Modeling of Concentrations of MSATs (Mobile Source Air Toxics) along Highways and near Intersections in Florida

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Final Report
to
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Project Officer
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by

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METRIC CONVERSION TABLE

Symbol	When you know	Multiply by	To find	Symbol
ft	feet	0.305	meters	m
mi	miles	1.609	kilometers	km
in	inches	25.4	centimeters	cm
m	meters	3.28	feet	ft
km	kilometers	0.621	miles	mi
cm	centimeters	0.472	inches	in

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16. Abstract

There is a growing concern that emissions of mobile source air toxics (MSATs) from motor vehicles may pose a threat to human health. At present, no agencies require dispersion modeling of these compounds, and until now, highway models that could predict such dispersion did not exist. The widely accepted roadway and intersection model CAL3QHC was modified at the University of Central Florida (UCF) to allow the dispersion modeling of various MSATs at selected large intersections and roadways in Florida. The Environmental Protection Agency (EPA) model MOVES2010a (MOVES) was used to generate MSAT emission factors, and the modified CAL3QHC program (dubbed CAL3MSAT) was used to conduct the modeling.

MSAT modeling was conducted at 7 large intersections and 7 large freeway segments in Florida. The year 2010 was used with peak-hour traffic speeds in MOVES to generate emission factors. It is noted that emission factors of MSATs are projected to decrease over the next 20 years, faster than traffic volumes are projected to grow. So the 2010 models produced the highest concentrations, and all future years should have lower concentrations than those modeled in this study. In all of our modeling for all of the intersections and freeway segments in the various FDOT districts, all of the modeled MSAT concentrations were extremely low, leading to the conclusion that MSATs from motor vehicles do not pose a threat to human health in Florida.

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EXECUTIVE SUMMARY

There is a growing concern that emissions of mobile source air toxics (MSATs – also known as hazardous air pollutants or HAPs) from motor vehicles may pose a threat to human health. The U.S. Environmental Protection Agency (EPA) presently has no ambient air quality standards for MSATs, and the Federal Highway Administration (FHWA) presently does not require dispersion modeling of these compounds. Nevertheless, the Florida Department of Transportation (FDOT) decided to conduct modeling to ascertain if there was a potential MSATs problem from highway vehicles in Florida. To accomplish this, the widely accepted roadway and intersection model CAL3QHC was modified at the University of Central Florida (UCF) to allow for the dispersion modeling of various MSATs at selected large intersections and roadways in various FDOT Districts. The EPA model MOVES2010a (MOVES) was used to generate MSAT emission factors, and the modified CAL3QHC program (dubbed CAL3MSAT) was used to conduct the modeling.

MSAT modeling was conducted at 7 large intersections and 7 large freeway segments in Florida. The intersections and freeway segment scenarios were developed from data obtained from various FDOT Districts, and represented the urban areas of Jacksonville, Miami-Ft. Lauderdale, Orlando, Pensacola, Naples-Sarasota, Tallahassee, and St. Petersburg-Tampa. The MSATs modeled were acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde. A worst-case approach was utilized, meaning that the peak-hour traffic volumes were used, along with worst-case meteorology (1.0 m/s wind speed, class D stability, and a wind angle search around the compass) to obtain the worst-case (highest) 1-hour concentrations of MSATs at each facility.

The U.S. EPA has not established ambient air quality standards for MSATs, and there are no published values for maximum acceptable concentrations (MACs) of these compounds in ambient air. Based on an extensive literature search, these researchers suggested unofficial guidelines for MACs for each MSAT, so that the results of our modeling could be compared with some yardstick. In order to make an equal comparison among all cases, and since not all the data were collected from the same years, traffic volumes at each facility were projected to the year 2010, and that year was used with peak-hour traffic speeds in MOVES to generate emission factors. It is noted that emission factors of MSATs (as predicted from MOVES) are projected to decrease over the next 20 years, faster than traffic volumes are projected to grow. Thus, the 2010 models produced the worst-case (highest) concentrations, and all future years should have lower concentrations than those modeled in this study.

In all of our modeling for all of the intersections and freeway segments in the various FDOT districts, none of the modeled MSAT concentrations came close to exceeding our unofficial proposed MACs for the 1-hour averaging time concentrations. The annual average concentrations were estimated from the worst-case 1-hr concentrations by using a persistence factor approach. That is, the authors multiplied the worst-case 1-hour modeled concentrations by a factor of 0.05 to account for both traffic and meteorological persistence. At locations immediately adjacent to some of the intersections, the modeled annual concentrations did approach values that we had suggested as possible MACs for chronic risk. However, the overall conclusion from this research is that MSATs from motor vehicles do not pose a threat to human health in Florida.

The research team was composed of Dr. David Cooper and Mr. Kurt Westerlund of UCF, along with Dr. Michael Claggett of the Federal Highway Administration (FHWA). There are two main products of this research. The first is CAL3MSAT – a FORTRAN modification of CAL3QHC developed at UCF – that specifically can model the dispersion of various MSATs. The second is CAL3i – a graphical user interface (GUI) developed by Dr. Claggett at FHWA – that runs CAL3QHC or CAL3MSAT within a Windows environment. CAL3i allows the user to generate a standardized (yet flexible) highway layout including adjustable links, signal data, and numerous receptors. Concentrations of various pollutants can be calculated quickly and easily. During this project, this interface was developed, and extensively tested and de-bugged. CAL3i is easy to use, but does require that the user must have already run the latest EPA emission factor model (currently MOVES 2010a) so that the correct emission factors can be input into the interface.

The main benefit of this research is the development of a highway dispersion model that can handle MSATs should the need or desire arise to assess MSAT concentrations near a large roadway or intersection. Another benefit is demonstrating that worst-case MSAT concentrations near intersections and freeway segments are extremely low, leading to the conclusion that MSAT concentrations due to motor vehicles do not pose a threat to human health. The third major benefit of this research was the development and refinement of the FHWA model, CAL3i, a graphical user interface for running CAL3QHC and CAL3MSAT.

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LIST OF ABBREVIATIONS

Acronym	Meaning
$\mu g/m^3$	microgram per cubic meter
ADT	average daily traffic
AEGL-1	Acute Exposure Guidelines Level 1
AEGL-2	Acute Exposure Guidelines Level 2
ATHED	Air Toxics Heath Effects Database
ATHED	Air Toxics Health Effects Database
ATSDR	Agency for Toxic Substances and Disease Registry
CAA	Clean Air Act
CO	carbon monoxide
CR	cancer risk
DE	diesel exhaust
DEOG	diesel exhaust organic gases
DPM	diesel particulate matter
EF	emission factor
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
GUI	graphical user interface
HAP	hazardous air pollutant
HEI	Health Effects Institute
IRIS	Integrated Risk Information System
MAC	maximum acceptable concentration
MOVES	Motor Vehicle Emission Simulator
MOWT	molecular weight
MPF	meteorological persistence factor
MSAT	mobile source air toxic
NAAQS	National Ambient Air Quality Standards
NRC/NAC	National Research Council, National Advisory Committee
OAQPS	Office of Air Quality, Planning, and Standards
OEHHA	Office of Environmental Health Hazard Assessment
PM	particulate matter
ppb, ppbv	parts per billion, parts per billion by volume
ppm, ppmv	parts per million, parts per million by volume
RVP	Reid vapor pressure
TPF	total persistence factor
U.S. EPA	United States Environmental Protection Agency
UCF	University of Central Florida
URE	unit risk estimate

LIST OF ABBREVIATIONS (cont.)

Acronym	Meaning
V/C	volume to capacity ratio
VPF	vehicle persistence factor

CHAPTER 1. INTRODUCTION

1.1 Background

Hazardous air pollutants (HAPs), also known as air toxics, are pollutants that cause or that may cause cancer, other serious health effects, or adverse environmental and ecological damage. The United States Environmental Protection Agency (U.S. EPA) identified 187 HAPs by the Clean Air Act Amendments of 1990 [1]. Various HAPs can be attributed to mobile sources, and these are known as mobile source air toxics (MSATs). There are many MSATs, but the U.S. EPA identified six "primary" MSATs of concern in 2001. They are acetaldehyde, acrolein, benzene, 1,3-butadiene, formaldehyde, and diesel particulate matter plus diesel exhaust organic gases (DPM+DEOG). Projections have been done by the U.S. EPA, and they have shown that the Clean Air Act (CAA) has been effective at reducing the overall annual emissions of HAPs [2].

There is a growing concern that emissions of these MSATs from motor vehicles may pose a threat to human health. However, until recently, there has not been a good method for quantifying estimates of these emissions, and there still is no approved dispersion model for estimating concentrations of MSATs near roadways and intersections. The U.S. EPA presently has no ambient air quality standards for MSATs, and the FHWA does not require dispersion modeling of these compounds at present. However, FDOT decided to conduct "pre-emptive" modeling to ascertain if there was a potential MSATs problem from highway vehicles in Florida. Because there was no highway dispersion modeling software available to model the dispersion of MSATs, this research project was funded to develop such software and to conduct the modeling.

1.2 Statement of Objectives

There were three main objectives of this research: (1) to modify the CAL3QHC model to allow dispersion modeling of MSATs, (2) to model MSAT concentrations near several large intersections and freeway segments in Florida, and (3) to develop/refine a graphical user interface for the MSATs model.

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CHAPTER 2. DEVELOPMENT OF PROPOSED MACs

Since the U.S. EPA has not promulgated National Ambient Air Quality Standards (NAAQS) for any MSATs (such as 35 ppm and 9 ppm for the CO 1-hour and 8-hour standards, respectively), an approach to calculate maximum acceptable concentrations (MACs) was developed and subsequently used to derive threshold concentration values for the MSATs of interest. This included both acute (1-hour) and chronic (lifetime) concentrations.

