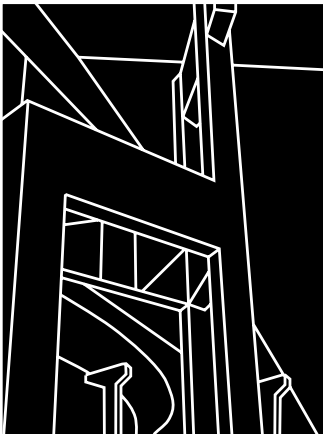RESEARCH REPORT 1838-2

REVIEW OF 1990 MOBILE-SOURCE EMISSIONS MODELING PROCEDURE FOR THE DALLAS-FORT WORTH NONATTAINMENT AREA

Harikesh S. Nair and Chandra R. Bhat

CENTER FOR TRANSPORTATION RESEARCH
BUREAU OF ENGINEERING RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

AUGUST 1999

1. Report No. FHWA/TX-00/1838-2	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle REVIEW OF 1990 MOBILE-SOURCE EMISSIONS MODELING PROCEDURE FOR THE DALLAS-FORT WORTH NON-ATTAINMENT AREA		5. Report Date August 1999	
		6. Performing Organization Code	
7. Author(s) Harikesh S. Nair and Chandra R. Bhat		8. Performing Organization Report No. Research Report 1838-2	
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. 0-1838	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Section/Construction Division P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Research Report (9/98-8/99)	
		14. Sponsoring Agency Code	
15. Supplementary Notes Project conducted in cooperation with the Federal Highway Administration.			

16. Abstract

The Dallas-Fort Worth (D-FW) metropolitan area in Texas includes all of Collin, Dallas, Denton, Rockwall, and Tarrant Counties and portions of Ellis, Johnson, Kaufman, and Parker Counties. The North Central Texas Council of Governments (NCTCOG), the metropolitan planning organization (MPO) for D-FW, is responsible for developing and maintaining the mobile-source emissions inventories in the area. The metropolitan planning area (MA) for NCTCOG's Dallas-Fort Worth Regional Travel Demand Model (DFWRTM) includes an approximately 4,980 square mile (12,898 square km) area, with about 32,400 unique (nonlocal) roadway links representing the roadway network. The MA covers the existing urbanized area and the contiguous area expected to be urbanized by the year 2000.

Within the D-FW planning area, the counties of Collin, Dallas, Denton, and Tarrant are designated as serious ozone nonattainment areas by the U.S. Environmental Protection Agency (EPA).

The NCTCOG models mobile-source emissions for these counties using EPA's MOBILE5 Emissions Factor model. Emission factors are generated for carbon monoxide (CO), nitrogen oxides (NO_x), and for volatile organic compounds (VOCs).

The rest of this report discusses the NCTCOG emissions modeling process in detail and is structured as follows: Section 1 identifies the steps involved in computing pollutant-specific emission factors using the MOBILE5 model. Section 2 then discusses the steps followed to apply the emission factors generated from the MOBILE5 model to compute the net emissions for the D-FW nonattainment area.

17. Key Words Nonattainment areas, ozone, transportation control measures, emissions modeling, travel demand modeling	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.		
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 22	22. Price

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

REVIEW OF 1990 MOBILE SOURCE EMISSIONS MODELING PROCEDURE

FOR THE DALLAS-FORT WORTH NONATTAINMENT AREA

by

Harikesh S. Nair and Chandra R. Bhat

Research Report Number 1838-2

Research Project 0-1838

Transportation Control Measure Effectiveness in Ozone Nonattainment Areas

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION

Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH

Bureau of Engineering Research

THE UNIVERSITY OF TEXAS AT AUSTIN

August 1999

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

NOT INTENDED FOR CONSTRUCTION,
BIDDING, OR PERMIT PURPOSES

Dr. Chandra R. Bhat
Research Supervisor

ACKNOWLEDGMENTS

TABLE OF CONTENTS

1. BACKGROUND

The Dallas-Fort Worth (D-FW) metropolitan area in Texas includes all of Collin, Dallas, Denton, Rockwall, and Tarrant Counties and portions of Ellis, Johnson, Kaufman, and Parker Counties. The North Central Texas Council of Governments (NCTCOG), the metropolitan planning organization (MPO) for D-FW, is responsible for developing and maintaining the mobile-source emissions inventories in the area. The metropolitan planning area (MA) for NCTCOG's Dallas-Fort Worth Regional Travel Demand Model (DFWRTM) includes an approximately 4,980 square mile (12,898 square km) area, with about 32,400 unique (nonlocal) roadway links representing the roadway network. The MA covers the existing urbanized area and the contiguous area expected to be urbanized by the year 2000.

Within the D-FW planning area, the counties of Collin, Dallas, Denton, and Tarrant are designated as serious ozone nonattainment areas by the U.S Environmental Protection Agency (EPA).

The NCTCOG models mobile source emissions for these counties using EPA's MOBILE5 Emissions Factor model. Emission factors are generated for carbon monoxide (CO), nitrogen oxides (NO_X), and for volatile organic compounds (VOCs).

