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16. Abstract

Documented analysis procedures of travel and emission impacts of Congestion Mitigation/Air Quality (CM/AQ) Improvement Program projects are required by the Intermodal Surface Transportation Efficiency Act (ISTEA). The Texas Department of Transportation (TxDOT) realized a need to assist Texas metropolitan planning organizations (MPOs) with their analysis of CM/AQ projects. A search of the current literature and telephone surveys with FHWA personnel was conducted to assess what procedures were available for use in Texas, and to determine what procedures were in use around the nation. Through the span of this project, the importance of vehicle emissions associated with the vehicle's operating mode became increasingly important from results of research work sponsored by the U.S. Environmental Protection Agency (EPA). Several analysis examples of transportation projects are presented. Discussions of their expected versus evaluated benefits and potential impact of vehicle operating emissions on analysis techniques are given in the report. The report concludes with several caveats detailing findings and aspects of analysis discussed in this report.

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RESEARCH CONCERNING THE ANALYSIS OF CONGESTION MANAGEMENT AND AIR QUALITY TRANSPORTATION IMPROVEMENT PROJECTS

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IMPLEMENTATION STATEMENT

The use of analysis tools throughout the nation to evaluate Congestion Mitigation/Air Quality (CM/AQ) projects are presented in this report. A general discussion is also included on the advantages and disadvantages for each of the analysis tool types. Sketch-planning tools were recommended for use because they can be used with the least amount of effort and are based on a logical set of equations which describe the effects of a particular project in relation to the transportation system. Several sketch-planning tools are demonstrated and discussed in this report. The common theme throughout this report on project documentation and analysis examples is the need for modal data, both vehicular and emission, to better evaluate the effects of transportation system management projects. Most analysis tools can reasonably predict the impacts of demand management measures but cannot reasonably predict the impacts of measures which modify the system operation. Until modal data are able to be used in project-level analyses, the benefits of transportation system management projects may be underestimated, both in terms of travel and emissions.

This report has not been converted to metric units because the software discussed in this report relies on input to and output from the United States Environmental Protection Agency's MOBILE emission factor mode. As of the publication of this report, English inputs are required for MOBILE, and inclusion of metric equivalents could cause errors.

DISCLAIMER

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

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SUMMARY

Documented analysis procedures of travel and emission impacts of Congestion Mitigation/Air Quality (CM/AQ) Improvement Program projects are required by the Intermodal Surface Transportation Efficiency Act (ISTEA). The Texas Department of Transportation (TxDOT) realized a need to assist Texas metropolitan planning organizations (MPOs) with their analyses of CM/AQ projects. A search of the current literature and telephone surveys was conducted to assess what procedures were available to use in Texas, and to determine what procedures were in use around the nation. Throughout the span of this project, the importance of vehicle emissions associated with the vehicle's operating mode became increasingly important based on results of research work sponsored by the U.S. Environmental Protection Agency (EPA). Several analysis examples are presented and issues concerning their analysis are raised and discussed further. The report concludes with several caveats detailing findings and issues discussed in this report.

I. INTRODUCTION

The Congestion Mitigation/Air Quality Improvement (CM/AQ) program was outlined in the Intermodal Surface Transportation Efficiency Act of 1991. The CM/AQ program provided an avenue for metropolitan areas, designated as nonattainment, to reach the goals outlined in the 1990 Clean Air Act Amendments for attaining the National Ambient Air Quality Standards (NAAQS). Rodney E. Slater, Federal Highway Administrator, notes that the "CM/AQ program emphasizes the importance of the link between transportation and air quality . . ." (1). Through the CM/AQ program, many areas were able to implement transportation projects, such as transportation control measures outlined in the CAAA, and other innovative emission control strategies and technologies that reduce mobile source emissions. Requirements of the CM/AQ program include the analysis and documentation of emission benefits for proposed projects to be funded under this program.

Guidance on the CM/AQ program notes that the air quality benefits of projects are an important basis for comparing the many types of proposed projects (1). The guidance recognizes that there is not a specified method for quantitative analysis but does stress that an analysis must be credible and based on a logical analytical procedure. Qualitative analyses of proposed projects are permitted occasionally but must be based on a reasoned and logical examination of how a proposed project will decrease emissions (1). Analysis of proposed projects should also include expected reductions in travel measures such as VMT or number of trips.

The Texas Department of Transportation (TxDOT) recognized a need for the development of analysis tools or procedures for use in Texas to meet the requirements of the CM/AQ program. At the time of this report, Texas has four nonattainment areas under three criteria pollutants; these are shown in Table 1-1.

Table 1-1
1995 Texas Nonattainment Areas

Nonattainment Area	Criteria Pollutants		
	Ozone (O_3)	CO	PM-10
Beaumont/Port Arthur	Serious		
Dallas/Fort Worth	Moderate		
El Paso	Serious	Moderate	Moderate
Houston/Galveston/Brazoria	Severe		

El Paso is the only metropolitan area in Texas to violate the NAAQS for three pollutants. Of the four nonattainment areas, Houston/Galveston and Dallas/Fort Worth are the only metropolitan areas with a sizable MPO in terms of staffing and resources. Beaumont/Port Arthur and El Paso have much smaller MPO staffs and resources. TxDOT was particularly concerned with providing assistance to these smaller MPOs in the analysis of CM/AQ projects. Because these MPOs have limited resources, they typically turn to TxDOT for assistance in completing the rigorous requirements of transportation planning and meeting planning deadlines.

The Texas Transportation Institute (TTI) was contracted under this project to discover or develop procedures for the analysis of CM/AQ projects. Literature reviews were conducted to determine if acceptable procedures currently existed before proceeding with the development of analysis techniques. Acceptable procedures were discovered and were further enhanced based on requests from the TxDOT technical panel. However, concerns remain that some types of projects are not properly considered in these procedures, and better analytical tools are needed. These tools await the outcome of current research into drive mode emissions.

OBJECTIVES

This report has two objectives. The first objective is to document the progress made through this project. The second objective is to make the reader aware of issues affecting current analysis tools such as limitations and forthcoming research which will influence future emission analysis techniques.

ORGANIZATION OF REPORT

This report is organized into four chapters. Chapter II documents the progress made on this project. Chapter III introduces various congestion management and air quality transportation improvement project analysis examples and provides discussion of several important issues concerning their use. Chapter IV presents the conclusions of this report and provides several caveats on the use of current analysis tools.

II. PROJECT DOCUMENTATION

LITERATURE REVIEW

Due to the short duration of this project initially, a literature search was performed to locate new and promising techniques for evaluating CM/AQ projects. Telephone interviews were conducted in the spring of 1994 with air quality specialists at several Federal Highway Administration (FHWA) regional offices. These interviews were conducted to determine what steps states were taking to evaluate proposed CM/AQ projects and distribute CM/AQ funding. The literature search revealed several sources pertaining to the development and critique of sketch-planning tools. Additionally, discussions are presented on relevant research focusing on emissions associated with vehicle activity (modal emissions) and how this new emission factor research is becoming a driving force in mobile source emissions research.

FHWA Interviews

FHWA regions with ozone nonattainment areas classified as extreme or worse were contacted to determine what CM/AQ analysis procedures were being used to determine emission benefits from potential projects. Some discussions led to varied information pertaining to the distribution of CM/AQ funds.

Analysis Tools/Techniques

Interviews revealed that the use of sketch-planning tools to analyze potential projects was spreading across the country with the adoption and use of the TCM Tools. TCM Tools was developed for the San Diego Association of Governments and is discussed later in this chapter. Some states continue to analyze emission benefits of projects through simple equations such as:

$$\Delta VMT \ x \ EF_{(grams/mile)}$$

$$or$$

$$VMT \ x \ \Delta EF_{(grams/mile)}$$

where VMT is vehicle miles traveled and EF represents an emission factor for a specific speed. TxDOT had developed very general guidelines for analyzing potential projects. Several state departments of transportation were interested in reviewing and possibly using these guidelines in their respective states. Those states not using either of these methods were using travel demand models and traffic simulation software to develop estimated benefits of projects.

Several FHWA regions noted that common analysis tools included Highway Capacity Software (HCS), TRANSYT, NETSIM, and TRANPLAN. TRANSYT and NETSIM are traffic simulation models. These models are typically used to simulate the effects of traffic flow improvements. Although traffic simulation models can explicitly represent most traffic control devices and provide better estimates of traffic flow conditions, very few models (e.g., NETSIM) have an emission estimation capability and are not responsive to shifts in travel demand (2).

Travel demand models, like TRANPLAN, are used by many metropolitan areas to estimate VMT and growth in vehicular travel which are used to prepare mobile source inventories required in the state implementation plan. Although travel demand models can analyze redistributions in vehicular demand on the transportation network, they cannot adequately or directly assess the impacts of all CM/AQ project types. In addition, use of travel demand models can also result in sizable errors in link volumes and speeds (3). As Knapp (2) notes, the magnitudes of the errors by themselves can greatly exceed the magnitude of the travel impacts of most TCMs that may be used as CM/AQ projects.

Discussions also revealed that consultants are playing a critical role in the evaluation of CM/AQ projects with the development of sketch-planning techniques. Examples of these tools are TCM Tools for the San Diego Association of Governments (mentioned previously), CM/AQ Evaluation Model for the Denver Regional Council of Governments, and TCM Analysis Software for the Houston-Galveston Area Council. These tools are discussed later in this chapter.

Distribution of Funding

Metropolitan areas around the nation were developing prioritization processes to channel CM/AQ funding to deserving projects. This was expected because a new funding source for financing selected transportation projects was created with the CM/AQ Improvement Program.

Virginia uses the allocation formula cited in the ISTEA legislation. The allocation formula weighs the severity of the air quality problem against the regional population of the nonattainment area (4). This method provides the most funding to nonattainment areas with the greatest need. By using this procedure, Virginia is able to consistently provide funding of CM/AQ projects at levels that MPOs can plan for during their TIP development. Prioritization processes at the MPO level were not discussed.

Pennsylvania uses panels comprised of transportation officials, environmental officials, and community leaders which rank projects on their merits. This panel is able to provide input from many different social levels and technical backgrounds. It provides for a checks-and-balances structure between all parties involved in a project's implementation, ensuring that each party has an opportunity to provide direction on changes to the transportation system in the community.

The North Central Texas Council of Governments (NCTCOG) is the MPO for the Dallas/Fort Worth, Texas, metroplex. NCTCOG's prioritization is based on several factors: cost-effectiveness, air quality/energy benefits, project commitment and funding matching from local jurisdictions and, finally, its impacts on intermodal/multimodal projects. NCTCOG's process assigns a rating to each project ranging from 0 to 100, where 100 is the maximum score allowable.

The Denver Regional Council of Governments has used a prioritization process based on four categories: travel impacts, emission impacts, cost-effectiveness, and early project effectiveness. Within each of these categories were several subcategories that were used to further weight the impacts of a proposed project. Under travel impacts, for example, VMT reduction, regional speed increase, and idling reductions are used to evaluate the overall travel impact score. Like NCTCOG's analysis, projects are assigned a rating ranging from 0 to 100.

Promising Technologies

Knapp et al. (2) defined and evaluated the applicability of three categories of analysis tools for TCMs. These categories were comparative empirical databases, network models (including models for traffic simulation and travel demand), and sketch-planning tools. As noted above, several states are using network models to evaluate proposed CM/AQ projects. Knapp's (2) conclusion was that sketch-planning tools ". . . are the most promising and cost-effective of the TCM evaluation methods [currently] available."

Based on this conclusion, the literature search for this project focused on sketch-planning tools and their applicability for use in Texas. Crawford and Krammes (5) previously reviewed several sketch-planning tools spanning ten years of development starting in 1985. The sketch-planning tools discussed here include TCM Tools, TCM Analyst, TCM Analysis Software, and the

CM/AQ Evaluation Model. Sketch-planning tools are a conglomeration of logical equations which describe the travel and emission impacts of projects. These equations may be used through means of "pencil and paper" or programmed into a software application. These logical equations satisfy the analysis requirements for the CM/AQ program which were previously discussed. Most sketch-planning tools evaluate project impact on a regional basis but may be used for corridor or site-specific analyses. Recently, there has been movement in this field to create models which can evaluate projects at all three levels. All of the sketch-planning tools examined were programmed in commonly available software applications.

TCM Tools (6) was developed for the San Diego Association of Governments (SANDAG) by Sierra Research in cooperation with JHK & Associates. This model can evaluate 25 project types using Lotus 1-2-3 as its operating environment. TCM Tools was developed as three modules: travel, emissions, and cost-effectiveness. The emissions module limited the use of the model to California because it was integrated with EMFAC, a California-specific emission factor model. This model, like many sketch-planning tools reviewed here, relies heavily on default data for beginning analysis (5). Three pollutants are evaluated in this model: reactive organic gases (ROG), carbon monoxide (CO), and oxides of nitrogen (NOx).

The Houston-Galveston Area Council's TCM Analysis Software (7) developed by SR Consultants, with assistance from Sierra Research, Inc., is similar to TCM Tools. It includes several modules: transportation, emissions, and cost-effectiveness. Unlike TCM Tools, the emission module in this tool uses MOBILE-generated emission factors. The scope of this model was expanded to evaluate 29 project types. The TCM Analysis Software operates in the Lotus 1-2-3 environment. The pollutants of interest in this model are hydrocarbons (HC), CO, and NOx.

The TCM Analyst software was developed by the Texas Transportation Institute (8) and is based on an analysis methodology developed by System Applications International (9) for the U.S. Environmental Protection Agency (USEPA). This software is limited in scope; it can evaluate only 11 project types. The model was programmed under Microsoft Excel to take advantage of the combination of simple spreadsheet analysis and a programming language. The TCM Analyst is composed of five modules: data input, travel, emissions, cost-effectiveness, and results. This model does not have a significantly different module structure from the two previously discussed. This model evaluates the same pollutants as the TCM Analysis Software: HC, CO, and NOx. The model is unique in that it provides easy-to-use tools to test the model's sensitivity to changes in input values.

CM/AQ Evaluation Model (10) was developed by JHK & Associates for the Denver Regional Council of Governments (DRCOG). It contains analysis procedures for 60 strategies covering a wide array of CM/AQ project types. The model, programmed in Borland Paradox, also includes an eligibility module to assess a project's eligibility for CM/AQ funding prior to analysis. This model evaluates volatile organic compounds (VOC), CO, and particulate matter less than 10 microns (PM-10) but does not assess emission reductions associated with NOx. The CM/AQ Evaluation Model is unique in that it includes a project weighting procedure to compare impacts between projects regardless of their dissimilarity.

The CM/AQ Evaluation Model was selected as the model of choice for use in Texas. The decision was based on several reasons:

1) Many project types - One of the most difficult tasks in model development is the creation of logical equations to characterize the system functions of transportation projects. By using the previously defined equations in the model, users can enhance or program additional project types into the model, as needed. This model provided twice as many project types as the scope of the nearest model.
2) Ability to be enhanced - Because the model uses the Paradox Application Language (PAL) to execute the logical equations, learning PAL would enable users to add additional measures or make enhancements to the emissions estimation as developments occur in emission factor research.
3) Use with MOBILE - This is an absolute must for an evaluation tool to be used in Texas as with most of the nation, with the exception of California. All tools reviewed here, with the exception of TCM Tools, are compatible with MOBILE.
4) Use of a criteria weighting module - This module makes this particular model unique. Although it would not have been difficult to create a weighting module for a newly developed sketch-planning tool, TTI sought to take advantage of a well developed module and tool for use in Texas. This model incorporated procedures that were being developed by MPOs across the nation.

Several areas of the model were identified for enhancement/conversion so that it could be easily used by TxDOT and Texas MPO staffs. The enhancements made to the model are discussed later in this chapter.

It should be noted that none of the sketch-planning tools reviewed had the ability to evaluate or address the impact of modal emissions for proposed projects, as explained in the next section. The development of modal emission factors will shape the analysis procedures used in the next generation of sketch-planning tools.

Modal Emissions

Mobile source emissions research has recently begun to focus on modal emissions from vehicles. Modal emissions are associated with each mode of activity the vehicle operates within. Modal vehicle activity includes acceleration, cruise, deceleration, and idle (ACDI). Past mobile source emissions research did not focus on the contributions of accelerations or decelerations toward the contribution of vehicle emissions.

Research sponsored by the USEPA has examined real-world driving characteristics against those used in the Federal Test Procedure (FTP). The FTP is the basis used for formulating current emission factors. This recent research has lead to surprising results that driving characteristics are different today than those used to develop the FTP in Los Angeles, California. LeBlanc et al (11) developed several important findings. One finding is that all current emission factor models treat variations between drivers as insignificant in the production of emissions (11). As a result, the emission factor models require the use of average speeds which reduce the effects of driver-to-driver variability. Another finding is that vehicle activity profiles, the way drivers tend to drive, is significantly different between United States cities (11). The research concluded that mobile source emissions are dependent on vehicle type, vehicle activity, and possibly the transportation network and/or driver behavior characteristics (11). The current USEPA emission factor model, MOBILE, accounts for only one (vehicle type) of the four variables mentioned in the previous sentence. Increasing the understanding of the effects of vehicle activity on the production of vehicle emissions has been a result of this research.

The operating ranges used in the FTP are ≤ 57 mph for speeds and ≤ 3.3 mph/sec for accelerations. Vehicle activity outside of the operating ranges used in the FTP are termed off-cycle.

Off-cycle accelerations are also termed commanded enrichments. Commanded enrichment events are representative of "aggressive" driving. LeBlanc et al (12) found that a small segment of drivers tend to drive very aggressively and contribute to an "inordinate" amount of the overall pollutants. This statement is supplemented by the results from work done by Austin and DiGenova (13) which found that between two drivers (one aggressive driver and one not aggressive), the aggressive driver produced 15 times more emissions for the entire test trip, even though both drivers' average speeds were nearly identical. Aggressive driving can be a characteristic of the individual driver or may be a forced event resulting from the geometric design of the transportation network. A general case of forced commanded enrichment may be from a metered freeway on-ramp with a short acceleration lane prior to the merge with the freeway mainlanes. LeBlanc et al (12) found that most vehicles spend less than 2 percent of their total driving time in commanded enrichment; however, this 2 percent accounted for up to 40 percent of the total CO emission production. Studies in Los Angeles by Kelly and Groblicki (14) have found that commanded enrichment of a vehicle results in increases of 2,500 and 40 times stoichiometric emission rates for CO and HC, respectively. Clearly, recent research is evidence that off-cycle emissions can cause a great deal of a vehicle's emissions produced on a trip.

Traffic engineers have long recognized the travel benefits of smoothing traffic on arterials by implementing low-cost solutions or coordinating signal systems or removing bottlenecks. With rapid developments in electronic technology, intelligent transportation systems (ITS), formerly termed intelligent vehicle-highway systems (IVHS), may very well have significant impacts on emissions production by reducing the likelihood of turbulent traffic streams and, instead, increase the likelihood of a more laminar flow for traffic. Current emission factor models cannot be used to adequately or accurately predict the emission benefits of traffic flow improvements which smooth the flow of traffic.