In order to quantify the primary MSATs risk levels and their associated MACs, many data sources were reviewed. These sources included the U.S. EPA's Integrated Risk Information System (IRIS) and Office of Air Quality, Planning, and Standards (OAQPS), the Agency for Toxic Substances and Disease Registry (ATSDR), the Health Effects Institute (HEI), the U.S. Department of Transportation Federal Highway Administration (FHWA), and the State of California's Office of Environmental Health Hazard Assessment (OEHHA) [3-8]. With information from these sources, a cancer inhalation unit risk estimate (URE) was determined for each primary MSAT. These values were key parameters used when determining proposed chronic lifetime MACs for the MSATs of interest.

2.1 Cancer Risk Considerations

2.1.1 Chronic Lifetime Cancer Risk

The URE for a chemical species is defined as the upper-bound excess lifetime (70-year) cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 $\mu g/m^3$ in air [9]. The inhalation unit risk is derived using mathematical models that assume a non-threshold approach where some risk of cancer would occur at any level of exposure. The methods used to derive these inhalation unit risk values result in an "upper bound" estimate, that is, the true risk is unlikely to exceed this value and may be much lower [10]. An example of the correct way to interpret the URE was given by the U.S. EPA in 2007 [9].

"The interpretation of the Unit Risk Estimate would be as follows: if the Unit Risk Estimate = $1.5x10^{-6}$ per $\mu g/m^3$, 1.5 excess tumors are expected to develop per 1,000,000 people if exposed daily for a lifetime to 1 µg of the chemical in 1 cubic meter of air."

The UREs for the six primary MSATs of interest can be seen in Table 1, along with their respective sources.

Table 1: URE Values for the Primary MSATs

Primary MSAT	Molecular Formula	Molecular Weight (g/mol)	Carcinogenic Class (EPA)	URE $(\mu g/m^3)^{-1}$	Source
Acetaldehyde	CH_3CHO	44.05	B2-Probable	2.20×10^{-6}	IRIS
Acrolein	C_3H_4O	56.06	Inl-Inadequate Information	Cannot be quantified	N/A
Benzene	C_6H_6	78.11	A-Known	7.80×10^{-6}	IRIS
1,3-Butadiene	C_4H_6	54.09	A-Known	3.00×10^{-5}	IRIS
Formaldehyde	CH_2O	30.03	B1-Probable	1.30×10^{-5}	OAQPS
(DPM+DEOG)	N/A	N/A	LH-Likely	3.00×10^{-4}	OEHHA

To measure risks of developing cancer, many assessments use the metric Cancer Risk (CR) [11]. This parameter represents the probability that an individual will develop cancer in their lifetime as a result of exposure to a pollutant. The U.S. EPA considers a CR benchmark of less than one-in-a-million (10^{-6}) to be acceptable [9]. In addition, the U.S. EPA has estimated that if an individual were to breathe air containing the risk-specific dose of the chemical over his or her entire lifetime, that person would theoretically have no more than a one-in-a-million increased chance of developing cancer as a direct result of breathing air containing the chemical [10].

Cancer risk (CR) for any primary MSAT can be calculated using its URE [Equation (1)]. To determine a cancer threshold concentration for the primary MSAT, the CR can be set to the U.S. EPA benchmark of 10^{-6} and Equation (2) can be derived [12]. The resultant concentration from Equation (2) is a mass concentration in units of $\mu g/m^3$. This concentration can also be expressed in the common air pollution units of parts per billion (ppbv) by utilizing Equation (3). In Equation (3), the numerator value was determined by assuming standard values for temperature (25 °C) and pressure (1 atm), while the denominator is the molecular weight of the particular MSAT [13].

$$\mathrm{CR} = \mathrm{MSAT_{mass}} \cdot \mathrm{URE} \qquad \textbf{(1)}$$

$$\mathrm{MSAT_{mass}} = \frac{\mathrm{CR}}{\mathrm{URE}} \qquad \textbf{(2)}$$

$$\mathrm{MSAT} = \mathrm{MSAT_{mass}} \cdot \left(\frac{24.45}{\mathrm{MOWT}}\right) \qquad \textbf{(3)}$$

Where:

CR = cancer risk
$\mathrm{MSAT_{mass}}$ = mass concentration of MSAT in $\mu g/m^3$
URE = unit risk estimate of MSAT in $(\mu g/m^3)^{-1}$
MSAT = concentration of MSAT in ppbv
MOWT = molecular weight of MSAT in g/mol

2.2 Proposed MACs

2.2.1 1-Hour Acute MACs

The acute response threshold concentrations in literature vary from source to source, but the National Research Council, National Advisory Committee Acute Exposure Guidelines Level 1 and 2 (AEGL-1,AEGL-2) values were selected as threshold concentrations [14]. These values were chosen over others since they are supported by the EPA's Air Toxics Health Effects Database (ATHED) acute dose-response values for screening risk assessment [9]. Table 2 presents these threshold concentrations in units of $\mu g/m^3$ and ppmv for all of the primary MSATs of concern except for DPM+DEOG. This is due to the fact that there are no acute criteria or relevant literature available on diesel particulates and DEOG [6]. From these values, proposed 1-hr acute MACs were established based on the more conservative set of threshold concentrations. These are also presented in Table 2 in units of parts per billion (ppbv).

Table 2: Proposed 1-hr Acute MACs for the Primary MSATs

Primary MSAT	NRC/NAC AEGL-1[a]		NRC/NAC AEGL-2[b]		Proposed 1-hr Acute MAC
	($\mu g/m^3$)-1 hr	(ppmv)-1 hr[c]	($\mu g/m^3$)-1 hr	(ppmv)-1 hr[c]	(ppbv)
Acetaldehyde	8.10×10^4	45.0	4.80×10^5	266	45,000
Acrolein	7.00×10^1	0.03	2.30×10^2	0.10	30
Benzene	1.66×10^5	52.0	2.55×10^6	798	52,000
1,3-Butadiene	1.48×10^6	669	1.17×10^7	5,290	669,000
Formaldehyde	1.11×10^3	0.90	1.72×10^4	14.0	900
(DPM+DEOG)	-	-	-	-	-

[a] National Research Council, National Advisory Committee Acute Exposure Guideline Level-1: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic nonsensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure [6].
[b] National Research Council, National Advisory Committee Acute Exposure Guideline Level-2: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape [6].
[c] All values were originally reported in terms of mass concentrations, but calculations were done using Equation (3), with noted assumptions, to report values in units of ppm

2.2.2 Chronic Lifetime MACs

Table 3 lists the respective proposed primary MSAT MACs for chronic cancer risk in units of $\mu g/m^3$ and ppbv. This was accomplished by using Equations **(2)** and **(3)** and setting the value of CR equal to 10^{-6}. The MACs were developed by just considering the carcinogenic risk since for pollutants that have both carcinogenic and non-carcinogenic impacts, the one-in-a-million carcinogenic risk occurs at a lower concentration than the non-carcinogenic chronic risk parameter [11]. Acrolein has no published URE and (DPM+DEOG) has a URE that was developed in California. The EPA does not have any carcinogenic risk parameters for either HAP. Therefore, MACs were not proposed for these two HAPs. This has been expressed by the U.S. EPA as the following: *"Data are inadequate for an assessment of human carcinogenic potential by either the inhalation or oral routes of exposure"* [15].

Table 3: Proposed Chronic Lifetime MACs for the Primary MSATs

Primary MSAT	MOWT	URE	Proposed Chronic Lifetime MAC	
	(g/mol)	$(\mu g/m^3)^{-1}$	$(\mu g/m^3)$	(ppbv)
Acetaldehyde	44.05	$2.20x10^{-6}$	0.4545	0.252
Acrolein	56.06	-	-	-
Benzene	78.11	$7.80x10^{-6}$	0.1282	0.0401
1,3-Butadiene	54.09	$3.00x10^{-5}$	0.0333	0.0151
Formaldehyde	30.03	$1.30x10^{-5}$	0.0769	0.0626
(DPM+DEOG)	-	-	-	-

CHAPTER 3. EMISSION FACTORS MODELING

In order to predict the concentration of pollutants along roadways, the emission rate (i.e., the mass of a pollutant emitted per unit activity rate) of the vehicles traveling on the roadway must be known. The way these values for a vehicle fleet have been determined historically has been through the use of an emissions modeling program developed by the U.S. EPA. The emissions models have evolved over time, but the fundamental concept has remained the same. The modeler inputs (as needed) user-defined and national-default data, in order to produce fleet-average emission factors (EFs). Typically, results for moving vehicles are reported as a mass emitted per distance (i.e., grams per vehicle mile) and for idling vehicles as a mass emitted per time (i.e., grams per vehicle hour). These emission factors are a function of many variables including vehicle type, age, condition, speed, and fuel. Also, the road grade, ambient temperature, humidity, and local control programs can all have an influence on the predicted value. For this research specifically, the results from an emissions model were used in order to run a dispersion model that predicts near-road pollutant concentrations.

3.1 MOVES2010a

The MOVES (MOtor Vehicle Emissions Simulator) is a computer program designed by the U.S. EPA to estimate air pollution emissions from mobile sources. The newest version was released in 2011, and MOVES2010a replaces the U.S. EPA's previous emissions model for on-road mobile sources, MOBILE6.2 [16]. MOVES can be used to estimate exhaust and evaporative emissions as well as brake and tire wear emissions from all types of on-road vehicles. It can be used to estimate national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile source air toxics from highway vehicles. Key parameters in MOVES2010a for predicting emission factors include the following:

- The source (vehicle) types (cars, trucks, etc.)
- The source type fractions (fraction of vehicles)
- The age distribution of the vehicles (newer pollution control equipment that has not deteriorated yet)
- Inspection/Maintenance programs
- The operating mode distribution (speed, idling, acceleration, load)
- The "link" parameters (road type, length, volume, average speed, average grade)
- The fuel supply and formulation (gasoline, diesel, Reid vapor pressure (RVP), oxygen content, sulfur content)
- Meteorological conditions (temperature, humidity)

The program itself was designed with the Java programming language, and the model is integrated with the MySQL relational database management system. The national-default and user-defined input files are stored in a MySQL input database, and after the model runs, the results are stored in a similar MySQL database. The results from MOVES can then be accessed using the MySQL Query Browser program. In this program, query statements can be created to manipulate the data, and the final results can then be exported into another format.