The rest of this report discusses the NCTCOG emissions modeling process in detail and is structured as follows: Section 1 identifies the steps involved in computing pollutant-specific emission factors using the MOBILE5 model. Section 2 then discusses the steps followed to apply the emission factors generated from the MOBILE5 model to compute the net emissions for the D-FW nonattainment area.

2. COMPUTING EMISSION FACTORS

MOBILE5 utilizes an input file that provides program control information and the data describing the scenarios for which emission factors are to be estimated to calculate pollutant specific emission factors. The input file comprises three distinct sections: the Control section, the One-time Data section, and the Scenario section.

The first section the input file — the Control section — controls the input, output, and execution of the program. For example, the Control section indicates whether MOBILE5 will require the user to supply additional input data, or analyze a scenario that includes an inspection and maintenance program, or output the emission factors in a format suitable for

visual inspection or in a format suitable as input to another program. These selections are made by assigning values to various flag variables.

The second section of the input file — the One-time Data section — allows the user to define emission-related parameter values that differ from the internal default values of MOBILE5. These parameter values are applied universally to all scenarios within a given run. For example, in the One-time Data section, the user can specify alternate annual mileage accumulation rates or registration distributions by age for each vehicle type. In addition, the One-time Data section allows the user to specify further control program parameters, such as description(s) of inspection and maintenance program(s).

The third section of the input file — the Scenario section — provides information on the individual scenarios for which emission factors are to be calculated. For example, in the scenario section the user specifies the calendar year of evaluation and the average speed(s) to be assumed. Each MOBILE5 run can include many scenarios, and each scenario can have different scenario parameters.

This section discusses only the One-time Data and the Scenario selection sections of the input file. The values of the flag variables used in the control section for D-FW can be found in a report by NCTCOG (Ref 4), and a description of each of these flag variables in the MOBILE5 User's Guide (Ref 5).

2.1. One-Time Data

As discussed earlier, the One-Time Data section contains information that is input only once in a given MOBILE5 input file. This input information is used to alter MOBILE5 internal data to reflect alternate (i.e., locality-specific) data when such information is available for use. These records are all optional, their use being dictated by the values of some of the flags in the Control section. The NCTCOG provides the following one-time data during the application of the MOBILE5 model:

- Vehicle Miles Traveled (VMT) mix
- Vehicle Registration Distribution
- Inspection/Maintenance Program Credits
- Antitampering Program Credits
- Local Area Parameters
- Trip Length Distribution

Each of these inputs is discussed below.

2.1.1 Vehicle Miles Traveled (VMT) Mix

The VMT mix represents the proportion of the total VMT accumulated by each of the eight vehicle types identified by the EPA. Data required for the development of the VMT mix is obtained from 24-hour Local Vehicle Classification surveys conducted by TxDOT's Transportation Planning and Programming Division and TxDOT's Regional Planning Office. However, vehicle counts obtained from TxDOT classify vehicles into vehicle types that differ from the eight-vehicle classification scheme followed by EPA. Appropriate conversion factors based on MOBILE5 national defaults are applied to convert the VMT mix fractions obtained for the TxDOT vehicles classes into the EPA classes.[*]

The VMT mix (based on the EPA classification) is stratified by area type (urban and rural counties) and roadway type (freeways and arterials). The VMT mix for lower order roads (local roads and collectors) are assumed to be the same as for arterials. For inventory purposes, Dallas and Tarrant are considered urban counties and Collin and Denton defined as rural.

The VMT mix is applied directly to the VMT on each link on the network to calculate the VMT accrued by each vehicle class. This vehicle type-specific VMT is multiplied by the MOBILE5 emission factors for the corresponding vehicle type and pollutant type on a link-by-link basis, in order to compute the emissions for each pollutant. These emissions are aggregated across all links to estimate the net emissions from an area.

2.1.2. Vehicle Registration Distribution

Vehicle Registration Distribution data refer to the distribution of vehicles by vehicle type and vehicle age. MOBILE5's emission factor calculations rely on travel fractions for vehicles of each given age and type, which in turn are based on vehicle type-specific estimates of average annual mileage accumulation by age and registration distribution by age. The NCTCOG accepts default MOBILE5 mileage accumulation rates but uses vehicle registration distribution data specific to D-FW. Data provided by TxDOT's Vehicle Registration Division

---

[*] See Bhat and Nair (Ref 1) for a more appropriate method for developing these conversion factors.

are used to develop these distributions for each of the EPA vehicle classes. These distributions are developed separately for both urban and rural areas.

2.1.3 Inspection/Maintenance Program Credits

Inspection and maintenance programs are mandatory emissions control programs that identify vehicles whose emissions' systems are not functioning within acceptable limits. Most I/M tests involve measuring the pollution levels in the vehicle's exhaust and checking that critical emission-control components are present and operational. Through periodic vehicle checks and required repairs for vehicles that fail the test, I/M encourages proper vehicle maintenance and discourages tampering with emission control devices. MOBILE5 has the capability of modeling the impact of I/M programs on the calculated emission factors, based on user specification of certain parameters describing the program(s) to be modeled. These parameters include details of the starting year of the program, the stringency level used, the first and last model years of vehicles subject to the program, and the compliance rate. The NCTCOG obtains the values of these parameters for D-FW from the Texas Natural Resource Conservation Commission (TNRCC).

