Air Quality Aspects Of Traffic Management

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Prepared by

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The University of Alabama, The University of Alabama at Birmingham, and
The University of Alabama in Huntsville

UTCA Report Number 00108
December, 2000

Technical Report Documentation Page

1. Report No FHWA/CA/OR-	2. Government Accession No.	3. Recipient Catalog No.

4. Title and Subtitle Air Quality Impacts of Traffic Management	5. Report Date 12/20/2000 6. Performing Organization Code
7. Authors Dr. Derek Williamson and Mr. Sasidhar Chidanamarri	8. Performing Organization Report No. UTCA Report 00108
9. Performing Organization Name and Address The University of Alabama Civil and Environmental Engineering Department 260 MIB, Box 870205 Tuscaloosa, AL 35487-0205	10. Work Unit No. 11. Contract or Grant No. DTRS98-G-0028
12. Sponsoring Agency Name and Address University Transportation Center of Alabama Box 870205, 275 H M Comer Mineral Industries Building Tuscaloosa, AL 35487-0205	13. Type of Report and Period Covered Final Report/ 01/01/00-12/31/00 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The MOBILE model is used for conformity assessments in transportation projects. With several ozone non-attainment zones in the state, more stringent regulations, and an increased public awareness, it is very important to apply the MOBILE model as appropriately as possible. Discussions with involved regulatory personnel and performance of sensitivity analysis lead to the finding that local data should be used if obtaining that data is reasonable.

Local registration data was used to determine the impact of local fleet composition on emissions estimates, as opposed to default fleet composition. It was concluded that local data can make significant changes in MOBILE model estimates of emissions inventories.

17. Key Words Conformity, Air Pollution, Emission, Transportation	18. Distribution Statement

19. Security Classif (of this report)	20. Security Classif. (of this page)	21. No of Pages	22. Price
		49	

Form DOT F 1700.7 (8-72)

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Executive Summary

Air quality is perhaps the single most visible impact of the transportation industry on the environment. Through emissions of nitrogen oxides (NOx) and volatile organic compounds (VOCs), vehicles contribute to ground-level ozone concentrations in urban and even some rural locations. In the southeast in general, and in Alabama in particular, non-attainment with National Ambient Air Quality Standards (NAAQS) for ozone presents major challenges to industrial growth, including growth in the transportation sector. As regulatory standards become more stringent, more locations will be facing non-attainment status. At the start of this project, Jefferson and Shelby counties were the only non-attainment counties in Alabama. Currently, Jefferson, Shelby, Clay, Madison, and Mobile counties are designated as non-attainment.

In addition, public awareness of the ozone problem is growing. Meeting increasingly stringent air quality standards, demand for economic growth (and associated industrial and transportation air emissions), and local meteorological conditions favorable for ozone formation, are engineering and planning challenges. In accordance with the Clean Air Act (CAA), transportation and environmental agency planners must perform inventories and conformity assessments where estimates of emissions from roadways are necessary. The standard tool for such estimates is the U.S. EPA MOBILE emissions model. However, using the model appropriately and placing the results of the model in the proper context for the public and transportation planners can be quite difficult.

Therefore, this project consisted of two goals: (1) to work with stakeholders to develop educational and outreach materials that could be used by transportation and planning officials to explain the ozone issue to the public, and (2) to improve the applicability of the MOBILE model results to Alabama conditions.

An informal group of stake holders, consisting of: the Alabama Department of Transportation (ALDOT), the Birmingham Regional Planning Commission, the Alabama Department of Environmental Management (ADEM), the U.S. Environmental Protection Agency (EPA) Region IV, and the Alabama Partners for Clean Air (APCA-a nonprofit air quality action group in Birmingham) was assembled. Two public outreach tools were developed to meet some of the educational needs identified by these stakeholders: (1) an electronic presentation to be used by planners when talking to the public, and (2) a website that will serve as the clearinghouse for ground-level ozone information in Alabama (www.alabamacleanair.com), which was developed and delivered to APCA for maintenance. Meetings with stakeholders also identified (1) the use of local registration data as a major need for improved emissions modeling, and (2) the need for simple, spreadsheet-based methods for estimating emission benefits of traffic control measures (TCMs).

Jefferson and Tuscaloosa County vehicle registration data were collected and used in the MOBILE model to evaluate the use of local vs. default data. The use of local data was determined to be significant in cases where the local fleet differs from the default fleet. The only way to estimate local fleet composition is to obtain local data (through registration or counting).

A spreadsheet method was developed (based on MOBILE emission relationships) for evaluating TCMs that increase flow on urban arterials (synchronized signalization and railroad overpasses). This method was tested using local fleet composition data from Jefferson County. For preliminary estimates to prioritize TCMs, the method developed performed satisfactorily.

1.0 Introduction

1.1 Problem Statement

Motor vehicles are a major source of air pollutant emissions in U.S. cities. Motor vehicles emit Volatile Organic Chemicals (VOCs), Nitrogen Oxides (NO_X), and Carbon Monoxide (CO) (1)[*]. VOCs and NO_X react in presence of sunlight to form ground-level ozone, which irritates the eyes, damages lungs, and aggravates respiratory problems (1). Motor vehicles (on-road and off-road) contribute approximately 50% of the total U.S. NO_X and VOC emissions (1). The contribution of emissions from motor vehicles varies greatly from one location to another. In Birmingham, on-road mobile sources contributed 29% of VOC and 18% of NO_X emissions in 1996. In order to control the pollution, the Clean Air Act (CAA) gave the Environmental Protection Agency (EPA) the authority to frame more stringent automobile emission standards. The EPA used its authority to force automakers to invent new control measures, improve engine efficiency, and require the use of non-leaded and reformulated gasoline in vehicles. Since the CAA was passed, automobile tailpipe emissions have been greatly reduced. However, the number of miles driven has doubled (since CAA passage), offsetting the benefits achieved by stringent tailpipe emissions standards. Ozone has remained a persistent air pollution problem in many urban areas and even in several rural areas.

The Intermodal Surface Transportation Efficiency Act (ISTEA) linked transportation planning with transportation conformity requirements of CAA (15). The Clean Air Act Amendments of 1990 provided much more stringent regulations to ensure that transportation planning or investments in non-attainment areas are consistent with State Implementation Plans (SIPs). SIPs are planning documents, which demonstrate how a state will attain National Ambient Air Quality Standards (NAAQS). Conformity regulations have compelled transportation planners to make air quality a factor in the planning process by ensuring that transportation projects do not cause any new air quality violations, do not increase the severity of existing air quality violations, and emphasize the need of timely implementation of transportation control measures (TCMs). Conformity has also encouraged the transportation planning agencies to interact with air quality agencies (16). The approval or denial process for transportation projects is accomplished by first using transportation models and mobile source emission models to make a 20-year forecast of emissions from the transportation projects, accounting for land uses, changing demographics, and improvements in auto emission systems. These predicted emission levels are then compared with emissions permissible under applicable SIPs. Also, conformity requires the upgrading of the analytical tools used in

[*]Please note: Due to many specialized terms, a list of abbreviations and a glossary are included in the Appendix.

transportation and air planning (17). Conformity assessment calls for the use of latest versions of Highway Performance Monitoring System (HPMS) and MOBILE emissions model. HPMS is used for forecasting of Vehicle Miles Traveled (VMT) and MOBILE is needed for forecasting mobile source emissions.

Alabama had one non-attainment area in Birmingham (Shelby and Jefferson counties) as a result of exceeding the one-hour standard for ozone. On June 28, 2000, Governor Don Siegelman designated the following areas as non-attainment with the new eight-hour ozone standard: Jefferson, Shelby (Birmingham), Madison (Huntsville), Clay, and Mobile counties. Baldwin and Montgomery counties are being considered for designation in the near future.

1.2 Objective

The goal of this research is to demonstrate the impact of traffic management decisions on air quality in Alabama. This goal is supported by two objectives. The first objective is to prepare educational materials explaining how transportation (specifically, traffic management) impacts air quality in Alabama (i.e., ozone concentrations in Birmingham). These materials may be used when discussing air quality in Alabama (especially in non-attainment areas). The second objective is to improve the current (default) air quality assessment methodology (MOBILE5b modeling) by exploring a number of input data/parameter modifications. These improvements will be used to demonstrate the impact of: (1) using local data to assess emissions in Alabama, and (2) traffic control measures on vehicle emissions.

1.3 Approach

This project consisted of two separate but related tasks to accomplish the project objectives. The first task was to develop an informal group of stakeholders to help identify the most pressing needs in ozone conformity assessment in Alabama. The stakeholders included: Ms. Rebecca Fulks, Mr. George Ray, and Mr. Charles Tunney of the Alabama Department of Transportation (ALDOT); Ms. Lynn Garthright and Ms. Cala Obenhauff of the Alabama Department of Environmental Management (ADEM); Mr. Bill Foisey (Birmingham Regional Planning Commission); Mr. Sam Bell (Alabama Partners for Clean Air); Ms. Pamela Lewis (Birmingham Chamber of Commerce); and Mr. Dale Espy of the U.S. Environmental Protection Agency (EPA Region IV). This group served as a source of input to the University of Alabama (UA) project team in developing relevant communication/education tools and in identifying gaps and needs in Alabama's approach to meeting CAA conformity requirements.

The second set of tasks was to collect local input data and evaluate improvement in MOBILE emissions estimates, and to prepare several illustrations of how simple, conservative estimation of the emission benefits of transportation control measures (TCMs) could be performed. Specifically, the evaluations included:

1) Determination of input parameters which strongly influence MOBILE5b emission factors by conducting sensitivity analyses,
2) Collection of data for the "master variables" (those variables that are considered critical to emissions estimates either due to sensitivity analyses or due to the recommendations of stakeholders),
3) Comparison of emission factors using national and local fleet composition data, and
4) Construction of simple spreadsheets to estimate emission benefits of TCMs.

2.0 Background

2.1 Improving Emissions Model (MOBILE) Representation of Alabama Conditions

2.1.1 *Background and Introduction to MOBILE Models*

An effective air quality improvement program requires identification, inventory, and control of mobile emissions. Accurate assessment of motor vehicle emissions is an essential part of this process. There is need for broader understanding of the spatial and temporal variability of emissions, physical and chemical characteristics of pollutants, exposure levels, and the actual effectiveness of control strategies. In order to quantify VOC, NO_X and CO emissions from mobile sources, EPA has developed a series of computer models referred to as the MOBILE models. MOBILE is a powerful tool used by air quality planners at national, state, and regional levels to estimate the emissions from on-road vehicles. The current version (MOBILE5b) and the forthcoming version (MOBILE6) provide estimates of emission factors for various categories of on-road vehicles using average vehicle speed to reflect driving conditions. MOBILE5b generates emission factors for eight vehicle categories while the enhanced version MOBILE6 will have 30 categories. Tables 2.1 and 2.2 list the various vehicle categories in MOBILE5b and MOBILE6, respectively. MOBILE vehicle categories are classified according to their fuel and gross vehicle weight characteristics. The MOBILE model provides the amount of emissions generated per mile (emission factor) for each vehicle category. The MOBILE model emissions factors can be combined with output from traffic models (outside of the MOBILE model) to estimate emission inventory (mass per investigated time period) of a given area.