3.1.1 MOVES in This Study

Using the methods mentioned previously, on-road vehicular fleet-average emission factor values for the primary gaseous MSATs (DPM and DEOG were excluded for reasons explained in Section 3.1.2 below) were obtained for the seven urban areas of interest for arterial and freeway road types. Additionally, for the intersections, EFs were obtained for both the specific A.M. and P.M. peak hours, while for the freeways, the peak-hour EFs were determined. These resultant factors were then used in the dispersion model CAL3MSAT to predict the concentrations of primary MSATs near the modeled roadway. Table 4 presents emission factors generated by MOVES as a function of average speed for the A.M. peak hour in Duval County, FL. Similar results were obtained, but not reported, for the six remaining urban areas analyzed and for the different peak hours and modeled road types.

Table 4: Example of MOVES MSAT Emission Factors by Average Speed

Speed (mph)	Emission Factors (g/veh-hr, idle; g/veh-mi, cruise)				
	Acetaldehyde	Acrolein	Benzene	1,3-Butadiene	Formaldehyde
Idle	0.0530	0.0042	0.1105	0.0216	0.0846
10	0.0085	0.0007	0.0176	0.0035	0.0136
20	0.0053	0.0004	0.0113	0.0022	0.0082
30	0.0039	0.0003	0.0085	0.0016	0.0060
40	0.0032	0.0002	0.0067	0.0013	0.0049

3.1.2 Exclusion of DPM+DEOG Emission Factors

After much thought, it was concluded that there was no satisfactory way to obtain emission factors for diesel particulate matter and diesel exhaust organic gases. This is because MOVES2010a does not have the capability to report EFs for these specific pollutants, unlike the other five primary MSATs. The possibility of using a surrogate compound was investigated, but it was decided that, scientifically, there were no good means by which to do this. Diesel Exhaust (DE) is a complex mixture of hundreds of constituents in gas or particle phase, and diesel particulate matter (DPM) is composed of elemental carbon plus many other particles, which further complicates any attempt to produce a justifiable emission factor [17].

3.1.3 Adjustment of Vehicle Speeds

For dispersion modeling (discussed in further detail below), emission factors on each roadway link are needed. However, EFs are functions of the speed of the vehicles on each link. These specific data were not available, so for this study, the posted speed limits for the roadways were obtained, and then the modeled speeds were adjusted downwards (as explained below) to account for congestion associated with peak-hour traffic conditions. Assumed vehicle saturation flow rates were obtained from the Transportation Research Board's Highway Capacity Manual, and then graphs expressing the decline in vehicle operating speed as a function of volume to capacity ratio (V/C) were first used to determine speed reduction as a function of approach traffic per lane [18]. Next, actual hourly traffic counts from the turning movements obtained from the various FDOT Districts were developed for the peak hours. Finally, the numbers of lanes for a given roadway were used to determine the approach traffic per lane, and then resultant "congested" cruise speeds were established.

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CHAPTER 4. DEVELOPMENT AND DESCRIPTION OF CAL3MSAT

4.1 Methodology

With the aid of an air pollution dispersion modeling program, different "typical" intersections and freeways in Florida could be modeled to see if the modeled concentrations would exceed our proposed MACs. In order to accomplish this, a new dispersion model named CAL3MSAT, based on the U.S. EPA's CAL3QHC dispersion model for CO, was developed. Vehicle fleet average emission factors were obtained from the latest U.S. EPA mobile source emissions model, MOVES2010a. Seven urban areas in Florida were selected including Jacksonville, Miami-Ft. Lauderdale, Orlando, Pensacola, Naples-Sarasota, Tallahassee, and St. Petersburg-Tampa. This modeling determined "worst-case" maximum 1-hr concentrations of MSATs in each area, as discussed in more detail later in this report.

CAL3MSAT is a computer based dispersion model, written in the FORTRAN computer programming language, used to predict mobile source air toxics concentrations from motor vehicles at roadways and intersections. Since CAL3MSAT is based on CAL3QHC, a traffic algorithm for estimating vehicular queue lengths at signalized intersections is included in the program code [19]. Therefore, CAL3MSAT also incorporated methods to estimate the contribution of a particular pollutant due to the emissions from idling vehicles. CAL3MSAT has the capability to predict the concentration of numerous MSATs including acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde. The model also has the ability to model naphthalene, nitrogen dioxide, other gases, and other particulates. In addition, predicted concentrations of MSATs are reported in both units of $\mu g/m^3$ and ppbv. The internal calculation and dispersion algorithms/routines are based on the U.S. EPA's recommended freeway and intersection CO and PM screening model, CAL3QHC. One of the reasons for this is that the model and the science behind it are tested and proven to be valid for mobile source air pollution modeling. Since CAL3MSAT has the same dispersion algorithms as the CAL3QHC model, all of those input variables are the same. However, the pollutant "mode" variables are different. In addition, all results are reported in exponential format.

4.2 Input Files

Area specific data used to populate the input files for the various intersections and sections of freeway were obtained after contacting six of the FDOT districts. These data included the traffic counts, intersection signal timing, and roadway geometry. Specifically, items such as traffic turning movements, signal phase diagrams, and intersection schematics were obtained. The most current data on record from the contacted districts were obtained and from this, an intersection and freeway segment were selected. Table 5 lists the FDOT districts that were contacted, the cities from where the intersection and freeway segment data were obtained, the specific intersection roadways, and the specific freeway. All data obtained were normalized to the year 2010, so that the results from the various input files could be compared at the same temporal level. Also, individual input files were created for each primary MSAT (except for DPM) and for each peak hour modeled. For each intersection, both the A.M. and P.M. peak hours were modeled due to the differences in traffic conditions and site geometry for each scenario; whereas, only the peak hour where the greatest traffic volume occurred was chosen for the freeway segments due to symmetrical site geometry. For each intersection and peak hour, 5 MSATs were modeled. In total, 105 different input files were created for both the intersections (70 – 7 intersections, 2 hours, 5 MSATs) and freeway segments (35 – 7 freeway segments, 5 MSATs).

Table 5: Intersections and Freeway Segments for Which Data were Gathered

FDOT District	Urban Area	City	Intersection	Freeway Section
1	Naples-Sarasota	Sarasota	SR-72 & Beneva Rd	I-75
2	Jacksonville	Jacksonville	SR-115 & SR-152	I-95
3	Pensacola	Pensacola	SR-290 & SR-291	I-10
3	Tallahassee	Tallahassee	SR-261 & SR-20	I-10
5	Orlando	Orlando	SR-50 & SR-434	I-4
6	Miami-Ft. Lauderdale	Miami	SW 8th St & SW 137th St	I-95
7	St. Petersburg-Tampa	Tampa	SR-600 & W Columbus Dr	I-4

4.2.1 Additional Variables

In an input file, a user must define different "links." A link is defined as a straight segment of roadway having a constant width, height, traffic volume, and vehicle emission factor [20]. Therefore, for a given roadway or intersection, if any one of these constants change on the traveled way, a new link is defined. Depending on the scenario, the number of links can be quite large. Taking this into account, for increased accuracy and to better characterize a "typical roadway," all modeled intersections and freeway segments were drawn out in AutoCAD and the "real world" geometry of the roadways were modified, if necessary, to ensure that the lanes were perfectly aligned north-south and east-west. Example AutoCAD drawings can be seen in the Appendix for the cities of Jacksonville and Orlando. CAL3MSAT estimates air pollutant concentrations at user-defined receptor locations given the on-road vehicular fleet-average emission factors, the roadway geometry, signal and traffic conditions, and the site meteorology. To obtain emission factors, they are estimated from the U.S. EPA approved emission factors model; currently MOVES2010a. The roadway geometry, signal, and traffic data were obtained from the various FDOT districts.

4.2.2 Worst-Case Meteorology and Receptors

With CAL3MSAT, the user must make certain assumptions concerning the meteorological variables. The meteorological variables of atmospheric stability, wind speed, and wind direction are taken as constants for the modeled averaging time which is typically 1-hour. These variables are the main determinants of the diluting effect of the atmosphere as the pollutant is carried along and dispersed by the wind [21]. When one uses the program, the most site-specific geometric information should be used; however "worst-case" meteorological variables should be utilized. This means that the most stable class reasonable for the specific land use is automatically selected (in Florida, the stability class is D for urban or suburban land uses, and class E for rural). Additionally, the wind speed is set to a minimum speed of 1.0 m/s, and all wind angles are tested around the compass. Also, the surface roughness is assumed to be reasonably uniform through the roadway area and nearby surroundings (in Florida, 175 cm, 108 cm, and 10-30 cm are the standard surface roughness values for urban, suburban, and rural areas, respectively) [20]. Worst-case receptors were located at distances of 3 m (10 feet) from the roadway edges.

4.3 Modeling

4.3.1 Total Persistence Factor Selection

Since the CAL3MSAT model predicts worst-case 1-hour concentrations, these values must be compared to an acute 1-hour threshold concentration. However, with MSATs, the chronic health risk is also of concern and a factor must be determined that can help adjust from a 1-hour concentration to a chronic annual concentration. The annual concentration of a pollutant around a roadway will be much lower than the worst-case (peak) 1-hour concentration. The practice of using a total persistence factor (TPF) that is comprised of a meteorological persistence factor (MPF) and a vehicular persistence factor (VPF) has been used for years in CO modeling to convert 1-hour concentrations to 8-hour concentrations. Therefore, a similar method was applied to the CAL3MSAT results for the various MSATs of concern. There are two reasons for adjusting the peak 1-hour concentrations downwards. First, the average rate of emissions from vehicles during an average year period is much lower than during the peak hour because there are fewer vehicles on the roads during most of the day (or week or year) compared with either the morning or afternoon rush periods [22]. Second, the adverse meteorological conditions assumed in modeling a worst-case 1-hour concentration do not persist over a continuous year long period.