Because sketch-planning tools rely on a defined set of logical equations to characterize a project's travel impacts, they fail to accurately predict travel and emission impacts resulting from transportation system measures (TSM). TSM projects are used to modify the transportation system to improve the operating efficiency without influencing a reduction in travel demand. Traffic flow improvements are a set of strategies which are included in TSM. Typically, TSM projects are evaluated with traffic simulation software; however, current traffic simulation software are unable to integrate emission factors for estimating an emission benefit. The results of the modal emission research may have dramatic impacts on the current analysis procedures used to estimate emission benefits of transportation projects, especially those that improve the operation of the transportation system.

TTI CM/AQ EVALUATION MODEL DEVELOPMENT

Arrangements were made with JHK & Associates to enhance the DRCOG CM/AQ Evaluation Model for use in Texas. Further enhancements were then made by TTI to supplement the changes by JHK & Associates. These enhancements and instructions for operating the model are documented in TTI Research Report 1358-1 (15).

The JHK enhancements were not focused on one particular aspect of the model. Several different enhancements were made. First, the model was converted to reference MOBILE vehicle types instead of equivalent vehicle types with different names. This was thought to relieve any confusion while working with the model and MOBILE. Second, the evaluation of NOx was added within the model. DRCOG had concerns for NOx emissions but did not desire to have it evaluated in the original model. Finally, enhancements were made to improve the model-user interaction through the creation of input screens for baseline travel data and MOBILE emission factors. After review by the technical panel, further recommendations were made for enhancements to the model. These enhancements were performed by TTI.

TTI modified the model's PM-10 estimation procedures to provide compatibility with USEPA's PART5 model. Input screens were created for the user to input PART5-generated particulate emission rates. The TxDOT technical panel viewed this as an important enhancement with recent results from studies on public health from particulate matter. Fine particulate matter (2.5-microns and less) generated from combustion sources was found to have a consistent and statistical association with cardiopulmonary mortality (16). USEPA officials note that the results of this particulate study will be taken into consideration when the review of standards for particulate matter are completed in 1997.

Options were also evaluated for ranking the model's output by the final project rating. Due to limitations with the software, the model's output was not able to be sorted by the project rating. Should the procedures be programmed into another software environment, or the foundation software be modified so this function could be programmed, the ability of ranking projects by their overall score should be considered.

TTI CM/AQ EVALUATION MODEL WORKSHOP

In response to the anticipated enhancements to the Denver Regional Council of Governments (DRCOG) CM/AQ Evaluation Model, a workshop was designed and taught on the Texas A&M University campus to introduce and teach the use of this model to Texas engineering and planning professionals. Representation at the workshops ranged from MPOs to state DOT and environmental agencies to transit agencies. Participants were invited from the surrounding states with students attending from Texas, New Mexico, and Louisiana. Representatives from Oklahoma did not attend because they do not have a nonattainment area within their state. The workshop is documented in TTI Research Report 1358-1 (15).

The workshop began with an overview of the CM/AQ program. The overview covered eligible and ineligible projects, funding availability, past obligation history, selected experiences from other states, and an introduction of CM/AQ analysis tools. This discussion was followed by an introduction to the DRCOG CM/AQ Evaluation Model.

An overview of the CM/AQ Evaluation Model introduced the model's available strategies, pollutants examined, and discussion of its modules. Each module was discussed pertaining to its purpose and data flow within the model as a whole. The overview concluded with a discussion of the general model process used by sketch-planning tools, as shown in Figure 1.

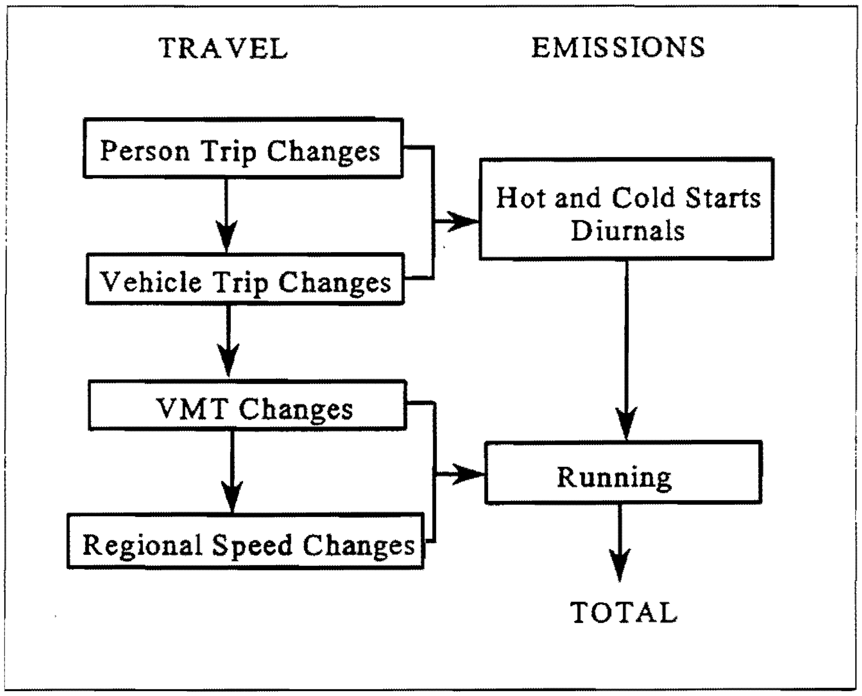

Figure 1 General model process

Data requirements for the CM/AQ Evaluation Model were then presented to the workshop participants. Discussions of travel data focused on defining commute/non-commute trips, time periods, and development of elasticities. Participants were then introduced to methods of developing the emission data. Cold/hot start rate development used in the most recent sketch-planning tools was presented. A comparison of vehicle types used in the model with vehicle types defined by USEPA's MOBILE emission factor model were also made.

After data requirements for the model were discussed, the instructors focused on explaining where and how the required data could be developed. Data sources, such as the Census Transportation Planning Package (CTPP), Nationwide Personal Transportation Study (NPTS), and traditional planning models, were discussed for their relevance in obtaining baseline input values for the model.

The remainder of the workshop was used to familiarize the workshop participants with using the CM/AQ Evaluation Model. Instructors covered basic Paradox commands used in the model. The menu system was also reviewed and explained. Hands-on application of the model taught the participants how to edit Paradox tables used by the model. Throughout the hands-on exercises with the model, fictional projects were input into the model and analyzed. Participants were able to view the results of this analysis and discover how sketch-planning tools work. Examples of CM/AQ projects from Dallas and Houston, Texas, are presented and discussed in Chapter III.

QUICK EVALUATION TABLES

TTI prepared several quick evaluation tables early in this project to quantify some traffic characteristics related to CM/AQ improvements. The various improvements can be divided into two broad categories: improvements which reduce travel delay and improvements which reduce trips or vehicle miles of travel. Improvements which reduce travel delay are typically traffic flow improvements. Table 2-1 presents an overview of the various types of TCMs. This table shows, in general, the expected regional opportunities for emission benefits for each type of TCM.

Traffic flow improvements encompass a variety of projects which can be divided into three groups: traffic signalization improvements, traffic operation improvements, and incident management projects. Table 2-2 shows possible travel benefits from a variety of traffic signalization improvement projects. The table summarizes the results of the Texas Traffic Light Synchronization (TLS) Grant Program. The TLS program was an extensive program which made possible improvements to signal systems across Texas. Though the benefits may vary widely from system to system, the results represent what may be expected from traffic signal improvements. Any project which involves retiming, upgrading, or coordinating traffic signals could produce similar benefits.

Table 2-3 shows the estimated emission changes for traffic signal improvements when only the delay is considered in the emission estimation procedure. Idle emission rates were obtained from NCTCOG for VOC, CO , and NOx (included in Appendix A). The emissions were estimated simply by multiplying the intersection delay per vehicle by the respective idle emission rate to obtain the emissions per vehicle. This method is an oversimplification of the actual conditions in such that average travel delay per vehicle includes the time to decelerate as well as to accelerate from the signal.

Table 2-1
Potential for Regional Emission Benefits Generated from Travel Impacts of Selected TCM Projects

Transportation Control Measures		Opportunity for Regional Emission Benefits					
		Trips (per veh)	VMT (per veh)	Travel Rate (min/mile)			Idling (veh-hours)
				Auto	Transit	Other [1]	
Traffic Flow Improvements	Traffic Signalization	0	0	++	++	++	++
	Traffic Operations	0	0	++	++	++	++
	Incident Management	0	0	++	++	++	++
Improved Transit Facilities	System/Service Expansion	++	++	0	+0	0	+0
	System/Service Operational Improvements	++	++	+0	+0	0	+0
	Demand/Market Strategies	++	++	0	0	0	+0
Intelligent Transportation Systems		+	+	++	++	0	++
Parking/Park-and-Ride		0	++	+0	+0	0	+0
Pedestrian/Bicycle Programs		+	+	0	0	++	0
Employer-based Transportation Management		+	+	0	0	0	0
HOV Lanes [2]		+	+	+	++	0	+

Notes: [1] Travel rate for pedestrian or bicycle alternatives
[2] Project 0-1353 addresses the air quality benefits of HOV lanes

<u>Legend</u>

++	Major regional benefit expected
+	Minor regional benefit expected
+0	Minor regional benefit to no regional change expected
0	No regional change expected
-	Minor regional disbenefit expected
--	Major regional disbenefit expected

Table 2-2
Reported Travel Benefits of Traffic Signalization Improvements

Annual Change in Measure of Effectiveness When Optimizing:	Number of Intersections	Stops/Intersection			Delay/Intersection (vehicle-hours)		
		Before	After	Percent Decrease	Before	After	Percent Decrease
Uncoordinated Arterial with Existing Equipment	75	3,865,772	3,505,442	9.3	88,969	49,512	44.3
Uncoordinated Network with Existing Equipment	230	3,279,470	2,866,323	12.6	32,161	26,020	19.1
Uncoordinated Arterial with New Equipment	103	5,817,553	4,827,612	17.0	65,104	40,408	37.9
Uncoordinated Network with New Equipment	321	3,920,052	3,438,950	12.3	50,466	39,698	21.3
Partially Coordinated Arterial with Existing Equipment	265	7,044,032	5,871,085	16.7	91,903	70,312	23.5
Partially Coordinated Network with Existing Equipment	105	4,328,166	4,125,593	4.7	48,612	35,168	27.7
Partially Coordinated Arterial with New Equipment	249	4,954,948	4,171,615	15.8	47,904	34,341	28.3
Partially Coordinated Network with New Equipment	50	2,873,079	2,388,285	16.9	24,144	17,431	27.8
Coordinated Arterial with Existing Equipment	201	7,497,652	6,102,093	18.6	139,588	90,794	35.0
Coordinated Network with Existing Equipment	501	5,502,368	4,642,856	15.6	66,994	48,159	28.1
Coordinated Arterial with New Equipment	82	4,273,383	3,735,530	12.6	42,637	26,968	36.7
Coordinated Network with New Equipment	126	4,405,603	3,604,385	18.2	42,809	30,375	29.0
Average for All Intersections	2308	5,099,461	4,325,623	15.2	65,026	46,259	28.9

Source: Adapted from (17)

Table 2-3
Estimated Emission Benefits of Traffic Signalization Improvements

Traffic Signal Improvements	Delay per Stop (seconds)			Reduction in Emissions per Stop (grams/delayed veh)		
	Before	After	Percent Decrease	VOC	CO	NOx
Uncoordinated Arterial with Existing Equipment	82.85	50.85	44.3	0.23	3.43	0.08
Uncoordinated Network with Existing Equipment	35.30	32.68	19.1	0.02	0.28	0.01
Uncoordinated Arterial with New Equipment	40.29	30.13	37.9	0.07	1.09	0.02
Uncoordinated Network with New Equipment	46.35	41.56	21.3	0.03	0.51	0.01
Partially Coordinated Arterial with Existing Equipment	46.97	43.11	23.5	0.03	0.41	0.01
Partially Coordinated Network with Existing Equipment	40.43	30.69	27.7	0.07	1.04	0.02
Partially Coordinated Arterial with New Equipment	34.80	29.64	28.3	0.04	0.55	0.01
Partially Coordinated Network with New Equipment	30.25	26.27	27.8	0.03	0.43	0.01
Coordinated Arterial with Existing Equipment	67.02	53.56	35.0	0.10	1.44	0.03
Coordinated Network with Existing Equipment	43.83	37.34	28.1	0.05	0.70	0.02
Coordinated Arterial with New Equipment	35.92	25.99	36.7	0.07	1.06	0.02
Coordinated Network with New Equipment	34.98	30.34	29.0	0.03	0.50	0.01
Average for All Intersections	45.91	38.50	28.9	0.05	0.79	0.02

In the deceleration mode, the emission rates should be similar to the idle rate; however, the emission rates for VOC and CO are probably much higher under acceleration conditions. Recent research, which is discussed under modal emissions in this chapter, has shown that vehicle accelerations result in large increases in emissions compared to emission production during steady state conditions. Considering these emission rate differences, this method can be viewed conservatively depending on the actual time each vehicle spends stopped or idling. This method does not account for impacts from vehicles which are not stopped by the signal. The total number of vehicles or the speeds of vehicles at each of intersections was neither considered for this analysis nor was it reported in the results of the TLS program.

The most typical traffic operation improvements are geometric improvements at signalized intersections. In order to identify the general potential impacts for travel improvements to geometry at signalized intersections, a hypothetical, four-leg intersection of two four-lane arterial streets was analyzed for improvements in delay. For purposes of this example, a 60/40 directional split was assumed on each arterial; and 10 percent of each approach volume turned right and 10 percent of each approach volume turned left. The addition of left-turn lanes, through lanes, and right- turn bays were analyzed separately and in combination using the PASSER II-90 signal optimization program. Modeled improvements were made only on the two approaches of one arterial, though similar approach volumes were used on the crossing arterial street. Three different approach volumes with low, medium, and high volume-to-capacity (v/c) ratios were used to show a range of the potential benefits related to possible intersection improvement alternatives. The results of PASSER II-90 analysis for traffic operations improvements are shown in Table 2-4.

It is important to note that the potential benefits are highly dependent on the intersection and turning movement volumes, as well as the existing geometry of the intersection. For example, in the hypothetical intersection above, the left-turn volume was set at 10 percent of the through volume for each approach. If the left-turn volume were increased, the percent reduction in delay resulting from adding a left-turn bay would increase while the improvements for adding a through lane would be reduced.

Table 2-5 uses the same method to estimate emissions as was used in Table 2-3. The emissions per vehicle were estimated by multiplying the delay per vehicle by an assumed idle emission rate. The percent reduction in each emission corresponds to the same percent reduction in delay estimated in Table 2-4.

Table 2-4
Potential Travel Benefits of Simulated Intersection Improvements[1]

Case	Description of Intersection Improvements[2]	Percent Potential Reduction in Delay		
		Low[3]	Medium[4]	High[5]
1	Baseline (No Turn Bays)	-	-	-
2	Add Left-Turn Bays Only	10	15	50
3	Add Through Lanes Only	15	20	55
4	Add Right-Turn Bays Only	5	10	30
5	Add 2, 3, and 4 Jointly	20	25	65

1 Intersection delay for the example intersection was determined with the PASSER II-90 signal optimization program.
2 All improvements were made on both approaches of one arterial. No improvements were made on the crossing arterial.
3 Low approach volume = v/c < 0.75
4 Medium approach volume = v/c < 0.90
5 High approach volume = v/c > 0.90

Table 2-5
Potential Emission Benefits of Simulated Intersection Improvements

Pollutant	Case	Potential Emission Reduction (grams/delayed veh.)		
		Low[1]	Medium[2]	High[3]
VOC	1	0.10	0.13	0.27
	2	0.08	0.10	0.13
	3	0.08	0.10	0.12
	4	0.09	0.11	0.19
	5	0.08	0.09	0.09
CO	1	1.45	1.88	3.96
	2	1.27	1.57	1.96
	3	1.21	1.45	1.79
	4	1.35	1.70	2.83
	5	1.12	1.38	1.41
NOx	1	0.03	0.04	0.09
	2	0.03	0.04	0.04
	3	0.03	0.03	0.04
	4	0.03	0.04	0.06
	5	0.02	0.03	0.03

[1] Low approach volume = v/c < 0.75
[2] Medium approach volume = v/c < 0.90
[3] High approach volume = v/c > 0.90

Table 2-6 uses simulated model data to demonstrate the difference in benefits for several freeway incident management methods. Incident management includes several project types ranging from mobility assistance to various traffic advisory methods. A spreadsheet program was prepared using the analytical methods outlined by Morales (18). Basic delay equations are used by the program to estimate the delay for various incident management methods. Data input includes roadway capacity, the expected typical flowrates, and the time duration of an incident; and it calculates the expected delay and the time required to return to normal flow. Three incident management options were analyzed for a typical three- and four-lane facility for two cases: (1) an incident on the shoulder and (2) an incident that forces the blockage of a single lane. The table below shows the potential benefits for reduction in delay for each option compared to a base case where no mobility enhancements are in place.

Table 2-6
Potential Travel Benefits of Incident Management Methods: Possible Improvements for Peak-Hour Freeway Flows[1]

Description of Incident Management Method	Percent Potential Reduction in Delay			
	Incident on Shoulder		Incident Forcing Single Lane Blockage	
	3 Lanes[2]	4 Lanes[3]	3 Lanes[4]	4 Lanes[5]
No Incident Management[6]	-	-	-	-
Mobility Assistance Patrols (MAP) Only[7]	30	35	40	30
MAP and Surveillance[8]	50	55	50	45
MAP, Surveillance, and Traffic Advisories[9]	60	60	65	60

1 Assumes each incident to occur 15 minutes into the peak hour, and the vehicle demand after 45 minutes reduces to 80 percent of the initial demand.
2 Assumes an initial capacity of 6600 vph and incident capacity of 5500 vph.
3 Assumes an initial capacity of 8800 vph and incident capacity of 7500 vph.
4 Assumes an initial capacity of 6600 vph and incident capacity of 3300 vph.
5 Assumes an initial capacity of 8800 vph and incident capacity of 5200 vph.
6 Assumes a 25-minute detection and response time and a 25-minute clearance time.
7 Assumes a reduction in detection, response, and clearance time of five minutes each. Five minutes of total closure are assumed to clear the lane blockage and any debris.
8 Assumes an additional reduction in detection time of five minutes.
9 Assumes a 30 percent reduction in the initial demand after 30 minutes due to changeable message signs (CMS) and/or other methods of warning motorists of delay and alternative routes such as highway advisory radio or real-time video displays of traffic information.

