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16. Abstract

This report documents a study to analyze the sensitivity of the Urban Airshed Model to mobile source emissions. Included in the report is an overview of some of the key features and requirements of the Clean Air Act Amendments; a discussion of the emission inventory process and procedures; an overview of the Urban Airshed Model's inputs, sequence of events, and outputs; a discussion of the sensitivity of the Urban Airshed Model to changes in mobile source emissions; and a discussion of the implications of this sensitivity.

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Urban Airshed Model Sensitivity to Mobile Source Emissions

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Urban Transportation Investment Decisions

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College Station, Texas

Implementation Statement

This report discusses the sensitivity of the Urban Airshed Model to changes in mobile source emissions and is, therefore, primarily informational. No recommendations regarding procedures to be implemented by the Texas Department of Transportation are made.

Disclaimer

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration 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. Raymond Krammes, Ph.D., was the Principal Investigator for the project.

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Summary

Studies on the sensitivity of the Urban Airshed Model to changes in mobile source emissions are limited. Few studies have been specifically undertaken to examine this subject. Most of the research on UAM sensitivity to mobile source emissions has been conducted by Systems Applications International and sponsored by the Environmental Protection Agency. The accuracy of the emission inventory is essential to produce realistic results when running the UAM. Evidence suggests that the UAM is sensitive to large changes in mobile source emissions; however, research has provided little or no evidence to support the sensitivity of the UAM to small changes in mobile source emissions. Because data are insufficient to support the UAM's sensitivity to small changes in mobile source emissions, decisions to implement projects or programs that will yield only small benefits in mobile source emission (i.e., TCMs) to solve air quality problems are brought into question.

TCMs are a strategy aimed at primarily reducing VMT through an attempt to change human behavior; i.e., a shift from single occupancy vehicles to carpools, mass transit, etc. To reduce VMT, people must be encouraged to use multiple occupancy vehicles such as transit or carpool, use alternative transportation modes, or eliminate the trip altogether. Encouragement may be either positive, such as a tax break, or negative, such as a toll. A difficulty also arises with TCMs when congestion is reduced, but latent travel demand returns the congestion and produces a net status quo or increase in VMT. TCMs have been projected to yield approximately a 2 percent reduction in mobile source emissions. Preliminary results on the sensitivity of the UAM to mobile source emissions suggest that the model is insensitive to small changes in mobile source emissions, making the cost-effectiveness of TCMs uncertain.

The current research is adequate to make only a preliminary conclusion that the UAM is insensitive to small changes in mobile source emissions. More research is needed to formulate a concrete conclusion. It is probable that UAM sensitivity to mobile source emissions varies from nonattainment area to nonattainment area. Thus, an analysis of UAM mobile source emission sensitivity may be valid only for the particular nonattainment area analyzed.

I. Introduction

Accurately estimating mobile source emissions impacts on urban air quality is necessary in order to develop regional strategies that improve urban air quality. This issue is particularly important due to the recent implementation of the 1990 Clean Air Act Amendments (CAAA). The CAAA requires greater cooperation between transportation and air quality officials to develop transportation plans and programs that achieve emission reductions which will result in attainment.

The main objective of the study is to determine the sensitivity of the Urban Airshed Model (UAM) to mobile source emissions inputs. A detailed literature review, meetings, and follow-up phone calls to state and private agencies concerned with mobile source emissions and the UAM were conducted as background to the research. The impact of emission inventories and the methodologies used to collect the inventory data are also of interest. The UAM is a three-dimensional photochemical model which uses meteorological and precursor emission data to determine ozone conditions for an urban air shed. Precursor emission data include mobile source emissions. The research is focused on one of the inputs to the UAM, mobile source emissions. The study provides better understanding of the relationship between mobile source emissions and regional ozone concentrations. This research focuses primarily on examining the results of the UAM where all inputs remained constant except for mobile source emissions. By evaluating the UAM's sensitivity to mobile source emissions, transportation planners can better evaluate the potential regional air quality benefits that can be realized by reductions in mobile source emissions. The UAM was not run in conjunction with this study. The authors relied on UAM applications performed by others for the sensitivity analysis data reported in Chapter V, Sensitivity of UAM to Changes in Mobile Source Emissions.

This report is one of several reports prepared as a part of Project 1279, Air Pollution Implications of Urban Transportation Investment Decisions.

Problem Statement

An understanding of the sensitivity of the UAM to changes in mobile source emissions is needed to enhance the decision-making process that determines regional air quality strategies. Applications of the UAM is used to demonstrate that prepared air quality strategies will result in attainment of the ozone standard. Final attainment is established through ambient monitoring. Thus, it is necessary for the relationship between the inputs of the UAM, in this case mobile source emissions, and the output of the UAM, ozone concentrations, to be understood so that appropriate air quality strategies can be developed.

Report Objectives

The objective of this report is to examine the sensitivity of the Urban Airshed Model (UAM) to changes in mobile source emissions. The study examines how changes in mobile source emissions may impact the ozone concentrations predicted by the UAM. Also examined were the smallest level of change to which UAM is expected to be sensitive. The study also examines the potential effects of Transportation Control Measures, TCMs, on, mobile source emissions.

II. Background

The Clean Air Act Amendments

The Clean Air Act (CAA) of 1963 was the first environmental clean air law authorized by Congress. The original Act has been amended three times, in 1970, 1977, and 1990. The CAA requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS), and it empowers the individual states to implement and enforce regulations to attain the standards. The NAAQS are threshold concentrations. Concentrations below the standard are expected to have no harmful effects on humans and the environment. The NAAQS have a primary standard and a secondary standard. The primary standard is designed for safeguarding public health with consideration of a safety factor, and the secondary standard is designed to protect the public welfare as measured by the effects of the pollutant on vegetation, materials, and visibility (1). The EPA measures NAAQS by grams of pollutants per cubic meter of air (g/m^3) or in parts of pollutant per million parts of air (ppm) (2).

The CAA requires that a State Implementation Plan (SIP) be established for areas in nonattainment of the NAAQS to reduce criteria pollutant emissions to within NAAQS compliance. SIPs must be adopted by local and state governments and approved by the EPA. Once the EPA approves a SIP, it is a legally binding contract under both state and federal law.

The Clean Air Act Amendments (CAAA) of 1970 established 1975 as the deadline for meeting the NAAQS. However, by 1977, two years after the deadline, numerous areas were still in nonattainment. The CAAA of 1977 authorized delayed compliance of the ozone and carbon monoxide NAAQS until 1982, and areas that demonstrated that the 1982 deadline was too rigid were given until 1987. In 1990, three years after the final deadline, more than 133 million Americans were living in 98 nonattainment areas (1).

The CAAA of 1990 mandated that areas with air pollutant concentrations above national standards for any of six pollutants follow the regulatory guidelines laid out in the Act to bring the area to attainment of the standards. Further reference to the CAAA in this report refers 1990 amendments.

Mobile Source Emissions

Mobile source emissions are produced primarily by on-road vehicles such as automobiles and trucks. Mobile sources are major producers of air pollution, generating volatile organic compounds (VOCs) and nitrogen oxides (NOx) that contribute to the formation of ozone and also producing the majority of the carbon monoxide (CO) pollution. The transportation sector is responsible for assisting air quality agencies in estimating the current and future amount of emissions from mobile sources and in

implementing control measures to reduce mobile source pollution.

Part of the purpose of the CAAA is to reduce of mobile source emissions in urbanized areas. TCMs are required in areas designated as severe or extreme ozone nonattainment areas. The EPA lists 16 TCMs in their guidance document, but additional TCMs may also be implemented if they are shown to reduce mobile source emissions. Failure to comply with CAAA requirements can result in sanctions against the state, including the withholding of federal highway funding. A list of eligible TCMs are listed in Section 108(f) of the CAAA and are shown in Table 1 (3).

What is Air Quality?

Air quality is determined by the amount of harmful effects caused by pollution to humans, other living organisms, or man-made materials. In simple terms air quality is a concentration of pollutants that is potentially damaging to the environment. Transportation specialists focus on reducing mobile source emissions to improve overall air quality. Air quality and mobile source emissions are not the same but are undeniably closely related. Mobile source emissions help cause the air quality problem of the nation but are not the only emission source. Area sources, such as dry cleaners or print shops, and point sources, such as industrial stacks, also contribute emissions which deteriorate air quality. The meteorology and topography of a geographic region also play a significant role in the formation of ozone and carbon monoxide "hot spots." Thus, the reduction of mobile source emissions will help improve air quality but the magnitude of the effect is dependent on many variables such as the portion of the region's total emissions that originate from mobile sources, meteorology, and the topography of the region. Understanding the effect of changes in mobile source emissions on regional air quality is complex.

