison with similar experience in other regions. The major benefit of this method, its simplicity, is also its main drawback. Ensuring that the area which its data is used is comparable to the local area is a challenging task. Moreover, the evaluation of TCM's impacts and the validity of all data must be examined carefully (22).

Network-Based Modeling

Network modelling uses a simulation of a transportation system in the form of modal links with specific transportation operating characteristics to estimate the effects of transportation system changes. This can be done for past, present or future transportation systems at different levels of detail. Most transportation network models are sensitive to changes in travel demand, facility capacities, travel distances, speeds, and volumes. Some are multimodal and others are roadway only. Most current transportation network models have the ability to produce estimates of vehicular emissions and to produce outputs that can be used in more specific and detailed post-processing emissions analyses.

The effectiveness of TCMs that improve traffic flow on a regional or subarea level can be evaluated using regional or other travel demand models. More project specific analyses can be performed using traffic simulation models such as NETSIM, PASSER II and III, CORSIM, VESSIM and TRANSYT-7F. TCMs that are supposed to reduce travel demand, or change the mode, route or destination of the trips are more complicated to evaluate and most are evaluated using some kind of separate method, often using outputs from the above types of models as inputs. Traditional travel demand modeling is often recommended for evaluation of these TCMs (22).

Sketch Planning

Sketch planning approaches combine elements from the other two approaches to produce general order-of-magnitude estimates of transportation and land use air quality impacts. This often achieved in the form of changes in network-based activity and emissions based on empirically derived correction factors. Sketch planning approached are usually implemented in spreadsheet– or GIS–based tools. Sketch planning is often used as an alternative to developing complex travel demand models for forecasting future travel demand.

Sketch planning is accepted as a cost-effective alternative to a more expensive, complex, and data intensive network-based approach. However, estimates produced by sketch planning tools are generalized and often dependent on aggregated data and other simplifying assumptions that limit the use of them for applications that require high accuracy.

Examples of Emission Reduction Effectiveness Evaluation Methods – Agency Methods

A number of state DOTs, and MPOs have developed methods for estimating emissions impacts within their jurisdictions. Many are applicable for analyzing emissions benefits of TCMs. Other organizations and agencies have also developed methods for similar applications.

Most of these methods take the form of standalone equations or multiple step methods, but some use or are more sophisticated models. Some use Microsoft Excel™ based worksheets. Some are documented on agency or organization websites, in agency conformity documentation, or in research reports. Some methods are basic with a few "common" inputs. Others are more complex offering more considerations and variables and come with more demanding input data requirements.

TxDOT's MOSER manual, *The Texas Guide to Accepted Mobile Source Emission Reduction Strategies (MOSERS),* is one of the most comprehensive documents containing methods for analyzing emissions impacts of TCMs (24). It was developed to both (1) provide methods to analyze various mobile source emissions measures (including TCMs) being considered by Texas nonattainment, maintenance, and near nonattainment areas, and (2) to help to standardize methods used to analyze similar emissions reduction measures being considered in different areas. The latest edition contains methods for analyzing 56 different measures. Methods vary in complexity and data needs, but all can be accomplished by typical Texas MPOs or other local agencies in affected areas with normally available resources.

Among other sources found were:

State Environmental and Transportation Agencies

- California Air Resources Board - *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects* (24)

- Michigan Department of Transportation - CMAQ Program Website, Application and Emissions Forms (25)

MPOs and COGS

- Maricopa Association of Governments - "Methodologies for Evaluating Congestion Mitigation and Air Quality Improvements Projects" (26)
- Metropolitan Washington Council of Governments - *Air Quality Conformity Determination of the 2013 Constrained Long Range Plan and the FY2013-2018 Transportation Improvement Program for the Washington Metropolitan Region* (27)
- Regional Transportation Council of Southern Nevada - agency conformity determination documentation and agency staff interviews (28)
- Wasatch Front Regional Council - online CMAQ project application process (29)