The apparent discrepancies for incidents on a shoulder for the percent potential reduction in delay is due to the fact that the capacity is reduced by similar amounts. The capacity is reduced 17 percent for three lanes and 15 percent for four lanes. For a lane blockage, the capacity for three lanes is reduced 50 percent and only 41 percent for four lanes. A greater reduction in capacity results in a greater impact from the benefits of incident management; thus the management of a lane blockage for a 3-lane section yields greater benefits than that of a 4-lane section.

The reduced capacity due to an incident on a shoulder is assumed to occur as a result of motorists slowing as they pass the incident; however, the relationship between speed and capacity is not clear. For example, as speeds slow for such a described incident, the capacity may not change significantly. Considering this, this program may overestimate the total delay for incidents which result in no lane blockage, especially after motorists become more accustomed to mobility assistance patrol (MAP) vehicles or other emergency vehicles at incident locations.

TTI did not prepare detailed tables showing the expected benefits for improved transit facilities, parking/park-and-ride programs, pedestrian/bicycle programs, or employer-based transportation management. The benefits to air quality for these types of improvements are a result of a reduction in the number of trips or a reduction in vehicle distance traveled (VDT). Also, for these types of improvements, it is difficult to define a typical improvement; and insufficient data to evaluate the expected benefits often exist. For example, the success of park-and-ride lots depend on several factors including location, origin and destination of trips through the lot, availability of transit, and the effectiveness of regional rideshare programs (e.g, ridematching or rideshare incentives).

III. ANALYSIS EXAMPLES AND ISSUES

This chapter discusses three aspects of congestion management and air quality project analysis. First, a demonstration of the TTI CM/AQ Evaluation Model is presented. Next, bottleneck improvement analyses are discussed in terms of levels of analysis and concerns with the results of these analysis levels. Presented last is a comparison of two techniques for analyzing the emission impacts of grade separation projects.

The impacts and importance of modal emissions were discussed earlier in Chapter II. The issue is revisited in this chapter with discussions in the three sections on the impacts modal emissions would make in the analysis methods.

TTI CM/AQ EVALUATION MODEL DEMONSTRATION

Introduction

Example projects were chosen from the Dallas/Fort Worth and Houston/Galveston nonattainment areas to demonstrate the applicability of the TTI CM/AQ Evaluation Model discussed in the previous chapter. A park-and-ride lot was selected from the Dallas/Fort Worth area. In Houston, a park-and-ride lot was selected again in addition to a motorist assistance program. Brief descriptions of the projects selected are included in the discussion below.

Required data, both travel and emissions, were developed for both nonattainment areas for this demonstration. Both MPOs, NCTCOG, and Houston-Galveston Area Council (H-GAC) were contacted to develop the required travel data to demonstrate this model. Travel data used for this demonstration are included in Appendix B. Emission data were generated from MOBILE5a and PART5 input files shown in Appendix C. MOBILE5a input files were the same as those used for conformity analyses. TTI developed PART5 input files for these nonattainment areas because they are not in violation of the PM-10 NAAQS standards. Data sources for the PART5 input files included information provided by the Texas Natural Resource Conservation Commission (TNRCC) and guidance contained in the PART5 user's manual (19).

The analysis performed was very similar to the operations and procedures one would use to evaluate potential CM/AQ projects with this model. Examination and discussion of the results are also included to point out model areas where users should understand the processes to make sound judgments on the validity of the model estimates.

Dallas/Fort Worth CM/AQ Projects

A park-and-ride lot in Arlington, Texas, was planned in the 1994 TIP. The goal of this project was to reduce the amount of vehicle miles traveled in the nonattainment area. Park-and-ride lots encourage ridesharing or transit use.

The park-and-ride lot is planned to be built near the intersection of IH-20 and Park Springs Boulevard in south Arlington, Texas. The lot will mix ridesharing (carpools and vanpools) with an independent (private) shuttle service provided by TBS Transportation to the Dallas central business district. TBS Transportation plans to use mini-buses on fixed routes and schedules for peak commute travel. The park-and-ride lot also includes a shelter for protecting travelers from sun and rain. The capacity of the lot is 343 full-size spaces with access for handicapped vehicles. The initial utilization rate (spaces used) of this park-and-ride lot is expected to be 27 percent. Arlington is the largest city situated between Dallas and Fort Worth. IH-20 is a major highway connecting the southern portions of Dallas and Fort Worth. Recent growth in Arlington has occurred near and south of IH-20. These factors make the placement of this park-and-ride lot potentially very successful. The Dallas/Fort Worth area has typically had low participation in ridesharing activities, although efforts are underway to educate the public and encourage ridesharing.

Houston/Galveston CM/AQ Projects

A park-and-ride lot planned for north Houston, Texas, and the implementation of courtesy or motorist assistance patrols (MAP) on freeways in Houston were planned in the 1994 TIP. The goals of these two projects are very different. Park-and-ride lots encourage ridesharing or transit use; whereas courtesy patrols function as tools to prevent non-recurrent congestion on freeways in the metropolitan area, thus improving or maintaining the level-of-service on area freeways.

The park-and-ride lot used in this demonstration is planned to be built near the intersection of Kuykendahl Road and IH-45 in north Houston. The lot is designed to provide 2,244 full-size spaces with handicapped vehicle access. It is situated with access to pubic transit (METRO) and the North HOV lane, one of five HOV lanes in the Houston HOV system. The North HOV lane carries the fourth largest amount of vehicular traffic and the largest amount of person traffic of the five HOV lanes in the Houston area. These statistics and characteristics make the potential impact of this park-and-ride lot on reducing vehicle trips to the Houston CBD very great. The lot was analyzed with a 47 percent utilization rate (used parking spaces), which represented the average utilization rate for the Houston area park-and-ride lots.

Houston's courtesy patrols monitor traffic operations on its major urban freeways. The MAP program currently patrols 150 miles (241 kilometers) of freeway with nine mini-vans (20). These mini-vans operate between 6:00 a.m. and 10:00 p.m., continuously, on non-holiday weekdays. They are equipped to handle minor non-recurrent traffic congestion, such as stalled or disabled vehicles. Each mini-van is equipped with hand tools, gasoline, water, jumper cables, and other items needed to assist motorists. The mini-vans also are equipped with a push-bumper which is used to move stranded vehicles from the travel lanes to the emergency shoulder.

Results

The results of the model demonstration are summarized in the tables below. Complete model output is provided in Appendix B. Table 3-1 shows the model generated travel impacts predicted by the TTI CM/AQ Evaluation Model. Discussion of these results is provided below.

Table 3-1
Model Generated Travel Impacts for Demonstration

Area	**CM/AQ Project**	**Absolute Change (per day)**		**Relative Change (%)**	
		Vehicle Trips	**VMT**	**Vehicle Trips**	**VMT**
Dallas/Fort Worth	Park-and-Ride	-119	-1,995	-0.0020	-0.0021
Houston/Galveston	Park-and-Ride	-1,150	-18,131	-0.0194	-0.0176
	MAP	0	0	0.0000	0.0000

The results from the park-and-ride lots and the MAP program appear to be reasonable. The Dallas/Fort Worth park-and-ride lot was not expected to produce a large impact on the regional transportation system because it has such a small scope. The Houston/Galveston park-and-ride lot did show a larger impact on the transportation system since it has a larger capacity and more established ridesharing programs. As expected, the MAP program produced no changes in vehicle trips or VMT. Reductions in vehicle trips and VMT is not an objective of the MAP program.

Table 3-2 shows the regional speed changes from implementing the selected CM/AQ projects. The courtesy or motorist assistance patrol (MAP) shows the largest impact on improving peak and off-peak regional speeds. The two park-and-ride lots have a minimal effect on regional peak speeds and no effect on the regional off-peak speeds. This is a reasonable result from park-and-ride lots because they are planned to capture commute trips from suburban areas to the urban CBD or other major employment centers. It should be noted that the park-and-ride lot in the Dallas/Fort Worth area is very small and its regional speed impacts so slight that they do not register in this analysis.

Table 3-2
Model Generated Percent Change in Peak and Off-Peak Speeds

Area	CM/AQ Project	Percent Change (%)	
		Peak	Off-Peak
Dallas/Fort Worth	Park-and-Ride	0.0000	0.0000
Houston/Galveston	Park-and-Ride	0.0004	0.0000
	MAP	0.0260	0.0260

Table 3-3 displays the predicted reduction in mobile source emissions from implementation of the selected CM/AQ strategies in this model demonstration. The percent reduction in mobile source emissions from baseline values is shown in Table 3-4. After review of the estimated emission reduction, the reductions in particulate (PM-10) emissions appear to be overestimated. Review of the PM-10 analysis procedures shows that they are very sensitive to (1) reductions in VMT and (2) the fugitive dust rate of paved and unpaved roads. For example, the fugitive dust rate for paved roads in Houston was 8.01 grams per mile which is approximately equivalent to the VOC rate at 5.4 mph. Because each vehicle mile traveled which is removed is subject to a fugitive dust reduction, it can be seen that this rate has a dramatic effect on the estimation of PM-10 emission reduction. Initial perception of the paved road fugitive dust rate was thought to be high, and this inference is reinforced by the results shown below.

The only increase in NOx emissions is evidenced by the MAP strategy. This is due to the increases in regional speed for the peak and off-peak periods as a result of the MAP program. It should be noted that this result is probably incorrect. The MAP program will significantly reduce emissions in the highly localized area of an incident, and then the overall effect for the region will be positive. However, under a macro model average-speed methodology, there appears to be an increase in speed and, thus, emissions. This is the danger in using this or any model based on average speeds. The reported PM-10 impact of no emissions reduced is correct because the MAP program does not reduce VMT and, therefore, will not impact PM-10.

Table 3-3
Model Generated Reduction in Mobile Source Emissions

Area	CM/AQ Project	Reduction in Mobile Source Emissions (kg/day)			
		CO	VOC	NOx	PM-10
Dallas/Fort Worth	Park-and-Ride	48.3	6.0	5.1	939,969.3
Houston/Galveston	Park-and-Ride	363.4	40.5	43.5	1,019,477.6
	MAP	14,807.4	1,493.4	-340.2	0.0

Table 3-4
Model Generated Percent Reduction in Mobile Source Emissions

Area	CM/AQ Project	Percent Reduction			
		CO	VOC	NOx	PM-10
Dallas/Fort Worth	Park-and-Ride	0.0022	0.0022	0.0020	19.6242
Houston/Galveston	Park-and-Ride	0.0192	0.0190	0.0170	19.6046
	MAP	0.7826	0.7004	-0.1332	0.0000

Results of the criteria weighting module for this model demonstration are shown in Table 3-5. All three projects were evaluated with the goal of achieving early project effectiveness to ensure consistent analysis between the projects. It can be seen that two of the three projects used in the demonstration achieved the highest rating in the cost-effectiveness. Only the MAP program scored a point in travel impacts; however, it did not score points for emission impacts. This may be attributed to the erroneous increase in NOx emissions. The bottleneck removal analysis example problem in the next section of this chapter, provides a clearer description of the problem with average speed calculations on a macro basis.

Table 3-5
Model Generated Criteria Weighting Results

Area	CM/AQ Project	Travel	Emissions	Cost-Effectiveness	Early Effectiveness	Total Score
Dallas/Fort Worth	Park-and-Ride	0	2	30	10	42
Houston/ Galveston	Park-and-Ride	0	2	30	10	42
	MAP	1	0	18	10	29
Maximum Scores		30	30	30	10	100

Remarks

Development of baseline travel values usually requires the use of a travel demand model to develop elasticities, VMT estimates, and information on trip making. Travel demand models were used by the MPOs for this demonstration to develop estimates of regional VMT, vehicle trips, and person trips by the peak and off-peak periods. The travel demand models can also act as a test bed to determine regional elasticities for such data as speed with respect to volume or as transit use with respect to cost. Inevitably there will be data, either baseline or project specific, where some assumption must be made to satisfy the analysis requirements.

Assumptions were made throughout the analysis from baseline travel variables to TCM-specific data. These assumptions dealt with missing data which could not be provided by the respective MPOs and for elasticities used in the analysis. For example, the elasticity of speed with respect to volume is used in most sketch-planning tools to estimate the change in regional speeds by using changes in regional VMT. It is assumed that the VMT parallels volumes found on the transportation system; and, therefore, relative changes in VMT would approximate relative changes in traffic volumes on streets and highways in the metropolitan area. When these data are not derived from traditional data sources and assumptions are made for analysis purposes, there exists a potential for erroneous results from any model and require the judgment of the transportation professional to determine if the estimates are reasonable.

It becomes readily apparent from the discussion above that the use of sketch-planning tools is for a rapid evaluation of a project's potential emission benefit. The results of these sketch-planning tools may not be accurate but may be precise in nature. They will allow the user to see if a project will have a negative or positive impact on the transportation system. In some cases, the sketch-planning tools may also provide a reasonable magnitude of the benefit experienced.

Neither this model nor any other sketch-planning tool used today can account for modal emission changes from project implementation. Modal analysis would be most beneficial on the evaluation of the MAP program of the three projects selected for this model demonstration. The TTI CM/AQ Evaluation Model handles this strategy by requiring the user to input the expected regional speed change as a result of this program being implemented. Experience and good professional judgment is required to make an accurate estimate of these effects. A MAP program would be better evaluated by investigating the effects it has on smoothing traffic through reductions in vehicle idling and hard accelerations. These characteristics of a program truly evaluate the merits of a project without the use of very general measures describing obscure but relevant performance measures. As new research on modal emissions becomes readily available, those results can be incorporated into the update or development of sketch-planning tools. The greatest potential of modal emission data may lie with the use of traffic simulation models, which are able to model the microscopic characteristics of vehicle flows.

FREEWAY BOTTLENECK REMOVAL ANALYSIS

Introduction

The mobile source emissions impacts of freeway bottleneck improvements were researched in a project sponsored by the Southwest University Transportation Center (SWUTC) titled "Energy and Air Quality Benefits of Freeway Bottleneck Improvements" (28). This research investigated the relationships between traffic operating characteristics and environmental factors such as fuel consumption and vehicle emissions (hydrocarbons, carbon monoxide, and oxides of nitrogen) when freeway bottlenecks are relieved and traffic conditions are improved. The primary goal of this research project was to develop a method for estimating the fuel consumption and emission benefits for any freeway bottleneck removal project.

Freeway bottlenecks are geometric design constraints in short sections which reduce the overall capacity of the freeway by forcing stop-and-go (or turbulent) operation. This operation is known to cause increases in fuel consumption, vehicle emissions, and motorist delays, as well as vehicle breakdowns and accidents. Bottlenecks create recurrent congestion which should not be confused with non-recurrent congestion caused by incidents or construction.

The Dallas District of TxDOT has funded and implemented many freeway bottleneck improvement projects to reduce the negative effects of bottlenecks. These improvement projects are known to provide significant benefits in terms of increased vehicle speeds and reduced motorist delays; however, little information exists on quantifying air quality benefits associated with the implementation of bottleneck improvement projects. The premise of bottleneck improvement projects is to reduce congestion and eliminate stop-and-go traffic so that vehicles will be able to operate at a more uniform speed, closer to free-flow operation. The resulting operational improvement should reduce vehicle emissions.

Freeway bottlenecks result from some element of the facility having a higher demand than its physical capacity. What differentiates these congested sections from overcapacity freeway corridors is that often a low-cost improvement over a short section of the freeway, such as restriping a merge or converting a shoulder to add an additional lane, can significantly relieve congestion. TTI studied several bottleneck improvement projects implemented by TxDOT. Volume and travel time data was collected at these study locations prior to and after project implementation. This before-and-after data was reduced to determine the travel time savings realized by the motorists, which is the primary benefit from freeway bottleneck improvement projects. The before-and-after volume and travel time data was then used, although not planned for originally, to estimate the secondary benefits of reduced vehicle emissions.

For this project, the emissions were analyzed using an average travel speed methodology. This method, shown in the equation below, uses an emission rate, for a specific average travel speed, multiplied by vehicle distance of travel to estimate the total emissions of the freeway section.

$$EM = (VOL)(L)(EF_{speed})$$

where:

EM	=	Emissions produced in section (grams)
VOL	=	Traffic volume through section
L	=	Length of section (unit distance)
Ef_{speed}	=	speed-sensitive emission factor (grams/unit distance).

Emission rates were obtained from the NCTCOG (included in Appendix A). NCTCOG provided 1993 MOBILE5a emission factors for Dallas County and Tarrant County freeways for eight vehicle types and a vehicle composite for a typical summer day.

The results of this methodology did not produce satisfactory results. Examination of the results did not appear consistent with knowledge about traffic impacts associated with bottleneck improvement projects. The poor results of the emission estimates are primarily due to the average travel speed methodology. The average travel speed methodology does not account for the change in speed or frequent accelerations of stop-and-go driving that are eliminated by bottleneck improvements, though the available data for this analysis only allowed the average travel speed to be determined. Another problem with this method, discussed below, may be that the emission rates are inadequate.

Transportation officials agree that VOC and CO emissions from mobile sources are underestimated by existing mobile source models (22). It is believed that a significant source of emissions underestimation is that the test procedures used to develop the emissions rates do not fully represent actual driving conditions. The source and impact of modal emissions was previously discussed in Chapter II.

Description of Project Location

One of several bottleneck improvements examined for this project is discussed below. The results of the other bottleneck improvement projects were similar and are documented in the research report, *Energy and Air Quality Benefits of Bottleneck Improvement Projects* (21). The bottleneck selected for discussion here was implemented on IH-35E (Stemmons Freeway), between the Loop 12 /IH-35E merge and the IH-635 (Lyndon Baines Johnson Freeway)/IH-35E interchange. Figure 2 shows the northbound lane configurations of IH-35E before and after the bottleneck removal.

Before the improvement was implemented, traffic during the evening peak period was subject to recurrent congestion on the Loop 12 approach prior to the merge with IH-35E and on IH-35E from the merge through to the diverge at IH-635. The primary improvement consisted of a fifth lane being created on the inside shoulder of the IH-35E northbound main lanes between the interchanges, which eliminated the recurrent congestion and allowed freeflow speeds through the corridor during the evening peak period. A travel time analysis of this bottleneck improvement showed a benefit-cost ratio of 36 to 1.

Benefit Analysis

The travel times through the bottleneck were determined using a single vehicle traveling in the traffic stream, which recorded the travel time through the corridor every 15 to 30 minutes. By using the known distance between travel time checkpoints, the average travel speed of the traffic stream was measured. The volume through each section of the corridor was measured from both manual and automatic traffic recorder counts. The volume on the mainlanes of a corridor was manually counted, and the downstream or upstream volume was calculated using the automatic counts on the entrance and exit ramps along the corridor. The volumes were counted and recorded every 15 minutes for both the morning and evening peak periods. Only the volumes recorded before the bottleneck improvement are used to estimate the benefits. Any increase in volume after the improvement is ignored because these trips are assumed to be diverted from other alternate routes.