Table 2.1 MOBILE5b Vehicle Classes

Vehicle Class	MOBILE5b Code	Gross Vehicle Weight (GVW)	Example
Light-duty gasoline vehicles	LDGV	Up to 6000 lb	Civic, Camry, Taurus
Light-duty gasoline trucks (pick-ups, minivans, passenger vans, and sport utility vehicles)	LDGT1 LDGT2	Up to 6000 lb 6001-8500 lb	Blazer, S 10 Pick up Silverado, Expedition
Heavy-duty gasoline vehicles	HDGV	8501 lb and higher GVW equipped with heavy-duty gasoline engines	Delivery Trucks
Light-duty diesel vehicles (passenger cars)	LDDV	Up to 6000 lb	Volkswagen Golf
Light-duty diesel trucks	LDDT	Up to 8500 lb	Ford F 250 Diesel
Heavy-duty diesel vehicles	HDDV	8501 lb and higher	Tractor-Trailers, Delivery Trucks, and Buses
Motorcycles	MC		

Table 2.2 MOBILE6 Vehicle Classes

Vehicle Class	MOBILE6 Code	Gross Vehicle Weight (GVW)	Loaded Vehicle Weight
Light-duty gasoline vehicle	LDGV	Up to 6000 lbs	
Light-duty gasoline truck 1	LDGT1	0-6000 lbs	0-3750 lbs
Light-duty gasoline truck 2	LDGT2	0-6000 lbs	>3750 lbs
Light-duty gasoline truck 3	LDGT3	6000-8500 lbs	3751-5750 lbs
Light-duty gasoline truck 4	LDGT4	6000-8500 lbs	>5750 lbs
Heavy-duty gasoline vehicle class 2B	HDGV2B	8501-10,000 lbs	
Heavy-duty gasoline vehicle class 3	HDGV3	10,001-14,000 lbs	
Heavy-duty gasoline vehicle class 4	HDGV4	14,001-16,000 lbs	
Heavy-duty gasoline vehicle class 5	HDGV5	16,001-19,500 lbs	
Heavy-duty gasoline vehicle class 6	HDGV6	19,501-26,000 lbs	
Heavy-duty gasoline vehicle class 7	HDGV7	26,001-33,000 lbs	
Heavy-duty gasoline vehicle class 8A	HDGV8A	33,001-60,000 lbs	
Heavy-duty gasoline vehicle class 8B	HDGV8B	>60,000 lbs	
Heavy-duty gasoline bus	HDGas Bus	All	
Motorcycle	Motorcycle		
Light-duty diesel vehicle	LDDV	Up to 6000 lbs	
Light-duty diesel truck 1	LDDT1	0-6000 lbs	0-3750 lbs
Light-duty diesel truck 2	LDDT2	0-6000 lbs	>3750 lbs
Light-duty diesel truck 3	LDDT3	6000-8500 lbs	3751-5750 lbs
Light-duty diesel truck 4	LDDT4	6000-8500 lbs	>5750 lbs
Heavy-duty diesel vehicle class 2B	HDDV2B	8,501-10,00 lbs	
Heavy-duty diesel vehicle class 3	HDDV3	10,001-14,000 lbs	
Heavy-duty diesel vehicle class 4	HDDV4	14,001-16,000 lbs	
Heavy-duty diesel vehicle class 5	HDDV5	16,001-19,501 lbs	
Heavy-duty diesel vehicle class 6	HDDV6	19,501-26,000 lbs	
Heavy-duty diesel vehicle class 7	HDDV7	26,001-33,000 lbs	
Heavy-duty diesel vehicle class 8A	HDDV8A	33,001-60,000 lbs	
Heavy-duty diesel vehicle class 8B	HDDV8B	>60,000 lbs	
Heavy-duty School Bus	Diesel School Bus	All	
Heavy-duty Transit Bus	Diesel Transit Bus	All	

2.1.2 *Modeling Issues and the Use of MOBILE5b in Alabama*

Air pollution from on-road vehicles is an area of concern in many cities in Alabama. Birmingham is designated as one of the non-attainment* areas in EPA Region IV. Shelby and Jefferson counties are in non-attainment of the one-hour ozone standard (currently enforced as law). Alabama currently has five counties (Jefferson, Shelby, Madison, Mobile, and Clay) designated as non-attainment with the new eight-hour standard. The eight-hour standard is awaiting Supreme Court approval as a legally enforceable standard. An area designated as non-attainment may face penalties such as cancellation of federal funding for transportation projects that do not conform to the National Ambient Air Quality Standards (NAAQS), hence the economic development of the area could be hindered. The countermeasures, represented by the official State Implementation Plan (SIP), to reduce pollution must specify what type of input data (local or default) has been used to demonstrate the attainment of the area.

MOBILE is used to develop emissions inventories and reductions in SIPs, demonstrate conformity of transportation and air quality plans, assess the air quality impacts of transportation control measures, and provide emissions estimates for dispersion and photochemical air quality modeling (2). Transportation agencies, metropolitan planning organizations (MPOs), and state DOTs also use MOBILE as an analytical tool in the development of SIP and transportation conformities. State environmental and transportation agencies, practioners and researchers combine results from transportation models, MOBILE, and air-quality models to estimate the pollutant concentration in a given area, thereby, demonstrating the compliance or violation of the NAAQS.

As MOBILE has become an "official" model for air quality analysis in many regions, many have questioned the accuracy of the MOBILE model (2). While the MOBILE model provides default information on vehicle fleet characteristics (composition by vehicle types and ages), EPA urges the states to use locality specific data for those input parameters that vary considerably from the national average values. MOBILE6 is being developed to address many inaccuracies in the MOBILE5b model (as indicated in Table 2.1) and will allow much greater description of the local vehicle fleet and road conditions.

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*An area not meeting the NAAQ standards

Table 2.3 Differences between MOBILE5b and MOBILE6 Emission Factor Models

MOBILE5b (Drawbacks)	MOBILE6 (Advantages)
Non-FTP driving behavior and impacts of vehicle air conditioning on emission rates	New supplemental FTPs were performed to represent the real world driving patterns
Input of same average speed for all roadway/facility types	Realistic estimates are generated by adjusting the emission factors using speed correction factors for roadway types
Outdated fleet data in MOBILE5b results in inappropriate emission rates	Fleet data reflecting the 1996 calendar year is incorporated into MOBILE6
Provides a single emission factor for any vehicle type, pollutant, and scenario	Users can input engine soak times to get distinct emission factors for "start" and "running" modes
MOBILE5b provides emission factors for only eight vehicle classes	MOBILE6 addresses emission factors for wider range of classes (30+) broken down by vehicle weights and fuel type

2.2 A MOBILE-based Transportation Control Measures (TCMs) Emissions Evaluation

As explained in Section 2.1, MOBILE is being used in numerous areas for predicting future emissions as a result of changes in the transportation and environmental sectors. Amendments to CAA specifically call for transportation control measures (TCMs) to reduce the extent of mobile source emissions in urban areas (12). According to the California Clean Air Act Amendments of 1988, TCMs are defined as the strategies that "reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, or traffic congestion for the purpose of reducing motor vehicle emissions" (12). However, limited availability of both traffic and emission rate data (as a function of vehicle operation) have made accurately estimating the impact of TCMs problematic. There are data limitations in numerous areas that will have an impact on emissions (5).

When examining TCMs, the impact of passenger vehicles (vehicles types are listed in Tables 2.1 and 2.2) is crucial, as these vehicles account for the majority of mobile source emissions. In many cities such as New York, Atlanta, Charlotte, and Chicago, exhaust and evaporative emissions from light-duty vehicles (cars and trucks) contribute at least 75% of the total on-road VOC emissions and 60% of the total on-road NO_X emissions (8). Such great contribution could be attributed to increasing auto population and vehicle miles traveled. According to the FHWA, autos (cars and trucks) contribute nearly 90%

of the total passenger miles of travel in U.S. (13). In view of the fact that emissions are the product of vehicle miles traveled (VMT) for each vehicle class and emission factor for that class, light-duty vehicles and light-duty trucks are responsible for the majority of VOC and NO_X emissions. In general, emission inventory is developed by multiplying class specific emission factors by their corresponding VMT. Emission factors for a vehicle type are a result of the internal calculations performed by the MOBILE5b, accounting for vehicle age and population. This basic principle is used in Sections 4.5, 4.6, and 4.7 to compare the default emissions with local estimated values.

Before TCMs can be used to reduce mobile source emissions in metropolitan areas, the type and extent of their implementation must be defined. Mobile source emission benefits from TCMs, as estimated by MOBILE inventories, are determined by reducing the VMT or speeds. Many TCMs such as rideshare programs, parking management programs, transportation system management (TSM) programs, traffic signal improvements, and traffic flow improvements are funded by the ISTEA Congestion Mitigation for Air Quality (CMAQ) program. TCM concepts often overlap considerably with three other procedures: transportation demand management (TDM), TSM, and land use measures (18). However, the objective of all these four tools is to relieve congestion and reduce mobile source emissions.

3.0 Methodology

3.1 Outreach Program

In order to keep the results of this research as useful to practitioners as possible, an informal group of stakeholders (listed in Section 1.3) was assembled. The need for outreach materials to help air quality professionals communicate with planners in their own organizations and with the public became apparent. Therefore, two outreach products were produced and distributed. The first item produced was a general ozone education, PowerPoint™ slide presentation. This item has been provided to Alabama Partners for Clean Air (APCA) and its members (including ADEM, ALDOT) for use in ozone education meetings and workshops. In addition, a web page was developed. This web page (www.alabamacleanair.com) was provided to APCA, which is now maintaining and updating the web page as a clearinghouse for ozone information in Alabama.

In addition to providing outreach opportunities, the stakeholder group helped identify two areas of possible improvement in the air quality modeling being performed in Alabama to meet Clean Air Act requirements. The first identified point was the need to use local data in the MOBILE model (specifically registration data). Unfortunately, institutional barriers have made collection of registration data very difficult for air quality modelers in ALDOT and ADEM. As discussed in Section 3.4, registration data was obtained for Tuscaloosa and Jefferson counties for use in this research. The second area identified by the stakeholders was the need for simple spreadsheet models to estimate the impact of TCMs on emissions. This need is discussed in Section 3.5.

3.2 Overview of MOBILE Model Investigation

The generation of emission rates requires a multitude of input assumptions. For most of the input parameters, MOBILE provides national default values or users can input locality-specific values. Default values in MOBILE5b were developed using the 1993 calendar year vehicle count, scrappage rate, and gas-diesel sales data. Three input variables have been identified as key factors in order to conduct an air quality analysis in Alabama: average vehicle speed, registration distribution data, and the mixture of vehicle miles traveled (VMT mix). VMT mix specifies the fraction of total VMT that is accumulated by each of the eight MOBILE5b vehicle types. Sensitivity analyses were performed to evaluate how much MOBILE emission factors would vary as a result of changes in input parameters (such as using local instead of default data).

The need for sensitivity analyses has been noted by others (7). In this project, two basic types of sensitivity analyses were performed. A standard or conceptual analysis was performed where an input value for one parameter was varied consistently and the impact on the output parameters (emission factors) was observed. The second type of sensitivity analysis was a comparative analysis where local data was used as input to the model and the output was compared to that generated using national default data. For both analyses, it was necessary to develop a base case.

A set of base conditions was established and held constant while each investigated parameter was varied. The base case was designed to represent the conditions in Alabama without inspection and maintenance (I/M) or anti-tampering programs. Base case emissions were for 90°F with a 75°F low and a 92°F high temperature for the day. The operating mode VMT mix was set to the FTP default values of 20.6 percent cold start, 27.3 percent hot start, and 52.1 percent hot stabilized engine operations. National default values for vehicle type mix, vehicle registration, and mileage accumulation rates were used. Some of the most important parameters in the application of MOBILE to an individual region are discussed in the subsequent paragraphs.

3.3 Sensitivity Analyses – "Conceptual"

3.3.1 *Average Speed*

MOBILE provides the user with the option of either entering one average speed for the eight categories or a different value for each of the eight categories. The base emission rates generated by MOBILE were developed from emission rates for various vehicles under standard driving conditions given by the Federal Testing Procedures (FTP)(3). Speed correction factors were used to adjust the emission rates for non-FTP driving behavior. Rates of emissions from vehicles depend on acceleration and deceleration, load on the engine, grade, etc. Moreover, the traffic models estimate average speeds from traffic volumes by assessment of the relationship between them. Errors in measurements of traffic volume propagate in the MOBILE model thereby causing discrepancies in output values. MOBILE requires the input of average speed over a length of roadway, including delays (5). Speed varies by facility type, and the calculation of average speed on arterials and on local roads is complicated, involving free-flow speeds, intersection spacing, signal timing, and other factors. Emission rates from MOBILE are sensitive to changes in average speeds. If the speed input to MOBILE is inaccurate, there may be severe under- or overestimates of emissions.