Research and Other Organization Guidebooks

- Center for Clean Air Policy - Transportation Emissions Guidebook (30)
- ICF International - *Multi-Pollutant Emissions Benefits of Transportation Strategies* (31)

Examples of Emission Reduction Effectiveness Evaluation Tools and Models

COMMUTER model

EPA developed its COMMUTER model, first released in 2001, to assist worksite transportation coordinators and local planners to estimate impacts of workplace-based commuter programs (32). This model interfaces with EPA's emission factor model (latest version – 2005 – interfaced with MOBILE 6.2). It estimates commuter program benefit on emissions, fuel use, and costs. Measures it can analyze include:

- Transit fare decreases or other incentives that reduce the cost of using transit;
- Transit service improvements (faster or more frequent service);
- Ridesharing programs, in which employers support carpooling and/or vanpooling through on-site programs, financial incentives, or preferential parking;
- Other actions, such as increased parking charges or cash-out programs, that change the time and/or cost of traveling by any particular mode;
- Non-motorized (e.g., bicycle and pedestrian) commuting programs;
- Alternative work schedules, including flex-time, compressed work weeks, and staggered work hours; and
- Telecommuting.

Trip Reduction Impacts of Mobility Management Strategies (TRIMMS)

TRIMMS is a spreadsheet model that estimates the impacts of a range of transportation demand measures to assess program cost effectiveness, such as net program benefit and benefit-to-cost ratio analysis (33). Outputs include estimates of emissions impacts of those strategies. TRIMMS evaluates strategies directly affecting the cost of travel, like employer-based subsidies to promote public transportation use, parking pricing, pay-as-you-go pricing, and other financial incentives. Employer-provided subsidies reduce the costs associated with the use of a particular method of commuting to employees. Subsidies can take different forms such as cash, discount passes, and vouchers. TRIMMS also evaluates the impact of strategies affecting access and travel times and a host of employer-based program support strategies, such as TDM program support initiatives, alternative work schedules, telework and flexible work hours, and worksite amenities.

EPA sponsored a study that developed some sketch planning estimates emissions impacts of several TDM-related measures using TRIMMS model (34).

General Approach for TDM strategies

General steps for evaluating the impacts of TCMs that make changes in travel demand, i.e. demand managements strategies, are:

Step 1: define project scope including all physical limits and participants. Any assumption needs to be documented.

Step 2: transform person trips into vehicle trips.

Step 3: estimate changes in VMT by applying vehicle trips over average applicable trip length.

Step 4: determine changes in speed or duration in idling.

Step 5: determine if the percentage of cold starts will change.

Step 6: determine vehicle fleet mix for affected trips

Step 7: if vehicle types, fuel type or other characteristics of the TCM changes emissions factors, note those changes for step 8.

Step 8: use emission factors derived from MOVES and estimated vehicle travel from previous steps to estimate changes in emissions.

Conclusions

Transportation is expected to continue to be a major contributor to regional air pollution for the foreseeable future. State and local transportation agencies have a long history of implementing strategies to reduce air pollutant emissions in nonattainment and maintenance areas, generally known as Transportation Control Measures or TCMs. Under the conformity rule only approved TCMs can be included on State Implementation Plans (SIPs).

The Congestion Mitigation and Air Quality Improvement (CMAQ) program continues to provide funding to transportation agencies for projects that reduce emissions and relieve congestion. CMAQ funds can be used for transportation strategies that can be documented to have emission and congestion reduction benefits in nonattainment and maintenance areas, whether or not they are in approved SIPs. There are currently few resources that document the actual quantified effects of CMAQ and non-CMAQ funded projects on vehicular emissions. Furthermore, there is a significant lack of documentation of the methodologies and data used to estimate these effects.

The purpose of this white paper report is to provide a compendium of transportation-related control strategies that are used by transportation agencies; either included in SIPs or funded through the CMAQ program. Additionally, the document provides summary information on the estimated cost and emission reduction benefits of these strategies as documented by the agencies. The document provides a general overviews of the methodologies used in practice to estimate the impacts of these strategies. The majority of these methodologies can be categorized as sketch planning approaches; combining elements of detailed network-based analysis with simplifying assumptions and empirically-derived correction factors.