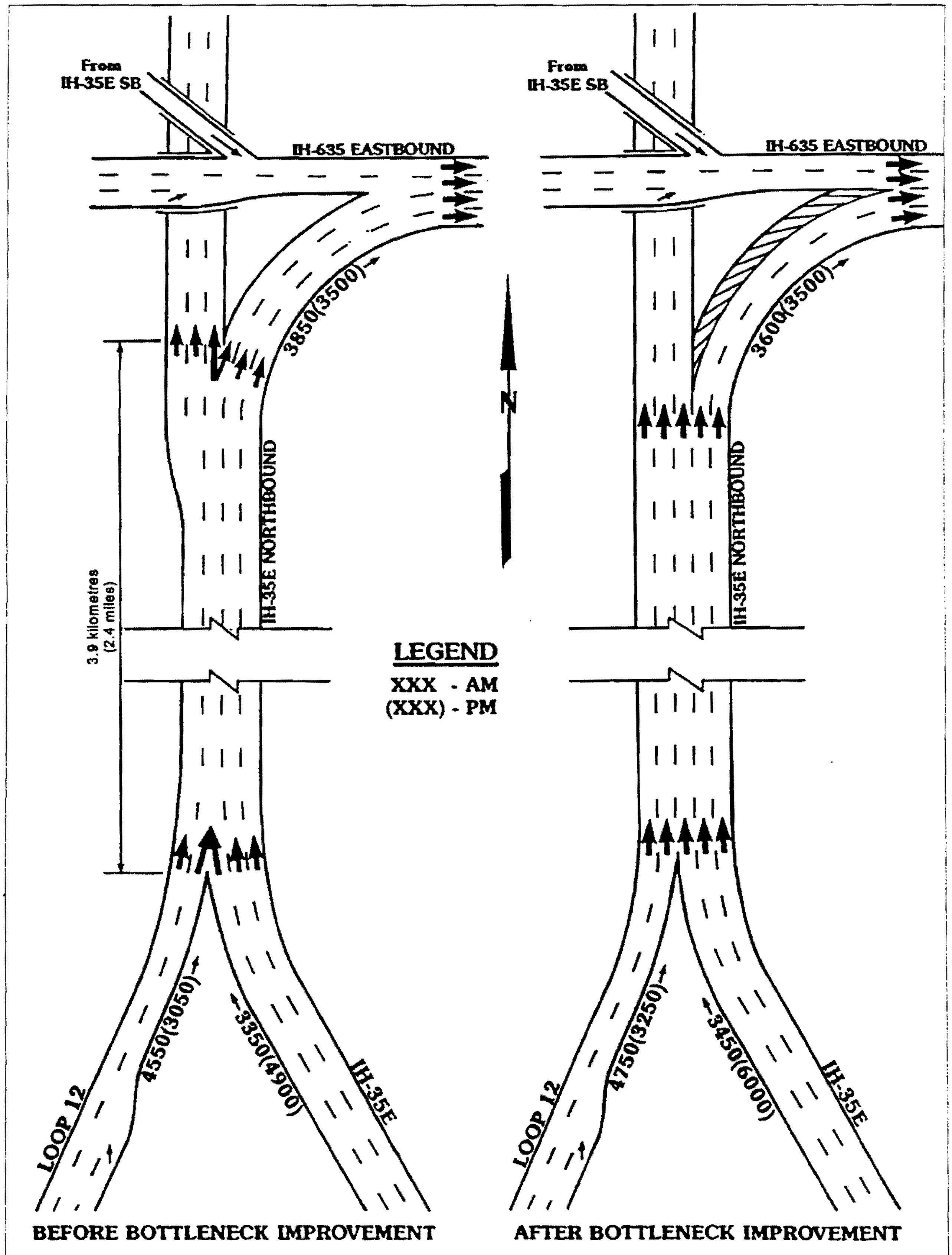

Figure 2 **Bottleneck Improvement Project**

Analysis Method 1

Initially, the average travel speed was determined for the entire corridor to use with the average speed method. Figure 3 shows the before and after average travel speeds through the IH-35E corridor for the 15 minute period from 5:00 p.m. to 5:15 p.m. in the evening. The emission changes for each 15 minute period in the evening peak period from 3:30 p.m. to 7:00 p.m. were determined by multiplying the specific emission rate for the average speed by the known distance and the original volume traveling through the corridor. Vehicles that did not travel completely through the corridor were not included in the analysis, though additional vehicles entering part way through the corridor benefited from the reduced congestion as well.

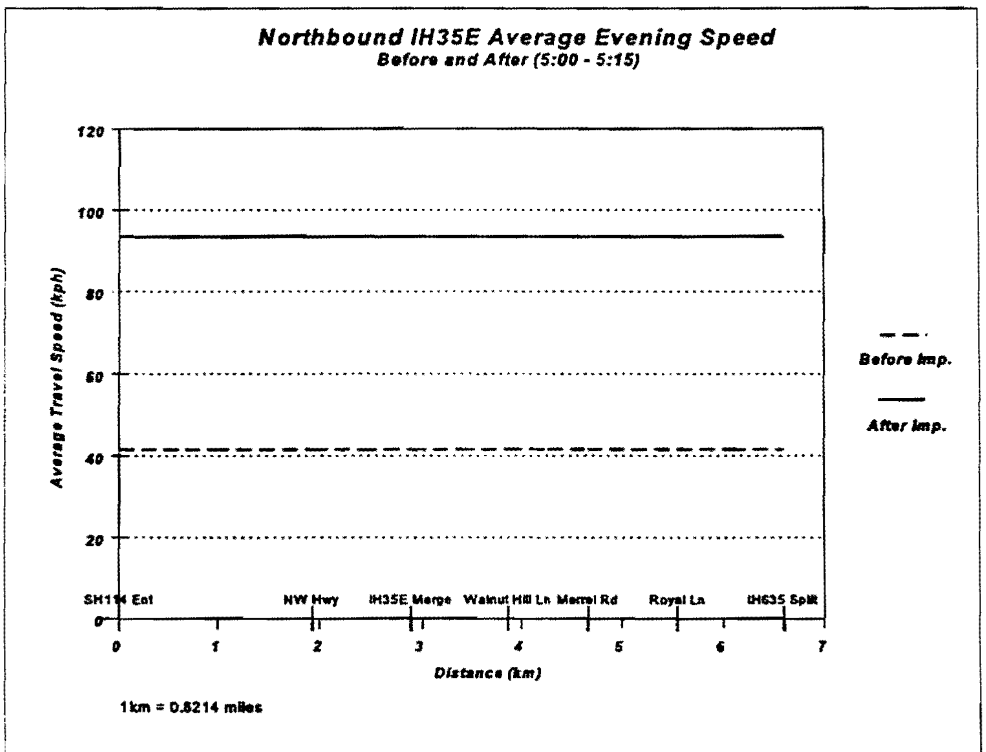

Figure 3 **Method 1 Analysis of Freeway Bottleneck Improvement Project**

VOC and CO emissions are expected to decrease for bottleneck improvement projects; however, a slight increase in NOx emissions is also expected. These expectations are based on emission versus speed curves and vehicle operating characteristics. For instance, at higher average speeds, the vehicle flow is stabilized and production of VOC and CO is decreased. At low average speeds, the vehicle flow is unstable with a high variation in speeds which shows as an increase in VOC, CO and NOx emissions. Also, at high speeds approaching the speed limit (88 kph) all emission rates show a steady increase; however, NOx emissions begin increasing at average speeds above 50 kph.

The results of the Method 1 analysis is shown in Table 3-6. VOC emissions are shown to decrease; however, CO emissions are shown to increase, which is counter-intuitive to the operations of a relieved bottleneck. NOx emissions increased as was expected; however, the increase appears to be greater than expected.

Table 3-6
Comparison of Average Speed Methodologies

Pollutant		Method 1	Method 2
VOC	Change (kg)	-9.60	-11.00
	Percent Change	-11.4	-12.3
CO	Change (kg)	+116.10	+57.00
	Percent Change	+17.5	+6.4
NOx	Change (kg)	+32.50	+19.70
	Percent Change	+32.5	+16.0

Analysis Method 2

Because Method 1 produced results counter-intuitive to the known travel benefits of bottleneck improvements, a more discrete method using all the available data was developed. In order to analyze the emissions of the bottleneck improvement, the corridor was divided into several sections for the purpose of recording the travel time and changes in volume. The sections were defined by the existing checkpoints used in recording the travel time data. The checkpoints are also located where changes in volume occur. Each section was about 1.0 km in length. The average speed for each section was determined for 15-minute time periods. A shorter time period and a shorter section of corridor may provide more accurate results, but it would require more detailed data to be collected. Figure 3 shows the before and after travel speeds for each section through the IH-35E corridor for the 15 minute period from 5:00 p.m. to 5:15 p.m. in the evening. The same volumes are used in both methods for comparison, though more accurate results could be expected if the 15 minute volume for each individual section were used. The results of Method 2 are also shown in Table 3-6.

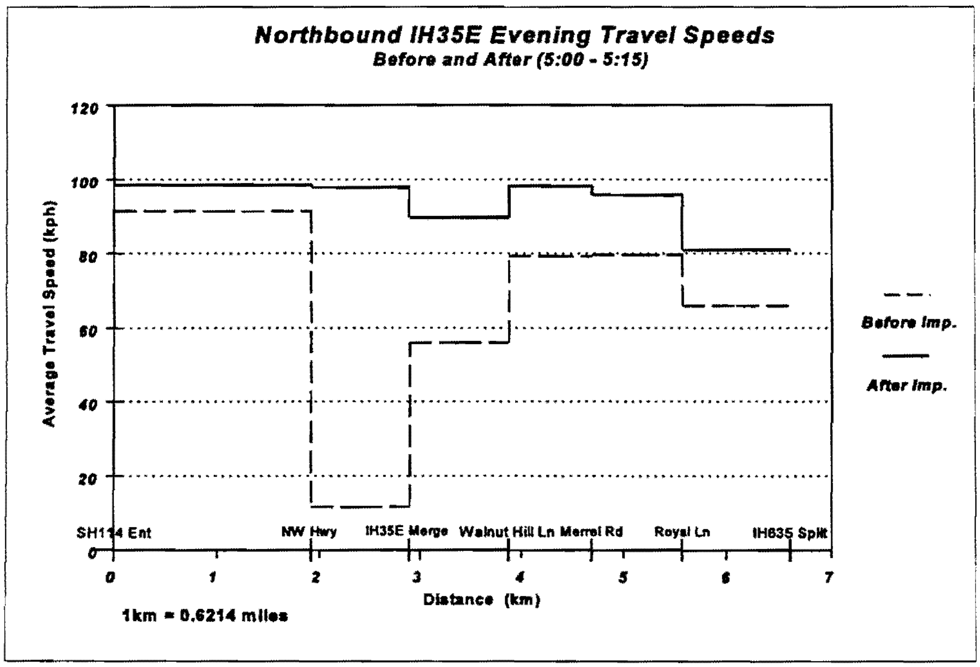

Figure 4 **Method 2 Analysis of Freeway Bottleneck Improvement Project**

The expected changes in emissions are the same as described in Method 1 above. The Method 2 results show a larger decrease in VOC emissions than in Method 1. This decrease appears logical when the critical bottleneck section experiences a large increase in travel speed. CO and NOx emissions are also decreased in this analysis case versus results from Method 1. Although CO emissions were reduced from Method 1 to Method 2, these emissions remain contradictory to expectations of vehicle operating behavior in a relieved bottleneck, where reduced idling and increased speeds should result in decreases in CO emissions.

The Method 2 analysis method does not fully account for changes in stop-and-go traffic because the section lengths used may be too long to capture the significant changes in erratic vehicle operations (lower speeds and enriched events) than an average speed of 12 kph as shown in Figure 4. Noting the differences between Figures 3 and 4, one can see that the traffic and emission problem area is clearly defined in Method 2 (the section of IH-35E between NW Highway and the merge) and the highest benefit of bottleneck relief is achieved at that point.

Issues/Concerns

As noted above in Methods 1 and 2, the average travel speed methodology cannot account for enrichment events eliminated by traffic improvements. Another methodology to measure emissions is envisioned to use second-by-second travel data, or "modal data," and emission rates from improved mobile source models. The before-and-after data for the bottleneck improvement discussed above were not collected for emission analysis purposes. The equipment for collecting modal data has now been developed and is used by TTI in Houston to monitor the performance of the HOV system. The modal data are collected in the same manner as the traditional travel time data with a single probe vehicle moving with the traffic stream (floating car) or following a randomly selected vehicle. The equipment measures the spot speed of the vehicle at a fixed time interval set by the operator, usually every half-second or second. The data are saved digitally to a computer disk and can then be loaded into a spreadsheet program to create detailed speed-time profiles. This method assumes that all vehicles in the corridor are operating in the same manner as the data collection vehicle. Regardless, this is a much more accurate representation of a traffic flow than the average travel speed method.

For traffic flow improvements that smooth the flow of traffic and raise the average travel speed, it is important that modal data be collected. It is not possible to accurately determine the changes from eliminating the accelerations from stop-and-go driving or enrichment events using traditional methods. At the present time, models to make use of modal data do not exist, but research is ongoing to improve mobile source models.

Theoretical Analysis

A simplified bottleneck example was analyzed in the same manner as the bottleneck described above to show what results should be expected, if data could be collected optimally, even without the benefit of modal emission factors. The theoretical bottleneck is assumed to be on an urban freeway with an adjacent arterial street that can be used as an alternative route. The section of freeway impacted by the bottleneck is 7.2 km in length. The average peak-hour speeds approaching and departing the bottleneck queue are freeflow or 88 kph. The average speed in the bottleneck queue is assumed to be 8 kph. A bottleneck removal project is assumed to increase the average speed through the section to freeflow or 88 kph. Figure 5 shows the peak-hour vehicular speed-distance profiles on the freeway before and after the bottleneck improvement and on an equivalent length of the adjacent arterial.

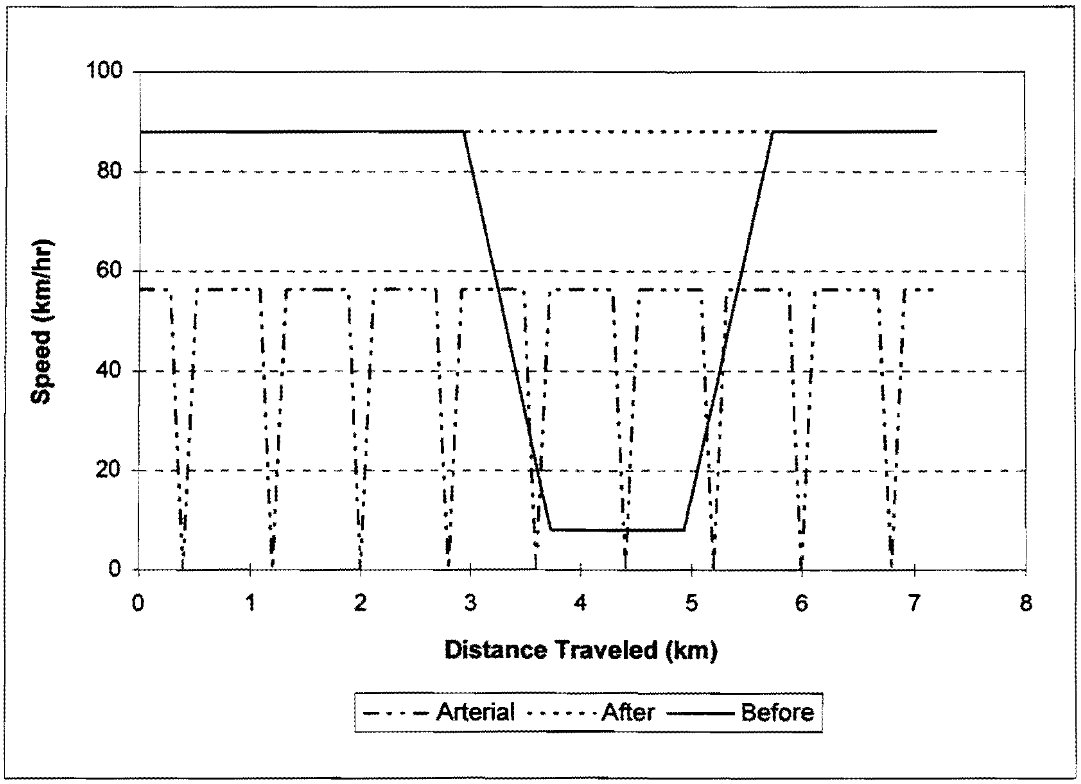

Figure 5 Speed-Distance Profile for Theoretical Bottleneck Improvement

The before speed profile shows five distinct phases through the bottleneck: an approach cruise phase, a deceleration phase, a stop-and-go (turbulent) phase, an acceleration phase, and a departing cruise phase. An average speed can be estimated for each phase, and emissions can then be estimated using the average speed methodology and the MOBILE5a emission rates contained in Appendix A. Table 3-7 below shows the estimated emission impacts per vehicle of the bottleneck improvement.

Table 3-7
Potential Change in Emissions for Theoretical Bottleneck Improvement

Pollutant	Emissions (grams per vehicle)			% Change
	Before Improvement	After Improvement	Difference	
VOC Emissions	15.5	7.4	-8.1	-52.1
CO Emissions	129.2	57.1	-72.1	-55.8
NOx Emissions	13.0	13.7	+0.7	+4.9

For the existing bottleneck that was analyzed earlier in this chapter, it was not possible to estimate the emission changes for vehicles that diverted from alternate arterial streets to the improved freeway; however, for this example, the conditions on an adjacent alternate arterial street can be theoretically estimated. A signal spacing of 0.8 km was assumed on the arterial street. Each signal was assumed to operate with a 30 percent green time on each two-minute cycle for the through movements. This assumption equates to an average of 42 seconds of delay per stopped vehicle. About 30 percent of the vehicles will pass through each signal during the green time at 56 kph. In this example, an assumption of nine signals along the arterial for an equivalent section length of 7.2 km was made.

Figure 6 shows the speed-time profile of the data shown in Figure 4. It is important to note that the speed-time profile for the arterial street shows a stop at each of the nine signals for a total travel time of 16.2 minutes over 7.2 kilometers; however, only 70 percent of the vehicles will be stopped at any given signal. The weighted average travel time on the arterial was calculated to be 13.6 minutes, which is slightly less than the bottlenecked freeway. Vehicle operation through a signalized intersection is similar to operation in a bottleneck; five phases can be identified at each signal, although the bottleneck's turbulent phase is represented by a complete stop or idle phase at a signalized intersection. The emissions for each phase except the idle phase can be estimated using the average speed method. To estimate the emissions during the idle phase, the idle time is simply multiplied by an idle emission rate in grams per second to arrive at emissions in terms of grams per vehicle. The idle emissions were obtained from NCTCOG and are from the same MOBILE output as the running emission rates used for the average speed method shown in Appendix A. Table 3-8 below shows the change in emissions per diverted vehicle from the arterial to the improved freeway. The table shows that the increase in traffic on the freeway, as a result of the improvement, also contributes to a reduction in emissions.