In the case of average speed, a "conceptual" sensitivity analysis was performed. This involved running the model at various speeds and summarizing the results in several figures that relate the changes in emission rates to changes in average travel speed. It has been widely recognized that both VOC and NO_X follow a U-shaped curve with 1) high emission rates at low speeds, 2) decreasing rates as speed increases, and 3) high rates at high speeds. However, quantitative analysis is needed to clearly demonstrate the velocity-emission factor relationship. The MOBILE5b model was run at various speeds and the resulting emission factors were multiplied with a travel activity factor (VMT) to obtain the emissions in grams. The emission factor for the "all vehicle" category was chosen in this analysis. The all vehicle emission factor is obtained by multiplying the emission factors of the eight vehicle classes by their respective VMT mix.

3.3.2 Small Variations in Average Speed

The sensitivity of emissions to small changes in the average speed was also studied. This analysis deals with the emission characterization due to small variations (20%) in the average speed values: 10, 20, 30, 40, 50, and 60 mph. The uncertainty or the variability of the model's prediction about the actual emissions at 10, 20, 30, 40, 50, and 60 mph for a 32.5*-mile trip was examined. Input speed entered in MOBILE5b is the average travel speed of vehicles as they travel on a network instead of spot speeds (5). A 20% variation was selected because cruise speed measurements are subjected to errors. This variation was arbitrarily selected assuming that the cruise speeds vary by a maximum amount of 20%. Errors in measuring the input variables are passed to the MOBILE model's output. Hence, the uncertainty in the model as result of the propagation of error was explored as described below.

Ten random numbers between zero and one were generated for each of the six average speeds. The numbers were assigned a positive and negative sign depending on whether the number was even (+) or odd (-). The random numbers were multiplied by 20% of the mean speed and the result was added to the average speed. For example, the calculations below illustrate the generation of vehicle speed variation for an average speed of 20 mph. The random number was multiplied by 20% of 20 mph and the result was added to the average speed, which in this illustration was 20 mph. In this way ten speeds, around each mean speed value (10 mph, 20 mph, 30 mph, 40 mph, 50 mph, and 60 mph) were obtained.

(-0.534921*0.2*20)+ 20 mph = 17.9 mph.

(0.498682*0.2*20)+ 20 mph = 22.0 mph.

Table 3.1 summarizes the ten random speeds around a given average speed. The means of these ten speeds were calculated as 10.3 mph, 19.6 mph, 30.5 mph, 40.0 mph, 51.5 mph, and 58.5 mph, respectively.

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*Approximate daily commuting distance in Birmingham

Table 3.1 Individual Speeds around the Average Speeds

Average speed (mph)	Randomly generated speeds by the method described above										Mean of the ten Random speeds
10	8.9	10.9	11.6	9.4	8.4	9.6	11.5	11.1	9.9	11.7	10.3
20	22.0	22.7	17.6	16.6	22.5	22.3	17.3	16.1	20.2	18.7	19.6
30	35.8	29.9	34.1	27.6	27.3	27.2	34.1	31.9	31.2	25.7	30.5
40	42.6	36.1	38.4	35.0	36.2	47.1	38.2	42.4	37.1	47.2	40.0
50	45.0	59.4	57.2	55.7	59.7	53.1	42.5	54.8	40.1	47.2	51.5
60	51.9	64.7	51.9	59.3	62.3	52.8	48.6	68.8	63.5	61.6	58.5

Composite (all vehicle) emission factors at the ten randomly generated speeds were obtained from the MOBILE5b model. The quantities of VOC and NO_X emitted by the entire fleet were estimated by multiplying the emission factors by the trip length 32.5 miles. The emissions around an average speed are the average of all the emissions at the ten speeds.

3.3.3 Impact of Trip Speed Distribution

EPA's MOBILE5b model uses data that represent trip travel characteristics. However, the speed estimates for the input data are generated using a link-based approach because many transportation models are designed to estimate speed on a particular section (or link) of the highway (9). Obviously, the format from which the input speed is obtained impacts the emission inventory. This change causes a mismatch between the conformity and inventories because of the continued use of link-based VMT and speed for conformity analysis. Inventories developed from trip-based distributions are well suited for regional inventories and the impacts due to changes in roadways (such as widening of roads and addition of new lanes) are more evident in link-based distributions than in trip-based distributions (9).

This hypothetical case study demonstrates the use of speed in trip-based format and its importance in the development of emissions inventory. In this process, five cases containing five trips each having an average speed of 20.0 mph, 30.0 mph, 40.0 mph, 50.0 mph, and 60.0 mph respectively were chosen. Three speeds (5mph, 35 mph, and 65 mph) were selected, and the percentage distance traveled in each trip at these speeds was adjusted and weighted by distance so that the average speed in all the trips approximately equaled the average speeds mentioned above. The calculations to find the total amount of VOCs and NO_X involved the multiplication of emission factors at speeds of 5 mph, 35 mph, and 65 mph by the distance traveled at each speed. Then, the VOC and NO_X emissions from all the trips in each case were averaged and compared to MOBILE5b emissions at the corresponding "case" speeds. The VOC and NO_X emissions vary depending on the type of trip distribution made by the commuter. The 95% confidence intervals and the coefficient of variation were constructed for each average emission value in a case to estimate the variance in the emission estimates. As discussed in earlier sections, MOBILE5b takes one value of average speed for all the eight classes or eight separate values of average speed, one for each vehicle class. Since in the real world travelers follow a trip-based speed distribution, the input of one value of average speed might underestimate emissions. This calls for disaggregation of emissions based on the traveler's mode of trip distribution. Large errors could be passed on to the emission inventory when only one average speed value is used instead of breakdown speeds based on trip distance.

3.4 Default versus Local Data

3.4.1 *Importance of Vehicle Registration Distribution Data*

MOBILE5b assigns different emission rates for each of the eight vehicle categories. Emission factors are specific to vehicle category and age, and the relative contribution of differing ages is a function of how many miles such vehicles are operated (10). The two main types of fleet characterization data are registration distribution by age and annual mileage accumulation rates by age. Registration distribution by age defines what fraction of a particular vehicle type is of a given age at a given point in time. The default registration distribution data reflects the characteristics of the national average fleet in 1993. Obviously with the growth of sport utility vehicles (SUVs) and light-duty trucks, the current fleet is expected to have different characteristics than the default fleet. MOBILE uses registration distribution and mileage accumulation rates to determine the overall fraction of VMT associated with each vehicle type. This is defined as VMT mix, which is typical of the urban area to be modeled because the registration distribution might vary significantly across regions. Therefore, the EPA strongly urges regions to use locality-specific registration distributions when such data reflect significant changes from the national average (6). The choice of a particular vehicle registration distribution can affect on-road emissions inventories by approximately 5 to 10% (Pollack et al.1991) (2).

3.4.2 *Use of Tuscaloosa and Jefferson County Registration Data*

EPA recommends the input of local registration distribution data. As a result of conversations with stakeholders (Section 3.1), the use of local data to make more accurate estimates of emissions was investigated. The registration data for Tuscaloosa and Jefferson Counties was collected, and the division of vehicles to EPA MOBILE5b classes was performed using the latest MOBILE6 gas and diesel sales percentages. The collected data was a onetime snapshot afforded by obtaining registration data. The registration data was used as a surrogate for the vehicle fleet operating in these counties. Local registration data also plays a key role in the estimation of VMT mix of the region. The local inputs are important because of the variation between local and default age distribution data. An accurate picture and more realistic representation of local vehicle fleet distribution can be made using the composition of the registered fleet in a county.

The vehicle registration data was collected from the local tax assessor's office. Sorting the data proved to be a challenging task because of inconsistencies and nonuniformity in the data (135,000 records in Tuscaloosa and 816,000 records in Jefferson County). The records often contained misspellings, as there was no standardization for inputting the entries. First, the raw data was queried and imported to a table containing headings for model name and designated EPA class. All the vehicles were classified into six EPA categories with Light-Duty Diesel Vehicles (LDDV) and Light-Duty Diesel Trucks (LDDT) were excluded, as it was not possible to split the vehicles into diesel type based on model names. This table was linked to the central database where a query was run segregating the raw data into six EPA classes. Finally, the light-duty vehicles and light-duty trucks were divided into Light-Duty Gasoline Vehicles (LDGV) and Light-Duty Diesel Vehicles (LDDV), and Light-Duty Gasoline Trucks (LDGT) and Light-Duty Diesel Trucks (LDDT) from the percentages of gas and diesel fueled vehicles using the recognized EPA methodology (11).

The local vehicle registration distribution data in both Jefferson and Tuscaloosa Counties varied from the default national data in several ways. The local data contained far more vehicles aged one year or less and vehicles aged 25 or more. The default data contained a greater number of vehicles aged two to seven (eight for Jefferson). The remaining years generally had larger default portions for Tuscaloosa County and larger local portions for Jefferson County. These trends commonly continued across all the vehicle classes in the two counties as compared to the national default data.

3.4.3 *VMT Mix*

VMT mix is defined as the percentage of VMT accumulated by each of the eight vehicle types identified in MOBILE model (6). VMT mix is used to generate composite emission factors. The effect of age and registration distribution was addressed in Section 3.4.2, but there is another parameter that is impacted by the registration distribution data in the MOBILE model. VMT mix combines information on the number of vehicles (registration distribution) and typical amount of driving done by each class (mileage accumulation). If the above variables differ significantly for a region, then the default VMT mix may not accurately represent the VMT mix of that region, leading to under- or overestimation of emissions.

The MOBILE5b methodology of calculation of VMT mix is quite complex, and is considered to be an outdated method; the VMT mix that MOBILE5b calculates is no longer an accurate estimate of present day VMT mix (2,11). Today's vehicle counts and their corresponding annual mileage rates are established by Arcadis in the report entitled "Update of fleet characterization data for use in MOBILE6"(11). The report describes the methodology EPA used to convert the July 1,1996 registration profile into a national average registration distribution by age and the use of average annual mileage accumulation rates.

3.4.4 ***Development of VMT Mix***

It is assumed that the procedure of developing VMT mix in MOBILE5b does not result in an up-to-date VMT mix. Therefore, the mileage accumulation curve-fit equations and vehicle counts based on vehicle class were used in the calculation of VMT mix using local Tuscaloosa and Jefferson County registration distribution data. Arcadis classified the vehicles into 18 categories with their respective counts as of July 1996. MOBILE5b has only eight classes and this presented a problem in estimating the annual mileage accumulation rates. To overcome this inequality in division, the fraction of all the categories in Arcadis was found for every model year and this fraction was applied to Tuscaloosa and Jefferson vehicle count data. In this way, the vehicles in Tuscaloosa and Jefferson counts were translated into the Arcadis classification so that it would be easy to use the mileage accumulation curve-fit equations to develop class-specific VMT. The class-specific VMT was summed to get the total VMT, hence the VMT mix. A case study was conducted to compare MOBILE emissions from (1) default VOC and NO_X emissions estimated with default emission factors and the default VMT mix, and (2) emissions estimated using local registration and VMT mix. The local estimated emission factors were obtained by running the model using the user-supplied vehicle registration distribution data and the local estimated VMT mix using the methodology discussed above.

3.5 Proposed Methodology for Evaluating Transportation Control Measures

There are many TCMs identified in the CAA of 1977 and the amendments of 1990. There are many other favorable alternatives that relieve congestion and improve air quality, and the most commonly used TCMs include: traffic flow improvements (traffic operations and signalization), transit improvements, work schedule changes, and car, van, and bus pooling.

3.5.1 ***Overall Approach to TCM Emission Estimate***

Many methodologies have been developed for the calculation of emission benefits achieved of implementing a TCM. All models, ranging from transportation modeling approaches to sketch planning approaches, involve some relationship between transportation activity and emissions. The methodology changes from one level of investigation to another because of varying transportation data associated with these methodologies. Although all the models developed so far provide useful approaches for estimating the effects of TCMs on emissions, they are often too complex for use in air quality planning applications. A simple methodology, distilling information from MOBILE into a spreadsheet calculation is proposed here. The proposed methodology treats all the vehicles as "lead vehicles". Lead vehicles are those vehicles that appear in the front and stay for the entire duration of stopped time delay[*]. It must be stressed that no single methodology can quantitatively explain the effects of all the TCMs identified in the CAA.