During the review of literature, some information was found on the persistence of concentrations resulting from the dispersion of emissions from stationary sources [23]. One of the reasons why this source was chosen is that the factors were developed for when emission heights are very low, which is the case for roadways. Also, the factors from this document were intended as a rough guide for estimating maximum concentrations for averaging times greater than one hour and it is noted that a degree of conservatism is incorporated in the factors to provide reasonable assurance that maximum concentrations for annual values will not be underestimated [23]. Those authors suggested that, to obtain the estimated maximum concentration for an annual averaging time, one should multiply the 1-hour maximum by a factor of 0.08 ± 0.02 [23]. Thus, in their view, a conservative persistence factor would be 0.10.

However, in that modeling study, the hourly source emissions rate was held constant at the maximum permitted rate. That means that their persistence factor was due solely to variability in meteorology, and thus was really a meteorological persistence factor (MPF). With traffic emissions, the source emissions do not remain constant, but rather vary significantly from the peak-hour traffic to all the other hours of the day. Previous work [24] suggests that about 8-9% of the average daily traffic (ADT) occurs during the peak hour. The other 91-92% occurs in the other 23 hours, yielding an average hourly traffic flow of about 4% of the ADT. Therefore, a worst-case 1-hour to 24-hour vehicle persistence factor (VPF) of 0.50 can be derived (4%/8%). An annual VPF would be even lower. The U.S. EPA has suggested [24] that the total persistence factor (TPF) is the product of the MPF times the VPF. In this case, the MPF is 0.10 and the VPF is 0.50, so we recommend a TPF of 0.05 to estimate a worst-case annual concentration from a modeled worst-case 1-hour concentration.

4.3.2 Background Concentrations

The total concentration near a roadway is the sum of the roadway contribution and of the background. For this study, it was assumed that there is no natural background of these modeled pollutants. Some may be present from industrial emissions, but those cases are site specific, and therefore no background concentrations were added to our modeling results.

4.4 Results

The following sections present the CAL3MSAT results for both the modeled intersections and freeway segments in tabular and graphic forms.

4.4.1 Intersections

The predicted worst-case, peak-hour maximum concentrations for the primary MSATs at the modeled intersections can be seen compared to the proposed 1-hour acute MACs in Table 6. Similarly, the predicted worst-case, chronic lifetime maximum concentrations for the primary MSATs at the modeled intersections can be seen compared to the proposed chronic lifetime MACs in Table 7. A graphical form of both these Tables can be seen in Figure 1 and Figure 2, respectively.

After viewing these results, it can be seen that the predicted worst-case, peak-hour maximum concentrations are multiple orders of magnitude different then proposed MACs. However, for benzene, butadiene, and formaldehyde, the predicted worst-case, chronic lifetime maximum concentrations exceed the proposed MACs. Several comments about these modeled exceedances are in order. First, the proposed MACs are extremely conservative values. Second, we used worst-case receptor placement. Third, the TPF used to adjust the 1-hour averaging time to an annual averaging time is also a very conservative value. Fourth, we used maximum values for peak-hour traffic volumes. Fifth, and perhaps most importantly, these high concentrations are found only at receptors very near the roadways, where lifetime exposure and chronic risk may not be meaningful. It is extremely unlikely that a single person would stay located only a few feet away from a large intersection for 70 years. Several modeling runs were done to predict concentrations at several distances from intersections. The results are shown in Table 8 and Table 9, and in Figure 3. At many reasonable residential or commercial receptors, the concentrations likely would be below the proposed MACs even if the 10-foot (3-m) concentration would be above the proposed MAC. So ultimately, this means that, based on our modeling, there is no evidence that exposure to the primary MSATs near intersections in Florida poses any significant risk to human health.

Table 6: Worst-Case A.M. and P.M. Intersection Peak-Hour Maximum Concentrations Compared to Proposed MACs

Pollutant	Predicted Worst-Case Peak-Hour Concentration (ppbv)														Proposed 1-hr Acute MAC
	Jacksonville		Miami		Orlando		Pensacola		Sarasota		Tallahassee		Tampa		
	A.M.	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	(ppbv)
Acetaldehyde	1.27	1.67	1.44	1.75	1.35	1.50	1.48	1.49	1.17	1.34	1.13	1.13	1.59	2.18	45,000
Acrolein	0.0792	0.104	0.0883	0.107	0.0845	0.0937	0.0923	0.0929	0.0730	0.0831	0.0707	0.0707	0.0970	0.134	30
Benzene	1.51	1.98	1.64	1.98	1.60	1.78	1.75	1.76	1.38	1.58	1.34	1.34	1.79	2.47	52,000
1,3-Butadiene	0.423	0.556	0.495	0.600	0.451	0.500	0.493	0.496	0.389	0.445	0.396	0.396	0.543	0.747	669,000
Formaldehyde	2.95	3.86	3.33	4.06	3.14	3.49	3.43	3.45	2.73	3.11	2.64	2.64	3.67	5.04	900

Table 7: Worst-Case Chronic Lifetime A.M. and P.M. Intersection Concentrations Compared to Proposed MACs

Pollutant	Predicted Average Annual Concentration (ppbv)														Proposed Chronic Lifetime MAC
	Jacksonville		Miami		Orlando		Pensacola		Sarasota		Tallahassee		Tampa		
	A.M.	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	***A.M.***	***P.M.***	(ppbv)
Acetaldehyde	0.0635	0.0835	0.0720	0.0875	0.0675	0.0750	0.0740	0.0745	0.0585	0.0670	0.0565	0.0565	0.0795	0.1090	0.252
Acrolein	0.0040	0.0052	0.0044	0.0054	0.0042	0.0047	0.0046	0.0046	0.0037	0.0042	0.0035	0.0035	0.0049	0.0067	-
Benzene	0.0755	0.0990	0.0820	0.0990	0.0800	0.0890	0.0875	0.0880	0.0690	0.0790	0.0670	0.0670	0.0895	0.1235	0.0401
1,3-Butadiene	0.0212	0.0278	0.0248	0.0300	0.0226	0.0250	0.0247	0.0248	0.0195	0.0223	0.0198	0.0198	0.0272	0.0374	0.0151
Formaldehyde	0.148	0.193	0.167	0.203	0.157	0.175	0.172	0.173	0.137	0.156	0.132	0.132	0.184	0.252	0.0626

Figure 1: Worst-Case A.M. and P.M. Peak-Hour Maximum MSAT Concentrations for Various Urban Florida Intersections

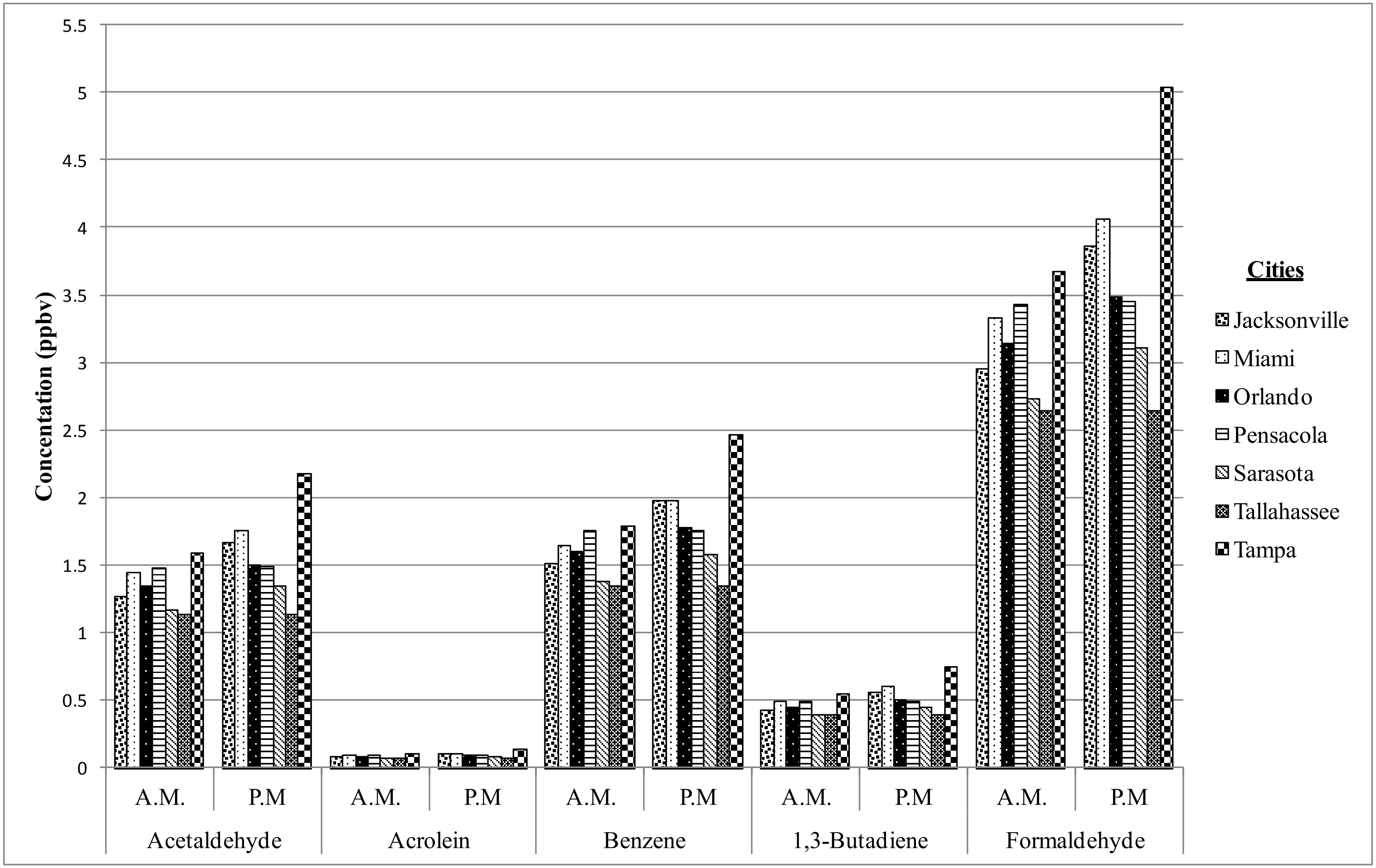


Figure 2: Worst-Case Chronic Lifetime Maximum MSAT Concentrations for Various Urban Florida Intersections