Appendix A

This appendix summarizes some of the types of evaluation methods that have been used for a selected group of TCMs. These are presented by TCM type. This information has been assembled from a cross-section of regions around the country. Virtually all of these methods are used to forecast anticipated TCM effectiveness. These are not before-and-after studies.

Alternative Fuel Vehicles/Fueling Facilities

Approximately 7.6 percent of the total CMAQ funding has been allocated for Alternative Fuel Vehicles/Fueling Facilities projects. Like most of the methods described in this section, these methods are all applied outside the regional travel forecasting process. They involve the use of independent equations using as inputs such variables as: number of gasoline vehicles being replaced, average VMT per new vehicle, and on-road emission factors for affected vehicles.

Conventional Bus and Paratransit Replacements

Similar to alternative fuel strategies, the essential computation is the current activity (e.g., VMT) of the vehicles being replaced multiplied by the difference in before and after replacement emission factors. Inputs typically consist of number of buses being replaced, annual vehicle hours operated per bus, vehicle brake horsepower, emissions factors for old and new buses, and possibly vehicle life or vehicle life remaining.

Diesel Engine Retrofits

The methods for analysis used for this strategy are typically based on the number of vehicles being retrofitted, their current VMT, and comparative emission factors for the vehicles in previous and retrofitted conditions. The methods use equations. The focus is on heavy duty diesel vehicles which are higher emitters for PM emissions.

Vehicle Activity Programs

Idle Reduction

Idle reduction and operational strategies reduce emissions by maximizing efficient use of equipment and limiting the amount of time an engine needs to operate. Models typically include idle reduction equations and analysis methodologies. In general, the analysis methods focus on calculating the amount of time spent idling by the affected vehicle type(s) and multiplying that time by the appropriate idling emission factor. Some models use both start and idling emission factors in the analysis. One model uses weighting factors for each pollutant in the analysis based on regional air quality goals while still following the same equation structure (idle time × emission factor by time).

Truck stop electrification estimate equations typically include truck idling hours reduced (number of TSE truck stops, average number of truck parking spaces utilized, average daily idling hours per truck, estimated daily idling hours per truck with project, and idling emissions factors. Drive-thru restrictions estimation equations usually include percent of vehicles that park instead of using the drive-through facility due to imposed control, average number of vehicles using the drive-through facility, time spent in queue after implementation of control, time spent in queue before implementation of control, and idling emission factors.

Traffic Flow Improvements

Traffic Signalization

Traffic signalization and improvements can include the following:

- Updating traffic signal hardware to enable more efficient traffic flow strategies;
- Interconnecting, coordinating and re-timing traffic signals to reduce unnecessary delays; and
- Removing signals at intersections where no longer required.

Most methods utilize equations and related methodologies. Most of those equations are based on estimates of delay reduction at intersections as a result of the measure. They apply the equations to daily volume or VMT at the project location and utilize idling emissions factors. Some equations use a speed-based analysis capturing the effects on average speed along a segment and applying the emission changes to the daily VMT affected. Some methods separately compute emission changes for both peak and off-peak hours. One method even includes AADT conversion factors.

Traffic Engineering (Roadway Improvements)

Estimation equations for this category typically seek to estimate the vehicle delay reduction achieved from the improvement. Some types of roadway improvements have different bases for generating emissions reductions, namely speed changes (e.g., improved alignments or capacity increases) and/or reductions in delay (e.g., at-grade railroad crossing eliminations). The number of affected vehicles and the amount of delay before the project are the key inputs to the equations. Some models use speed-based running emission factors to determine the emission rates while other models use idling emission factors to determine emission rates.