The methodologies presented here are quick and easy, and can be applied using a simple hand calculator and a spreadsheet. The methodologies can be viewed as a sketch planning technique to produce approximate emission estimates during preliminary stages of prioritizing TCM projects. Generally, MOBILE model estimates such as VMT mix, operating modes, and speeds vary from region to region. If accurate data for a corridor, facility, or traffic analysis zone are available, more precise estimates can be generated (14). This proposed methodology uses the tools derived from air models and attempts to quantitatively estimate the travel and emission changes that are possible from implementing TCMs. It is ideal to use the regional data for some input parameters in top-down, preliminary modeling of travel zones or corridor-specific areas (14).

It is important to note that the proposed methodology for the TCM evaluation study utilizes the concept of lead vehicle instead of a distribution of vehicle arrivals and departures. The lead vehicle concept eliminates the intricacies involved in adopting a distributed pattern of vehicular flow. It is well known that the arrival pattern of vehicles at an intersection follows a Poisson distribution (19). For this reason, the time between arrivals varies and not all vehicles stop for the entire red light time interval. Thus, vehicles arriving some time after the lead vehicle and staying for fractions of the stopped time delay have lower idle emissions. Hence, it is expected that using a lead vehicle analysis (as opposed to a distributed arrival time analysis) will result in larger emission estimates. This overestimation of emissions is expected to be particularly relevant in cases where idling is responsible for a significant fraction of total emissions.

3.5.2 *Signalization*

Traffic intersections are critical for air quality analysis in urban areas. Vehicles at intersections display a variety of operating modes including: idling, acceleration, deceleration, and cruising. A simple off-model methodology is developed without the use of a travel demand model. As such, this methodology provides a preliminary

[*]Amount of time the signal stays red at most intersections

estimate of air quality benefits of TCMs. The goal of signal optimization is to reduce vehicle idle emissions (one of the objectives of applying TCM).

A case study was performed to assess the emissions from a road segment having traffic signals at regular distances. This was intended to represent an urban arterial road segment of a given free-flow speed having signalized intersections positioned at regular distances. As stated in Section 3.5.1, all vehicles were considered lead vehicles. Stopped time delay and traffic volume at each intersection can be obtained from local transportation departments. The emissions during this analysis are:

1) Emissions during deceleration
2) Emissions during idling
3) Emissions when the vehicle is cruising
4) Emissions during the acceleration phase, which is considered equivalent to that from the deceleration phase.

The calculations are based on the composite[*] VOC and NO_X emission factors obtained as a result of entering Jefferson registration distribution data instead of default data.

STEP 1: Emissions during deceleration and acceleration phases
First, the time taken to decelerate or accelerate from the posted speed limit to one mph is found using simple distance-velocity equations. The rate of emission is not uniform during these phases, so some form of rate expression must be developed. The MOBILE model emission factors (grams per mile) for speeds between one mph and 65 mph are plotted for the Jefferson County and a best-fit curve analysis was performed. A third order polynomial explaining the rate of change of emissions with speed was used for VOCs emissions and a second order polynomial equation was found to be satisfactory for NO_X emissions. Integrating the polynomial equations between one mph and cruising speed mph gives the rate of emissions during this speed change in grams per hour. Multiplying this new rate of emissions (grams per hour) by the time taken to decelerate or accelerate produces the amount of VOCs and NO_X generated during this process. Equations 4-1 and 4-2 describing the VOC and NO_X emission rates in acceleration and deceleration stages are:

$$Y = - 0.0002 X^3 + 0.0238 X^2 – 0.9346 X + 13.157 \quad (4-1)$$

$$Y = 0.0015 X^2 – 0.0926 X + 3.7832 \quad (4-2)$$

Where X = speed in mph
Y= emission factors in grams/mile

In general, during acceleration and deceleration, the load varies on the engine. Since the equations (see above) are developed using the MOBILE5b speed – emission factor relationship provided by uniform FTP engine operations, modeling of emissions in

[*]Sum of emission factors of the eight categories weighted by the respective VMT mix fraction

acceleration and deceleration phases using non-variable loads on the engine results in underestimating the emissions. Emissions increase with load on the engine and the quantification of load on emissions is being addressed in the forthcoming MOBILE6 model.

STEP 2: Emissions in idling stage

The idling emissions are determined by multiplying the idle emission factor (grams per hour) from MOBILE5b by the amount of time the vehicle idles. Idle VOC and NO_X emission factors for "all vehicle" category are 26.3 grams per hour and 9.66 grams per hour, respectively. The idling time is assumed to be equal to the stopped time delay i.e., time the signal stays red. Signalized intersections are major contributors of VOC and NO_X in a microscale or corridor emission analysis.

STEP 3: Emissions in cruising phase

In order to estimate the emissions in this phase, the basic principle of combining the emission factor with the travel activity factor (vehicle miles traveled on a roadway, which in this case, is the length of the road segment) is followed. The vehicles can be presumed to cruise at the posted speed limit, so the emission estimation is obtained by multiplying the emission factors (at that speed) by the cruising distance.

STEP 4: Total emissions when the signal is red

This step is representative of the worst case of a corridor emission study. If there were more than one signalized intersection on that road segment, emissions would be greatest if the vehicle encounters red at each junction. When a car approaches the first signal, it reduces speed to come to a complete halt. Hence, emissions from the following three phases contribute to the total amount: cruising period, deceleration period, and idling stage. After idling until the light turns green, the vehicle accelerates, cruises, decelerates, and idles at the second signal intersection. Considering that the emission rate in the acceleration phase is equal to that in the deceleration phase, the total emissions at the second signalized intersection will be the sum of emissions from acceleration, cruising, deceleration, and idling stages. Similarly, the emissions at other intersections can be calculated as described above.

STEP 5: Total emissions when the signal is green

This is a very simple and direct method, assuming that the vehicle travels at the posted speed limit when there is no red signal. This is the ideal case, as the emissions would be lowest if the vehicle encounters green at every intersection. Emissions at free-flow speeds are the product of emission factors (at that speed) and the distance it traveled (in this case, the distance is the length of the road segment).

3.5.3 *Railroad Intersections*

Simulation of emissions on a roadway with a railroad intersection is similar to the method established for signalized intersections. This simple case study deals with the emission benefits achieved when a tunnel or a bridge is constructed over the railroad crossing. The construction of a bridge or a tunnel reduces the amount of idling time, hence idling emissions. Before implementation, the eligibility of this TCM must be evaluated. Careful analysis is required to demonstrate that the TCM conforms to the NAAQS.

The methodology developed to simulate railroad crossings is similar to the simulation of signalized intersections. This methodology was designed for a road segment of a certain length with the railway gates placed at the midpoint of the segment. In this analysis, the lead vehicle concept was utilized for the reasons described in Section 3.5.1. When the gates are down, the vehicle initially approaching the crossing at the posted speed slows down and remains idle until the gates are up. The total emissions are the sum of the following components: emissions during cruising, deceleration, and idling stages. This is considered as worst-case scenario as the vehicle operational pattern changes thus releasing more emissions. Again, mathematical equations 4-1, and 4-2, and calculations as described in the signalized intersection study (Section 3.5.2) are used to find the emissions during these three phases. The composite emission factors obtained by inputting the Jefferson registration distribution are applied herein. After the gates are up, the vehicle first accelerates until it reaches the posted speed limit and maintains at that speed thereafter. Hence, the total emissions are due to acceleration and cruising phases. If a tunnel or bridge is constructed to improve the traffic flow, one can easily calculate the emission benefits from the new conditions. Under these new circumstances, the vehicle engine operation is invariable and travels at a uniform speed representing the best-case situation. Assuming a certain free-flow speed on the new road, MOBILE5b emission factors at that speed are multiplied by the length of the road segment. The difference in the total VOC and NO_X emissions may be used as a measure of the effectiveness of the TCM.

4.0 Results and Discussion

4.1 Introduction

MOBILE5b model has several input parameters that a user should enter to estimate emission factors for VOCs and NO_X. Average speed is considered to be an important variable as the tailpipe emissions vary according to facility type and vehicle operation. A nonlinear relationship between speed and emission factors (or total emissions) can be established by running the model at speeds ranging from one mph to 65 mph with the base conditions specified in Section 3.2. The nonlinearity shows that behavior of emissions is different at different speed ranges. Before analyzing the case studies described in Sections 3.3.2, 3.3.3, 3.5.2, and 3.5.3, there is a need for understanding and establishing the relationship between emission factor and vehicle speed in drawing informative results on the MOBILE5b model and on the effectiveness of TCMs.

4.2 Emissions vs. Speed - Sensitivity Analyses

First the U-shape of the plot, as shown in Figures 4.1 and 4.2 was established as described in Section 3.3.1 and a correlation was found for VOC and NO_X emissions with speed ranging from 10 mph to 60 mph. NO_X emissions were most sensitive (with a positive correlation) to speed at high velocities (> 50 mph). VOC emissions were most sensitive (with a negative correlation) at lower velocities (< 10 mph).

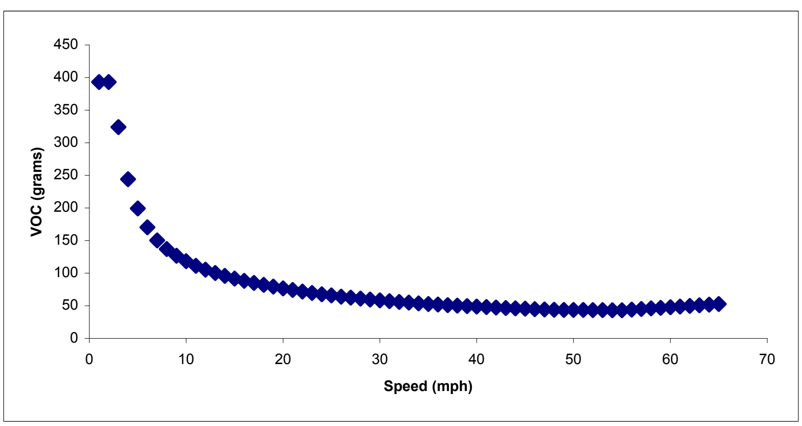

Figure 4.1 Plot of VOC emissions (all vehicle emission factor*vehicle travel activity) against average speed.

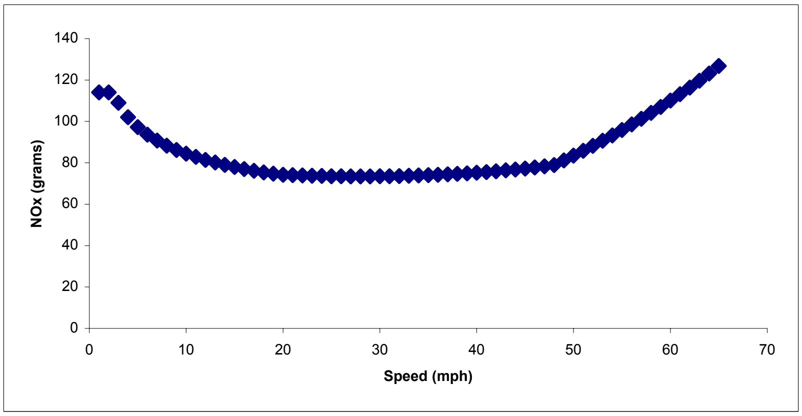

Figure 4.2 Plot of NO_X emissions (all vehicle emission factors* vehicle travel activity) against average speed.