Nonattainment Areas

Nonattainment areas as defined by the EPA are geographical areas where air quality does not meet federal air quality standards designed to protect the public health (4). The CAAA of 1990 require the EPA to designate the boundaries and classifications of the nonattainment zones. Nonattainment areas are classified according to the degree of noncompliance with the NAAQS. For example, ozone classifications are extreme, severe, serious, moderate, or marginal, depending on the level of noncompliance severity. The level of noncompliance severity is factored by comparing the NAAQS and the percentage of nonattainment over the standard. The classifications of nonattainment are shown in Table 2. Table 3 shows the four ozone nonattainment areas in Texas (5). CO nonattainment standards (5) are shown in Table 4 (5).

Table 1. EPA-approved TCMs: Section 108(f)(1)(A) of CAAA of 1990

Eligible TCMs	
(I)	programs for improved public transit
(ii)	restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high-occupancy vehicles (HOV)
(iii)	employer-based transportation management plans, including incentives
(iv)	trip-reduction ordinances
(v)	traffic flow improvement programs that achieve emission reductions
(vi)	fringe and transportation corridor parking facilities serving multiple-occupancy vehicle programs or transit service
(vii)	programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use
(viii)	programs for the provision of all forms of high-occupancy, shared ride services
(ix)	programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicles or pedestrian use, both as to time and place
(x)	programs for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas
(xi)	programs to control extended idling of vehicles
(xii)	reducing emissions from extreme cold-start conditions*
(xiii)	employer-sponsored programs to permit flexible work schedules
(xiv)	programs and ordinances to facilitate non-automobile travel, provision and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel, as part of transportation planning and development efforts of a locality, including programs and ordinances applicable to new shopping centers, special events, and other centers of vehicle activity
(xv)	programs for new construction and major reconstruction of paths, tracks or areas solely for the use by pedestrian or other non-motorized means of transportation when economically feasible and in the public interest. For purposes of this clause, the Administrator shall also consult with the Secretary of the Interior
(xvi)	programs to encourage removal of pre-1980 vehicles*

* Excluded by ISTEA
Source: Section 108F, CAAA

Table 2. Classification of Ozone Nonattainment Areas

Designation	% above 0.12 pm ozone	Ozone design value range, ppm	Years allowed to attain ozone NAAQS	Number of areas, 1989
Extreme	>133	>0.280	20	1
Severe	50-133	0.180-0.280	15	8
Serious	33-50	0.160-0.180	9	16
Moderate	15-33	0.138-0.160	6	35
Marginal	0-15	0.121-0.138	3	36

Table 3. Ozone Nonattainment Areas in Texas

Nonattainment Area	Classification	Design Value	Attainment Date
Dallas-Fort Worth	moderate	0.14 ppm	November 15, 1996
Beaumont-Port Arthur	serious	0.16 ppm	November 15, 1999
El Paso	serious	0.17 ppm	November 15, 1999
Houston-Galveston-Brazoria	severe-17	0.22 ppm	November 15, 2007

Table 4. Carbon Monoxide Nonattainment Areas

Classification	Design Value (ppm)	Attainment Deadline
Moderate<=12.7	9.1 - 12.7	December 31, 1995
Moderate>12.7	12.8 - 16.4	December 31, 1995
Serious	16.5 and above	December 31, 2000

Note: El Paso is also a nonattainment area for CO (12.6 ppm) moderate 9.1-12.7 ppm, attainment date: 12/31/95).

Transportation Related Criteria Pollutants

The four principal criteria pollutants for transportation are volatile organic compounds, nitrogen oxides, carbon monoxide, and ozone.

VOCs are compounds of carbon and hydrogen which are chemically reactive and participate in chemical reactions with nitrogen dioxide that form ozone. The NAAQS for VOCs is 0.24 ppm during the hours of 6 to 9 A.M. (4).

NOx, the sum of nitric oxides and nitrogen dioxides, is associated with causing the brown color of smog. NOx acts as an important contributor to acid rain. NOx is formed in high temperature combustion processes such as those occurring in fossil-fueled engines. Nitrogen dioxide is formed when nitrogen oxide undergoes oxidation in the air. The NAAQS for NOx is .05 ppm during a one-hour average (4).

Carbon monoxide, CO, is an odorless gas whose principal anthropogenic source is incomplete combustion of organic fuels. It is toxic because it combines with the hemoglobin of the blood to produce carboxyhemoglobin and, thereby, reduces the blood's ability to carry oxygen. Observed health effects include headaches, dizziness, vision impairment, and slowed reaction time. The NAAQS for CO is 9 ppm during an eight-hour period (4).

Ozone (O3) is a colorless gas with a pungent odor. Ozone has no significant direct emission sources. It is formed in the troposphere by photochemical reactions involving VOCs and NOx. Large quantities of ozone are also found in the stratosphere above 50,000 feet. Ozone is a strong pulmonary irritant that causes discomfort and reduced pulmonary function in sensitive individuals. Ozone may also cause increased susceptibility to respiratory infections such as lung inflammation, breathing difficulty, chest pain, and coughing, and the increased probability of asthma attacks. Furthermore, ozone damages many materials and is toxic to plants. The NAAQS for ozone is 0.12 ppm during a one-hour average (4).

Motor vehicles are a dominant source of VOC, NOx, and CO in most nonattainment areas (6). Cars and trucks built today produce 60 to 80 percent fewer pollutants than vehicles built in the 1960s, but they still produce almost half of the emissions of VOCs and NOx, the precursors of ozone. Today's vehicles produce up to 90 percent of the CO in urban areas. The reasons that the total emissions produced have not decreased are (1) an increase in the number of vehicles on the road, and (2) an increase in the total miles driven (VMT). These increases have offset a large portion of the huge gains made by improved vehicle emission technology (7).

Transportation Control Measures

TCMs are one of the tools available to transportation specialists to reduce mobile source emissions. TCMs are required in severe and extreme nonattainment areas; however, TCMs may be

implemented in any nonattainment area or even attainment areas. TCMs are strategies designed to reduce single occupancy vehicle (SOV) travel and encourage high occupancy, bicycle, and pedestrian trips instead, and/or discourage the trip entirely. VMT growth has offset the gains made by improvements in vehicle emission technology. General strategies which are implemented by TCMs to reduce VMT are: reduce the total number of trips and increase vehicle occupancy.

Reducing the total number of trips is the most powerful strategy because trips are eliminated altogether. This can be accomplished by the implementation of telecommuting and teleconferencing, building/improving non-motorized facilities such as bicycle or pedestrian walkways, and to some extent increased transit use. Vehicle occupancy can be increased by implementing ridesharing programs, constructing high occupancy vehicle (HOV) lanes, adding park-and-ride lots, implementing parking management such as restricting the parking supply or increasing parking charges (congestion pricing), and making transit improvements.

The State Implementation Plan (SIP)

The SIP is the technical and regulatory process for demonstrating NAAQS attainment and maintenance. The EPA must approve the SIP; and, once approved, it is supported through enforcement of federal law. The SIP dictates the required reduction in criteria pollutants or precursor emissions needed to reach attainment by a designated target year. The SIP is monitored by reasonable further progress (RFP) which tracks the rate of emission control progress needed to attain the NAAQS for ozone. RFP is required by the SIP to demonstrate measurable advancement in attaining emission goals. The RFP provision of the act requires a 15 percent reduction in VOC emissions over the first six years below the base year inventory and 3 percent per year averaged over each three-year period thereafter for all but marginal nonattainment areas. SIPs will rely on enhanced monitoring of ozone, NOx, and VOCs to demonstrate attainment and maintenance of the NAAQS in serious, severe, and extreme areas. A less stringent process is allowed for moderate and marginal areas (1).

The SIP is made up of three primary components, emission inventory, demonstration phase, and implementation phase. The emission inventory is a report of all the emission data including air quality measurements, meteorological data, and criteria pollutant emissions (both anthropogenic and biogenic).

In the demonstration phase, air quality models are developed to test the SIP and verify its accuracy. This is accomplished by developing an air quality model for the inventory year and comparing the model results with the actual measurements. This process is repeated, and the model is adjusted and calibrated with each iteration until the model produces results comparable to the actual measurements. The next step is to apply control measures to the model and run the model for the target year for the attainment demonstration. The target year air quality model includes projected precursor emissions, reactivity

reductions, and control measures. The demonstration phase may take from one to four years and ends when the EPA approves the SIP. The implementation phase begins with EPA approval and ends with attainment or when the EPA has determined that the SIP is deficient and issues a recall, or, as a last resort, develops a Federal Implementation Plan (FIP). The FIP either supplements (sanctions) or completely replaces the SIP (1).