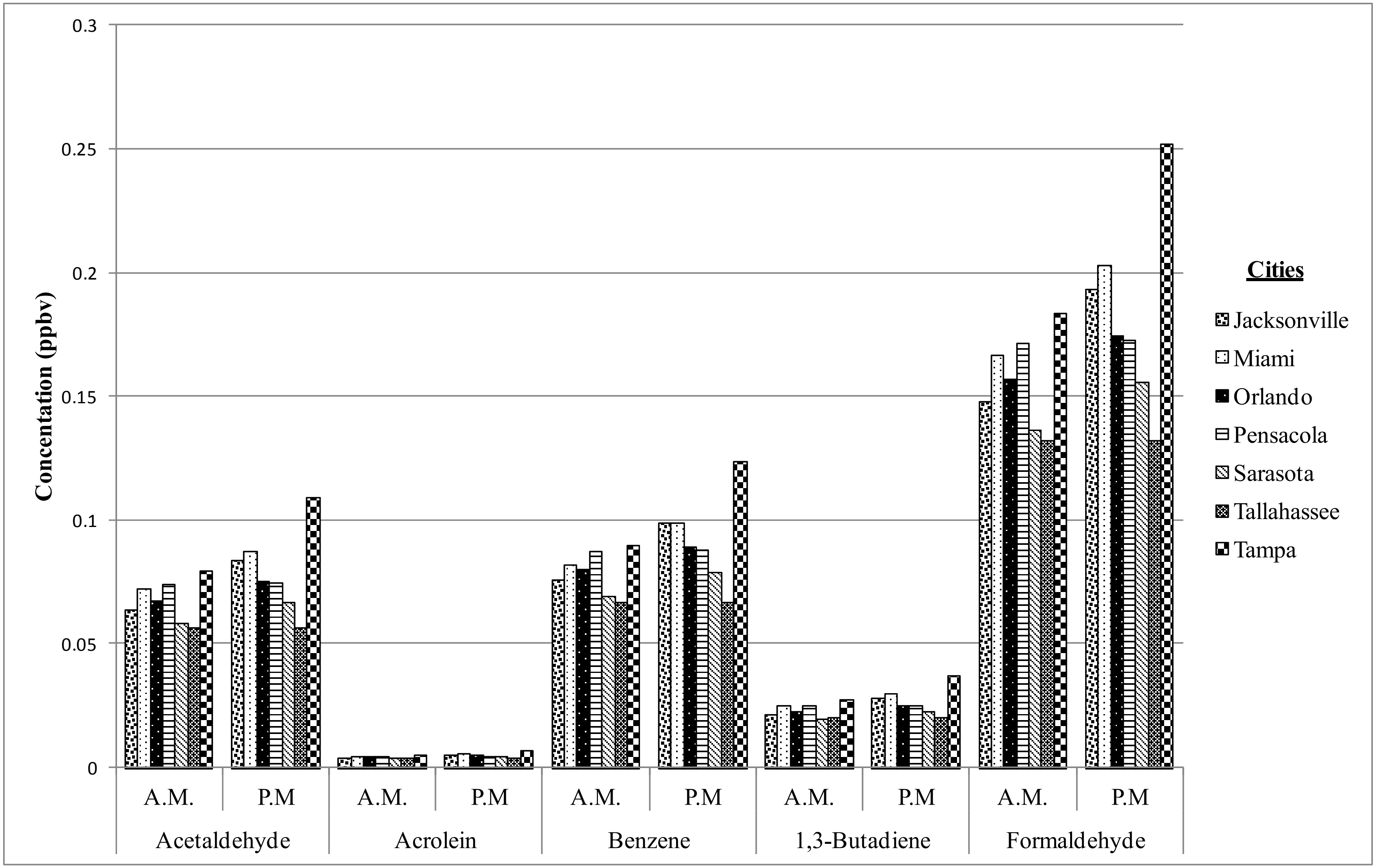


Table 8: Modeled Worst-Case 1-hr MSAT Concentrations at Various Distances

Pollutant	Worst-Case Peak-Hour Concentration (ppbv) Receptor Distance from Roadway			Proposed 1-hr Acute MAC
	3 m	*50 m*	*100 m*	(ppbv)
Acetaldehyde	1.35	0.625	0.378	45,000
Acrolein	0.0845	0.0390	0.0236	30
Benzene	1.60	0.740	0.448	52,000
1,3-Butadiene	0.451	0.208	0.126	669,000
Formaldehyde	3.14	1.45	0.876	900

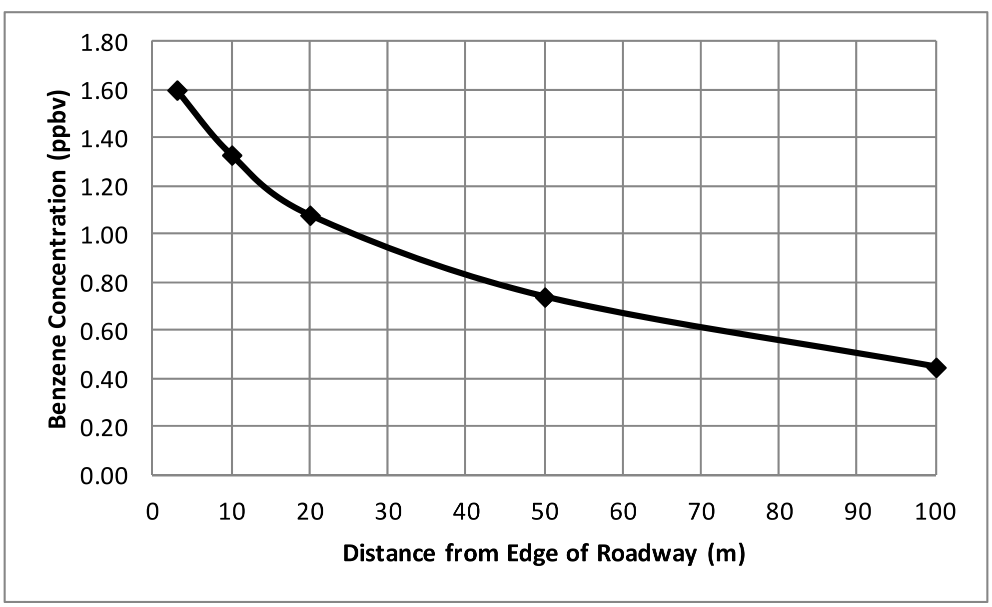
**Results are from using the Orlando intersection during the A.M. peak hour*

Table 9: Modeled Worst-Case Annual Average MSAT Concentrations at Various Distances

Pollutant	Predicted Average Annual Concentration (ppbv) Receptor Distance from Roadway			Proposed Chronic Lifetime MAC
	3 m	*50 m*	*100 m*	(ppbv)
Acetaldehyde	0.0675	0.0313	0.0189	0.252
Acrolein	0.0042	0.0020	0.0012	-
Benzene	0.0800	0.0370	0.0224	0.0401
1,3-Butadiene	0.0226	0.0104	0.0063	0.0151
Formaldehyde	0.157	0.0725	0.0438	0.0626

**Results are from using the Orlando intersection during the A.M. peak hour*

Figure 3: Example of Declining MSAT Concentration as a Function of Distance from Edge of Roadway



**Results are from using the Orlando intersection during the A.M. peak hour*

4.4.2 Freeway Sections

The predicted worst-case, peak-hour maximum concentrations for the primary MSATs at the modeled freeway segments can be seen compared to the proposed 1-hour acute MACs in Table 10. Similarly, the predicted worst-case, chronic lifetime maximum concentrations for the primary MSATs at the modeled freeway segments can be seen compared to the proposed chronic lifetime MACs in Table 11. A graphical form of both these Tables can be seen in Figure 4 and Figure 5, respectively.

After viewing these results, it can be seen that the predicted worst-case, peak-hour maximum concentrations are multiple orders of magnitude different then proposed MACs. However, for benzene, butadiene, and formaldehyde, the predicted worst-case, chronic lifetime maximum concentrations slightly exceed the proposed MACs. Several comments about these modeled exceedances are in order. First, the proposed MACs are not ambient standards, and should not be interpreted as such. Also, they were developed using a very conservative process. Second, the TPF used to adjust the 1-hour averaging time to an annual averaging time is also a very conservative value, and perhaps should be much lower. Third, and perhaps most importantly, these high concentrations are found only at receptors very near the roadways (at 3 meters from road edge), where lifetime exposure and chronic risk are not meaningful. As discussed previously in Section 4.4.1, for these and other reasons (peak-hour traffic, worst-case receptors, etc.), the authors believe that there is no evidence that exposure to the primary MSATs near freeways in Florida poses any significant risk to human health.