Managed Lanes

Managed lanes are specialized lanes in corridors that control lane usage by vehicle eligibility, price, or access control. HOV facilities are managed lanes but also include exclusive HOV ramps, lots directly connected to HOV lanes, and improvements that permit HOVs expedited movements through the roadway system (e.g., queue jumpers). Some methods include equations that attempt to estimate the number of previous single occupant vehicle travelers using the lane as rideshare or transit passenger. Those participants are the primary emission reduction of the strategy due to less vehicle trips and VMT. Equations may also calculate potential emission benefit from the improved traffic flow on the main lanes as a result of the managed lane. Factors included can be the change in running exhaust emissions from vehicles shifting from general purpose lanes to HOV lanes, change in running exhaust emissions of vehicles remaining in general purpose lanes as a result of vehicles shifted away from general purpose lanes, reduction in auto start and running exhaust emissions from trip reductions, as well as vehicle volumes and trip lengths.

Roundabouts

The equation found for this type of TCM computes the emission benefit through the reduction in vehicle delay at the intersection and the subsequent reduction in idling emissions using reduced hours of hours of delay, ADT and idling emissions factors.

Intelligent Transportation Systems

General ITS

General ITS equations estimate the reduction in running emissions on the ITS project length, AADT (under peak and off-peak conditions) over the project length, regional vehicle fleet emission factors, reductions in vehicle delay, and speed-based and idling emission rates. Since ITS is usually implemented in phases over many years, estimates reflect proportionality benefits over that time.

Freeway Management Systems

Freeway management systems consist of strategies and technology to monitor, control, and manage freeway traffic efficiently. Equations for emissions analysis of freeway management systems typically calculate a regional freeway emissions rate and estimate the emission reduction based on delay reduction (less idling emissions) or improved traffic flow (speed) on affected freeways. Both recurring and non-recurring emissions can be considered. Equations include speed-based running exhaust emission factor for mainline before and after implementation, idling emission factor, length of freeway corridor impacted by ramp metering, average time spent in queue waiting to enter or on the freeway, and number of vehicles affected by the measure being evaluated, using metered ramps. The equations can be made very complex or use microscopic simulation models since extensive freeway operations research has been completed. Input data requirements can become correspondingly intensive to feed those models and equations.

Traveler Information Systems

Advanced Traveler Information System (ATIS) provides the information travelers need from their origin to destination for travelers to minimize the impact of nonrecurring congestion on major roadways in a region. Equations used to calculate emissions benefits from delay reduction from nonrecurring congestion compare before and after idling emissions of all vehicle types. For example, an equation applicable for incident avoidance includes factors for percentage of lanes blocked during incidents, incident duration, incident delay with project; traffic volume during incident, and emissions factors for idling and applicable speeds and distances.

Improved Public Transit

Transit Facilities, Systems, and Services

Five methods for analyzing transit facilities, systems, and services projects estimates are based on the number of new transit users and their former mode of travel which in turn is focused on former vehicle drivers. Some methodologies attempt to estimate that number and the previous vehicle activity (VMT and number of starts) combined with number of effective days per year and start and running emission factors for light duty vehicles in the local fleet. This information may be derived from multimodal regional travel demand models that involve extensive input data and modelling equations and algorithms. Separate equations can also be complex and data intensive.

New Bus Services

As with all transit projects, the key input for air quality benefits is the number of new transit users resulting from the project that previously drove a single occupant vehicle. For new bus service, most equations account for the increase in emissions due to the increase in number and/or activity of the buses and they may also reflect new riders rather than assuming all previous VMT is removed as a result of the strategy. Emissions estimation equations typically include number of new transit riders multiplied by the percentage of riders shifting from single-occupant auto use, education in auto running exhaust emissions from VMT reductions, number of vehicle trips reduced multiplied by the average auto trip length, increase in emissions from additional bus starts and running, average trip length, and speed-based running exhaust emission factors for affected roadway before and after implementation.

New Rail Services

New passenger rail services involves establishing new routes, increasing the frequency of current service, expanding the hours of operation, or the overall coverage of transit corridors. Free-standing equations may be straight forward or quite complex. Factors included may include but are not limited to the vehicle travel replaced by the rail service, VMT added as a result of trips driven to the rail station, onroad light duty vehicle emission factor for each pollutant, and the off-network vehicle emission factor for each pollutant.