Attainment

Ambient air quality measurements are the basis for determining NAAQS attainment. The EPA has strict guidelines for site location, instrumentation, and quality assurance. State and local agencies are required to maintain standard operating procedures for air quality monitoring in accordance with National Air Monitoring Systems (NAMS)/State and Local Air Monitoring Systems (SLAMS). The NAMS/SLAMS network consists of 231 NAMS and 420 SLAMS sites as of 1990. The number and spatial distribution of the ozone air quality monitoring stations is a function of the population in the air quality region. Each region is required to have a minimum of two sites, one upwind of the population during high ozone concentration episodes and one downwind of those episodes (1).

A pivotal element of an ozone SIP is the relation of VOC and NOx emissions to ozone concentration via air quality models such as the UAM. An air quality model is a mathematical simulation (computer program) that utilizes the emission data and subjects the data to atmospheric transport, mixing, photosynthesis, and removal processes to estimate ozone concentrations.

Conformity

In order to achieve NAAQS, nonattainment areas must be analyzed and controlled on a regional basis. Projects contained in transportation plans and programs should be analyzed in the aggregate, rather than individually. The process does not require that each project in the transportation plan and program be analyzed individually; rather it requires transportation plans and programs, when taken as a whole, to conform to the SIP. This necessitates close coordination and cooperation between transportation and air quality officials during the development of transportation plans and programs and of the SIP to ensure that sufficient control measures are included in the implementation plans to achieve timely attainment of the standards (8).

The conformity provisions of the 1990 CAAA shift the emphasis from SIP conformity to conforming to a SIP's "purpose" of eliminating NAAQS violations or reducing the severity and number of NAAQS violations and achieving expeditious attainment of the standards. This provision places a greater burden on the transportation program by shifting the conformity process plan comparison during the

system planning process back to an analytical process during the development of plans, programs, and projects. It also significantly increases the contributions that transportation plans, programs, and projects must make toward air quality improvements in nonattainment areas (8).

Interim Guidance is the current conformity guidance established by the EPA and U.S. Department of Transportation. Interim Guidance does not apply to non-federal transportation projects, but emissions from non-federal transportation projects must be included in regional emission analyses. Therefore, emission growth in non-federal projects will have to be offset by emission reductions in federal projects.

III. Emission Inventories

The SIP relies on accurate emission inventories. Thus, the emission inventory is the foundation of the SIP. The CAAA and the SIPs place specific emphasis on developing reliable precursor emission inventories. The emission inventory is used to determine source types by area, the quantity and rate of pollutants emitted, and the kinds of processes and controls used at each source. The emission inventory is the base building block of the SIP because RFP, which is the SIP's built-in monitoring device, will be based on the emission inventory. The demonstration, implementation, and finally attainment of goals delineated in the SIP are critically dependent on the accuracy of the emission inventory. Therefore, it is crucial that the inventory be as accurate and as detailed as possible.

An emission inventory is designed to be a comprehensive, accurate, and current accounting of air pollutant emissions and associated data from sources within the inventory area over a specific time interval. Information contained in the emission inventory data includes source type, source dispersion modeling, pollution control, and compliance information which can be used by the agency to determine the ambient and projected air quality.

Emission inventories are used by state and local agencies to quantify pollutant emissions within their jurisdictions. The emission inventory, in conjunction with ambient monitoring, is a direct indicator of whether the SIP will be demonstrated successfully. The 1977 CAAA mandates the use of inventories for certain areas. The nonattainment plan provisions (Section 172) of the amendments require that an inventory document emissions in nonattainment areas. To meet this requirement, the states are required to provide an emission inventory of point, area, and mobile sources for the nonattainment pollutant.

States are required to develop four kinds of inventories under the CAAA: a base year inventory, RFP projection inventories, periodic inventories, and modeling inventories (9).

The base year inventory is required for all nonattainment classifications and is the primary inventory from which all other inventories are derived. All inventories should be consistent with data provided in the base year inventory. The CAAA calls for states to ensure that this inventory is comprehensive, accurate, and current for all actual emissions of VOCs, NOx, and CO in the area. The inventory must include emissions of these pollutants from stationary point and area sources (anthropogenic and biogenic) and mobile sources including both on-road and off-road.

States must develop RFP projection inventories to demonstrate the strategies by which the CAAA-required RFP emission reductions will be achieved in ozone nonattainment areas. RFP projection inventories are required for moderate, serious, severe, and extreme nonattainment areas. They are based on allowable emissions rather than actual emissions where allowable emissions exist. The number of RFP

projection inventories required of an area increases with the severity of the nonattainment classification.

Periodic inventories are based on actual emissions and must address VOC, NOx, and CO emission sources. Periodic inventories are required for all classifications of ozone nonattainment areas. The primary function of periodic inventories is to track emission reductions in relation to RFP requirements of the CAAA.

Modeling inventories are required for ozone nonattainment areas where photochemical grid modeling is required (serious areas and above and multi-state moderate areas) and in areas where modeling is necessary for demonstrating attainment but photochemical grid modeling is not specifically required. Base year and RFP projection inventories are required for modeling inventories.

The Emission Inventory Process

The EPA has developed and published several guidance documents delineating how the 1990 base year emission inventories are to be prepared. Implementation guidance has been prepared detailing minimum inventory requirements and specific procedures to be followed during inventory preparation. The primary guidance document is *Procedures for the Preparation of Emission Inventories for Carbon Monoxide and Precursors of Ozone, Volume I: General Guidance for Stationary Sources* (EPA-450/4-91-016), which is known as the Procedures Document (10). Minimum inventory requirements for ozone and CO nonattainment areas are described in *Emission Inventory Requirements for Ozone State Implementation Plans* (EPA-450/4-91-010) (11) and *Emission Inventory Requirements for Carbon Monoxide State Implementation Plans* (EPA-450/4-91-011) (12), known collectively as the Requirements Documents. Another report, *Example Documentation Report for 1990 Base Year Ozone and Carbon Monoxide State Implementation Plan Emission Inventories* (EPA-450/4-92-007) (9) is a supplement to the Procedures and Requirements Documents and is designed to provide instructional guidance on how to present and document data for an inventory.

Emissions from biogenic and anthropogenic sources are the basic elements of the emission inventory. Anthropogenic sources include point, area, on-road mobile, and off-road mobile. The inventory process of each emission source will be described individually.

Biogenic Sources

The principal pollutants have significant biogenic (natural) sources, as well as anthropogenic (manmade) sources. Natural sources of CO include oceans, forest fires, green plants, and oxidation of naturally produced hydrocarbons. Biogenic sources of hydrocarbons include anaerobic decomposition of plants in swamps and marshes, seepage from natural gas and oil fields, and emissions from trees. Decomposition of plants in swamps and seepage from natural gas and oil fields primarily produce methane

hydrocarbons. However, trees produce photochemically reactive hydrocarbons (VOCs). Soil bacteria produces nitrogen oxides (NOx). Ozone has no natural biogenic sources, but it is produced in small quantities by atmospheric chemical reactions involving the photosynthesis of biogenically generated volatile organic carbons and nitric oxides. Ozone is also produced in the stratosphere when oxygen atoms collide with oxygen molecules. Stratospheric ozone may be transported to the troposphere through vertical atmospheric mixing. Large quantities of stratospheric ozone may be transported to ground level during a meteorological condition called tropospheric folding which produces an extremely large negative vertical gradient in air circulation (4).

Estimates of global rates of criteria pollutant production can be made for both anthropogenic and biogenic sources. Table 5 below gives global production rates of principal transportation air pollutants in kilograms per year (4).

Table 5. Global Production Rates of Transportation Related Air Pollutants

Pollutant	Biogenic Production (kg/yr)	Anthropogenic Production(kg/yr)
Carbon Monoxide	10^{12}	10^{11}
Volatile Organic Compounds	10^{11}	10^{10}
Nitrogen Oxides	10^{12}	10^{11}

It appears that biogenic sources of primary transportation pollutants exceed those of anthropogenic sources; however, this may be misleading. Biogenic sources tend to be very dispersed over a broad area, whereas anthropogenic sources are typically concentrated in populous regions. This raises the question of the significance of pollution concentration in ozone creation. It would seem that the more concentrated the pollutants, the more ozone produced, but atmospheric mixing plays a major role in determining ozone concentration.