Table 10: Worst-Case Freeway Peak-Hour Maximum Concentrations Compared to Proposed MACs

Pollutant	Predicated Worst-Case Peak-Hour Concentration (ppbv)							Proposed 1-hr Acute MAC
	Jacksonville	Miami	Orlando	Pensacola	Sarasota	Tallahassee	Tampa	(ppbv)
Acetaldehyde	1.08	1.62	1.04	0.262	0.584	0.364	0.661	45,000
Acrolein	0.0736	0.108	0.0700	0.0174	0.0391	0.0245	0.0435	30
Benzene	1.12	1.62	0.902	0.268	0.600	0.372	0.652	52,000
1,3-Butadiene	0.333	0.515	0.322	0.0803	0.179	0.112	0.208	669,000
Formaldehyde	2.76	4.12	2.65	0.672	1.49	0.938	1.68	900

Table 11: Worst-Case Chronic Lifetime A.M. and P.M. Freeway Concentrations Compared to Proposed MACs

Pollutant	Predicted Average Annual Concentration (ppbv)							Proposed Chronic Lifetime MAC
	Jacksonville	Miami	Orlando	Pensacola	Sarasota	Tallahassee	Tampa	(ppbv)
Acetaldehyde	0.0540	0.0810	0.0520	0.0131	0.0292	0.0182	0.0331	0.252
Acrolein	0.0037	0.0054	0.0035	0.0009	0.0020	0.0012	0.0022	-
Benzene	0.0560	0.0810	0.0451	0.0134	0.0300	0.0186	0.0326	0.0401
1,3-Butadiene	0.0167	0.0258	0.0161	0.0040	0.0090	0.0056	0.0104	0.0151
Formaldehyde	0.138	0.206	0.133	0.0336	0.0745	0.0469	0.0840	0.0626

Figure 4: Worst-Case Peak-Hour Maximum MSAT Concentrations for Various Urban Florida Freeways

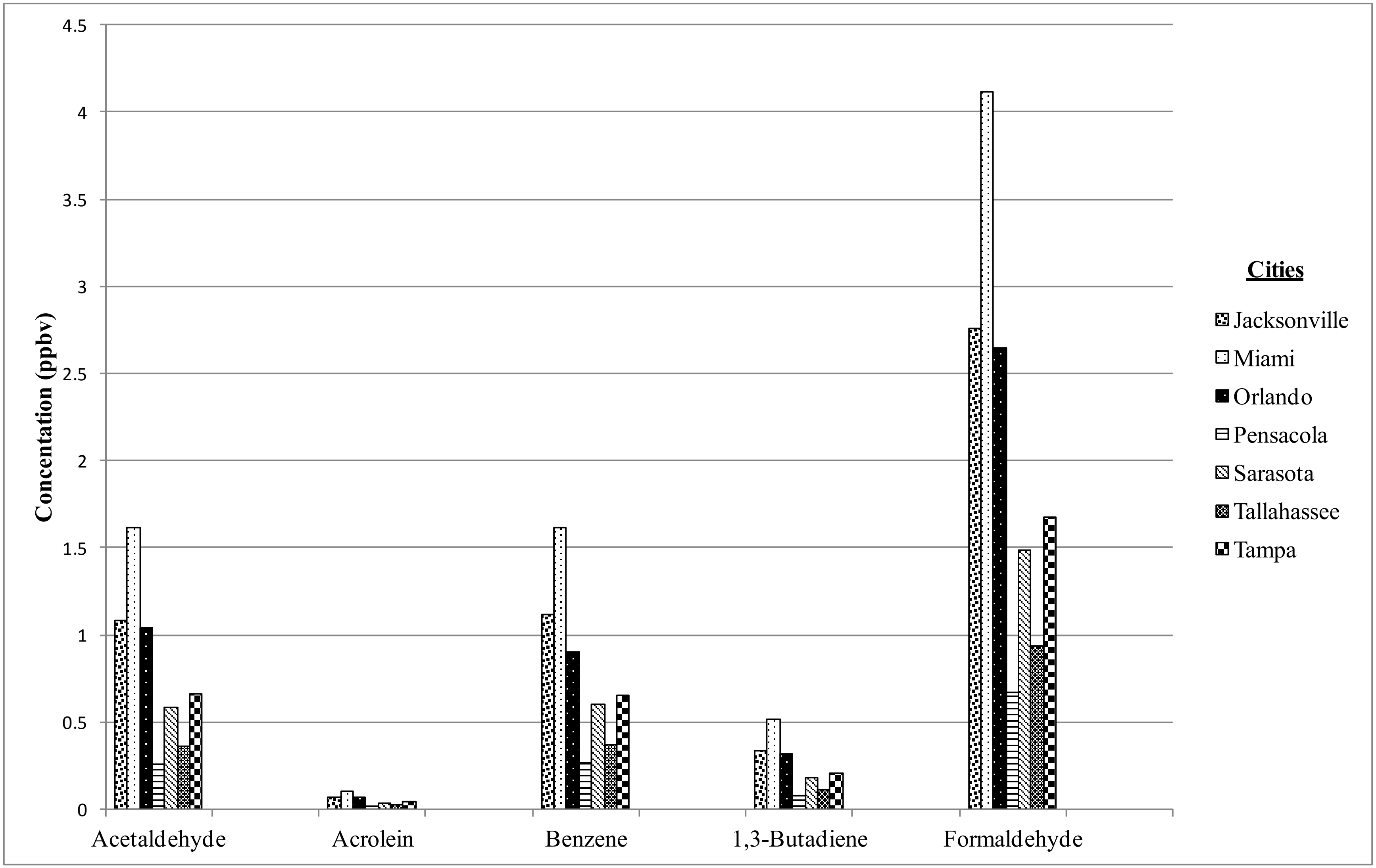
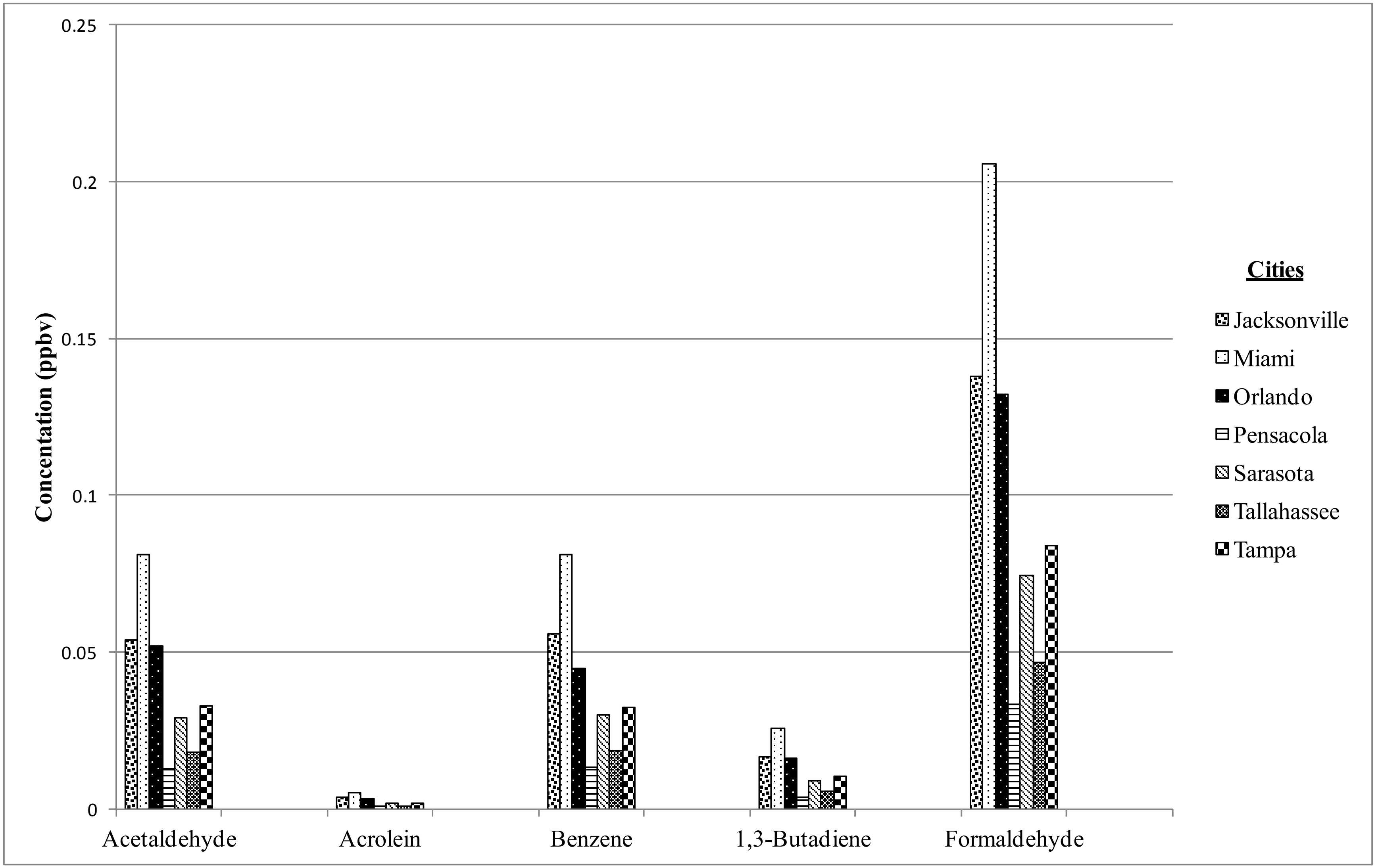


Figure 5: Worst-Case Chronic Lifetime Maximum MSAT Concentrations for Various Urban Florida Freeways



CHAPTER 5. COLLABORATION WITH FHWA; DEVELOPMENT OF CAL3i

This project benefitted significantly from a close collaboration between UCF, FDOT, and FHWA. The FHWA had previously developed a graphical user interface for CAL3QHC. Rather than UCF researchers writing their own separate interface for CAL3MSAT, it was suggested that we work together with FHWA to incorporate CAL3MSAT into the CAL3i interface. The CAL3MSAT FORTRAN program was developed by Kurt Westerlund as part of his PhD work at UCF and the CAL3i interface was created by Dr. Michael Claggett of FHWA.