Transportation Demand Management

Public Education/Outreach (Information/Marketing)

Public education, marketing, and other outreach efforts include advertising available alternatives to SOV travel in a nonattainment area, employer outreach, and public education campaigns about transportation and air quality. The primary benefit of these activities is enhanced communication and outreach that is expected to influence travel behavior and air quality. Ozone Action Days is an example of this type of project.

According to the FHWA interim CMAQ program guidance of November 2013 these strategies may fall into the category of Qualitative Assessment. Although quantitative analysis of air quality impacts is expected for almost all project types, an exception is made when it is not possible to accurately quantify emissions benefits. In the case of public education, marketing, and other outreach efforts, qualitative assessments based on reasoned and logical determinations that the projects or programs will decrease emissions and contribute to attainment or maintenance of a NAAQS are acceptable. (FHWA, 2013)

Travel Demand Management

The wide range of project types under TDM require a variety of inputs specific to each program, project, or strategy. Vanpool programs require vanpool occupancy as an input, some programs require number of vehicle trips or VMT, and still others need the number of commuters or students or new participants. Regardless of the project type, all of the equations attempt to calculate new VMT reductions or vehicle trips reductions by the TDM strategy, and then multiply that VMT reduction by an appropriate emission factor. Most equations use start and running emission factors and specify light duty vehicles for analysis. Some include soak and evaporative emissions.

Park and Ride Facilities

Equations for park-and-ride analysis typically use as inputs average trip length from home to the facility (to be subtracted from the average home–work trip length and the parking lot utilization rate (not just assuming full utilization) and speed-based running exhaust emission factor before implementation. The equations limit themselves to running emissions for light duty passenger vehicles since this strategy does not remove start emissions from vehicle activity.

Value/Congestion Pricing

Value/congestion pricing strategies are TDM projects that regulate roadway demand and discourage travel during peak periods or in highly congested areas by charging fees to system users. Emissions analysis for pricing strategies can be more complex than many other strategies. The amount of emission benefit is affected by driver response to costs and changes in regional travel behavior. Equation inputs can include price change, price elasticity, and travel changes on alternate facilities as a result of a priced roadway, trip length, before and after speeds on priced and unpriced lanes, and start and running emission rates at before and after speeds.

Other Strategies

Pedestrian/Bicycle

Equations for this type of measure differ based on specific strategy, but all use a similar process in their calculations. They attempt to quantify the VMT and vehicle-trip reductions from previous SOV driver's use of the bike lane or pedestrian facility, and then multiply the reductions by a speed-based and start emission factor. The result is the emission benefit. All limit the analysis to light duty passenger automobiles and trucks.

Dust Mitigation

Dust mitigation strategies are of particular concern to nonattainment areas for particulate matter (PM-2.5, PM-10). There are two main types of projects within the strategy: road paving and street sweeping. For road paving equations, the basic approach is to determine the VMT within the project scope and calculate the current PM emissions factor on the unpaved road and estimate the future PM emissions factor on the paved roadway segment, multiplying the VMT by each emission factor. For street sweeping, the focus for the emission factor is on the pre-swept road and then the factor for the swept road. VMT on the affected roadway remains an input.

Equations for both project types can have extensive inputs. For street sweeper replacement with a more efficient engine, greater attention is paid to fuel consumption. One of the models allows analysts to consider road surface silt loading factors, number of wet days in winter, and antiskid abrasive applications, silt content, moisture content in both project types.

Freight/Intermodal

Intermodal freight transportation is the movement of freight using more than one mode of travel where all parts of the transportation network are effectively connected and coordinated. The environmental benefits are gained through using cleaner technologies that improve air quality. One equation calculates the emission benefit for mode shifting (e.g., trucks to rail) multiplied by the truck annual VMT multiplied by a load factor and then the truck emission factor. A second equation calculates the benefit from shifting truck traffic to off-peak hours.

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