The EPA requires that VOC emissions from biogenic sources be estimated and reported for the base year emission inventories in moderate, serious, severe, and extreme ozone nonattainment areas. States use the PC-Biogenic Emissions Inventory System (PCBEIS), a personal-computer-based model, to estimate biogenic non-methane hydrocarbon emissions from biogenic sources. The model estimates emissions by county on an hourly basis. Results are used as part of the typical operating day emissions for the ozone season. The PCBEIS program accesses information on crop acreage and land use from program's data files. The user then assigns emission rates to different land use types. The model estimates emissions based on a mathematical model utilizing crop acreage and leaf biomass data; thus, it can be used

only for the summer growing season. The input data include location, ozone concentration, and hourly meteorological data. The typical operating day to be run in the model is selected by choosing the highest 10 days of ozone concentration in the last three years. Of the 10 days, the day with the fourth highest temperature is selected as the typical ozone season day and input into PCBEIS. Once the typical ozone season day is determined, more detailed meteorological data from the National Weather Service must be obtained. PCBEIS requires hourly data for cloud cover, relative humidity, wind speed, and temperature (9).

Anthropogenic Sources

Stationary Point Sources

Under the CAAA, the EPA requires that all 100 ton/year and greater VOC, NOx, and CO emission sources located within 25 miles of the designated nonattainment area be included in the area's 1990 base year inventory. Within the designated inventory area, the point source cutoff for VOC sources is 10 tons/year, and the point source cutoff for NOx and CO sources is 100 tons/year. Point sources are those facilities/plants/activities for which individual records are maintained in the inventory because they meet the cutoff minimum (9).

Potential point sources are compiled from existing inventories, state permit files, county business directories, and even telephone books. Once the potential point sources are identified, a survey is conducted to verify the results. This can be accomplished by direct contact via telephone calls, indirect contact via mail surveys, inspections, and consulting air pollution agency files. The final step in the stationary point emission survey, once all point sources are identified and verified, is to provide emission estimates. The emissions from each source are determined using source test results, material balance, and calculations that use appropriate emission factors (9).

Stationary Area Sources

Area sources of VOC, NOx, and CO emissions must be addressed and inventoried in accordance with CAAA requirements. Examples of area sources are gasoline distribution losses, dry cleaning, graphic arts, cutback asphalt pavement, pesticides, commercial solvent use, orchard heaters, and woodstoves.

Gasoline distribution losses are estimated from information on gasoline throughput and tank fill methods. Gasoline throughput is determined using population data and state gasoline use information. Tank fill methods are determined by surveying a percentage of the service stations in the county. Emissions from each tank fill method are different and, therefore, must be calculated separately. The emissions from each fill method are then summed to give the total emissions. Emissions of VOCs from dry cleaning operations may be estimated on a per employee basis. Emissions of VOCs from graphic arts facilities are determined by using population data and emission factors from the EPA Procedures document. Graphic art

facilities with VOC emissions greater that 10 tons/year should not be counted as an area source, because they are counted as a point source. Emissions from cutback asphalts (a mixture of asphalt and either gasoline, kerosene, or diesel) are based on a volume usage basis and type of cutback asphalt. Emulsion asphalts are more environmentally sound because they use water and an emulsifier instead of a petroleum ingredient. The VOC emission total is based on the density multiplied by the volume of each of the types of cutback asphalts, and their sums equal the total. Pesticide VOC emissions are based on acreage of crops and the application rate. CO emission factors for woodstoves and fireplaces are calculated based upon number of woodstoves and fireplaces and the amount of wood burned in cords. Both factors are determined through surveys (9).

Non-road Mobile Sources

Non-road emissions include aircraft, locomotives, agricultural equipment, industrial equipment, construction equipment, lawn and garden equipment, marine vessels, non-road motorcycles, and snowmobiles (13). Emission calculations are typically based on fuel consumption, but farm and garden equipment also include an acreage factor.

On-road Mobile Sources

On-road mobile sources are made up of the registered fleet of motor vehicles used on surfaced roadways. The emission estimation calculation is composed of a vehicle miles traveled (VMT) estimation procedure and an emission factor estimation procedure. The results are summarized by vehicle class, pollutant, and county (9).

The VMT estimation procedure is normally completed by a transportation planning agency. At a minimum, the following subjects need to be included in the VMT discussion (9):

1. Identification of the agency responsible for developing the VMT data;
2. Description of the method used to estimate VMT for the nonattainment area (i.e.,traffic counts, network-based model) that:
    a) explains how functional classifications of road types were defined for the nonattainment area;
    b) explains how speed estimates were developed for each functional class;
    c) explains any assumptions made in developing VMT data;
    d) shows how daily VMT estimates were developed by road type and vehicle class;
3. How the VMT data were developed on a county basis; and
4. How VMT were adjusted for the appropriate peak ozone or CO season day;
5. Summary of VMT data for the nonattainment area by road type classification and by

vehicle class.

The VMT estimation procedure is completed by using the EPA's MOBILE5a model to develop emission factors for on-road mobile sources. At a minimum, the following subjects need to be included (9):

1. Identification of the emission factor model used (MOBILE5a) and the agency responsible for running it;
2. Explanation of the development of all MOBILE inputs;
3. Explanation of the MOBILE output and the emission factors used;
4. Summary of the emission factors developed for each vehicle class and road type by county; and
5. Explanation of how MOBILE-generated emission factors were combined with VMT data to produce emission estimates for on-road mobile sources.

Primary inputs to MOBILE5 are vehicle classification, vehicle age distribution, and predicted travel speeds. Vehicles of different types and of different ages produce different emission quantities. The output of MOBILE5 is grams of pollutant per vehicle mile (g/mile) broken down by vehicle class and speed for any given vehicle fleet. VMT data are collected by utilizing the procedures outlined in Section 187(a) of the CAAA of 1990. The MOBILE5 output is multiplied by VMT from Section 187(a) to obtain mobile source emission estimates for on-road mobile sources.

The EPA specifies systematic traffic ground counts as the underlying data for future estimates of urbanized area VMT. In this approach, traffic counts taken at various locations in an urban road network are directly expanded into an estimate of areawide VMT using statistical methodology and the number of roadway miles associated with each sampling location. The method is designated by the Federal Highway Administration as the Highway Performance Monitoring System (HPMS). The EPA specifies the HPMS approach for purposes of tracking 1993 and later VMT (11). However, the EPA has chosen network models as the best method for forecasting VMT. The EPA guidance addresses only serious CO nonattainment areas or moderate CO areas with a design value greater than 12.7 ppm. In summary, MOBILE5 emission factors are multiplied by VMT to estimate mobile source emissions.

Emission Accuracy

Current emission inventories have significantly underestimated anthropogenic emissions of VOCs, and the accuracy of biogenic emissions of VOCs are questionable (14). Errors in anthropogenic emissions are primarily in mobile sources and in point and area sources that were overlooked or not adequately acknowledged due to the emission inventory procedures used. As a result, past ozone control strategies may have been misdirected (14).

Ozone control strategies are based on VOC/NOx ratios. When this ratio is 10 or less, VOC

controls are generally more effective; whereas when VOC/NOx ratios are 20 or more, NOx controls are more effective (14). Most ozone control strategies have been based on a VOC/NOx ratio of less than 10 and, therefore, VOC control. Because doubts about the accuracy of both anthropogenic and biogenic VOC emission inventories exist, the prevalent control strategies may be subject to change if the VOC/NOx ratio changes based on more accurate emission inventory data.

It is important to understand the relationship between NOx, VOCs, and ozone. Figure 1 outlines the relationship between NOx emissions and ozone formation and destruction. The atmospheric chemistry is cyclic, and the net effect of NOx emissions depends on when and where they occur. A greater understanding of this relationship may reveal new and alternative control strategies.

Emission inventories need to be accurate. In the past, the inventories have been accepted as accurate; but the inventory method has been inadequately tested for accuracy. Also, in the past, the estimation of biogenic emissions and their role in ozone formation was not carefully examined; however, it has been demonstrated that when biogenic emissions are included in the ozone mixing equation, the result is significantly altered.

Another deficiency in emission inventories is the lack of ambient monitoring capability and the reliance on allowable emissions (14). Allowable emissions are the lawful emissions that a point or area source can emit. Allowable emissions are determined by an engineering calculation based on a theoretical fuel consumption rate; therefore, they are not the actual emissions of the point or area source as may be determined through ambient monitoring. For example, a company is allowed to produce paper calculations as a method of demonstrating that their pollution sources meet EPA tolerances. Allowable emissions demonstration through paper calculations instead of ambient monitoring may be an inadequate method of determining precursor emissions.