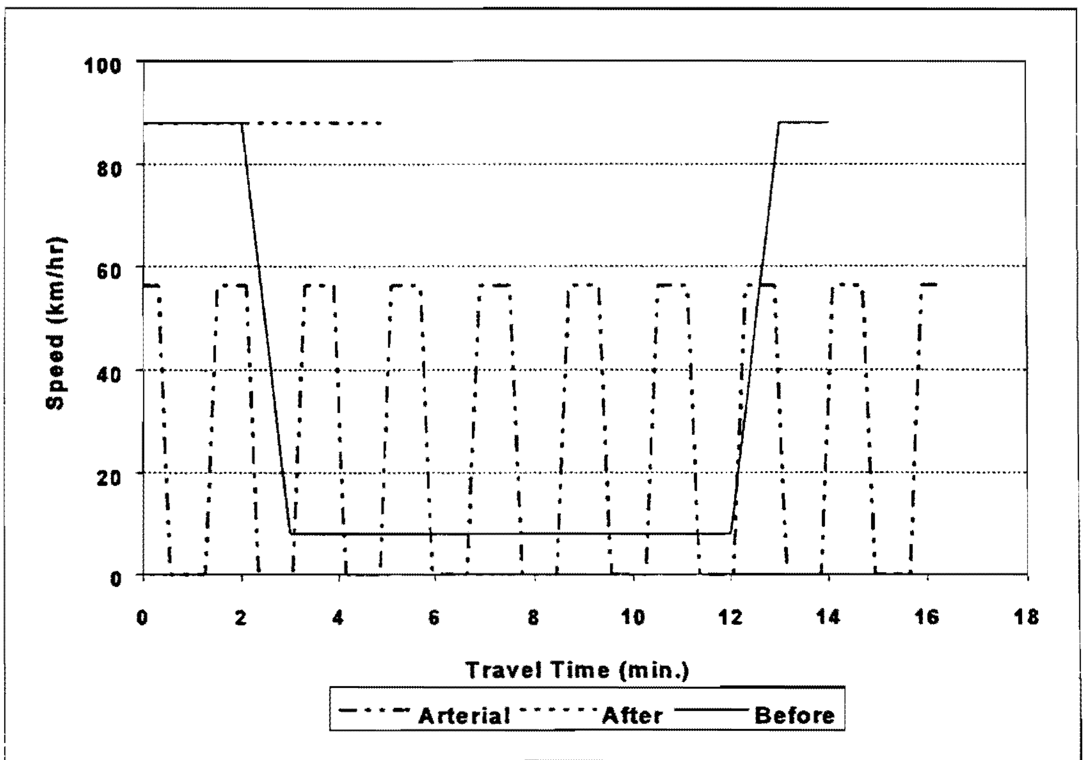

Figure 6 Speed-Time Profile for Theoretical Bottleneck Improvement

Table 3-8
Potential Change in Emissions for Diverted Vehicles

Pollutant	Diverted Vehicle Emissions (grams per vehicle)			% Change
	Before Improvement on Arterial	After Improvement on Freeway	Difference	
VOC Emissions	12.4	7.4	-5.0	-40.2
CO Emissions	110.4	57.1	-53.3	-48.3
NOx Emissions	11.3	13.7	+2.4	+21.6

For this example, if 20 percent of the vehicles on the freeway after the bottleneck is improved are assumed to divert from the arterial street then on a weighted average basis, the total change in VOC emissions per vehicle will be -49.7 percent, the total change in CO emissions per vehicle will be -54.3 percent, and the total change in NOx emissions per vehicle will be +8.2 percent. It can be seen from this theoretical example that VOC and CO emissions can have a large potential reduction for traffic flow improvements, even using the available average speed methodology. However, the VOC and particularly the CO reductions are expected to be significantly higher when the effect of eliminating accelerations out of a bottleneck queue or leaving a signal can be incorporated.

It is important to note that traffic flow improvements such as bottlenecks should be analyzed using either the same volume for before and after conditions or on a per vehicle basis. Often traffic flow improvements result in reclaimed capacity in the immediate area of the project, and the localized increase in traffic volume should not be confused with an increase in demand or in overall trips. Traffic flow improvements do not necessarily alter the number of trips made in a region, and any increase in vehicle activity, through a relieved bottleneck for instance, is a result of traffic diversions from alternate routes or a temporal shift in traffic demand.

COMPARISON OF GRADE SEPARATION ANALYSES

A comparison of analysis procedures used to estimate emission benefits of grade separated intersections was performed at five locations in Victoria, Texas, as part of conformity requirements. The two sketch-planning methods reviewed included one procedure developed by NCTCOG and the other procedure developed by TxDOT. The grade separation analysis used forecast vehicle volumes on the transportation network links feeding into each sample intersection. The analysis also uses time-specific emission factors for generating daily emission benefits.

Project Descriptions

Five locations were analyzed for grade separation improvements. The locations, defined by node numbers from the 2015 Victoria, Texas, Transportation Network, are shown in Table 3-9. Nodes 203 and 620 do not currently exist; construction of these two intersections is planned before the year 2015. The existing traffic control at the remaining three intersections is also shown in Table 3-9.

Table 3-9
Present Traffic Control at Project Locations

Node	Intersection	Present Traffic Control	Notes
203	Loop 463 at FM 1685	None	Construction planned
219	US 77 at Loop 175	Four-way STOP	None
602	Loop 463 at Salem Road	Two-way STOP	Control on Salem Road
608	Loop 463 at Airline Drive	One-way STOP	Control on Airline Drive
620	Loop 463 at SH 236	None	Construction planned

The analysis described here assumes that each of the intersections progresses through the levels of traffic control devices ending with traffic signal control, prior to constructing the grade separated interchange.

The 2015 forecast volumes for each approach at each of the project locations are provided in Table C-1 in Appendix C. These forecast approach volumes are divided into four time periods defined in TTI Report 1375-3 (23) and shown in Table 3-10. The projected volumes were then adjusted for seasonal variation and scaled using Highway Performance Monitoring System (HPMS) factors per procedures detailed and used in TTI Report 1375-3 (23).

Table 3-10
Time Period Designation

Time Period		Time
TP1	Morning Peak Hour	7:15 a.m. - 8:15 a.m.
TP2	Midday	8:15 a.m. - 4:45 p.m.
TP3	Afternoon Peak Hour	4:45 p.m. - 5:45 p.m.
TP4	Overnight	5:45 p.m. - 7:15 a.m.

The estimated daily emissions for Victoria County were previously reported in TTI Report 1375-3 (23). The estimated daily baseline emissions for Victoria, Texas in Summer 2015 are shown in Table 3-11. These values provide a baseline to measure the effectiveness of the five grade separation projects in this analysis.

Table 3-11
Daily Baseline Emissions
Victoria, Texas, for Summer 2015

Pollutant	Daily Baseline Emissions	
	lbs per day	kg per day
VOC	7,273	3,299
CO	53,610	24,317
NOx	13,284	6,026

Procedures

Both the NCTCOG and TxDOT methods were used to estimate the emission reduction potential of the grade separation projects. The NCTCOG procedure has previously been used to demonstrate conformity in the Dallas/Fort Worth TIP. TxDOT outlined the method in their CM/AQ Analysis Methodology informational procedures.

The NCTCOG method emission reductions were computed from the following equation:

$$EM_R = (VOL_{2\text{-}way,\ 24\text{-}hour})\left[(DIR_{split})(PHF)(HRS_{peak})\right](L_{appr})(\Delta EF)(QUAN)(PERCENT)$$

where:

EM_R	=	emission reduction
$VOL_{2\text{-way, 24-hour}}$	=	total 2-way approach volume at intersection
L_{appr}	=	approach distance in miles
ΔEF	=	change in emission factors, *f(speed)*
QUAN	=	number of locations per project
PERCENT	=	spending of project funds through 1996 (for partial benefit in preceding years)
PHF	=	peak hour factor
HRS_{peak}	=	total number of hours in AM and PM peak periods
DIR_{split}	=	directional split (converts 2-way volumes to 1-way)

The total 2-way approach volumes are computed by summing the approach volumes for all legs of the at-grade intersection and dividing by 2, as shown in the equation below:

$$VOL_{2\text{-}way,\ 24\text{-}hour} = \frac{\sum_{i=1}^{n} VOL_{appr,\ 24\text{-}hour}}{2}$$

NCTCOG used the emission reduction equation to determine the emission reductions in the peak period only. NCTCOG did not expect a substantial increase in emission savings during the off-peak period and, therefore, did not compute emission benefits for that time period.

TxDOT developed an empirical equation to be used for a variety of intersection improvements including grade separations. The equations are outlined below:

$$EM_{no\ build} = (EF_{no\ build})(VOL_{appr,\ peak})(L_{appr})(HRS_{peak})$$

$$EM_{build} = (EF_{build})(VOL_{appr,\ peak})(L_{appr})(HRS_{peak})$$

where:

$EM_{no\ build}$	=	emissions per day from no-build scenario
Em_{build}	=	emissions per day from build scenario
$EF_{no\ build}$	=	emission factor for no-build speeds
Ef_{build}	=	emission factor for build speeds
$VOL_{appr,\ peak}$	=	peak-hour 4-way approach volume
L_{appr}	=	length of approach (miles)
HRS_{peak}	=	hours in peak period

The emission reduction for the project would be determined from the difference between the build and no-build scenarios ($EM_{benefit} = EM_{build} - EM_{no\ build}$). The peak-hour approach volume is calculated from the sum of the peak-hour approach volumes for each leg of the intersection.

The NCTCOG method was used in this analysis to estimate the 24-hour and peak-period emission reductions from the projects. The 24-hour period was segmented into four time periods according to the time periods previously defined. The TxDOT method was used to calculate only the peak-period benefits of emission reductions.

Listed below are the assumptions used in this analysis. Data for the analysis were taken from work performed through Project 1375 ("Develop Air Quality Data for Federal Submission") as part of the conformity analysis of the Victoria 2015 metropolitan transportation plan (MTP).

Assumptions

1) Peak speeds increased from 15 mph before the improvement to 30 mph after the improvement during the peak periods. This speed represents the average travel speed through

the intersection and partially accounts for intersection delay incurred by traffic control devices.

2) Approach distance to the intersection was 0.11 mile. The distance represents the minimum approach distance length for all intersections on all legs. Several intersection legs have approach distances greater than 0.11 mile. The range of approach distances for these intersections was 0.11 mile to 1.97 miles.

3) Emission factors are specific to time periods analyzed. The MOBILE5a control flag settings and VMT mix are shown in Appendix D for time periods 1 through 4, respectively.

NCTCOG-Specific

This method required several additional assumptions. These assumptions included peak-hour factors (PHF), directional splits, and assumed speed changes.

The PHF used in this analysis was taken from TTI Research Report 1375-3 (23). The factors are provided in Appendix C for each of the time periods. The directional split for each time period was also taken from TTI Research Report 1375-3 (23), except for the overnight period where a 0.50 directional split was assumed. The values for directional split are also provided in Appendix D.

Additional speed changes from the projects were required to assess the interchanges for a 24-hour period. Assumed speed changes in the midday and overnight time periods are 20 mph to 30 mph and 25 mph to 30 mph, respectively. The "before" speeds are higher than the peak period because the intersection should not be operating at capacity in off-peak hours. The overnight before speed is higher than the midday speed because volumes at these intersections should decrease into the night and increase into morning.

TxDOT-Specific

Each peak period was analyzed separately using the PHF determined as part of Project 1375 ("Develop Air Quality Data for Federal Submission") and presented earlier.

Results

Emission reduction estimates are provided for the five locations using both methods. The NCTCOG method was used to estimate the 24-hour benefits. Both the NCTCOG and the TxDOT methods were used to estimate the peak-period benefits. Samples of the spreadsheet analysis are included in Appendix F.

The 24-hour period NCTCOG results are shown below in Table 3-12 for reference. The emission reductions are reported in grams of pollutant reduced per day. A noticeable trend is that as intersection volumes increase, a greater emission reduction is estimated. This is a logical trend because as intersection volumes increase, more vehicles experience the predicted average travel speed increase, thus increasing the emission benefit of the grade separation project.

The combined AM and PM peak-period emission reduction estimates are shown in Table 3-13. The two peak periods were combined to show the total peak-period emission reduction from the grade separation projects. The TxDOT method results are approximately three times greater than the estimates provided from the NCTCOG method.

Tables 3-14 and 3-15 show the relative emission reduction of these projects per day with respect to the results presented in Tables 3-12 and 3-13. It can be seen that the benefits of these five projects have little impact on the regional emissions of the area.

Table 3-12
NCTCOG Method Results (24-Hour Period), Summer 2015

Project Location	24-Hr 2-Way Approach Vol.	Emission Reduction (grams per day)		
		VOC	CO	NOx
US 77 & SH 175	5,805	-1,229	-16,142	-34
Loop 463 & FM 1685	14,060	-2,978	-39,097	-82
Loop 463 & SH 236	10,665	-2,259	-29,656	-62
Loop 463 & Salem Rd	26,802	-5,676	-74,529	-155
Loop 463 & Airline Dr	19,188	-4,064	-53,357	-111
TOTAL	N/A	-16,206	-212,781	-444

Table 3-13
NCTCOG and TxDOT Peak-Period Emission Reduction Estimates, Summer 2015

Project Location	24-Hr 4-Way Approach Vol.	Emission Reduction (grams per 2 peak hours)					
		NCTCOG			TxDOT		
		VOC	CO	NOx	VOC	CO	NOx
US 77 & SH 175	11,610	-90	-1,024	-9	-267	-3,303	-28
Loop 463 & FM 1685	28,119	-218	-2,480	-23	-646	-7,346	-67
Loop 463 & SH 236	21,330	-165	-1,881	-17	-490	-5,571	-51
Loop 463 & Salem Rd	53,603	-415	-4,728	-43	-1,231	-14,001	-128
Loop 463 & Airline Dr	38,376	-297	-3,385	-31	-882	-10,024	-92
TOTAL	N/A	-1,185	-13,498	-123	-3,516	-40,245	-366

Table 3-14
NCTCOG Method Results of 24-Hour Relative Emission Reduction for Victoria County, Summer 2015

Project Location	Relative Emission Reduction (%)		
	VOC	CO	NOx
US 77 & SH 175	-0.0372	-0.0662	-0.0006
Loop 463 & FM 1685	-0.0901	-0.1604	-0.0014
Loop 463 & SH 236	-0.0683	-0.1217	-0.0010
Loop 463 & Salem Rd	-0.1717	-0.3058	-0.0026
Loop 463 & Airline Dr	-0.1229	-0.2190	-0.0018
TOTAL	-0.4902	-0.8732	-0.0074

Table 3-15
Peak 2-Hour Emission Reduction for Victoria County, Summer 2015

Project Location	Relative Emission Reduction (%) NCTCOG VOC	CO	NOx	TxDOT VOC	CO	NOx
US 77 & SH 175	-0.0027	-0.0042	-0.0001	-0.0081	-0.0136	-0.0005
Loop 463 & FM 1685	-0.0066	-0.0102	-0.0004	-0.0195	-0.0301	-0.0011
Loop 463 & SH 236	-0.0050	-0.0077	-0.0003	-0.0148	-0.0229	-0.0008
Loop 463 & Salem Rd	-0.0126	-0.0194	-0.0007	-0.0372	-0.0575	-0.0021
Loop 463 & Airline Dr	-0.0090	-0.0139	-0.0005	-0.0267	-0.0411	-0.0015
TOTAL	-0.0358	-0.0554	-0.0020	-0.1064	-0.1652	-0.0061

Method Differences

The differences between the NCTCOG and TxDOT estimates are attributed to the use of a 2-way, 24-hour approach volume and a directional split at the intersections by NCTCOG. The 2-way, 24-hour approach volumes are calculated by dividing the 4-way, 24-hour approach volumes by two. The directional splits are applicable only to 2-way volumes and, thus, cannot be used in the TxDOT method without converting the 4-way approach volumes to 2-way. When the 2-way, 24-hour approach volume and directional split are used in the TxDOT method, the estimated results are very similar. These two variables tend to focus on the peak approach to the intersection without full consideration for each approach, whether minor street or non-peak direction.

Vehicle Idling Not Directly Accounted For

Vehicle idling is the portion of the vehicle's operating mode that is most affected by grade separation improvements. Neither method here directly accounts for a reduction in vehicle idling. Without directly accounting for benefits from reducing idling emissions, these estimated emission reductions are conservative. Idling is indirectly accounted for through a surrogate variable, average travel speed, which includes delay time at signalized intersections.

Recommended Method

The TxDOT method is recommended for grade separation analysis, because it estimates emission reductions for all approaches to the intersection. The NCTCOG use of 2-way, 24-hour approach volumes and directional split make their estimates very conservative. The use of the 2-way, 24-hour approach volumes effectively ignores any benefits to the minor street of the grade separated intersection. Also, by applying the directional split, few emission benefits are shown for non-peak directional travel. The use of these two factors better represents the peak directional emission benefits.

IV. CONCLUSIONS

This report has discussed the increasing importance of modal emissions and suggests their use in sketch-planning tools and traffic simulation models to effectively evaluate traditional transportation system management strategies or traffic flow improvements. These strategies improve the system through smoothing the flow of traffic and, in the short term, do not change demand. Some strategies may increase demand over time, which must be carefully considered when comparing strategies.

Characteristics of traffic flow have been difficult to define and traffic flow data have been difficult to collect; however, with improvements in distance measurement instruments sufficient data can now be collected to describe modal characteristics. Questions on how the modal data are collected and used can be raised. Traditional floating car techniques, which are well suited for determining average travel speed, may inadequately describe the extreme variability of driver behavior which can be expected under most congested or unstable flow conditions. Car-following techniques, which are difficult to implement in congested conditions, may also be inadequate in describing the range of driver behavior unless a large number of data collection runs are performed.

Use of modal emissions analysis on typical transportation demand management strategies would probably not be considered effective or necessary unless there are significant changes in driver behavior. Current sketch-planning tools may be more apt to evaluate demand management strategies instead of system management strategies, because logical equations describing the effects of demand modifying strategies can be developed and data generated. Ambiguity in data and level of difficulty in estimating the effects of system management strategies call for the assistance of and more scientific evaluation through the use of modal emissions. In the meantime, before research is fully available, it is extremely important that TSM strategies not be discounted in favor of minor improvements in demand reduction strategies, if air quality is truly a concern.

CAVEATS

1. Current sketch-planning tools may reasonably predict the impacts of TDM projects but cannot reasonably predict the impacts of TSM projects. Reductions in trips combined with assumptions of trip length can be used to approximate travel changes on the transportation

network. Evaluating system changes becomes increasingly more difficult as the scope of the project increases in size or complexity.