Secondly, a detailed analysis was performed by breaking down the speed into intervals and performing regression analyses on each interval, which provided mathematical representation of how the emissions vary in those speed intervals. In addition, the relative sensitivities of VOC to speed and NO_X to speed were also observed. At very low speeds (between one mph and nine mph), VOC emissions showed a sharp decrease with increase in speed. The slope of the linear fit for VOCs in this range was –37.6 grams/mph, which indicates that for every unit increment in speed, VOC emissions decrease by 37.6 grams. On the other hand, NO_X showed a gradual downward trend with increase in speed at a rate of –3.88 grams/mph. Between one mph and nine mph, the sensitivity of NO_X to speed is 10.3% as sensitive as VOC to speed. Between 10 mph and 30 mph VOC emissions decrease by 2.8 grams for every one mph increase in speed. Between 30 mph and 55 mph, VOC emissions decreased by 0.61 grams for one unit increment in speed. VOCs in the 30-55 mph range are only 22% as sensitive to changes in speed as VOCs are between 10-30 mph. From 55mph to 65 mph, the VOC emissions showed gradual increase at a very low rate of 0.95 grams per mph. To explain the sensitivity of NO_X emissions to speed, different speed intervals were chosen that could offer a better understanding of the emission rate dependency on average speed. NO_X emissions between 10-20 mph decreased at a very gradual rate of –1.01 grams for every unit mph increase in speed. Between 20-26 mph, the rate of NO_X variation with speed was –0.117 grams/mph, showing a negative correlation at low speeds. NO_X emissions in interval 30-48 mph showed a slow but steady increase at 0.296 grams/mph. In the high-speed range (49-65 mph), NO_X emissions increased at a rate of 2.83 grams/mph.

4.3 Results of Small Variations in Average Speeds

As introduced in Section 3.3.2, the impact of small speed changes around mean speeds of 20, 30, 40, 50, and 60 mph were examined. The results of this analysis are summarized in Table 4.1.

Table 4.1 Details of Speed, and Emissions of VOC and NO_X.

Calculated Average Speed (mph)	VOC (grams)			NO_X (grams)		
	Average	Std Dev*	COV•	Average	Std Dev	COV
10.3	117	9.15	7.82	84.06	2.02	2.41
19.6	78.1	6.86	8.79	74.9	1.20	1.61
30.5	58.1	4.32	7.43	73.6	0.25	0.33
40.0	49.0	3.12	6.37	75.6	1.67	2.21
51.5	45.6	1.94	4.25	91.0	13.4	14.7
58.5	47.7	3.93	8.23	106.1	17.7	16.7

* Std Dev is the standard deviation of the 10 speeds

• Coefficient of Variation = (standard deviation/average)*100

Coefficient of Variation was used as a means for measuring the variation in the model's output (emission factors). The coefficient of variation for VOCs did not exceed the variation incorporated in mean speeds (i.e. 20%). NO_X varied by a small amount at low and medium speeds, and at speeds of 50 mph and 60 mph the coefficients of variation were 14.7% and 16.7%, respectively. Although large, coefficients of variation for NO_X at 50 mph and 60 mph were well within the input variation (20%). Hence, small variations around a mean speed did not lead to larger variations in emission factors.

4.4 Results of Trip Speed Distribution

Larger variations in speed were examined using the trip-based speed variation methodology developed in Section 3.3.3. For this case study, the variation in emissions was large for VOCs and relatively small for NO_X. Except at 20 mph, VOC had a wide dispersion at all speeds, as is evident from Table 4.2 and Figure 4.3. It was observed from Figure 4.4 that NO_X showed very small variation with changing trip speed distribution, with the maximum variation occurring at an average speed of 40 mph. Table 4.3 presents the variation in NO_X for all five cases.

Table 4.2 Details of VOC Emission Variation due to Trip Speed Distribution

VOC	Case1	Case2	Case3	Case4	Case5
Average (grams)	69.6	49.8	43.7	33.8	29.3
Average Speed (mph)	20.6	30.5	40.2	50	60
Standard Deviation (grams)	3.55	4.07	8.24	5.30	2.85
COV (%)	5.10	8.18	18.85	15.70	9.70
95% high (grams)	74.0	54.9	53.9	40.4	32.9
95% low (grams)	65.2	44.8	33.5	27.2	25.8

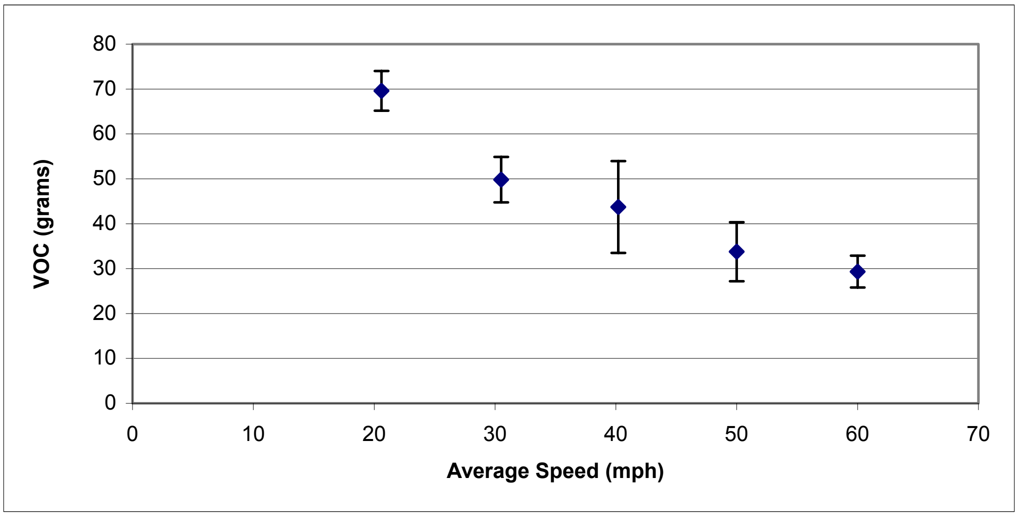

Figure 4.3 Variation in VOCs due to trip speed distribution. Errors bars are 95% confidence intervals.

Table 4.3 Details of NO_X Emission Variation due to Trip Speed Distribution

NO_X	Case1	Case2	Case3	Case4	Case5
Average (grams)	46.7	45.2	50.5	54.1	60.6
Average Speed (mph)	20.6	30.5	40.2	50	60
Standard Deviation (grams)	1.84	2.11	4.29	2.70	1.49
COV (%)	3.94	4.67	8.49	5.00	2.46
95% CI high (grams)	49.0	47.8	55.9	57.4	62.4
95% CI low (grams)	44.5	42.6	45.2	50.7	58.7

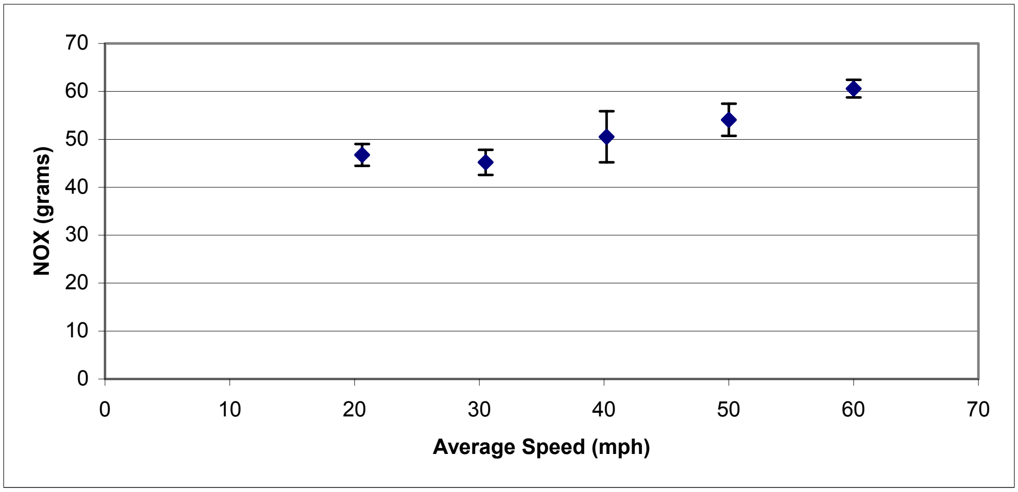

Figure 4.4 Variation in NO_X due to trip speed distribution. Error bars are 95% confidence intervals.

Table 4.4 Comparison of Emissions between Trip Distribution and Input of one Average Speed Value in MOBILE5b

Average speed (mph)	Mobile 5b emissions associated with single Speed (grams)		Emissions from distribution of Speed (grams)		% Error in VOCs	% Error in NO_X
	VOC	NO_X	VOC	NO_X		
20.6	38.4	37.1	69.6	46.7	81.3	25.9
30.5	29.2	36.7	49.8	45.2	70.9	23.0
40.2	24.3	37.6	43.7	50.5	79.6	34.3
50.0	21.8	41.7	33.8	54.1	54.8	29.6
60.0	23.9	55.0	29.3	60.6	22.6	10.1

Table 4.4 above shows the percentage error in VOCs and NO_X when the total emissions due to trip speed distribution were compared to total emissions at one average speed value. This sensitivity analysis of speed distribution indicated that severe underestimation of VOC emissions and moderate-to-severe underestimation of NO_X emissions were observed as a result of not including the trip-based distribution of speed in emission analyses (i.e., simply using one average speed for a trip consisting of variable speeds). A model that can predict emissions based on trip speed distribution, and vehicle-operating modes (i.e., idle, cruise, acceleration/deceleration) is critical for evaluating microscale traffic scenarios.

4.5 Evaluation of Emission Factors for Tuscaloosa and Jefferson Counties

As stated in Section 3.4.2, MOBILE5b was run for the two counties using the default and collected sets of registration data. Table 4.5 presents the emission factors for the eight categories of vehicles (See Table 2.1 for definitions), generated using the Tuscaloosa and national default registration data.

Table 4.5 VOC and NO_X Emission Factors from Default and Tuscaloosa Registration Data

VOC	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Default	2.14	2.62	3.46	6.11	0.69	0.94	2.27	4.74
Tuscaloosa	2.25	2.85	2.82	5.1	0.7	0.92	2.35	6.51
% Change	5.14	8.78	-18.5	-16.5	1.45	-2.13	3.52	37.3
NO_X	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Default	1.41	1.64	2.22	4.98	1.44	1.62	12.28	0.74
Tuscaloosa	1.44	1.65	1.78	4.83	1.44	1.58	12.59	0.74
% Change	2.13	0.61	-19.8	-3.01	0.00	-2.47	2.52	0.00

From the Table 4.5, it can be shown that local registration distribution more heavily impacted the VOC emission factors than the NO_X emission factors. The change in VOC emission factors was significant in the case of MC, LDGT1, and LDGV classes but not so significant for HDDV and LDDV. The local data has a higher number of one-year-old vehicles and over 25-year-old vehicles than the default, while the distribution between one and 25 was consistent with the default data. It was calculated that the one-year-old fraction in local data was 151% higher than the fraction seen in default data. Also, the over 25-year-old fraction in LDV is 140% more than the default fraction. The LDT data indicated that the fractions for registered vehicles were 148% (one-year-old vehicles) and 120% (over 25-year-old) of the default. In LDGT2, HDGV, and HDDV the age one vehicle fraction was 293%, 461%, and 338% higher than their fractions in the default data, respectively. The fraction of motorcycles (MC) in Tuscaloosa showed a significant departure from the default fraction by 358%.

New vehicles have smaller basic emission factors (BEFs) and greater VMT accumulation than older vehicles. That is why the emission factors of the categories having a larger fraction of very old vehicles are greater than the default emission factors. NO_X emission factors were not significantly impacted by Tuscaloosa registration distribution data except for LDGT2 where the emission factor dropped from its default value by 19.8%.

The input of registration distribution for Jefferson County showed remarkable changes in emission factors from the default value. The VOC emission factors were higher for LDGV, LDGT1, LDDV, and MC. Other groups showed a marginal increase in VOC emission factors with the exception of LDGT2 whose emission factor was smaller than the default value as shown in Table 4.6. Again, NO_X was not as significantly impacted as VOCs by the Jefferson registration data although LDGV, and LDDV indicated an increase. Other vehicle class NO_X emissions were not affected much, whereas LDGT2's NO_X emission factor was lowered by 11.7%.