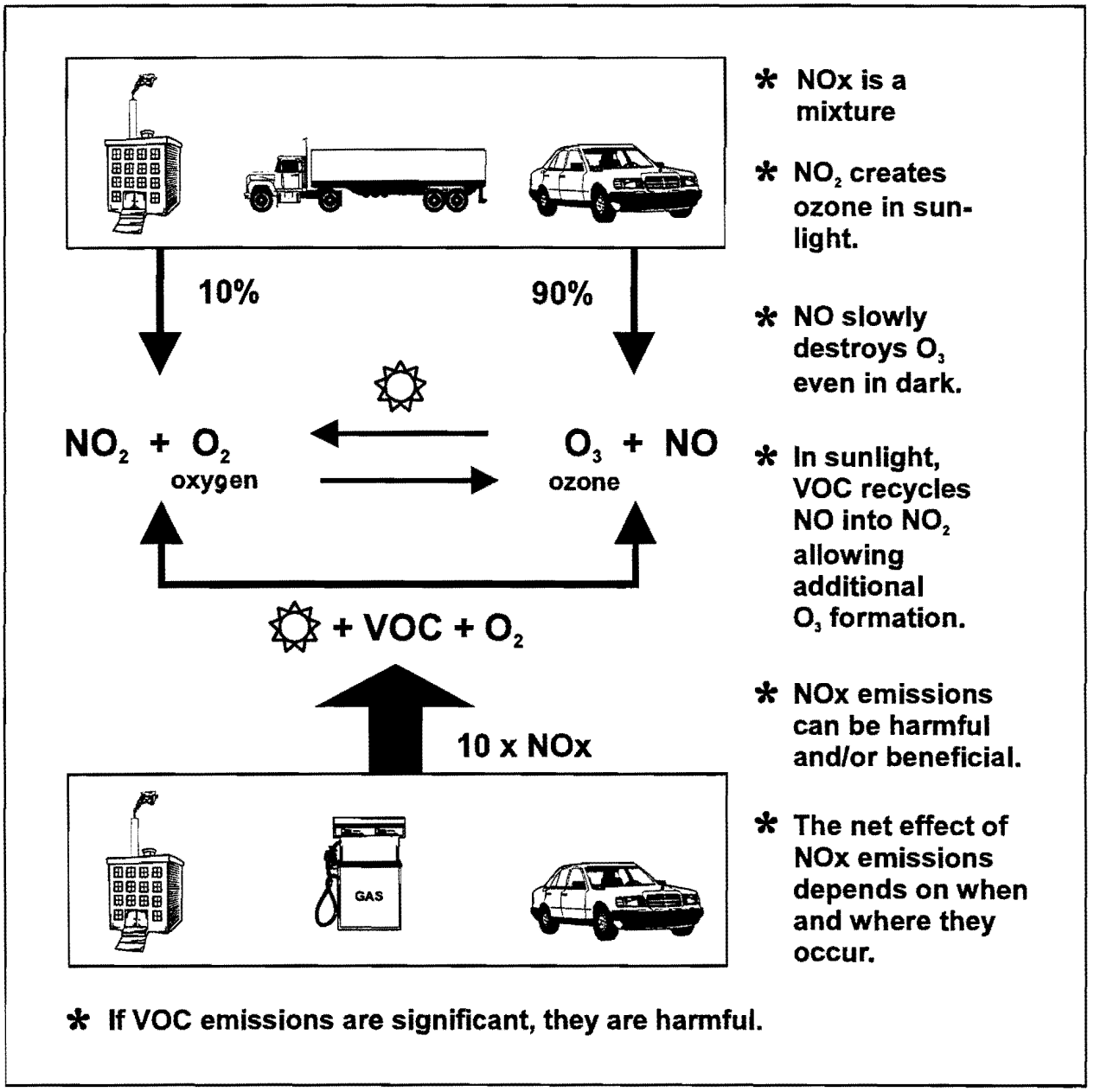

Figure 1. The Effect of NOx Emissions on Ozone Formation and Destruction.

Mobile source precursor emissions are determined by HPMS VMT multiplied by MOBILE5a's supplied emission factors. Mobile source emissions are forecast by the product of a network-model-generated VMT and MOBILE5a's emission factors (6). The HPMS method uses a region's traffic count studies and statistically expands the data from the studies to obtain a regional VMT. Network modeling is commonly used by transportation planners to forecast future VMT.

Summary of Texas Nonattainment Area Emission Inventories

Volatile Organic Compounds

VOC emissions for Texas nonattainment areas are summarized in Table 6. The table reveals that mobile source emissions (on-road and non-road) comprise 50.1 percent of the VOC emissions for the Dallas-Fort Worth nonattainment area. It is reasonable to expect that if mobile source VOCs are reduced substantially in the Dallas-Fort Worth area, the ozone concentrations can be reduced. The table reveals that 19.8 percent of the VOCs in the Houston nonattainment area are from mobile sources. Substantial reductions in mobile source emissions of VOCs will likely result in only modest reductions in ozone concentration. The Beaumont nonattainment area VOC emissions comprise only 10.2 percent of all VOC emissions; a substantial reduction in mobile source VOCs will likely result in a negligible reduction in ozone concentrations. The El Paso nonattainment area VOC emissions comprise 40.3 percent of all emissions. Moderate reduction in ozone concentrations reduction is likely if mobile source VOCs can be reduced significantly.

Table 6. VOC Emissions for Texas Nonattainment Areas

	Dallas-Fort Worth Area		Houston Area		Beaumont Area		El Paso Area	
Source	Tons/Day	%	Tons/Day	%	Tons/Day	%	Tons/Day	%
Point	65.64	08.8	651.18	42.2	266.74	61.6	9.35	10.0
Area	179.30	24.1	250.99	16.3	30.47	07.0	34.12	36.3
Non-Road Mobile	151.48	20.4	132.14	08.6	20.85	04.8	9.86	10.5
On-Road Mobile	220.94	29.7	173.60	11.2	23.44	05.4	28.00	29.8
Biogenic	126.09	17.0	335.47	21.7	91.95	21.2	12.62	13.4
Total	743.45	100	1543.38	100	433.45	100	93.95	100

Source: 1990 Base Year Ozone Emission Inventory of Volatile Organic Compound (VOC), Nitrogen Oxides (NOx) and Carbon Monoxide (CO) Emissions for Dallas-Fort Worth, Texas; Houston-Galveston-Brazoria, Texas; Beaumont-Port Arthur, Texas; and El Paso, Texas; Nonattainment Areas, Final Submittal November 1992 by Texas Air Control Board, 12124 Park 35 Circle, Austin, TX, 78753 (14).

Nitrous Oxides

NOx emissions for Texas nonattainment areas are summarized in Table 7. The table indicates the NOx emissions for the Texas nonattainment areas for mobile source emissions as Dallas-Fort Worth, 57.6 percent; Houston Area, 29.5 percent; Beaumont Area, 22.7 percent; and El Paso, 51.2 percent. In the Dallas-Fort Worth and El Paso nonattainment areas, mobile sources are the primary source of NOx emissions. In the Houston and Beaumont nonattainment areas, mobile sources of NOx comprise roughly

one quarter of all NOx emissions, and reductions in mobile NOx emissions may cause a small reduction in ozone concentrations. However, the effect of NOx emissions on ozone formation and destruction are complex (see Figure 1).

Table 7. NOx Emissions for Texas Nonattainment Areas

Source	Dallas-Fort Worth Area		Houston Area		Beaumont Area		El Paso Area	
	Tons/Day	%	Tons/Day	%	Tons/Day	%	Tons/Day	%
Point	111.05	17.4	920.45	66.2	252.80	75.7	23.36	28.8
Area	159.56	25.0	59.39	04.3	05.31	01.6	16.22	20.0
Non-Road Mobile	153.09	24.0	164.75	11.9	42.54	12.8	12.68	15.6
On-Road Mobile	214.04	33.6	244.5	17.6	33.09	09.9	28.90	35.6
Biogenic	NA	NA	NA	NA	NA	NA	NA	NA
Total	637.74	100	1389.09	100	333.74	100	81.16	100

Source: 1990 Base Year Ozone Emission Inventory of Volatile Organic Compound (VOC), Nitrogen Oxides (NOx) and Carbon Monoxide (CO) Emissions for Dallas-Forth Worth, Texas; Houston-Galveston-Brazoria, Texas; Beaumont-Port Arthur, Texas; and El Paso, Texas; Nonattainment Areas, Final Submittal November 1992, by Texas Air Control Board, 12124 Park 35 Circle, Austin, TX, 78753 (14).

Carbon Monoxide

CO emissions for Texas nonattainment areas (summarized in Table 8) are predominately from mobile sources (on-road and non-road). CO mobile source emissions (percentage of all CO emissions) for the nonattainment areas are Dallas-Forth Worth, 97.4 percent; Houston 92.2 percent; Beaumont, 68.8 percent; and El Paso, 95.8 percent. CO mobile source emissions reduction is the key and controlling strategy to obtain CO attainment classification. The greatest gains will come in the Dallas-Fort Worth, Houston, and El Paso areas. Beaumont has significant CO emission production from point sources; therefore, point sources need to be part of the reduction plan.