2. Emission benefits gained from traffic smoothing are not fully known. Increasing the profession's knowledge of the emission effects now hinges on upcoming developments in the modal emission research field. When emission rates are developed for vehicle accelerations and acceleration data are developed to generalize traffic behavior in certain scenarios, then a more detailed analysis can be performed with some assurance of its results.
3. To mitigate the use of several different tools for project analyses, future research and model improvement efforts should focus on developing data sharing techniques between demand models and system models such as TRANPLAN and NETSIM.
4. The TTI CM/AQ Evaluation Model is a helpful tool in determining the direction of benefits and, where local data are available, a reasonable magnitude of these benefits.
5. Methods for collecting modal traffic data have yet to be developed, tested, and proven. Traditional collection techniques may not provide accurate modal data because modal data are dependent on driver behavior and the interaction with surrounding vehicles in the traffic stream and roadway geometrics.
6. Many questions concerning the use of modal traffic data will need to be answered before this valuable information can be used in analysis tools. An examination of modal impacts on TCM strategies should be conducted to define which elements of traffic modal data could be used in evaluating specific TCM projects.

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APPENDIX A

MOBILE5a EMISSION RATES USED FOR QUICK EVALUATION TABLES AND BOTTLENECK ANALYSES

Table A-1
Emission Rates Used for Quick Evaluation Tables and Bottleneck Analyses

COMPOSITE EMISSION FACTORS
For All Vehicle Types

Dallas/Tarrant Freeways
Year 1993

SPEED (MPH)	Grams/Mi VOCs HC	Grams/Mi Exhaust HC	Grams/Mi Exhaust CO	Grams/Mi Exhaust NOx	Grams/Km VOCs HC	Grams/Km Exhaust HC	Grams/Km Exhaust CO	Grams/Km Exhaust NOX	SPEED (kph)
3	16.127	8.890	131.803	3.356	10.021	5.524	81.899	2.085	4.8
4	11.585	6.967	102.396	3.146	7.199	4.329	63.626	1.955	6.4
5	9.119	5.763	83.925	3.003	5.666	3.581	52.149	1.866	8.0
6	7.578	4.935	71.221	2.896	4.709	3.066	44.255	1.799	9.7
7	6.527	4.330	61.954	2.810	4.056	2.691	38.496	1.746	11.3
8	5.894	3.869	54.905	2.739	3.662	2.404	34.116	1.702	12.9
9	5.403	3.505	49.372	2.679	3.357	2.178	30.678	1.665	14.5
10	5.001	3.212	44.919	2.626	3.107	1.996	27.911	1.632	16.1
11	4.663	2.970	41.262	2.581	2.897	1.845	25.639	1.604	17.7
12	4.374	2.767	38.206	2.540	2.718	1.719	23.740	1.578	19.3
13	4.122	2.594	35.615	2.504	2.561	1.612	22.130	1.556	20.9
14	3.901	2.445	33.392	2.472	2.424	1.519	20.749	1.536	22.5
15	3.704	2.316	31.461	2.443	2.302	1.439	19.549	1.518	24.1
16	3.526	2.202	29.768	2.418	2.191	1.368	18.497	1.502	25.7
17	3.364	2.101	28.271	2.395	2.090	1.306	17.567	1.488	27.4
18	3.216	2.010	26.934	2.374	1.998	1.249	16.736	1.475	29.0
19	3.078	1.929	25.734	2.355	1.913	1.199	15.990	1.463	30.6
20	2.963	1.854	24.703	2.344	1.841	1.152	15.350	1.456	32.2
21	2.867	1.779	23.702	2.343	1.781	1.105	14.728	1.456	33.8
22	2.779	1.710	22.787	2.342	1.727	1.063	14.159	1.455	35.4
23	2.698	1.646	21.946	2.342	1.676	1.023	13.637	1.455	37.0
24	2.622	1.588	21.170	2.342	1.629	0.987	13.154	1.455	38.6
25	2.552	1.534	20.451	2.342	1.586	0.953	12.708	1.455	40.2
26	2.487	1.483	19.783	2.344	1.545	0.921	12.293	1.456	41.8
27	2.425	1.436	19.162	2.345	1.507	0.892	11.907	1.457	43.5
28	2.368	1.392	18.583	2.348	1.471	0.865	11.547	1.459	45.1
29	2.314	1.351	18.043	2.351	1.438	0.839	11.211	1.461	46.7
30	2.263	1.313	17.539	2.354	1.406	0.816	10.898	1.463	48.3
31	2.215	1.277	17.068	2.358	1.376	0.793	10.606	1.465	49.9
32	2.169	1.243	16.629	2.363	1.348	0.772	10.333	1.468	51.5
33	2.127	1.211	16.219	2.368	1.322	0.752	10.078	1.471	53.1
34	2.086	1.181	15.836	2.374	1.296	0.734	9.840	1.475	54.7
35	2.048	1.153	15.479	2.380	1.273	0.716	9.618	1.479	56.3
36	2.011	1.127	15.147	2.387	1.250	0.700	9.412	1.483	57.9
37	1.977	1.103	14.838	2.395	1.228	0.685	9.220	1.488	59.5
38	1.944	1.080	14.551	2.404	1.208	0.671	9.042	1.494	61.2
39	1.913	1.058	14.286	2.413	1.189	0.657	8.877	1.499	62.8
40	1.884	1.038	14.040	2.423	1.171	0.645	8.724	1.506	64.4
41	1.856	1.019	13.812	2.434	1.153	0.633	8.582	1.512	66.0
42	1.829	1.001	13.603	2.446	1.136	0.622	8.453	1.520	67.6
43	1.804	0.984	13.410	2.459	1.121	0.611	8.333	1.528	69.2
44	1.780	0.968	13.232	2.473	1.106	0.601	8.222	1.537	70.8
45	1.757	0.954	13.069	2.488	1.092	0.593	8.121	1.546	72.4
46	1.735	0.940	12.919	2.504	1.078	0.584	8.027	1.556	74.0
47	1.714	0.927	12.780	2.522	1.065	0.576	7.941	1.567	75.6
48	1.694	0.914	12.652	2.541	1.053	0.568	7.862	1.579	77.2
49	1.686	0.913	12.663	2.623	1.048	0.567	7.868	1.630	78.9
50	1.680	0.912	12.677	2.707	1.044	0.567	7.877	1.682	80.5
51	1.674	0.911	12.694	2.793	1.040	0.566	7.888	1.735	82.1
52	1.668	0.910	12.715	2.880	1.036	0.565	7.901	1.790	83.7
53	1.662	0.909	12.740	2.969	1.033	0.565	7.916	1.845	85.3
54	1.657	0.908	12.768	3.059	1.030	0.564	7.934	1.901	86.9
55	1.653	0.908	12.800	3.151	1.027	0.564	7.954	1.958	88.5
56	1.700	0.959	14.892	3.245	1.056	0.596	9.253	2.016	90.1
57	1.747	1.009	16.987	3.341	1.086	0.627	10.555	2.076	91.7
58	1.794	1.060	19.088	3.440	1.115	0.659	11.861	2.138	93.3
59	1.842	1.112	21.194	3.541	1.145	0.691	13.169	2.200	95.0
60	1.890	1.163	23.305	3.644	1.174	0.723	14.481	2.264	96.6
61	1.938	1.214	25.422	3.750	1.204	0.754	15.796	2.330	98.2
62	1.987	1.265	27.545	3.860	1.235	0.786	17.116	2.398	99.8
63	2.035	1.317	29.676	3.972	1.264	0.818	18.440	2.468	101.4
64	2.084	1.368	31.814	4.088	1.295	0.850	19.768	2.540	103.0
65	2.134	1.420	33.960	4.208	1.326	0.882	21.102	2.615	104.6

Idle Rates	VOC	CO	NOx
grams/hour	25.94	385.84	8.76
grams/minute	0.432	6.430	0.146

APPENDIX B

TTI CM/AQ EVALUATION MODEL DEMONSTRATION INPUTS AND OUTPUTS

Table B-1
Baseline Travel Data for the Dallas/Fort Worth Nonattainment Area

Baseline Table: CM/AQ EVALUATION MODEL
Baseline Data Summary

Page: 1
Date: 10/12/95
Time: 8:23 am

Baseline Variables	Value	User Defined?
Total vehicle trips	5,927,293.0	N
Base peak VMT	53,322,000.0	Y
Base off-peak VMT	41,729,000.0	Y
Pct of VMT on unpaved roads	0.0000	Y
Base peak speed	32.8	Y
Base offpeak speed	40.3	Y
Total commute vehicle trips	1,814,340.0	N
Total non-commute vehicle trips	4,112,950.0	N
Total commute person trips	3,160,744.0	Y
Total non-commute person trips	10,446,367.0	Y
Peak person trips	3,217,470.0	N
Off-peak person trips	4,388,840.0	N
Pct of all trips in peak period	.4200	N
Pct of all trips in off-peak period	.5800	N
Pct of all trips that are commute trips	.3060	N
Pct of all trips that are non-commute trips	.6940	N

** NOTE: All percentages are expressed as decimal values.

Table B-1
(Continued)

Baseline Table: CM/AQ EVALUATION MODEL
Baseline Data Summary

Page: 2
Date: 10/12/95
Time: 8:23 am

Baseline Variables	Value	User Defined?
Pct of person trips that are commute trips	.3000	N
Pct of person trips that are non-commute trips	.7000	N
Pct of peak trips that are commute trips	.3700	Y
Pct of peak trips that are non-commute trips	.6300	Y
Pct of off-peak trips that are commute trips	.0900	Y
Pct of off-peak trips that are non-commute trips	.9100	Y
Pct of non-commute trips that are peak trips	.4800	Y
Pct of non-commute trips that are off-peak trips	.5200	Y
Pct of commute trips that are peak trips	.8400	Y
Pct of commute trips that are off-peak trips	.1600	Y
Avg Carpool Size	2.3	Y
Avg vehicle occupancy	1.3	N
Pct of commute trips that are non-SOV	.1880	N
Pct of peak trips that are transit	.0220	N
Pct of off-peak trips that are transit	.0220	N
Pct of commute trips that are transit trips	.0410	N
Pct of non-commute trips that are transit	.0200	N

** NOTE: All percentages are expressed as decimal values.

Table B-1
(Continued)

Baseline Table:	CM/AQ EVALUATION MODEL Baseline Data Summary	Page: 3 Date: 10/12/95 Time: 8:23 am

Baseline Variables	Value	User Defined?
Pct of commute travel that is ridesharing	.1400	N
Base Pct of commute trips by bicycle	.0013	Y
Base Pct of non-commute trips by bicycle	.0100	Y
Pct of ridesharing that is commute	.0900	N
Pct of ridesharing that is non-commute	.9100	N
Pct of bicycling that is commute	.1000	N
Pct of bicycling that is non-commute	.9000	N
Pct of walking that is commute	.0600	N
Pct of walking that is non-commute	.9400	N
Pct of walking/bicycling that is commute	.0647	N
Pct of walking/bicycling that is non-commute	.9353	N
Avg commute trip length (miles)	10.0	N
Avg non-commute trip length (miles)	5.0	N
Avg transit commute trip length (miles)	5.0	N
Avg transit non-commute trip length (miles)	2.5	N
Avg carpool commute trip length (miles)	13.0	N
Avg carpool non-commute trip length (miles)	10.0	N

** NOTE: All percentages are expressed as decimal values.

Table B-1
(Continued)

Baseline Table:	CM/AQ EVALUATION MODEL Baseline Data Summary	Page: 4 Date: 10/12/95 Time: 8:23 am

Baseline Variables	Value	User Defined?
Avg vanpool commute trip length (miles)	13.0	N
Avg bicycling commute trip length (miles)	5.0	Y
Avg bicycling non-commute trip length (miles)	5.0	Y
Avg walking/bicycling commute trip length (miles)	1.4	N
Avg walking/bicycling non-commute trip length (miles)	.9610	N
Avg walking non-commute trip length (miles)	.8000	N
Avg walking commute trip length (miles)	.7500	N
Avg length of business-related trip (miles)	5.0	N
Avg trip length for truck trips (miles)	6.9	N
Pct of commute trips less than 6 miles	.3300	Y
Pct of non-commute trips less than 5 miles	.4000	Y
Avg daily commute out-of-pocket costs ($)	1.0	N
Avg daily non-commute out-of-pocket costs ($)	.4900	N
Pct of short-term parking that occurs during the peak	.7400	N
Pct of short-term parking that occurs during the off-peak	.2600	N
Peak elasticity of speed with respect to volume	-.7500	N
Off-peak elasticity of speed with respect to volume	-.2200	N

** NOTE: All percentages are expressed as decimal values.

Table B-1
(Continued)

Baseline Table:	CM/AQ EVALUATION MODEL Baseline Data Summary	Page: 5 Date: 10/12/95 Time: 8:23 am

Baseline Variables	Value	User Defined?
Elasticity of transit use with respect to wait time in the peak	-.3000	N
Elasticity of transit use with respect to wait time in the off-peak	-.3000	N
Elasticity of transit use with respect to travel time during the peak	-.6000	N
Elasticity of transit use with respect to travel time during the off-peak	-.6000	N
Elasticity of transit use with respect to travel time	-.2000	N
Elasticity of transit use with respect to service during the peak	.6800	N
Elasticity of transit use with respect to service during the off-peak	.6800	N
Elasticity of transit use with respect to headway	-.2000	N
Elasticity of transit use with respect to cost for non-commuters	-.5100	N
Elasticity of transit use with respect to cost for commuters	-.2000	N
Elasticity of parking demand with respect to cost for non-commute trips	-.2000	N
Elasticity of parking demand with respect to cost for commute trips	-.2000	N
Elasticity of auto use with respect to auto operating costs	-.1000	N

** NOTE: All percentages are expressed as decimal values.

Table B-2
Park-and-Ride Lot Data for Dallas/Fort Worth Nonattainment Area

CM/AQ EVALUATION MODEL
TCM Specific Input Values by Project

Baseline Table:		Page:	1 of 2
User Input Table:		Date:	10/12/95
Results Table:		Time:	8:23 am

Project Name: I-20 Arlington Park-and-Ride
TCM Category: Park-n-Ride Lots
TCM Name: CAR/VANPOOL-ORIENTED
Modules Run:

Travel Impact TCM Specific Input Values

Number of new park-n-ride lot spaces	351.0000
Avg utilization rate	.2700
Pct of lot use by previous carpoolers	0.0000
Number of non-vehicle trips to/from the lot	5.0000
Number of carpool passengers who previously did not drive	0.0000
Pct of travel to lot during the peak	1.0000
Avg length of carpool trip from lot (miles)	10.0000
Number of non-vehicle trips to/from the lot	5.0000
Number of new carpool trips	124.0000

Emissions TCM Specific Input Data

Impact on CO hot spot/hot grid	2.0 (No)
Impact on PM10 hot spot/hot grid	2.0 (No)
Area Type Affected	1
Peak TCM Speed	32.8
Off-Peak TCM Speed	40.3

Cost-Effectiveness TCM Specific Input Data

Daily Labor Cost	$	0.00
Daily Capital Cost	$	67.13
Daily Direct Operational Cost	$	0.00
Daily Overhead Cost	$	0.00
Daily Revenues	$	0.00
CM/AQ Funding Requested	$	67.13
Type of Funding Used for TCM		CM/AQ
Early Project Effectiveness		Yes

Table B-3
Model Output for Park-and-Ride Lot in Dallas/Fort Worth Nonattainment Area

```
                         CM/AQ EVALUATION MODEL
                           Results by Project

      Baseline Table: dallas_B                  Page:   1 of 2
    User Input Table: dallas_D                  Date: 10/12/95
       Results Table: dallas_R                  Time:   8:23 am

        Project Name: I-20 Arlington Park-and-Ride
        TCM Category: Park-n-Ride Lots
            TCM Name: CAR/VANPOOL-ORIENTED

Travel Impact Results

                           Peak            Off-Peak               Total
Base Vehicle Trips     2,489,463          3,437,830             5,927,293
    Trip Reduction           119                  0                   119
     Pct Reduction        .0048%            0.0000%                .0020%

          Base VMT    53,322,000         41,729,000            95,051,000
     VMT Reduction         1,995                  0                 1,995
     Pct Reduction        .0037%            0.0000%                .0021%

  Pct Speed Change        .0000%            0.0000%

          Change in Idling Time (if applicable):        0

Emissions Impact Results (Kg. per Day)

                            CO           VOC           NOX           PM10
    Base Emissions  2,162,416.8     272,083.2     251,966.2    4,789,851.3
         Reduction         48.3           6.0           5.1      939,969.3
       Pct Reduced       .0022%        .0022%        .0020%       19.6242%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

                            CO           VOC           NOX           PM10
    Public Sector          1.39         11.14         13.15            .00
    CM/AQ Funding          1.39         11.14         13.15            .00

                    Total Public Sector Cost: $        67.13
                     CM/AQ Funding Requested: $        67.13
      Cost Basis Used for Criteria Weighting: CM/AQ

Criteria Weighting Results

                          Travel Impact Score:    0
                       Emissions Impact Score:    2
                     Cost-Effectiveness Score:   30
                    Early Effectiveness Score:   10

                               Project Rating:   42
```

Table B-4
Baseline Travel Data for the Houston/Galveston Nonattainment Area

Baseline Table: CM/AQ EVALUATION MODEL
Baseline Data Summary

Page: 1
Date: 10/12/95
Time: 8:22 am

Baseline Variables	Value	User Defined?
Total vehicle trips	5,927,293.0	N
Base peak VMT	58,520,379.0	Y
Base off-peak VMT	44,676,761.0	Y
Pct of VMT on unpaved roads	0.0000	Y
Base peak speed	30.0	Y
Base offpeak speed	40.0	Y
Total commute vehicle trips	1,814,340.0	N
Total non-commute vehicle trips	4,112,950.0	N
Total commute person trips	2,060,290.0	N
Total non-commute person trips	5,546,019.0	N
Peak person trips	3,217,470.0	N
Off-peak person trips	4,388,840.0	N
Pct of all trips in peak period	.4200	N
Pct of all trips in off-peak period	.5800	N
Pct of all trips that are commute trips	.3060	N
Pct of all trips that are non-commute trips	.6940	N

** NOTE: All percentages are expressed as decimal values.

Table B-4
(Continued)