Table 4.6 VOC and NO_X Emission Factors from Default and Jefferson Registration Data

VOC	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Default	2.14	2.62	3.46	6.11	0.69	0.94	2.27	4.74
Jefferson	2.66	3.08	3.21	6.31	0.77	0.97	2.38	6.94
% Change	24.3	17.6	-7.2	3.3	11.6	3.2	4.8	46.4
NO_X								
Default	1.41	1.64	2.22	4.98	1.44	1.62	12.28	0.74
Jefferson	1.62	1.72	1.96	4.89	1.57	1.63	12.77	0.74
% Change	14.9	4.9	-11.7	-1.8	9.0	0.6	4.0	0.0

Jefferson registration distribution for LDVs was very different from the default and from Tuscaloosa as well. Jefferson LDVs are greater than the default by 79% but the vehicles between age 20 and age 25 have higher fractional values of 126%, 142%, 127%, 90%, 37%, and 299%, respectively, compared to the default emission values. LDTs also followed the same pattern as LDVs. In the case of MCs, the distribution was similar to the default except that the age 12 MCs exceeded the default fraction by 444%. Table 4.6 demonstrates the variation in emission factors of VOCs and NO_X due to locality specific data. It can be seen that VOCs are most affected by the use of local data and NO_X emission factors as a whole are unaffected. Figure 4.5 summarizes the light-duty vehicle (LDV) fraction of vehicles of a given age for national default, Tuscaloosa County, and Jefferson County. These two case studies also suggest the need for using local registration distribution data when such data differs from national default data. Under- or overestimation of VOC and NO_X emissions might occur depending on the vehicle distribution of the region to be modeled.

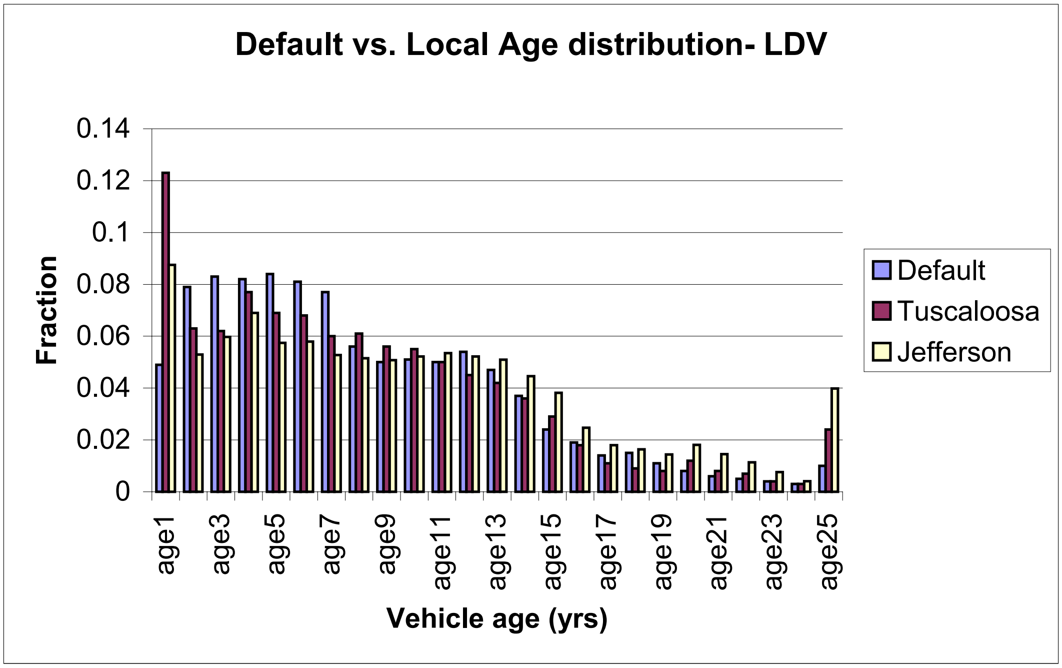

Figure 4.5 Registration distribution data of national default, Tuscaloosa and Jefferson Counties.

In order to evaluate the results of using local registration data compared to default data, one needs to understand the way the emission factors were influenced by local registration data. The local registration data varies the travel fraction component of the vehicle class. Travel fraction determines the fraction of all VMT by the given vehicle class and model year in the evaluated calendar year. Travel fraction decreases as model year decreases, with older vehicles having smaller travel fractions than the newer vehicles. The basic emission factors (BEFs), defining the average exhaust emission factor, are small for newer vehicles and large for older vehicles. FER, the average contribution of vehicles of a model year to the fleet average emission factor, is a product of BEF and travel fraction. Since some vehicle categories in Jefferson and Tuscaloosa counties have a large number of old vehicles, it is apparent that their contribution to the fleet average emission factor is significant. The impact can be better understood when the local distribution data is used for computation of VMT mix.

During meetings and discussions with stakeholders, it became clear that EPA Region IV is strongly in favor of using local registration data to calculate an accurate emission inventory. Even though the all vehicle emission factor (the emission factor of individual vehicle classes weighted by their corresponding VMT mix) is not used in building the emission inventory, it helps in understanding of the impact of age from local data. It is used to provide a first look at the emission inventory. From Tables 4.7 and 4.8, the all vehicle emission factor showed negligible change for Tuscaloosa data but significant change for Jefferson County data. These observations reveal that age distribution, which is a characteristic of the region, may have an observable impact on the emission inventoried using composite emission factors.

Table 4.7 "All Vehicle" Emission Factors from Default and Tuscaloosa Registration Distribution Data

All Vehicle	VOC (grams/mile)	NO_X (grams/mile)
Default	2.49	2.35
Tuscaloosa	2.54	2.36
% Change	1.93	0.13

Table 4.8 "All Vehicle" Emission Factors from Default and Jefferson Registration Distribution

All Vehicle	VOC (grams/mile)	NO_X (grams/mile)
Default	2.49	2.35
Jefferson	2.90	2.54
% Change	16.8	7.90

4.6 Impact of the Use of Local Registration Data in VMT Mix- Tuscaloosa

As stated in Section 3.4.3, VMT mix is an important parameter in the estimation of emission inventory. Since it represents the fraction of total VMT accumulated by the eight vehicle classes, any change in this travel activity factor will affect the emission inventory. As stated in Section 3.4.4, Arcadis equations developed for MOBILE6 were used to estimate the amount of driving done by each model year vehicle within a class. It was observed that the mileage accumulation differed from model year to model year with age one or new vehicles accumulating more mileage than the older vehicles. But the emission factors for older vehicles are far higher than the emission factors for the newer vehicle fleet. Table 4.9 summarizes the VMT mix and the percent change for the default and calculated VMT mix.

Table 4.9 Comparison of Default and Tuscaloosa VMT Mix

VMT Mix	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Tuscaloosa	0.48	0.28	0.16	0.006	0.001	0.003	0.071	0.002
Default	0.61	0.19	0.091	0.034	0.002	0.001	0.066	0.005
% Change	-21.2	48.7	71.3	-83.6	-30.9	192	6.92	-59.8
VMT* (Miles)	7.60E+08	4.30E+08	2.40E+08	8.70E+06	2.16E+06	4.56E+06	1.10E+08	3.14E+06

*Calculated from registration and Arcadis mileage accumulation rates

In the calculation of VMT mix, the vehicle miles and registration distribution were used, so the effect of age and mileage accumulation were studied in this analysis. In addition, this study allowed us to compare the differences in the quantities of VOCs and NO_X generated by using the default VMT mix and default emission factors, and VMT mix obtained with registration data and local estimated emission factors. Quantities of VOCs and NO_X released due to the multiplication of emission factors by local VMT mix and VMT are compared to that of the emissions released by using the default VMT mix, VMT, and default emission factors. In both the cases, the same VMT value is used in the emission estimation. Therefore, the impact of local estimated VMT mix versus default mix was examined (independent of the total VMT). Tables 4.10 and 4.11 present the amount of VOCs and NO_X emitted per year by all the MOBILE5b vehicle classes as a result of using default VMT mix and the Tuscaloosa VMT mix.

Table 4.10 VOCs Emitted with Tuscaloosa and Default VMT Mix*

VOC	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Tuscaloosa								
VMT Mix	0.48	0.28	0.16	0.006	0.001	0.003	0.071	0.002
VOC EF (grams/mile)	2.25	2.85	2.82	5.1	0.7	0.92	2.35	6.51
VOC (Tons)	1869	1362	755	49	2	5	285	23
Default								
VMT Mix	0.61	0.19	0.091	0.034	0.002	0.001	0.066	0.005
VOC EF (grams/mile)	2.14	2.62	3.46	6.11	0.69	0.94	2.27	4.74
VOC (Tons)	2257	842	541	357	2	2	257	41
% Change in VOC	-17.2	61.8	39.6	-86.3	-29.9	185.5	10.7	-44.7

*Emissions estimates are for comparison purposes only and do not represent an attempted mobile source inventory in each county

Table 4.11 NO_X Emitted by using Tuscaloosa and Default VMT Mix*

NO_X	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Tuscaloosa								
VMT Mix	0.48	0.28	0.16	0.006	0.001	0.003	0.071	0.002
NO_X EF (grams/mile)	1.44	1.65	1.78	4.83	1.44	1.58	12.59	0.74
NO_X (Tons)	1196	788	477	46	3	8	1526	3
Default								
VMT Mix	0.61	0.19	0.091	0.034	0.002	0.001	0.066	0.005
NO_X EF (grams/mile)	1.41	1.64	2.22	4.98	1.44	1.62	12.28	0.74
NO_X (Tons)	1487	527	347	291	5	3	1392	6
% Change in NO_X	-19.6	49.6	37.3	-84.1	-30.9	185	9.62	-59.8

Table 4.12 Comparison of Total VOC and Total NO_X Emissions in Tons between Tuscaloosa and Default VMT Mix*

	VOC (Tons)	NO_X (Tons)
Tuscaloosa	4.35E+03	4.05E+03
Default	4.30E+03	4.06E+03
% Change	1.15	-0.27

The impact studies of locality-specific registration data indicated a marked change in the emission factors for some vehicle classes. Along the same lines, one could establish that the VMT mix estimated using registration data has impacted different vehicle classes differently. It is extremely important to study the impact of VMT mix on emissions. For example, the local estimated and default VOC emission factors for LDGT2 were 2.82 gr/mile and 3.46 gr/mile, respectively (Table 4.10). However, as the VMT mix for LDGT2 was substantially higher for Tuscaloosa, the Tuscaloosa VOC emission for LDGT2 was much higher than the default. Similarly, the impact of VMT mix on NO_X emissions varied from vehicle to vehicle. From Table 4.12, the overall emission change is –0.27% with respect to the default emission estimate, while class-to-class emissions did show significant changes. The overall local estimated VOC and NO_X emissions showed a negligible amount of fluctuation from the default values as indicated in Table 4.12.

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*Emissions estimates are for comparison purposes only and do not represent an attempted mobile source inventory in each county

4.7 Impact of Using Jefferson Registration Data in VMT Mix

In Section 4.6, the impact of inputting user-supplied Tuscaloosa County registration distribution data was analyzed. Another analysis, on similar lines, was conducted using a onetime snapshot of Jefferson County's registration distribution data. Table 4.13 compares the Jefferson and default VMT mix values by their percentage difference relative to default. It is obvious that Jefferson County registration data has a VMT mix that is different from its default counterpart. Tables 4.14 and 4.15 display the annual amount of VOCs and NO_X emitted in both the default and Jefferson cases by all the vehicle classes defined in MOBILE5b.