Table 8. CO Emissions for Texas Nonattainment Areas

Source	Dallas-Fort Worth Area		Houston Area		Beaumont Area		El Paso Area	
	Tons/Day	%	Tons/Day	%	Tons/Day	%	Tons/Day	%
Point	13.88	00.5	198.00	06.7	132.67	26.6	7.67	02.1
Area	62.96	02.1	30.83	01.1	23.06	04.6	7.67	02.1
Non-Road Mobile	773.11	25.5	991.49	33.7	116.90	23.4	96.93	26.5
On-Road Mobile	2173.88	71.9	1718.10	58.5	226.49	45.4	253.29	69.3
Biogenic	NA	NA	NA	NA	NA	NA	NA	NA
Total	3023.83	100	2938.42	100	499.12	100	365.56	100

Source: 1990 Base Year Ozone Emission Inventory of Volatile Organic Compound (VOC), Nitrogen Oxides (NOx) and Carbon Monoxide (CO) Emissions for Dallas-Forth Worth, Texas; Houston-Galveston-Brazoria, Texas; Beaumont-Port Arthur, Texas; and El Paso, Texas; Nonattainment Areas, Final Submittal November 1992, by Texas Air Control Board, 12124 Park 35 Circle, Austin, TX, 78753 (14).

Summary of Texas Nonattainment Area Inventory Findings

Mobile sources of VOCs and NOx are the significant emission sources in the Dallas-Fort Worth and El Paso nonattainment areas. Mobile sources are the dominant source of CO emissions in all Texas nonattainment areas El Paso is the only CO nonattainment area in Texas). Measures to reduce mobile source emissions will have the greatest effect in reducing ozone concentrations in Dallas-Fort Worth and El Paso nonattainment areas.

IV. Urban Airshed Model

In 1984, the EPA's Office of Air Quality Planning and Standards proposed that the Urban Airshed Model be the preferred model for photochemical pollutant modeling applications involving entire urban areas. The EPA finalized the recommendation in 1986 by noting that the UAM is the most widely applied and evaluated photochemical model in existence. The UAM is the recommended air quality simulation model for use in ozone air quality analyses for SIPs as required by the 1990 CAAA (16).

The UAM is a three-dimensional "Eulerian" photochemical grid model designed to calculate the concentrations of both inert and chemically reactive pollutants by simulating physical and chemical atmospheric processes. The calculations are based on the continuity equation, a mathematical description of all relevant atmospheric diffusivity processes of precursor emissions including transport, diffusion, chemical reactions, and the removal processes. The model is a computer simulation which is normally run for a 36- to 72-hour period during which adverse meteorological conditions result in elevated pollutant concentrations (16).

The model uses a three dimensional grid system where horizontal grid size is constant but the vertical layer thickness may vary with time and space. Air is transported from cell to cell and the photochemistry occurs with each cell. This helps guarantee that emissions from major sources occur at the proper location.

The UAM accounts for spatial and temporal variations as well as reactivity speciations of emissions; thus, it is ideal for evaluating the effects of emission control scenarios on urban air quality. Prior to use, the model must be calibrated with emission data from the base year emission inventory. In practice, this is accomplished by running the UAM utilizing the same emission and meteorological data that produced the ambient measurements. When the UAM can replicate the same results that were obtained through ambient measurements (model validation), then the model is calibrated (fine tuned). Once the model is calibrated, the UAM may be used to simulate the future and test control strategies. Table 9 shows the general inputs to the UAM. Figure 2 shows the UAM sequence of events.

Factors that affect photochemical air quality and that must be modeled by the UAM include (16):

1. Spatial (vertical and horizontal) and temporal distribution of anthropogenic and biogenic emissions of NOx, VOCs, and CO;
2. Chemical composition of the emitted NOx and VOCs;
3. Spatial and temporal variations in wind fields;
4. Dynamics of the boundary layer including stability and mixing;

5. Chemical reactions involving VOCs, NOx, CO, and other important species;
6. Diurnal variations of solar insolation and temperature;
7. Loss of ozone and ozone precursors by dry deposition; and

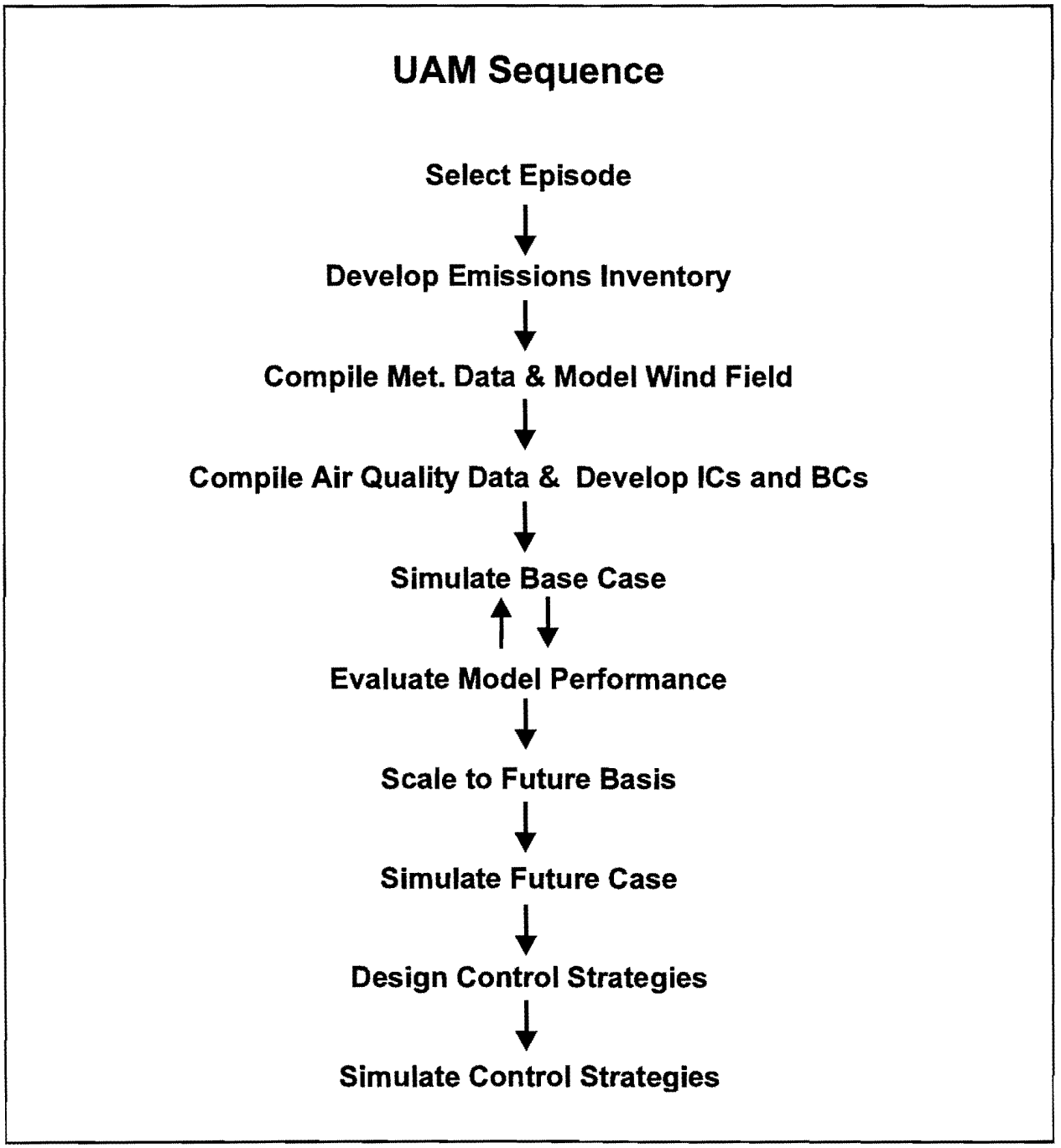

Figure 2. UAM Modeling Sequence

8. Ambient background concentrations of VOCs, NOx, CO, and other species in, immediately upwind of, and above the study region.

Table 9. General UAM Inputs

Meteorological	Temporal wind speed and direction
	Temporal mixing heights
	Temperature
	Terrain features
Air Quality Data	Boundary concentrations
	Initial concentrations
	Composition
	Intra-domain stations
Emissions	Point
	Area
	Mobile
	Gridded and speciated

Source: Texas Natural Resource Conservation Commission, 1994.