Baseline Table: CM/AQ EVALUATION MODEL
Baseline Data Summary

Page: 2
Date: 10/12/95
Time: 8:22 am

Baseline Variables	Value	User Defined?
Pct of person trips that are commute trips	.3000	N
Pct of person trips that are non-commute trips	.7000	N
Pct of peak trips that are commute trips	.4120	N
Pct of peak trips that are non-commute trips	.5880	N
Pct of off-peak trips that are commute trips	.1670	N
Pct of off-peak trips that are non-commute trips	.8330	N
Pct of non-commute trips that are peak trips	.3600	N
Pct of non-commute trips that are off-peak trips	.6400	N
Pct of commute trips that are peak trips	.6440	N
Pct of commute trips that are off-peak trips	.3560	N
Avg Carpool Size	2.1	Y
Avg vehicle occupancy	1.3	N
Pct of commute trips that are non-SOV	.1880	N
Pct of peak trips that are transit	.0220	N
Pct of off-peak trips that are transit	.0220	N
Pct of commute trips that are transit trips	.0410	N
Pct of non-commute trips that are transit	.0200	N

** NOTE: All percentages are expressed as decimal values.

Table B-4
(Continued)

Baseline Table: CM/AQ EVALUATION MODEL Baseline Data Summary

Page: 3
Date: 10/12/95
Time: 8:22 am

Baseline Variables	Value	User Defined?
Pct of commute travel that is ridesharing	.1400	N
Base Pct of commute trips by bicycle	.0072	N
Base Pct of non-commute trips by bicycle	.0226	N
Pct of ridesharing that is commute	.0900	N
Pct of ridesharing that is non-commute	.9100	N
Pct of bicycling that is commute	.1000	N
Pct of bicycling that is non-commute	.9000	N
Pct of walking that is commute	.0600	N
Pct of walking that is non-commute	.9400	N
Pct of walking/bicycling that is commute	.0647	N
Pct of walking/bicycling that is non-commute	.9353	N
Avg commute trip length (miles)	10.0	N
Avg non-commute trip length (miles)	5.0	N
Avg transit commute trip length (miles)	5.0	N
Avg transit non-commute trip length (miles)	2.5	N
Avg carpool commute trip length (miles)	13.0	N
Avg carpool non-commute trip length (miles)	10.0	N

** NOTE: All percentages are expressed as decimal values.

Table B-4
(Continued)

Baseline Table:	CM/AQ EVALUATION MODEL Baseline Data Summary	Page: 4 Date: 10/12/95 Time: 8:22 am

Baseline Variables	Value	User Defined?
Avg vanpool commute trip length (miles)	13.0	N
Avg bicycling commute trip length (miles)	4.0	N
Avg bicycling non-commute trip length (miles)	2.7	N
Avg walking/bicycling commute trip length (miles)	1.4	N
Avg walking/bicycling non-commute trip length (miles)	.9610	N
Avg walking non-commute trip length (miles)	.8000	N
Avg walking commute trip length (miles)	.7500	N
Avg length of business-related trip (miles)	5.0	N
Avg trip length for truck trips (miles)	6.9	N
Pct of commute trips less than 6 miles	.3770	N
Pct of non-commute trips less than 5 miles	.6490	N
Avg daily commute out-of-pocket costs ($)	1.0	N
Avg daily non-commute out-of-pocket costs ($)	.4900	N
Pct of short-term parking that occurs during the peak	.7400	N
Pct of short-term parking that occurs during the off-peak	.2600	N
Peak elasticity of speed with respect to volume	-1.2950	Y
Off-peak elasticity of speed with respect to volume	-.0170	Y

** NOTE: All percentages are expressed as decimal values.

Table B-4
(Continued)

Baseline Table: CM/AQ EVALUATION MODEL
Baseline Data Summary

Page: 5
Date: 10/12/95
Time: 8:22 am

Baseline Variables	Value	User Defined?
Elasticity of transit use with respect to wait time in the peak	-.3000	N
Elasticity of transit use with respect to wait time in the off-peak	-.3000	N
Elasticity of transit use with respect to travel time during the peak	-.6000	N
Elasticity of transit use with respect to travel time during the off-peak	-.6000	N
Elasticity of transit use with respect to travel time	-.2000	N
Elasticity of transit use with respect to service during the peak	.6800	N
Elasticity of transit use with respect to service during the off-peak	.6800	N
Elasticity of transit use with respect to headway	-.2000	N
Elasticity of transit use with respect to cost for non-commuters	-.5100	N
Elasticity of transit use with respect to cost for commuters	-.2000	N
Elasticity of parking demand with respect to cost for non-commute trips	-.2000	N
Elasticity of parking demand with respect to cost for commute trips	-.2000	N
Elasticity of auto use with respect to auto operating costs	-.1000	N

** NOTE: All percentages are expressed as decimal values.

Table B-5
Park-and-Ride Lot Data for Houston/Galveston Nonattainment Area

CM/AQ EVALUATION MODEL
TCM Specific Input Values by Project

Baseline Table:	Page: 1 of 2
User Input Table:	Date: 10/12/95
Results Table:	Time: 8:22 am

Project Name:	I-45 Park-and-Ride
TCM Category:	Park-n-Ride Lots
TCM Name:	CAR/VANPOOL-ORIENTED
Modules Run:	

Travel Impact TCM Specific Input Values

Number of new park-n-ride lot spaces	2,244.0000
Avg utilization rate	.4700
Pct of lot use by previous carpoolers	.0100
Number of non-vehicle trips to/from the lot	10.0000
Number of carpool passengers who previously did not drive	0.0000
Pct of travel to lot during the peak	1.0000
Avg length of carpool trip from lot (miles)	8.6000
Number of non-vehicle trips to/from the lot	10.0000
Number of new carpool trips	1,160.0000

Emissions TCM Specific Input Data

Impact on CO hot spot/hot grid	2.0 (No)
Impact on PM10 hot spot/hot grid	2.0 (No)
Area Type Affected	1
Peak TCM Speed	30.0
Off-Peak TCM Speed	40.0

Cost-Effectiveness TCM Specific Input Data

Daily Labor Cost	$	0.00
Daily Capital Cost	$	671.34
Daily Direct Operational Cost	$	0.00
Daily Overhead Cost	$	0.00
Daily Revenues	$	0.00
CM/AQ Funding Requested	$	671.34
Type of Funding Used for TCM		CM/AQ
Early Project Effectiveness		Yes

Table B-6
Courtesy Patrol Data for Houston/Galveston Nonattainment Area

CM/AQ EVALUATION MODEL
TCM Specific Input Values by Project

Baseline Table:		Page:	2 of 2
User Input Table:		Date:	10/12/95
Results Table:		Time:	8:22 am

Project Name: METRO MAP
TCM Category: Traffic Improvement Projects
TCM Name: COURTESY PATROL
Modules Run:

Travel Impact TCM Specific Input Values

Pct peak speed change	.0260
Pct off-peak speed change	.0260

Emissions TCM Specific Input Data

Impact on CO hot spot/hot grid	2.0 (No)
Impact on PM10 hot spot/hot grid	2.0 (No)
Area Type Affected	1
Peak TCM Speed	30.0
Off-Peak TCM Speed	40.0
Pct of peak VMT affected	.5
Pct of off-peak VMT affected	.5

Cost-Effectiveness TCM Specific Input Data

Daily Labor Cost	$	10,000.00
Daily Capital Cost	$	5,000.00
Daily Direct Operational Cost	$	5,000.00
Daily Overhead Cost	$	5,000.00
Daily Revenues	$	0.00
CM/AQ Funding Requested	$	25,000.00
Type of Funding Used for TCM		CM/AQ
Early Project Effectiveness		Yes

** NOTE: All percentages are expressed as decimal values.

Table B-7
Model Output for Park-and-Ride Lot in Houston/Galveston Nonattainment Area

CM/AQ EVALUATION MODEL
Results by Project

Baseline Table:	houstn_B	Page:	1 of 2
User Input Table:	houstn_D	Date:	10/12/95
Results Table:	houstn_R	Time:	8:21 am

Project Name: I-45 Park-and-Ride
TCM Category: Park-n-Ride Lots
TCM Name: CAR/VANPOOL-ORIENTED

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	1,150	0	1,150
Pct Reduction	.0462%	0.0000%	.0194%
Base VMT	58,520,379	44,676,761	103,197,140
VMT Reduction	18,131	0	18,131
Pct Reduction	.0310%	0.0000%	.0176%
Pct Speed Change	.0004%	0.0000%	

Change in Idling Time (if applicable): 0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	1,892,073.7	213,209.6	255,341.1	5,200,197.1
Reduction	363.4	40.5	43.5	1,019,477.6
Pct Reduced	.0192%	.0190%	.0170%	19.6046%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	1.85	16.57	15.43	.00
CM/AQ Funding	1.85	16.57	15.43	.00

Total Public Sector Cost: $ 671.34
CM/AQ Funding Requested: $ 671.34
Cost Basis Used for Criteria Weighting: CM/AQ

Criteria Weighting Results

Travel Impact Score:	0
Emissions Impact Score:	2
Cost-Effectiveness Score:	30
Early Effectiveness Score:	10
Project Rating:	42

Table B-8
Model Output for Courtesy Patrols in Houston/Galveston Nonattainment Area

CM/AQ EVALUATION MODEL
Results by Project

Baseline Table: houstn_B
User Input Table: houstn_D
Results Table: houstn_R

Page: 2 of 2
Date: 10/12/95
Time: 8:21 am

Project Name: METRO MAP
TCM Category: Traffic Improvement Projects
TCM Name: COURTESY PATROL

Travel Impact Results

	Peak	Off-Peak	Total
Base Vehicle Trips	2,489,463	3,437,830	5,927,293
Trip Reduction	0	0	0
Pct Reduction	0.0000%	0.0000%	0.0000%
Base VMT	58,520,379	44,676,761	103,197,140
VMT Reduction	0	0	0
Pct Reduction	0.0000%	0.0000%	0.0000%
Pct Speed Change	.0260%	.0260%	

Change in Idling Time (if applicable): 0

Emissions Impact Results (Kg. per Day)

	CO	VOC	NOX	PM10
Base Emissions	1,892,073.7	213,209.6	255,341.1	5,200,197.1
Reduction	14,807.4	1,493.4	-340.2	0.0
Pct Reduced	.7826%	.7004%	-0.1332%	0.0000%

Cost-Effectiveness Results (Dollars per Kg. Reduced)

	CO	VOC	NOX	PM10
Public Sector	1.69	16.74	0.00	0.00
CM/AQ Funding	1.69	16.74	0.00	0.00

Total Public Sector Cost: $ 25,000.00
CM/AQ Funding Requested: $ 25,000.00
Cost Basis Used for Criteria Weighting: CM/AQ

Criteria Weighting Results

Travel Impact Score: 1
Emissions Impact Score: 0
Cost-Effectiveness Score: 18
Early Effectiveness Score: 10

Project Rating: 29

APPENDIX C

MOBILE AND PART5 SETUPS FOR TTI CM/AQ EVALUATION MODEL DEMONSTRATION

Table C-1
MOBILE5a Setup for Dallas/Fort Worth Nonattainment Area

```
1       PROMPT
MOBILE5A DALLAS/TARRANT, BASE YEAR RUN SALTAR24, 1990, DIURNALS
1       TAMFLG - DEFAULT TAMPERING RATES
4       SPDFLG - ONE SPEED PER SCENARIO, VMT FRACTIONS BY TRIP LENGTH
1       VMFLAG - MOBILE5 DEFAULT VMT MIX FOR ALL SCENARIOS
3       MYMRFG - DEFAULT MILAGE RATES, USER SUPPLIED VEHICLE REG
1       NEWFLG - DEFAULT EXHAUST EMISSION RATES
2       IMFLAG - I/M PROGRAM IN DALLAS AND TARRANT COUNTIES
1       ALHFLG - NO ADDITIONAL EXHAUST EMISSION CORRECTION FACTOR INPUTS
1       ATPFLG - NO ANTI-TAMPERING PROGRAM IN DALLAS AND TARRANT
5       RLFLAG - ZERO-OUT REFUELING LOSSES
2       LOCFLG - ONE LAP RECORD APPLIES TO ALL SCENARIOS
1       TEMFLG - MOBILE5A TEMPERATURE CORRECTIONS FOR EXHAUST EMISSIONS
3       OUTFMT - 112 COLUMN DESCRIPTIVE OUTPUT FORMAT
4       PRTFLG - CALCULATE EMISSION FACTORS FOR CO, HC, AND NOX
1       IDLFLG - DO NOT CALCULATE IDLE EMISSION FACTORS
3       NMHFLG - CALCULATE VOC EMISSIONS
3       HCFLAG - PRINT HC TOTALS AND COMPONENTS
.0700.0890.0850.0810.0830.0830.0780.0540.0520.0510      LDGV AGES 1-10
.0450.0520.0440.0340.0220.0120.0120.0090.0080.0050      LDGV AGES 11-20
.0090.0060.0060.0050.0050                               LDGV AGES 21-25
.0570.0860.0780.0680.0920.0820.0770.0500.0490.0430      LDGT1 AGES 1-10
.0310.0450.0420.0350.0250.0140.0170.0170.0160.0140      LDGT1 AGES 11-20
.0160.0130.0110.0110.0110                               LDGT1 AGES 21-25
.0500.0720.0740.0470.0880.0850.0850.0550.0530.0340      LDGT2 AGES 1-10
.0360.0700.0530.0490.0410.0280.0220.0170.0090.0070      LDGT2 AGES 11-20
.0070.0050.0050.0040.0040                               LDGT2 AGES 21-25
.0520.0590.0670.0680.0960.0910.0710.0380.0480.0430      HDGV AGES 1-10
.0390.0650.0460.0380.0230.0240.0260.0230.0180.0120      HDGV AGES 11-20
.0150.0110.0100.0090.0080                               HDGV AGES 21-25
.0700.0890.0850.0810.0830.0830.0780.0540.0520.0510      LDDV AGES 1-10
.0450.0520.0440.0340.0220.0120.0120.0090.0080.0050      LDDV AGES 11-20
.0090.0060.0060.0050.0050                               LDDV AGES 21-25
.0570.0860.0780.0680.0920.0820.0770.0500.0490.0430      LDDT AGES 1-10
.0310.0450.0420.0350.0250.0140.0170.0170.0160.0140      LDDT AGES 11-20
.0160.0130.0110.0110.0110                               LDDT AGES 21-25
.0690.0620.0580.0730.0880.1080.1170.0470.0550.0660      HDDV AGES 1-10
.0520.0640.0390.0240.0110.0150.0130.0120.0070.0060      HDDV AGES 11-20
.0040.0030.0030.0020.0020                               HDDV AGES 21-25
.0220.0430.0490.0590.0950.0910.0610.0730.1170.0850      MC AGES 1-10
.0790.2260.0000.0000.0000.0000.0000.0000.0000.0000      MC AGES 11-20
.0000.0000.0000.0000.0000                               MC AGES 21-25
90 19 75 20 0. 1. 62. 2 1 2221 1 11                     I/M PROGRAM DAL/TAR
DALLAS TARRANT     76.0 102.  8.0  8.0 92               LAP RECORD
 09.8 19.0 23.8 19.4 13.6 14.4                          TRIP LENGTH DISTRIBUTION
1 90 02.5 93.0 16.5 14.6 24.9  7                        SCENARIO RECORD
```

Table C-2
PART5 Setup for Dallas/Fort Worth Nonattainment Area

```
Sample Dallas Input File
1      VMFLAG - DEFAULT VMT MIX
3      MYMRFG - USER REG DIST, DEFAULT MILAGE ACCUMULATION
2      IMFLAG - I/M PROGRAM IN DALLAS AND TARRANT
2      RfGFAG - REFORMUATLED GASOLINE
3      OUTFMT - 115-133 COLUMN TEXT FORMAT
2      IDLFLG - PRINT IDLE EMISSION FACTORS
2      SO2FLG - PRINT GASEOUS SO2 EMISSION FACTORS
3      PRTFLG - EXHAUST, WEAR, TOTAL AND FUGITIVE
1      BUSFLG - DO NOT PRINT ALT BUS CYCLE EF
 .070 .089 .085 .081 .083 .083 .078 .054 .052 .051   LDGV AGES 1-10
 .045 .052 .044 .034 .022 .012 .012 .009 .008 .005   LDGV AGES 11-20
 .009 .006 .006 .005 .005                            LDGV AGES 21-25
 .057 .086 .078 .068 .092 .082 .077 .050 .049 .043   LDGT1 AGES 1-10
 .031 .045 .042 .035 .025 .014 .017 .017 .016 .014   LDGT1 AGES 11-20
 .016 .013 .011 .011 .011                            LDGT1 AGES 21-25
 .050 .072 .074 .047 .088 .085 .085 .055 .053 .034   LDGT2 AGES 1-10
 .036 .070 .053 .049 .041 .028 .022 .017 .009 .007   LDGT2 AGES 11-20
 .007 .005 .005 .004 .004                            LDGT2 AGES 21-25
 .052 .059 .067 .068 .096 .091 .071 .038 .048 .043   HDGV AGES 1-10
 .039 .065 .046 .038 .023 .024 .026 .023 .018 .012   HDGV AGES 11-20
 .015 .011 .010 .009 .008                            HDGV AGES 12-25
 .022 .043 .049 .059 .095 .091 .061 .073 .117 .085   MC AGES 1-10
 .079 .226 .000 .000 .000 .000 .000 .000 .000 .000   MC AGES 11-20
 .000 .000 .000 .000 .000                            MC AGES 21-25
 .070 .089 .085 .081 .083 .083 .078 .054 .052 .051   LDDV AGES 1-10
 .045 .052 .044 .034 .022 .012 .012 .009 .008 .005   LDDV AGES 11-20
 .009 .006 .006 .005 .005                            LDDV AGES 21-25
 .057 .086 .078 .068 .092 .082 .077 .050 .049 .043   LDDT AGES 1-10
 .031 .045 .042 .035 .025 .014 .017 .017 .016 .014   LDDT AGES 11-20
 .016 .013 .011 .011 .011                            LDDT AGES 21-25
 .069 .062 .058 .073 .088 .108 .117 .047 .055 .066   2BHDDV - HDDV AGES 1-10
 .052 .064 .039 .024 .011 .015 .013 .012 .007 .006   2BHDDV - HDDV AGES 11-20
 .004 .003 .003 .002 .002                            2BHDDV - HDDV AGES 21-25
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000   LHDDV
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000   LHDDV
 .000 .000 .000 .000 .000                            LHDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000   MHDDV
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000   MHDDV
 .000 .000 .000 .000 .000                            MHDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000   HHDDV
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000   HHDDV
 .000 .000 .000 .000 .000                            HHDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000   BUSES
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000   BUSES
 .000 .000 .000 .000 .000                            BUSES
1 1995 1 02.5                   :region, year, speed cycle, speed
05.8 02.4   2                   :unpaved silt%, ind. silt g/m^2, WHEELFLG
079                             :precip days
Dallas/Ft. Worth, TX            :scenario name
10.                             :particulate cutoff size
6000                            :fleet avg veh wt
04                              :fleet avg # wheels
1 1995 1 55.0                   :region, year, speed cycle, speed
05.8 02.4   2                   :unpaved silt%, ind. silt g/m^2, WHEELFLG
079                             :precip days
Dallas/Ft. Worth, TX            :scenario name
10.                             :particulate cutoff size
6000                            :fleet avg veh wt
04                              :fleet avg 3 wheels
```