Table 4.13 Comparison of Default and Jefferson VMT Mix

VMT Mix	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Jefferson	0.598	0.24	0.095	0.002	0.002	0.002	0.061	0.002
Default	0.608	0.19	0.094	0.033	0.002	0.001	0.069	0.005
% Change in VMT Mix	-1.64	26.32	2.13	-93.94	0.00	100.00	-11.59	-60.00
VMT* (Miles)	5.28E+09	2.08E+09	8.39E+08	1.72E+07	2.20E+07	1.80E+07	5.41E+08	2.11E+07

- Calculated from registration and Arcadis mileage accumulation rates

Table 4.14 VOCs Emitted by using Jefferson and Default VMT Mix*

	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Jefferson								
VMT Mix	0.60	0.24	0.095	0.002	0.002	0.002	0.061	0.002
VOC EF (grams/mile)	2.66	3.08	3.21	6.31	0.77	0.97	2.38	6.94
VOC (Tons)	1.54E+03	7.06E+03	29.6E+03	119	19	19	1.42E+03	161
Default								
VMT Mix	0.61	0.19	0.094	0.033	0.002	0.001	0.069	0.005
VOC EF (grams/mile)	2.14	2.62	3.46	6.11	0.69	0.94	2.27	4.74
VOC (Tons)	1.26E+03	4.83E+03	3.16E+03	1.96E+03	13	9	1.52E+03	230
% Change in VOC	22.4	46.2	-6.15	-93.9	39.1	110	-6.80	-30.1

*Emissions estimates are for comparison purposes only and do not represent an attempted mobile source inventory in each county

Table 4.15 NO_X Emitted by using Jefferson and Default VMT Mix*

	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
Jefferson								
VMT Mix	0.60	0.24	0.095	0.002	0.003	0.002	0.061	0.002
NO_X EF (grams/mile)	1.62	1.72	1.96	4.89	1.57	1.63	12.77	0.74
NO_X (Tons)	9.40E+03	4.00E+03	1.81E+03	94	39	33	7.56E+03	17
Default								
VMT Mix	0.61	0.19	0.094	0.033	0.002	0.001	0.069	0.005
NO_X EF (grams/mile)	1.41	1.64	2.22	4.98	1.44	1.62	12.28	0.74
NO_X (Tons)	8.32E+03	3.02E+03	2.03E+03	1.59E+03	28	16	8.22E+03	36
% Change in NO_X	13.0	32.2	-10.4	-94.1	37.8	108	-8.07	-51.6

The impact of VMT mix was different on different vehicle classes. For instance, take the case of LDDT VOC emissions; the emission factors vary only by 3.2% whereas the VMT mix varies by 100%. The tons of VOC emissions released in the local estimate case and the default case are 19 and nine, respectively. The percentage change produced in VOC emissions is 111%. This illustrates the impact of VMT mix alone, as the change in emission factor is negligible.

In the preparation of the emission inventory, emissions from individual vehicle classes are added to get the final value. The fleet wide emission factors are not used in constructing emission inventory. Table 4.16 presents the total VOCs and NO_X emitted by summing the emissions from individual classes. Table 4.16 shows an increase of 11.76% in VOC emissions, which is significant because it could transform an attainment/moderate area into a non-attainment area. NO_X emission changes were small and decreased by 1.3%. The area has demonstrated a reduction in total NO_X emissions but this decrease was offset by an increase in VOC emissions. In summary, NO_X decreased slightly but VOC increase was significant.

*Emissions estimates are for comparison purposes only and do not represent an attempted mobile source inventory in each county

Table 4.16 Comparison of Total VOC and NO_X Emissions in Tons between Jefferson and Default VMT Mix*

	VOC (Tons)	NO_X (Tons)
Jefferson Estimates	27208	22957
Default	24344	23267
% Change	11.76	-1.33

4.8 Emission Benefits Analysis of TCM-Signalization

Using the methodology developed in Section 3.5.2, an analysis of the emission benefits of signalization was conducted. Total emissions in the worst case are considerably higher than in the ideal case, giving a compelling indication of how signal optimization could help in reducing vehicular emissions. For illustrative purpose, consider a one-mile road (2 lanes in each direction) with four signals separated at 0.25 miles having a free-flow speed of 25 mph, stopping time delay of 45 sec, and a traffic volume of 32,000 vehicles per day. Figure 4.6 presents a layout of the road segment modeled in this case study. Emissions from traffic volumes moving on roadways perpendicular to the direction shown by the arrows are not considered in this study.

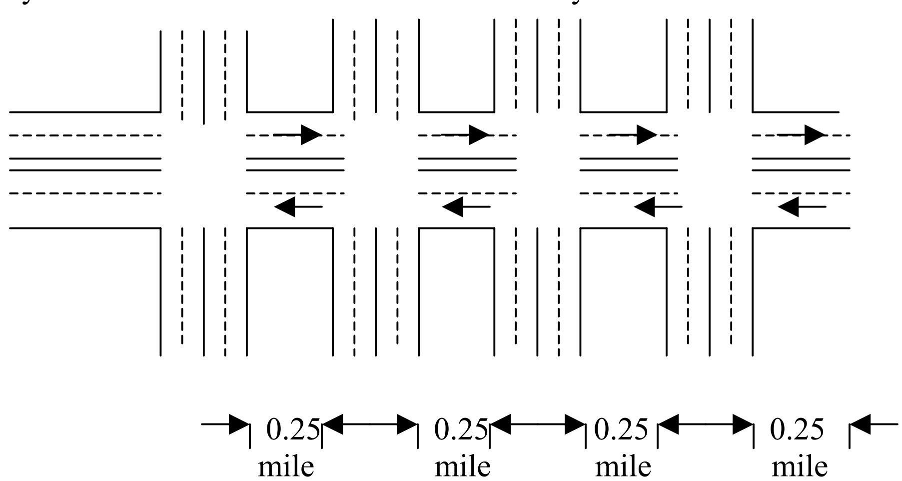

Figure 4.6 Schematic layout of a corridor of four signalized intersections.

Figure 4.7 is a comparison of total VOC and NO_X emissions from the worst and ideal cases using values closer to what one sees in a typical downtown. Large changes in VOC

*Emissions estimates are for comparison purposes only and do not represent an attempted mobile source inventory in each county

and NO_X emissions were observed in these calculations. As illustrated in Table 4.17 and Figure 4.7, VOCs in the worst case are nearly four times as much as in the ideal case. NO_X in the worst case is almost twice as high as the emissions in the ideal case. Pie charts (Figures 4.8 and 4.9) are shown below to illustrate the relative contributions of each operating phase to the total VOC and NO_X emissions generated by a single or a lead vehicle in the worst-case scenario.

Readers must bear in mind that this analysis employs the notion of lead vehicle as described in Section 3.5.1. It is apparent that the total emissions from the entire traffic, presupposed to be lead vehicles, are overestimated in the worst cases.

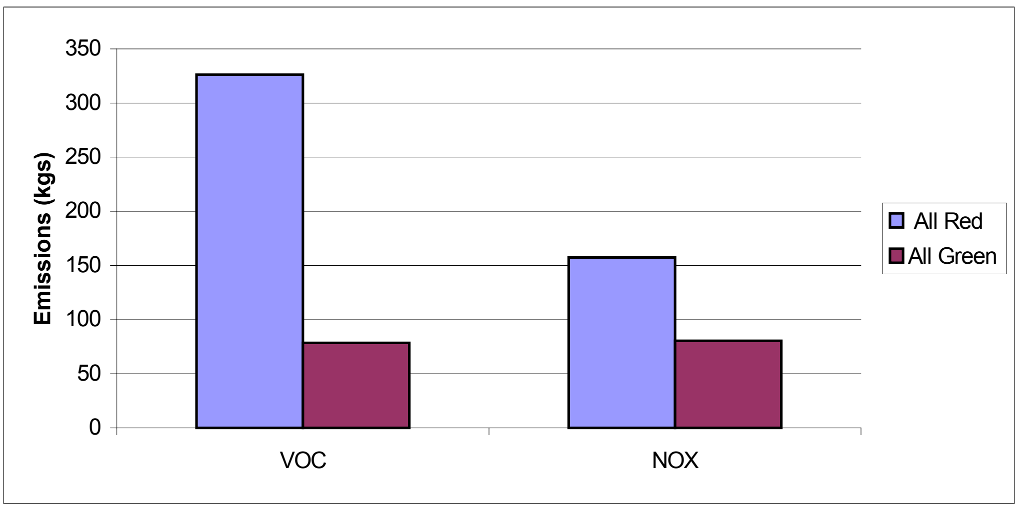

Figure 4.7 Comparison of VOC and NO_X emissions between the worst case and ideal case in signalization case study.

Table 4.17 Percentage Reduction in VOC and NO_X Emissions Achieved in the Ideal Case

	VOC (Kgs)	NO_X (Kgs)
Worst Case (All Red)	326	157
Ideal Case (All Green)	78.6	80.5
% Change	-75.9	-48.9

4.9 Emissions Reductions in a Railroad Analysis

Emission benefits achieved by implementing the proposed tunnel or road as described in Section 3.5.3 are dealt with herein. The methodology for calculating emissions is identical to that used in the signalization study. For instance, consider a road of length

0.5 miles with a free-flow speed of 35 mph and a traffic volume of 32,000 vehicles per day. Assuming that the engines' idle time is equal to the time the gates are closed, the following VOC and NO_X emission changes are observed as presented in Table 4.18 and Figure 4.10.

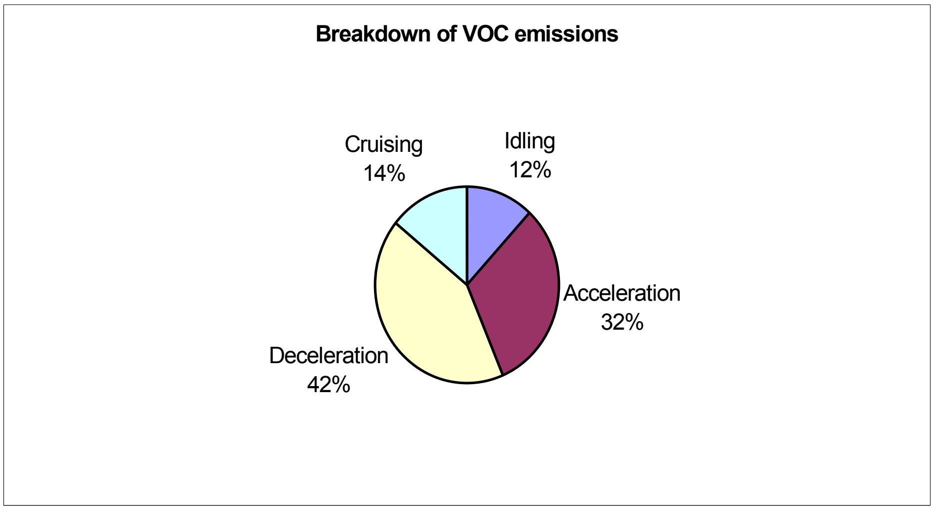

Figure 4.8 Contribution of emissions from different operating phases to the total VOC emissions in the worst-case scenario of single vehicle in signalization case study.

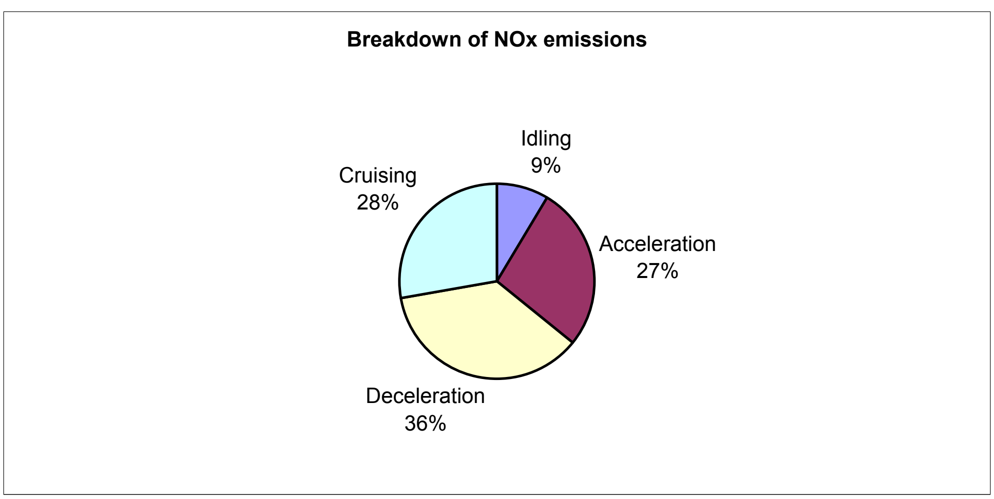

Figure 4.9 Contribution of emissions from different operating phases to the total NO_X emissions in the worst-case scenario of single vehicle in signalization case study.