Gridded photochemical modeling is recognized as the preferred analysis tool for simulating ozone formation and assessing the effectiveness of proposed strategies for reducing ozone precursors. The UAM is not a perfect model; and, accordingly, the continuation and enhancement of research and application efforts addressing the following areas are needed (14):

1. Improving the ability of chemical mechanisms to characterize biogenic and anthropogenic processes and predict future mixes of the atmospheric pollutants;
2. Integrating day-specific emission estimates, including direct emission measurements, into emission models which develop inputs to air quality models;
3. Integrating prognostic meteorological models capable of characterizing complex flow phenomena into air quality modeling;
4. Developing computationally efficient, bidirectional, variable grid systems offering high spatial resolution and broad geographic coverage;
5. Developing plume-in-grid modeling techniques to more rigorously treat major point source plumes in regional and urban ozone models; and
6. Evaluating models using special, research-grade ambient monitoring and emission inventory data bases.

Many of these recommended improvements and enhancements are being accomplished; however, as improvements in this area are made, the question of the accuracy of the inputs to the model will be

examined with increased scrutiny.

To offset errors in the data base (precursor emission inventory) the National Academy of Sciences (NAS) recommends the following (14):

1. Using multiple meteorological episodes to test emission strategies;
2. Modeling diagnostic and performance evaluations;
3. Expanding domains; and
4. Executing multi-day, as opposed to single day, simulation periods.

V. Sensitivity of UAM to Changes in Mobile Source Emissions

Literature on the UAM's sensitivity to mobile source emissions is limited. Three relevant studies were found; two of the studies are ten years old or more, and the third is a current EPA project being conducted by SAI. Every available information search was considered, including an EPA-TNRCC teleconference regarding UAM sensitivity.

Sensitivity Studies

Determining the sensitivity of the UAM to changes in mobile source emissions requires running the UAM using various levels of mobile source emissions while holding other variables constant. However, because the high number of variables that are held constant, the accuracy of sensitivity analysis is mitigated.

During the late 1970s and early 1980s, the EPA sponsored a series of UAM sensitivity tests (17). The research resulted in 22 sensitivity test cases of which only one is pertinent to this study, Case 12: "The impact of degrading the data base of the UAM in the Los Angeles area." Case 12 examined UAM sensitivity to mobile source emissions when an older mobile source emissions inventory was used in place of a current inventory. The results showed that the use of an older emission inventory (1974) increased the total mobile source emissions. In general, slightly higher ozone levels were obtained, but the changes from the base case (current mobile source emission inventory) were low. The changes in predicted ozone concentrations were less than 4 percent greater in magnitude. The overall maximum ozone level occurred in the same location in the model and it was not notably higher. The study concluded that the use of an older emission inventory for mobile sources has a negligible effect on air quality predictions and that the UAM was fairly insensitive to small changes in mobile source emissions. However, the study also concluded that higher ozone levels will be predicted as a result of higher emission levels from sources, but the level of sensitivity is uncertain. The level of effort required to achieve mobile source emissions reductions is unclear. Also unclear is whether the same resulting sensitivity is true for a different nonattainment area.

Another study sponsored by the EPA in the early 1980s reviewed UAM runs for four cities, St. Louis, Denver, Los Angeles, and Tulsa (18). One aspect of the report concentrated on the sensitivity of the UAM to selected input parameters (including mobile sources). The results of the St. Louis and Tulsa studies suggested that little relationship existed between the ambient measurements or the predicted ozone concentration and the sensitivity of UAM predictions when emissions are changed. Of important note is

that the study found that the days with the highest ozone concentrations were not necessarily the days with the highest emissions. Most likely, other factors, such as meteorology and temperature, dominated ozone formation on those days. This suggests that if the UAM is insensitive to changes in total emissions, then it is logical that the UAM is insensitive to changes in mobile source emissions.

SAI conducted a research project, "Uncertainty Investigation of Emissions Inventories" for the EPA (19). One of the analyses performed was the influence of mobile source VOC emissions on the production of ozone for Detroit and St. Louis. The effects of mobile source emissions on UAM ozone prediction was limited to VOC mobile source emissions. Table 10 shows the effect of varying mobile source emissions (VOCs) on modeled ozone concentrations in Detroit and St. Louis, and the data are plotted in Figure 3.

Table 10. Varying Mobile Source Emissions (VOC) and Predicted Ozone Concentrations

Mobile Source VOC Percent of Base Case	Detroit, Michigan Ozone (ppb)[1]	St. Louis, Missouri Ozone (ppb)[2]
-75	132	Not available
-50	135	122
BASE	157	127
+25	167	Not available
+50	179	130
+75	189	Not available
+100	200	135
+150	218	Not available
+200	229	142

[1] Mobile source VOC is 17% of total VOC (263/1528=17%)
[2] Mobile source VOC is 13% of total VOC (79/526=13%)
Source: Reference (19)

The effects vary greatly from city to city. Detroit is sensitive to large changes in mobile source emissions, whereas St. Louis is only moderately sensitive. Mobile source VOCs for the Detroit area accounts for 17 percent of the total VOCs, and mobile source VOCs consist of 13 percent of the total VOCs for St. Louis.

Although the percentages of mobile source emissions of the total VOCs are fairly similar, the effects caused by varying the mobile source emissions create dissimilarity because of the uncertainty of each of the nonattainment area models. Each nonattainment area has its own personality (or characteristic)

(e.g., total precursor emissions, composition of total emissions by emission type, topography, biogenics, wind, meteorology, mixing height, etc.). A general statement about the sensitivity of the UAM to mobile source emission inputs is unlikely to be feasible due to the large number of inputs and the variation of these inputs in different regions. Each nonattainment area needs to be examined individually to determine its specific sensitivity to mobile source emissions. The study reveals that Detroit, with 17 percent mobile source VOCs, is more sensitive to changes in mobile source VOC emissions than St. Louis, with 13 percent of the total VOCs. The UAM runs showed, however, that the model is insensitive to small changes in mobile source emissions in either case. It is reasonable to expect that other nonattainment areas will

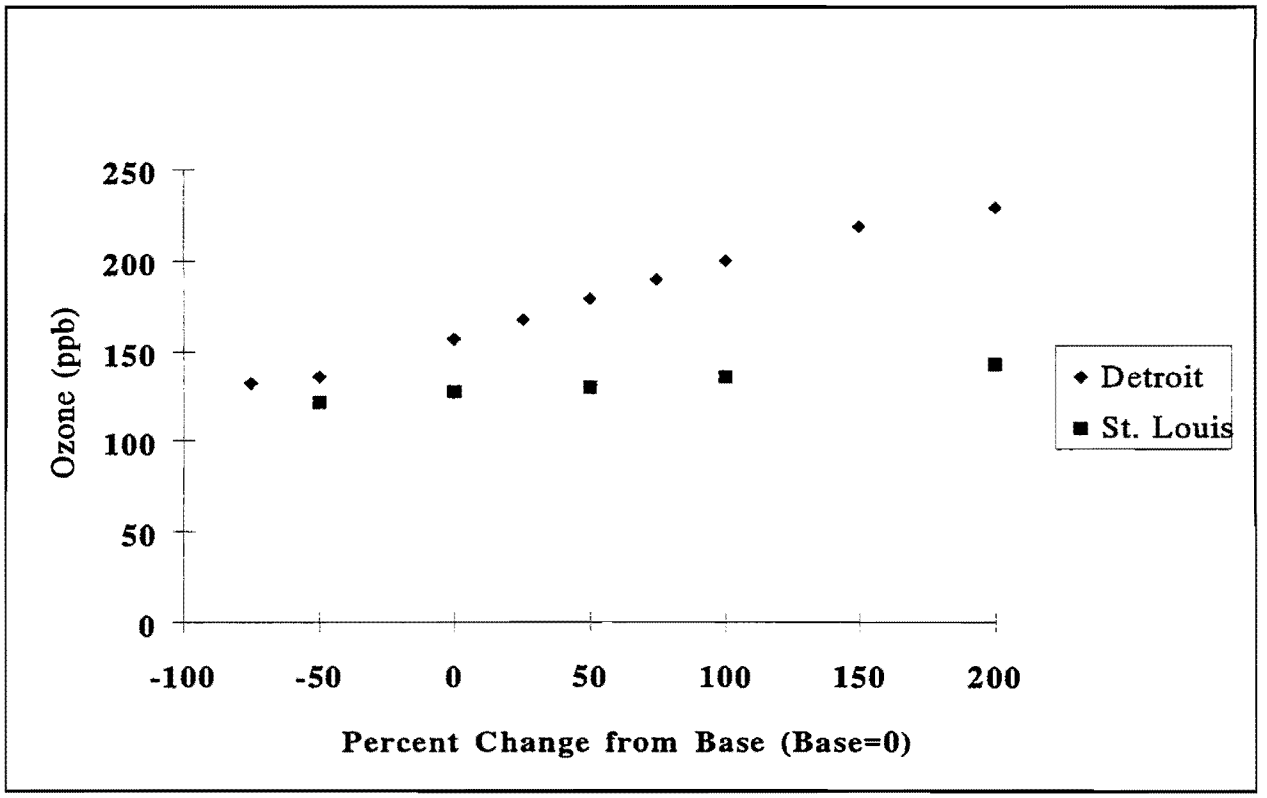

Figure 3. Mobile Source VOC Change Effect on Predicted Ozone

react differently to similar changes in mobile source VOC emissions.