Table C-3
MOBILE5a Setup for Houston/Galveston Nonattainment Area

```
1          PROMPT
 HARRIS COUNTY Ozone Season 1993; Run A = NO ATP
1          TAMFLG  - Default: Tampering Rates
4          SPDFLG  - One speed per scenario plus Trip Length Distribution
3          VMFLAG  - User input: single VMT mix for all scenario
3          MYMRFG  - User input: Reg. Distributions
1          NEWFLG  - Basic exhaust emission rates
1          IMFLAG  -      no   I/M
1          ALHFLG  - No additional correction factors
1          ATPFLG  -      no   atp
5          RLFLAG  - Zero-out refueling emissions
2          LOCFLG  - User input: one LAP record for all scenarios
1          TEMFLG  - MOBILE5A  calculates exhaust temperatures
4          OUTFMT  - 80-column descriptive format
4          PRTFLG  - Print all three pollutant emission factors
1          IDLFLG  - No idle emissions calculated or printed
3          NMHFLG  - Print HC = volatile organic compounds (VOC)
1          HCFLAG  - Print total HC
.697.172.076.017.010.002.024.002                   VMT Mix
.0663.0881.0794.0770.0777.0755.0682.0674.0694.0638 LDGV    HARRIS 93
.0428.0425.0373.0286.0308.0245.0167.0099.0052.0047 LDGV
.0042.0036.0025.0023.0116                          LDGV
.0624.0830.0798.0747.0798.0739.0595.0657.0676.0643 LDGT1
.0381.0456.0378.0237.0304.0273.0205.0138.0073.0074 LDGT1
.0063.0066.0043.0039.0167                          LDGT1
.0936.0984.0757.0702.0691.0592.0339.0523.0617.0624 LDGT2
.0427.0490.0293.0289.0462.0338.0304.0225.0140.0081 LDGT2
.0053.0029.0022.0019.0059                          LDGT2
.0610.0692.0661.0714.0658.0606.0523.0489.0557.0575 HDGV
.0311.0578.0482.0391.0515.0416.0269.0168.0168.0143 HDGV
.0123.0092.0074.0041.0148                          HDGV
.0663.0881.0794.0770.0777.0755.0682.0674.0694.0638 LDDV
.0428.0425.0373.0286.0308.0245.0167.0099.0052.0047 LDDV
.0042.0036.0025.0023.0116                          LDDV
.0624.0830.0798.0747.0798.0739.0595.0657.0676.0643 LDDT
.0381.0456.0378.0237.0304.0273.0205.0138.0073.0074 LDDT
.0063.0066.0043.0039.0167                          LDDT
.0482.0422.0711.0740.0639.0592.0534.0620.0754.0712 HDDV
.0360.0561.0668.0504.0529.0342.0243.0112.0134.0111 HDDV
.0083.0047.0020.0024.0056                          HDDV
.0557.0608.0427.0468.0570.0481.0519.0786.0713.0487 MC
.0610.3774.0000.0000.0000.0000.0000.0000.0000.0000 MC
.0000.0000.0000.0000.0000                          MC
HARRIS   DIURNAL C 76.7 97.7  7.2  7.2 20 1 1 1    LAP RECORD  8/17/93  LAP17HAR.
 12.2 25.9 22.8 15.6  9.6 13.9                     Trip Length Overnight
1 93 02.5 93.1 15.1 14.3 23.3  7                   SCN rec: 8/17/93 HARRIS1.A
```

Table C-4
PART5 Setup for Houston/Galveston Nonattainment Area

```
Sample Houston Texas File
3      : VMFLAG
3      : MYMRFG
1      : IMFLAG
2      : RFGFLG
3      : OUTFMT
2      : IDLFLG
2      : SO2FLG
3      : PRTFLG
2      : BUSFLG
0.6970 0.1720 0.0760 0.0170 0.0020 0.0100
0.0020 0.0240 0.0000 0.0000 0.0000 0.0000
 .066 .088 .079 .077 .078 .076 .068 .067 .069 .064  :LDGV    HARRIS 93
 .043 .042 .037 .029 .031 .024 .017 .010 .005 .005  :LDGV
 .004 .004 .002 .002 .012                           :LDGV
 .062 .083 .080 .075 .080 .074 .060 .066 .068 .064  :LDGT1
 .038 .046 .038 .024 .030 .027 .020 .014 .007 .007  :LDGT1
 .006 .007 .004 .004 .017                           :LDGT1
 .094 .098 .076 .070 .069 .059 .034 .052 .062 .062  :LDGT2
 .043 .049 .029 .029 .046 .034 .030 .022 .014 .008  :LDGT2
 .005 .003 .002 .002 .006                           :LDGT2
 .061 .069 .066 .071 .066 .061 .052 .049 .056 .058  :HDGV
 .031 .058 .048 .039 .052 .042 .027 .017 .017 .014  :HDGV
 .012 .009 .007 .004 .015                           :HDGV
 .056 .061 .043 .047 .057 .048 .052 .079 .071 .049  :MC
 .061 .377 .000 .000 .000 .000 .000 .000 .000 .000  :MC
 .000 .000 .000 .000 .000                           :MC
 .066 .088 .079 .077 .078 .076 .068 .067 .069 .064  :LDDV
 .043 .042 .037 .029 .031 .024 .017 .010 .005 .005  :LDDV
 .004 .004 .002 .002 .012                           :LDDV
 .062 .083 .080 .075 .080 .074 .060 .066 .068 .064  :LDDT
 .038 .046 .038 .024 .030 .027 .020 .014 .007 .007  :LDDT
 .006 .007 .004 .004 .017                           :LDDT
 .048 .042 .071 .074 .064 .059 .053 .062 .075 .071  :2BHDDV - MOBILE's HDDV
 .036 .056 .067 .050 .053 .034 .024 .011 .013 .011  :2BHDDV - MOBILE's HDDV
 .008 .005 .002 .002 .006                           :2BHDDV - MOBILE's HDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :LHDDV
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :LHDDV
 .000 .000 .000 .000 .000                           :LHDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :MHDDV
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :MHDDV
 .000 .000 .000 .000 .000                           :MHDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :HHDDV
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :HHDDV
 .000 .000 .000 .000 .000                           :HHDDV
1.000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :BUSES
 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000  :BUSES
 .000 .000 .000 .000 .000                           :BUSES
1 1995 1 02.5                     :region, year, speed cycle, speed
05.8 02.4   2                     :unpaved silt%, ind. silt g/m^2, WHEELFLG
106                               :precip days
Houston, TX                       :scenario name
10.                               :particulate cutoff size
6000                              :fleet avg veh wt
04                                :fleet avg # wheels
1 1995 1 55.0                     :region, year, speed cycle, speed
05.8 02.4   2                     :unpaved silt%, ind. silt g/m^2, WHEELFLG
106                               :precip days
Houston, TX                       :scenario name
10.                               :particulate cutoff size
6000                              :fleet avg veh wt
04                                :fleet avg 3 wheels
```

APPENDIX D

TRAVEL DATA USED FOR VICTORIA, TEXAS

Table D-1
2015 Forecast Approach Volumes

US 77 & SH 175

	Northbound			Eastbound			Southbound			Westbound			Intersection
Volume	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Totals
TP1	208	112	320	183	99	282	214	115	329	177	177	354	1,285
TP2	829	678	1,507	759	597	1,356	851	697	1,548	706	706	1,412	5,823
TP3	183	122	305	161	107	268	188	125	313	156	156	312	1,198
TP4	474	388	862	418	342	760	475	399	874	404	404	808	3,304
Totals			2,994			2,666			3,064			2,886	11,610

Loop 463 & FM 1685

	Northbound			Eastbound			Southbound			Westbound			Intersection
Volume	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Totals
TP1	558	239	797	296	160	456	742	318	1,060	433	433	866	3,179
TP2	1,990	1,765	3,755	1,180	966	2,146	2,645	2,345	4,990	1,542	1,542	3,084	13,975
TP3	494	266	760	260	174	434	656	353	1,009	383	383	766	2,969
TP4	1,139	1,010	2,149	675	553	1,228	1,513	1,342	2,855	882	882	1,764	7,996
Totals			7,461			4,264			9,914			6,480	28,119

Loop 463 & SH 236

	Northbound			Eastbound			Southbound			Westbound			Intersection
Volume	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Totals
TP1	112	60	172	383	206	589	558	239	797	414	414	828	2,386
TP2	447	366	813	1,527	1,249	2,776	1,990	1,765	3,755	1,648	1,648	3,296	10,640
TP3	99	66	165	337	225	562	494	266	760	364	364	728	2,215
TP4	256	209	465	874	715	1,589	1,139	1,010	2,149	943	943	1,886	6,089
Totals			1,615			5,516			7,461			6,738	21,330

Loop 463 & Salem Road

	Northbound			Eastbound			Southbound			Westbound			Intersection
Volume	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Totals
TP1	244	238	482	1,506	646	2,152	489	434	923	1,373	1,373	2,746	6,303
TP2	1,100	1,040	2,140	5,370	4,762	10,132	2,259	2,086	4,345	4,893	4,893	9,786	26,403
TP3	245	193	438	1,332	717	2,049	492	387	879	1,214	1,214	2,428	5,794
TP4	645	595	1,240	3,073	2,704	5,777	1,293	1,193	2,486	2,800	2,800	5,600	15,103
Totals			4,300			20,110			8,633			20,560	53,603

Loop 463 & Airline Dr

	Northbound			Eastbound			Southbound			Westbound			Intersection
Volume	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Peak	Off-Peak	Total	Totals
TP1	223	198	421	1,194	512	1,706	-	-	-	1,234	1,234	2,468	4,595
TP2	1,030	951	1,981	4,258	3,776	8,034	-	-	-	4,398	4,398	8,796	18,811
TP3	224	176	400	1,056	569	1,625	-	-	-	1,091	1,091	2,182	4,207
TP4	589	544	1,133	2,436	2,160	4,596	-	-	-	2,517	2,517	5,034	10,763
Totals			3,935			15,961			-			18,480	38,376

Table D-2
Peak Hour Factors (PHF) by Time Period

Time Period		PHF
TP1	Morning Peak Hour	0.1069
TP2	Midday	0.5033
TP3	Afternoon Peak Hour	0.1018
TP4	Overnight	0.2880

Table D-3
Directional Split by Time Period

Time Period		Directional Split
TP1	Morning Peak Hour	0.70
TP2	Midday	0.53
TP3	Afternoon Peak Hour	0.65
TP4	Overnight	0.50

APPENDIX E

MOBILE5a SETUPS FOR VICTORIA, TEXAS, EMISSION FACTORS

Table E-1
Summer 2015 Victoria County MOBILE5a Setup for TP1

```
1996           PROMPT
1 Victoria County  2015 Estimated Emissions - TP1
1              TAMFLG  - Default: Tampering Rates
1              SPDFLG  - User Input: one speed for all vehicle types
1              VMFLAG  - MOBILE5A VMT Mix for 1996
1              MYMRFG  - MOBILE5A Vehicle Registration Distribution
1              NEWFLG  - Default: Basic exhaust emission rates
1              IMFLAG  - No I/M
1              ALHFLG  - No additional correction factors
1              ATPFLG  - No ATP
5              RLFLAG  - Zero-out refueling emissions
2              LOCFLG  - User input: one LAP record for all scenarios
2              TEMFLG  - User input temperature
4              OUTFMT  - 80-column descriptive format
4              PTRFLG  - Print all three pollutant emission factors
1              IDLFLG  - No idle emissions calculated or printed
3              NMHFLG  - Print HC = volatile organic compounds (VOC)
1              HCFLAG  - Print total HC
.581.204.089.033.002.004.083.005                            VMT Mix
Victoria 2015       79.4 79.4 08.3 08.7 92                  LAP
1 15 30.0 79.4 20.6 27.3 20.6  7                            SCN 1.a
```

Table E-2
Summer 2015 Victoria County MOBILE5a Setup for TP2

```
1996           PROMPT
1 Victoria County  2015 Estimated Emissions - TP2
1              TAMFLG  - Default: Tampering Rates
1              SPDFLG  - User Input: one speed for all vehicle types
1              VMFLAG  - MOBILE5A VMT Mix for 1996
1              MYMRFG  - MOBILE5A Vehicle Registration Distribution
1              NEWFLG  - Default: Basic exhaust emission rates
1              IMFLAG  - No I/M
1              ALHFLG  - No additional correction factors
1              ATPFLG  - No ATP
5              RLFLAG  - Zero-out refueling emissions
2              LOCFLG  - User input: one LAP record for all scenarios
2              TEMFLG  - User input temperature
4              OUTFMT  - 80-column descriptive format
4              PTRFLG  - Print all three pollutant emission factors
1              IDLFLG  - No idle emissions calculated or printed
3              NMHFLG  - Print HC = volatile organic compounds (VOC)
1              HCFLAG  - Print total HC
.581.204.089.033.002.004.083.005                            VMT Mix
Victoria 2015       90.0 90.0 08.3 08.7 92                  LAP
1 15 30.0 90.0 20.6 27.3 20.6  7                            SCN 1.a
```

Table E-3
Summer 2015 Victoria County MOBILE5a Setup for TP3

```
1996           PROMPT
1 Victoria County  2015 Estimated Emissions - TP3
1              TAMFLG  - Default: Tampering Rates
1              SPDFLG  - User Input: one speed for all vehicle types
1              VMFLAG  - MOBILE5A VMT Mix for 1996
1              MYMRFG  - MOBILE5A Vehicle Registration Distribution
1              NEWFLG  - Default: Basic exhaust emission rates
1              IMFLAG  - No I/M
1              ALHFLG  - No additional correction factors
1              ATPFLG  - No ATP
5              RLFLAG  - Zero-out refueling emissions
2              LOCFLG  - User input: one LAP record for all scenarios
2              TEMFLG  - User input temperature
4              OUTFMT  - 80-column descriptive format
4              PTRFLG  - Print all three pollutant emission factors
1              IDLFLG  - No idle emissions calculated or printed
3              NMHFLG  - Print HC = volatile organic compounds (VOC)
1              HCFLAG  - Print total HC
.581.204.089.033.002.004.083.005                            VMT Mix
Victoria 2015       91.1 91.1 08.3 08.7 92                  LAP
1 15 30.0 91.1 20.6 27.3 20.6  7                            SCN 1.a
```

Table E-4
Summer 2015 Victoria County MOBILE5a Setup for TP4

```
1996           PROMPT
1 Victoria County  2015 Estimated Emissions - TP4
1              TAMFLG  - Default: Tampering Rates
1              SPDFLG  - User Input: one speed for all vehicle types
1              VMFLAG  - MOBILE5A VMT Mix for 1996
1              MYMRFG  - MOBILE5A Vehicle Registration Distribution
1              NEWFLG  - Default: Basic exhaust emission rates
1              IMFLAG  - No I/M
1              ALHFLG  - No additional correction factors
1              ATPFLG  - No ATP
5              RLFLAG  - Zero-out refueling emissions
2              LOCFLG  - User input: one LAP record for all scenarios
2              TEMFLG  - User input temperature
4              OUTFMT  - 80-column descriptive format
4              PTRFLG  - Print all three pollutant emission factors
1              IDLFLG  - No idle emissions calculated or printed
3              NMHFLG  - Print HC = volatile organic compounds (VOC)
1              HCFLAG  - Print total HC
.581.204.089.033.002.004.083.005                            VMT Mix
Victoria 2015       79.6 79.6 08.3 08.7 92                  LAP
1 15 30.0 79.6 20.6 27.3 20.6  7                            SCN 1.a
```

APPENDIX F

SAMPLES OF GRADE SEPARATION ANALYSIS

Table F-1
NCTCOG Grade Separation Analysis Example

NCTCOG Method: US 77 & Loop 175

AM Peak		*Midday*		*PM Peak*		*Overnight*	
Vol	5805	Vol	5805	Vol	5805	Vol	5805
Quan	1	Quan	1	Quan	1	Quan	1
Percent	1	Percent	1	Percent	1	Percent	1
2 to 1	0.0748	2 to 1	2.2673	2 to 1	0.0662	2 to 1	2.0606
App Dist	0.11	App Dist	0.11	App Dist	0.11	App Dist	0.11
PHF	0.11	PHF	0.5033	PHF	0.1018	PHF	0.288
Dir Split	0.7	Dir Split	0.53	Dir Split	0.65	Dir Split	0.53
Hours	1	Hours	8.5	Hours	1	Hours	13.5
Before speed	15	Before speed	20	Before speed	15	Before speed	25
After speed	30	After speed	30	After speed	30	After speed	30
Δ EF - co	-11.2594	Δ EF - co	-7.6985	Δ EF - co	-11.5025	Δ EF - co	-3.0186
Δ EF - nox	-0.1041	Δ EF - nox	-0.0154	Δ EF - nox	-0.1038	Δ EF - nox	-0.0016
Δ EF - voc	-0.9379	Δ EF - voc	-0.5890	Δ EF - voc	-1.0666	Δ EF - voc	-0.2179
EMr - nox	-5	EMr - nox	-22	EMr - nox	-4	EMr - nox	-2
EMr - co	-538	EMr - co	-11,146	EMr - co	-486	EMr - co	-3,972
EMr - voc	-45	EMr - voc	-853	EMr - voc	-45	EMr - voc	-287

EMr	Total	Peak Periods
NOx	-34	-9
CO	-16,142	-1,024
VOC	-1,229	-90

**Note: Emr in grams per day

Table F-2
TxDOT Grade Separation Analysis Example

TxDOT Method: US 77 & Loop 175

AM PEAK PERIOD

Before speed (mph)	15	NOTE: EFs are for TP1	NOx	CO	VOC
After speed (mph)	30	Before EF	1.9913	23.3721	2.2570
24-hour 4-way approach volume	11,610	After EF	1.8872	12.1126	1.3191
PHF	0.1069				
Peak hour 4-way approach volume	1,241	**Emission (g/day)**	NOx	CO	VOC
Approach distance (miles)	0.11	No Build	272	3,191	308
Hours in peak period	1	Build	258	1,653	180
		Difference	-14	-1,537	-128

PM PEAK PERIOD

Before speed (mph)	15	NOTE: EFs are for TP3	NOx	CO	VOC
After speed (mph)	30	Before EF	2.0107	23.8685	2.5438
24-hour 4-way approach volume	11,610	After EF	1.9069	12.3660	1.4772
PHF	0.1018				
Peak hour 4-way approach volume	1,182	**Emission (g/day)**	NOx	CO	VOC
Approach distance (miles)	0.11	No Build	261	3,103	331
Hours in peak period	1	Build	248	1,608	192
		Difference	-13	-1,496	-139

AM & PM Peak Period

Emission (g/day)	NOx	CO	VOC
No Build	533	6,294	639
Build	506	3,261	372
Difference	-28	-3,033	-267