The collaboration between Dr. Claggett, Kurt Westerlund, and Dr. Cooper worked beautifully, and resulted in an improved interface model that now can also run the CAL3MSAT program. The programming and modeling expertise of Dr. Claggett was extremely important to the success of this venture. His knowledge and attention to detail were outstanding. In addition the detail-oriented software review and debugging efforts of Mr. Westerlund and the UCF team were invaluable to creating a final piece of software that works well, is very stable, and is visually appealing to users.

The interface is called CAL3i and was turned over to the FDOT for free distribution from its website. It can run the traditional CALINE3 and CAL3QHC models, as well as CAL3MSAT. When CAL3MSAT is run, a user can automatically load Florida default values for many of the parameters. The interface operates from within Windows, and is very intuitive. It is best experienced by actually running it; however, for purposes of this report, its use is described briefly in the following paragraphs.

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CHAPTER 6. USE OF THE CAL3i MODEL

In this section, a short description of how a person can use CAL3MSAT is provided; more thorough step-by-step instructions are provided in the User's Guide (published separately). The user begins by either clicking on the desktop shortcut icon, or from the Windows "Start Programs" menu and clicking on "All Programs" and then selecting the folder "CAL3i." Once clicked, an icon appears for "CAL3MSAT" and upon selecting this icon, the program begins and the first input screen appears. On this opening screen, titled "Enter or Edit Program Control Data," the user enters a Job Title and Run Title, and then selects the particular Model he or she wishes to run. The user should select "CAL3MSAT" and then should select "Florida Default Data" as the Screening Level. The next few choices ("Input/Output Control") are automatically loaded. Next the user should select (from a drop-down menu) the particular Pollutant to be analyzed.

Now, the user can either begin to manually enter all data for the roadway receptors and links, or they can use the interface's "Generate a Simplified Receptor/Highway Layout for Screening" feature. If the user is trying to model an intersection, in the "Add Travel Lanes" section, the boxes next to "Northbound/Southbound" and "Eastbound/Westbound" should be selected. Conveniently, a graphic view of the intersection is displayed on the right-hand side of the screen in the "Layout Map". Numerous receptors are automatically added to the scenario, and all the default geometric distances are added to the CAL3MSAT input file that is being built by the program. This happens almost instantaneously and is invisible to the user. The user should then select the "Add Traffic Signal" box. Again, default data are added to the input file. However, if desired, the user may alter the default data and refine the intersection layout and traffic signal data. A screenshot of the "Enter or Edit Program Control Data" form after completing the above steps is shown in Figure 6.

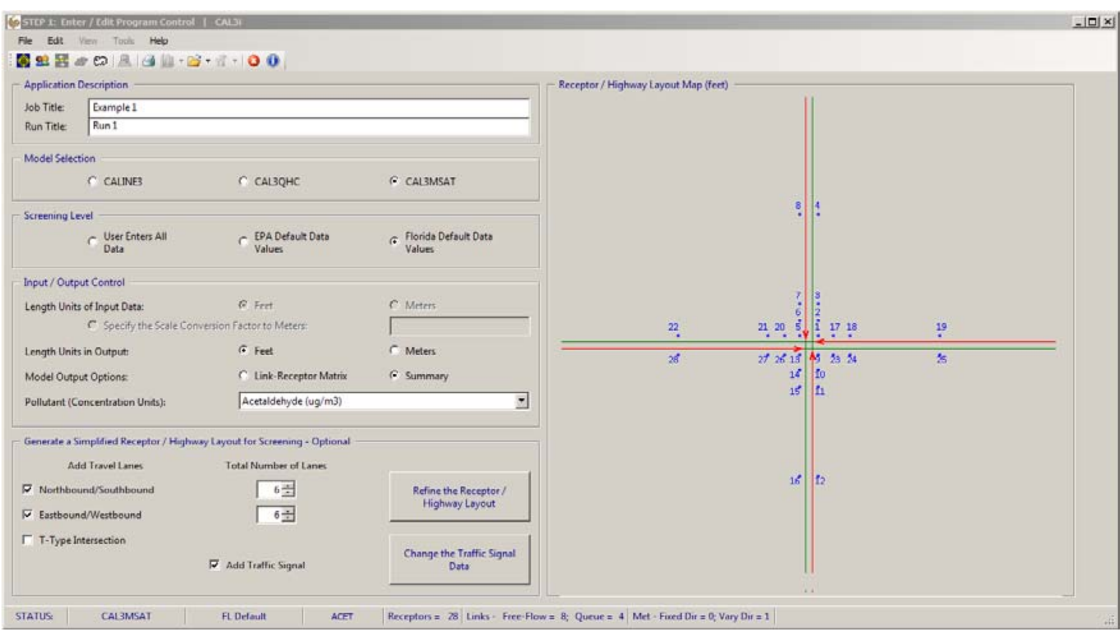
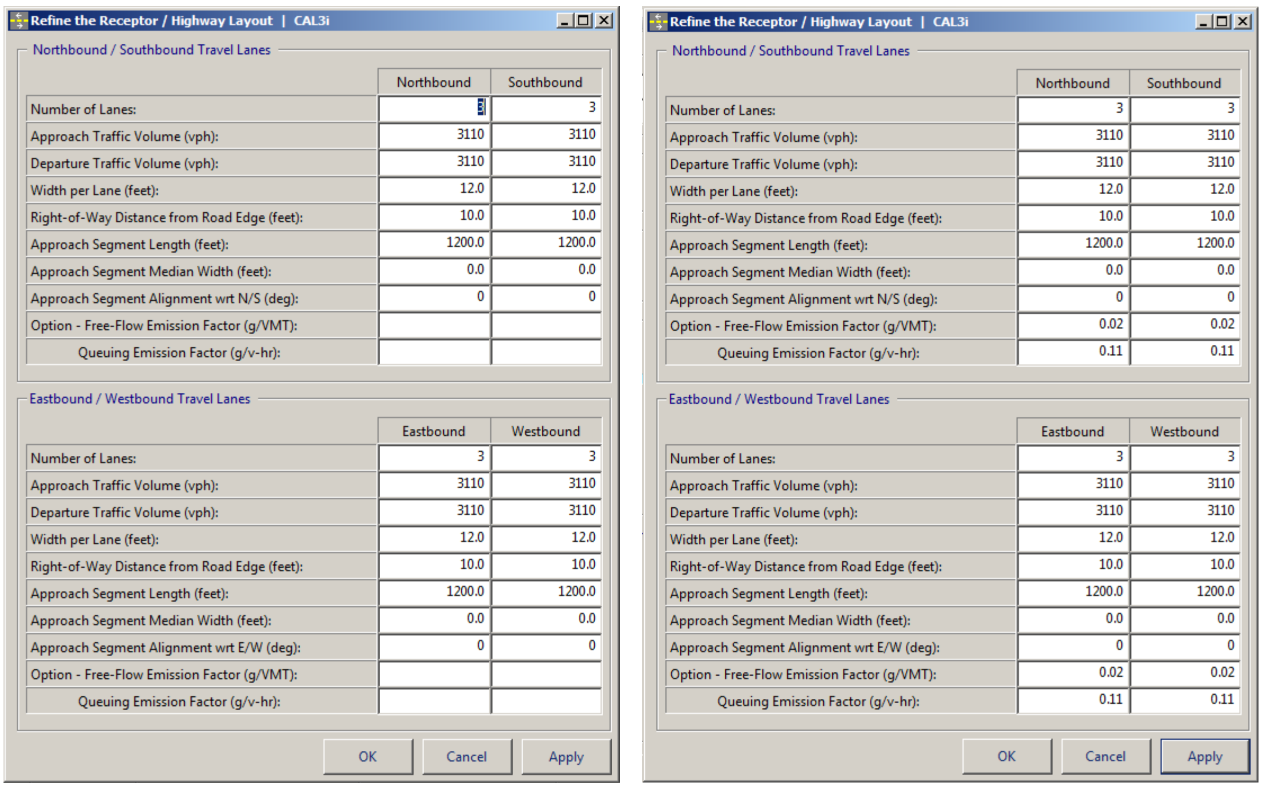


Figure 6: Screen Capture from CAL3i of the "Enter or Edit Program Control Data" Form after Completing All Entries

However, even though the screen looks complete, some crucial information still must be entered – the emission factors for the pollutant that was selected. Keep in mind that CAL3i is an interface for the dispersion models, and cannot generate the emission factors (EFs) for vehicles on the road. These EFs must be obtained from the U.S. EPA mobile-source emissions model (currently MOVES2010a); which must have already been run prior to starting CAL3i. These EFs are complex functions of the calendar year, the geographic region, the traffic mix, the speeds on the links, and many other variables (please refer to Section CHAPTER 3 for more detail). With the appropriate EFs in hand, the user clicks on the Refine “Receptor/Highway Layout” button, and another screen appears. The user enters the appropriate free-flow and queuing EFs into the blank spaces on this new screen and then clicks “OK” [see Figure 7 (a) and (b)].