Figure 3 is a plot of the data points for Detroit and St. Louis shown in Table 10. The data points for Detroit have a moderate positive slope and the data points for St. Louis have a small positive slope. These points suggest that Detroit is moderately sensitive to large changes in mobile source VOCs and St. Louis is fairly insensitive to large changes in mobile source VOCs.

The Texas Natural Resources Conservation Commission (TNRCC) conducted sensitivity tests of the UAM towards mobile source VOC emissions. The tests consisted of 1987 through 1991 UAM base cases runs compared to the same runs with mobile source VOCs doubled. Table 11, constructed from data

used for an EPA-TNRCC teleconference on September 3, 1993 (20), shows the results of these tests.

Table 11 : Results of Dallas-Fort Worth UAM Mobile Source Sensitivity Tests

Date	Ozone Measured (ppm)	Ozone UAM (ppm)	Ozone UAM 2XVOC Mobile (ppm)
6/17/87	90	135	141
6/18/87	160	169	194
8/24/88	80	111	132
8/25/88	130	131	134
8/26/88	160	144	149
8/26/90	80	146	182
8/27/90	140	147	184
8/28/90	160	131	165
8/29/90	140	136	177
8/30/90	160	143	175
7/30/91	80	128	158
7/31/91	130	133	138
8/01/91	170	155	179

Source: EPA-TNRCC Teleconference, September 3, 1993.

The first day of each UAM run is an attainment day, and the subsequent days are nonattainment days. Figure 4 shows that the UAM is insensitive to doubled mobile source VOC emissions on certain modeled days (8/25/88, 8/26/88, and 7/31/91). For these days the ozone concentrations predicted for the double mobile source VOC emissions exceeded the ozone modeled for the base case by less than 4 percent. The UAM was insensitive to mobile source VOC emissions on these days. Dallas-Fort Worth mobile source VOCs comprise approximately 50 percent of total VOCs for the region which greatly exceeds the portion of mobile source VOCs to all VOCs for Detroit (17 percent) and St. Louis (13 percent) in the SAI study. This suggests that Dallas-Fort Worth is insensitive to large variations in mobile source VOCs based on the ozone sensitivity runs and the large proportion of mobile source VOCs that are present in the Dallas-Fort Worth region. The other days modeled showed a greater sensitivity to mobile source VOC emissions. This suggests that the UAM's sensitivity to mobile source emissions may be day-to-day dependent.

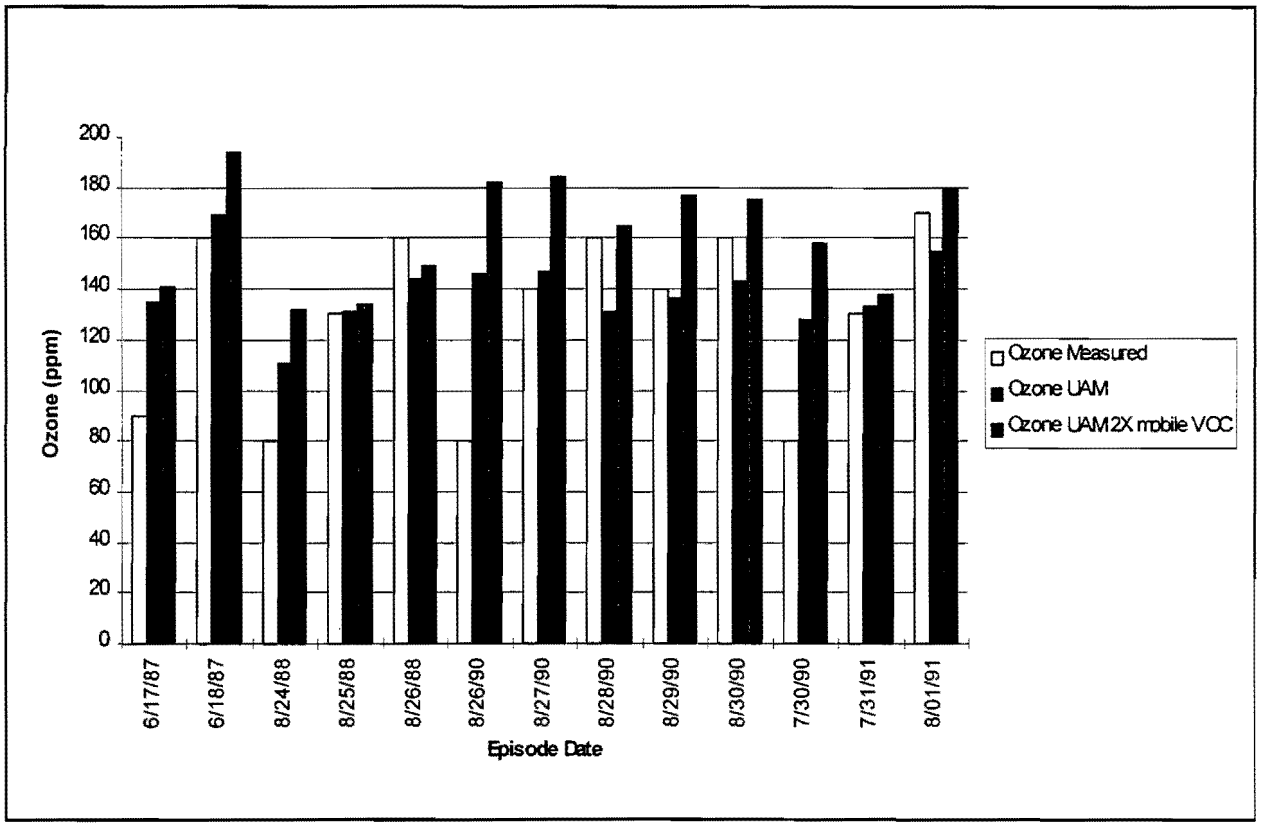

Figure 4. Ozone Sensitivity Runs

VI. Implications of the Sensitivity Study

Studies on the sensitivity of the UAM to changes in mobile source emissions are limited. Few studies have been specifically undertaken to examine this subject. Most of the research on UAM sensitivity to mobile source emissions has been conducted by Systems Applications International and sponsored by the EPA. The accuracy of the emission inventory is essential to produce realistic results when running the UAM. Evidence suggests that the UAM is sensitive to large changes in mobile source emissions; however, research has provided little or no evidence to support the sensitivity of the UAM to small changes in mobile source emissions. Because data are insufficient to support the UAM's sensitivity to small changes in mobile source emissions, decisions to implement projects as programs that will yield only small benefits in mobile source emissions (i.e., TCMs) to solve air quality problems are brought into question.

TCMs are a strategy aimed at primarily reducing VMT through an attempt to change human behavior; i.e., a shift from single occupancy to carpools, mass transit, etc. To reduce VMT, people must be encouraged to use multiple occupancy vehicles such as transit or carpool, use alternative transportation modes, or eliminate the trip altogether. Encouragement may be either positive, such as a tax break, or negative, such as a toll. A difficulty also arises with TCMs when congestion is reduced but latent travel demand returns the congestion and produces a net status quo or increase in VMT. TCMs have been projected to yield approximately a 2 percent reduction in mobile source emissions (21). Preliminary results on the sensitivity of the UAM to mobile source emissions suggest that the model is insensitive to small changes in mobile source emissions, making the cost-effectiveness of TCMs uncertain.

The current research is adequate to make only a preliminary conclusion that the UAM is insensitive to small changes in mobile source emissions. More research is needed to formulate a concrete conclusion. Future research should consist of running the UAM while varying mobile source emissions and holding the other variables of the UAM constant. A possibility exists in the utilization of the super-fast UAM to enhance research analysis capability and reduce cost. It is probable that UAM sensitivity to mobile source emissions varies from nonattainment area to nonattainment area. Thus, an analysis of UAM mobile source emission sensitivity may be valid only for the particular nonattainment area analyzed.

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