Table 4.18 Percentage Reduction in Emissions After Implementing the TCM in Railroad Case Study

	VOC (Kgs)	NO_X (Kgs)
With Gates	82.6	59.2
Without Gates	31.5	40.6
% Change	-61.9	-31.5

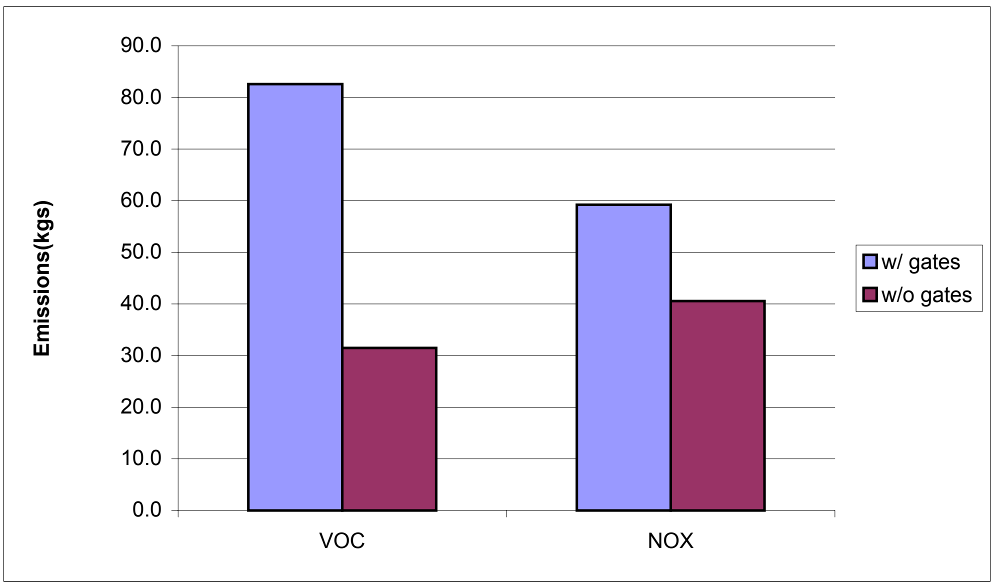

Figure 4.10 Comparison of VOC and NO_X emissions between "with gates" and "without gates" scenarios in railroad case study.

As indicated in Table 4.18 and Figure 4.10, a 60% reduction in VOC emissions and a 31% reduction in NO_X emissions are the benefits of this TCM (tunnel or bridge) at railroad crossing as estimated with our simplified approach. This emission reduction is obvious since the purpose of implementing congestion mitigation measures is to reduce the engines' idle emissions. The motorists initially cruise, decelerate, and finally idle until the gates are opened. Hence, the "approach" emissions consist of cruising, decelerating, and idling. As indicated by Figures 4.11 and 4.12, idling is the single largest contribution to "approach" emissions for this railroad-crossing example.

However, this simplified TCM evaluation methodology utilized a lead vehicle analysis of traffic through intersections. As stated in Section 3.5.1, lead vehicle analysis will tend to overstate idling emissions. This is due to applying lead vehicle idling time to vehicles that may arrive at the intersection after the lead vehicle and hence idle for a shorter time period. Therefore, while this analysis is qualitatively correct, the emissions at the intersection and in the gates down position are overestimated. This method produces conservative or maximum emissions. The overestimation of "stopped" emissions will consequently result in overstating the benefits of TCM.

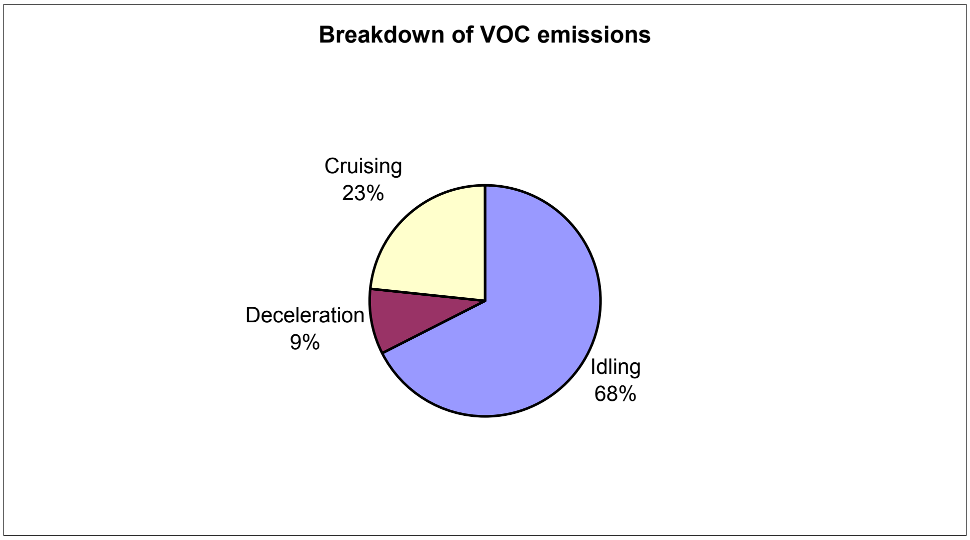

Figure 4.11 Breakdown of VOC "approach emissions" in railroad case study.

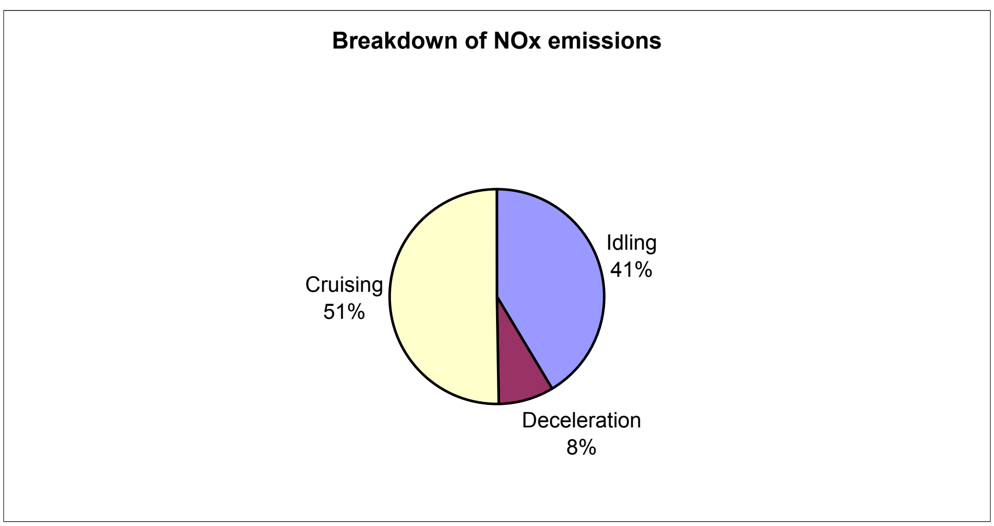

Figure 4.12 Breakdown of NO_X "approach emissions" in railroad case study.

5.0 Conclusions and Products

The goal of this research was to demonstrate the impact of traffic management decisions on air quality in Alabama. This goal is supported by two objectives. The first objective was to prepare educational materials explaining how transportation (specifically, traffic management) impacts air quality in Alabama (i.e., ozone concentrations in Birmingham). These materials may be used when discussing air quality in Alabama (especially in non-attainment areas). The second objective was to improve the current (default) air quality assessment methodology (MOBILE5b modeling) by exploring a number of input data/parameter modifications. These improvements were used to demonstrate the impact of: (1) using local data to assess emissions in Alabama, and (2) traffic control measures on vehicle emissions.

The following conclusions/products were produced during this study:

(1) A website was produced that now serves as a clearinghouse of information on ground-level ozone in Alabama (www.alabamacleanair.com).
(2) Local data is needed to produce more accurate air emissions inventories that have broader acceptance in the regulatory community than inventories produced with national default data.
(3) The mobile model is sensitive to changes in speed, but does not amplify variation in output emission beyond variation in input speed.
(4) Larger variations in speed, as would occur in a trip composed of several different speed zones, must be considered. Using an average speed for an entire trip, instead of several speeds, can lead to severe underestimation of emissions for a typical trip (20-80% underestimation of VOC emissions and 10-35% underestimation of NOx emissions). These differences in trip-based emissions are expected to be addressed in the MOBILE6 version of the emissions model, which will allow for different road types.
(5) The use of local data may create significant impacts in emission inventories due to the impact of registration data on both age (automatically incorporated by the MOBILE model), and VMT mix (calculations performed in a separate methodology in this research). The extent of impact depends largely on the age distribution of the local fleet as reflected in registration data.
(6) Using registration data in Tuscaloosa County did not cause large differences in the emissions estimate compared to default data.
(7) Registration data in Jefferson County showed an 11% larger yearly VOC emission rate than did the use of default data, while local data only showed a 1.3% decrease in NOx emissions.
(8) A spreadsheet scheme for calculating TCM impacts on emissions was developed and applied. This technique was based on the MOBILE model, but is simple to

apply and understand and has promise for evaluating TCMs that impact flow in urban road links.

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Appendix 1- Glossary

Alabama Partners for Clean Air (APCA) - A voluntary air quality improvement group.

Basic Emission Factors (BEFs) - It is the average exhaust emission factor, in grams per mile, for vehicle of that model year.

Clean Air Act (CAA) - The original Clean Air Act was passed in 1963,but the national air pollution control program is actually based on the 1970 version of the law.

Congestion Mitigation for Air Quality (CMAQ) - A program, jointly administered by the FHWA and Federal Transit Administration (FTA), to provide funds to state DOTs, and MPOs to invest in projects that reduce criteria air pollutants regulated from transportation-related sources.

Carbon Monoxide (CO) - A colorless, odorless gas resulting from the incomplete combustion of hydrocarbon fuels.

Federal Testing Procedure (FTP) - A certification test for measuring the tailpipe and evaporative emissions from new vehicles over the Urban Dynamometer Driving Schedule, which attempts to simulate an urban driving cycle.

Gross Vehicle Weight (GVW) - The value specified by the manufacturer as the maximum design loaded weight of a single vehicle.

Highway Performance Monitoring Network (HPMS) - A national highway transportation system data base designed to provide data that reflects the extent, condition, performance, use, and operating characteristics of the Nation's highways.

Intermodal Surface Transportation Efficiency Act (ISTEA) - An Act to develop a national Intermodal surface transportation system, to authorize funds for construction of highways, for highway safety programs, and for mass transit programs, and for other purposes.

Metropolitan Planning Organizations (MPO) - Organization with responsibilities for developing transportation plans and programs for urbanized areas with population of 50,000 or more people.

National Ambient Air Quality Standards (NAAQS) - Standards set by EPA for the maximum levels of criteria air pollutants that can exist in the outdoor air without unacceptable effects on human health or the public welfare.

Nitrogen Oxides (NO_X) - Oxides of Nitrogen created during combustion processes, and are major contributors to smog formation and acid deposition.

Speed-correction factor (SCF) - Factors used in the MOBILE model to adjust emission factors from average speed used in the Federal Test Procedure to other average speeds as driven by vehicles in the geographical area being modeled.

State Implementation Plans (SIPs) - A detailed description of the programs a state will use to carry out its responsibilities under the Clean Air Act for complying with the NAAQS.

Transportation Control Measures (TCMs) - Any control measure to reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, or traffic congestion for the purpose of reducing motor vehicle emissions.

Transportation System Management (TSM) - Any of various measures to improve the operation of a facility without construction of additional roadway lanes, such as: dynamic message signs (DMS), ramp metering and closed-circuit camera surveillance, and loop detection to detect and respond to emergencies.

Vehicle Miles Traveled (VMT) - The number of miles driven by a single vehicle, or by a fleet of vehicles over a set period of time, such as a day, month, or year.

Volatile Organic Compounds (VOCs) - Organic compounds that lead to ozone formation.

Appendix 2- Acronyms

ADEM	Alabama Department of Environmental Management
ALDOT	Alabama Department of Transportation
DOT	Department of Transportation
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
HDGV	Heavy-Duty Gasoline Vehicles
HDDV	Heavy-Duty Diesel Vehicles
LDV	Light-Duty Vehicles
LDGV	Light-Duty Gasoline Vehicles
LDDV	Light-Duty Diesel Vehicles
LDT	Light-Duty Trucks
LDGT	Light-Duty Gasoline Trucks
LDDT	Light-Duty Diesel Trucks
MC	Motorcycles