Refine the Receptor / Highway Layout | CAL3i (a)

Northbound / Southbound Travel Lanes

	Northbound	Southbound
Number of Lanes:	3	3
Approach Traffic Volume (vph):	3110	3110
Departure Traffic Volume (vph):	3110	3110
Width per Lane (feet):	12.0	12.0
Right-of-Way Distance from Road Edge (feet):	10.0	10.0
Approach Segment Length (feet):	1200.0	1200.0
Approach Segment Median Width (feet):	0.0	0.0
Approach Segment Alignment wrt N/S (deg):	0	0
Option - Free-Flow Emission Factor (g/VMT):		
Queuing Emission Factor (g/v-hr):		

Eastbound / Westbound Travel Lanes

	Eastbound	Westbound
Number of Lanes:	3	3
Approach Traffic Volume (vph):	3110	3110
Departure Traffic Volume (vph):	3110	3110
Width per Lane (feet):	12.0	12.0
Right-of-Way Distance from Road Edge (feet):	10.0	10.0
Approach Segment Length (feet):	1200.0	1200.0
Approach Segment Median Width (feet):	0.0	0.0
Approach Segment Alignment wrt E/W (deg):	0	0
Option - Free-Flow Emission Factor (g/VMT):		
Queuing Emission Factor (g/v-hr):		

OK Cancel Apply

Refine the Receptor / Highway Layout | CAL3i (b)

Northbound / Southbound Travel Lanes

	Northbound	Southbound
Number of Lanes:	3	3
Approach Traffic Volume (vph):	3110	3110
Departure Traffic Volume (vph):	3110	3110
Width per Lane (feet):	12.0	12.0
Right-of-Way Distance from Road Edge (feet):	10.0	10.0
Approach Segment Length (feet):	1200.0	1200.0
Approach Segment Median Width (feet):	0.0	0.0
Approach Segment Alignment wrt N/S (deg):	0	0
Option - Free-Flow Emission Factor (g/VMT):	0.02	0.02
Queuing Emission Factor (g/v-hr):	0.11	0.11

Eastbound / Westbound Travel Lanes

	Eastbound	Westbound
Number of Lanes:	3	3
Approach Traffic Volume (vph):	3110	3110
Departure Traffic Volume (vph):	3110	3110
Width per Lane (feet):	12.0	12.0
Right-of-Way Distance from Road Edge (feet):	10.0	10.0
Approach Segment Length (feet):	1200.0	1200.0
Approach Segment Median Width (feet):	0.0	0.0
Approach Segment Alignment wrt E/W (deg):	0	0
Option - Free-Flow Emission Factor (g/VMT):	0.02	0.02
Queuing Emission Factor (g/v-hr):	0.11	0.11

OK Cancel Apply

Figure 7: (a) Screen before Entering EFs, (b) Screen after Entering EFs

Entering these additional data for the EFs completes the data entry for the “Enter or Edit Program Control Data” form. Next, if the user wishes, click on the “Enter or Edit Receptor Data” icon (people) located near the top menu bar. If all the default data are sufficient and do not need to be changed, the user can then click on the “Enter or Edit Link Data” icon (two traffic lanes), and repeat. Finally, the user can progress to the “Enter or Edit Meteorology Data” form by clicking the appropriate icon (cloud). The meteorology variables have already been populated with Florida-specific data, however they can be changed by the user if desired. After reviewing the “Enter or Edit Meteorology Data” form, the “Run the Model” icon (computer), which had been grayed out, becomes active. Once clicked, CAL3i will run the CAL3MSAT dispersion model with the internally created input file. The output results are then displayed in the

“CAL3MSAT Results” table (see Figure 8). At this point the user may save the input file, results table (excel file), output file, or all of these files by clicking on “File” and then either “Save” or “Save All’ in the top menu bar. Now the user may either exit the program or start a new CAL3MSAT model run by going to the top menu bar, clicking “File” and then clicking “New.”

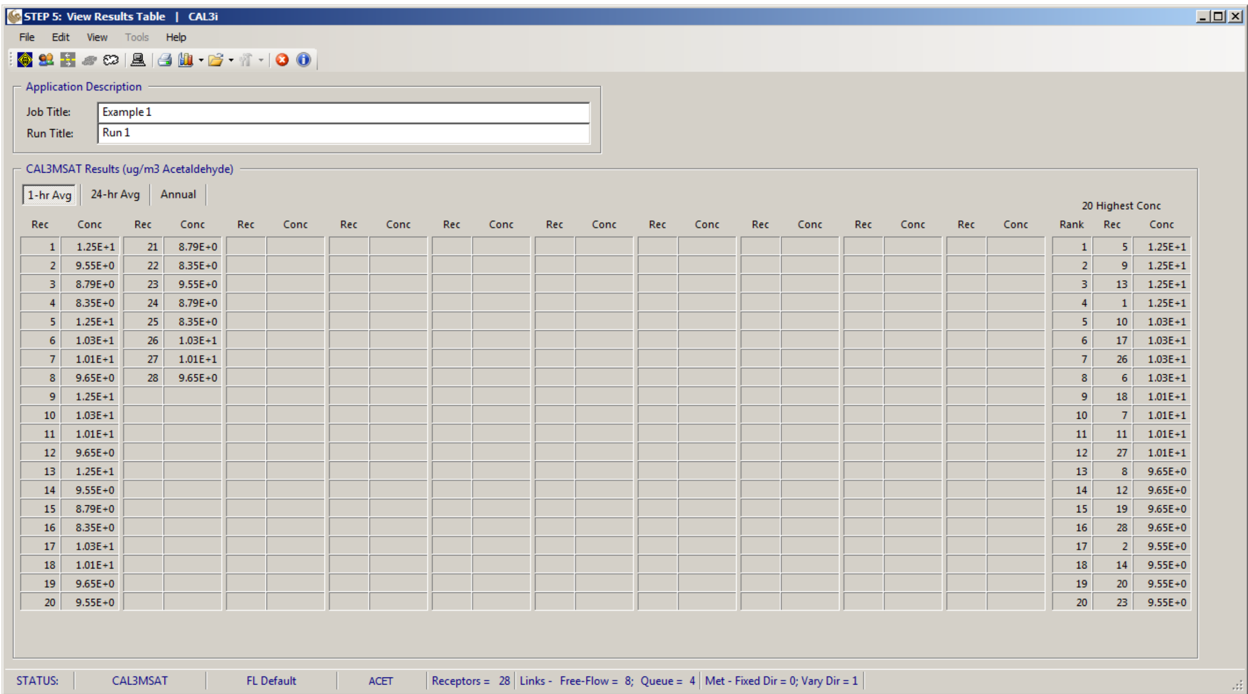


Figure 8: CAL3i’s CAL3MSAT Results Table

The CAL3MSAT model achieves one of the main objectives of this project. By incorporating CAL3MSAT into the CAL3i interface, the CAL3MSAT model runs in Windows. When run within the CAL3i program, it can predict the 1-hour, 24-hour, and annual averaging time concentrations (using built-in assumptions for persistence factors) of MSATs near intersections and roadways in Florida. It runs very quickly with a minimum number of inputs from the user, and can do a thorough screening of intersections and highways for potential concentrations of the major MSATs. However, keep in mind that it requires that the user input the emission factors for each MSAT for which a predicted concentration is desired. Currently, obtaining those emission factors requires that a separate run of the U.S. EPA model MOVES2010a be completed prior to using CAL3MSAT.

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CHAPTER 7. CONCLUSIONS

With a growing concern that the emission of MSATs from motor vehicles may pose a threat to human health, a dispersion modeling analysis in Florida was conducted to better understand the associated human health risks. Much literature and many sources were reviewed in order to determine values for applicable maximum permissible exposure limits. Resulting proposed MACs associated with chronic cancer scenarios, along with acute 1-hour concentrations, were proposed for the primary MSATs of concern. After obtaining fleet emission factors from the EPA's latest mobile source emissions model, MOVES2010a, intersection and roadway dispersion modeling was conducted with a new program titled CAL3MSAT. This program was based on the U.S. EPA's current recommended intersection and highway screening model CAL3QHC.

The results of this modeling analysis indicate that, in the state of Florida, concern over the acute (1-hr) concentrations of the primary MSATs at intersections and freeways is not warranted. Because of the very conservative nature of our approach to modeling lifetime concentrations and chronic risks, the modeled values were of the same order of magnitude as the proposed MACs. In some cases, the calculated annual averages of road-side concentrations exceeded our proposed chronic (annual) MACs. However, due to the very conservative approach followed in this modeling-based research study, the authors believe that chronic (lifetime) exposure to MSATs near intersections and freeways in Florida is minimal, and that cancer risk to the public is extremely low.

All of our objectives for this study have been met; specifically they include the following:

- Area-specific data needed to run the U.S. EPA's mobile source emissions model, MOVES2010a, were obtained and emission factors were generated.
- The FORTRAN source code for the dispersion model CAL3QHC was obtained and modified such that it can handle a variety of MSATs and other pollutants including acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, naphthalene, nitrogen dioxide, other gases, and other particulates. This program, named CAL3MSAT, was recompiled and thoroughly tested.
- Six FDOT districts were contacted in order to create the traffic scenarios for the seven urban areas of interest. After items such as traffic turning movements, signal phase diagrams, and site diagrams were obtained, typical intersections and freeways segments were created. Input files for CAL3MSAT were created using these data for both the intersections A.M. and P.M. peak hours and for the freeway segments peak hour.
- The technical literature was thoroughly reviewed, and 1-hour and annual MACs for the primary MSATs of concern were proposed.
- Dispersion modeling for the gaseous MSATs was then completed with the use of Florida-specific input files, and the results were analyzed and compared with the proposed MACs. In order to compare the results to a chronic lifetime proposed MAC, literature

was investigated, and a TPF was proposed to adjust predicted 1-hour concentrations to an annual averaging time.

- A Windows GUI titled CAL3i was created by Dr. Michael Claggett of the FHWA. This interface was tested and de-bugged extensively by personnel at UCF. In addition, Florida-specific default values for dispersion modeling were included as per one of the objectives of this project.

CHAPTER 8. RECOMMENDATIONS

It is recommended that the FDOT post the CAL3i model on their website for free distribution to any interested persons. The very low concentrations of MSATs predicted from our modeling results in this project lead to our recommendation that FDOT not conduct dispersion modeling for MSATs on a routine basis when doing air quality impact assessments of roadway projects. At the present time, it is not recommended that any further study on MSATs be done. However, in the future, if concern about lifetime exposure and chronic risk due to MSATs should arise, it is recommended that more detailed modeling be conducted to include using CAL3QHCR or AERMOD along with historical hourly meteorological data for an entire year. In addition, more attention should be placed on establishing hourly traffic (and emission) inputs to the model (for a whole year), and on determining reasonable receptor locations for chronic risk assessment. Finally, if concern about chronic risk should arise, then a more formal risk assessment may be warranted.

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