2.1.4. Antitampering Program Credits

Antitampering programs (ATPs) are implemented to reduce the frequency and impact of emission-control tampering (e.g., misfueling, removal, or disablement of catalytic converters). MOBILE5 allows the user to include the effects of such programs on the calculated emission factors by inputting parameters similar to those for inspection maintenance programs. The NCTCOG obtains the values of these parameters from TNRCC. The MOBILE5 model is executed several times to account properly for the antitampering program credits.

2.1.5 Local Area Parameters

The local area parameter (LAP) record consists of various locality-specific input variables, including the scenario name, the fuel volatility class, the minimum and maximum daily temperatures to calculate diurnal evaporative emissions, and the Reid Vapor Pressures (RVPs) to account for evaporative and refueling emissions that vary with fuel volatility. Local

area parameters for D-FW are obtained from TNRCC and used in the MOBILE5 runs by the NCTCOG.

2.1.6 Trip Length Distribution

The trip length distribution parameter is defined as the percentage of all VMT accumulated in each 10-minute period (0-10 min., 11-20 min., 21-30 min., 31-40 min., 40-50 min., and greater than 50 min.). This parameter is included as an input to MOBILE5 so as to obtain better estimates of running-loss emissions (emissions are categorized as diurnal emissions that vary with the ambient temperature cycle for at-rest vehicles, evaporative emissions that result from faulty control systems, and running-loss emissions that occur during vehicle operation). The running loss estimates are based on the results of running loss emission measurements conducted by the EPA over trips of different lengths (duration in time, not distance traveled). As a vehicle is driven longer, the vehicle engine/fuel system and the fuel increase in temperature, resulting in vapor generation.

The EPA's running-loss test procedure involves the measurement of running-loss emissions approximately every 10 minutes over the course of 1 hour. The measurements are cumulative; that is, the emission measurement at each 10-minute interval (10 min., 20 min., etc.) include all emissions from the start of the trip (0 min.) to that point. An emission factor for each 10-minute period, for each of three average trip speeds, is then determined on a grams-per-mile basis. The trip length distributions, representing the fraction of total VMT accumulated by vehicles during trips of each of these time bands, form the weighting factors that are used to weight these emission factors to derive the overall running-loss emission factor.

The NCTCOG determines the trip length distributions in the following manner: Initially, purpose-specific trip tables are merged with distance paths to give zone-to-zone VMT for "home-based work," "home-based nonwork," "nonhome based," and "other" trips. The travel time duration distribution for the zone-to-zone VMT is next determined from TxDOT's Travel Time (TT) tables. These tables provide the split of zone-to-zone trip duration among 1-minute increments. The VMT in each 1-minute time duration is obtained by multiplying the zone-to-zone VMT by the TT tables. This VMT is then aggregated into 10-minute time periods and summed over all trip purposes to obtain VMT by trip purpose for each 10-minute interval.

3. Scenario Selection

The Scenario data follow the One-time Data in the MOBILE5 input stream and are used to assign values to those variables that specifically define each of the scenarios to be evaluated. Each scenario is associated with a group of scenario records. MOBILE5 calculates a different set of emission factors depending on which record(s) are specified.

The first record must be included for every scenario of every MOBILE5 run and contains the following information: (1) region, (2) calendar year of evaluation, (3) average speed(s), (4) ambient temperature, (5) operating mode fractions, and (6) month of evaluation

The NCTCOG specifies the following parameters for each of these variables:

1) Region: The flag for low-altitude region is input, since D-FW falls in that category.

2) Calendar year of evaluation: 1990

3) Average speed(s): Speeds are 1-mph incremented values, from 3 to 65.

4) Ambient temperature: The ambient temperatures for the nondiurnal and diurnal time-of-day MOBILE5 runs obtained from TNRCC are input to the model.

5) Operating mode fractions: The operating shares of cold and hot starts are calculated based on the "abbreviated method" developed by George W. Ellis (Ref 2).

6) Month of evaluation: Because summer conditions are required, this is set to July 1.

3. SUMMARY OF EMISSIONS FROM ON-ROAD MOBILE SOURCES

The previous section described the various steps involved in generating pollutant-specific emission factors using MOBILE5. This section discusses the steps followed in order to apply the emission factors generated by the multiple runs to compute the net emissions from the D-FW nonattainment area.

The methodology used to calculate and adjust the emissions for the nonattainment area is as follows:

1) Calculate ozone season weekday VMT by vehicle type.

2) Determine base emissions by county, vehicle type, and functional class using VMT, VMT mix, and emission factors.

3) Add local street emissions.

4) Add emissions generated by nonrecurring congestion.

5) Add diurnal VOC emissions to the inventory.

Each of these steps is discussed next.

3.1. Calculation of Ozone Season Weekday VMT

From the DFWRTM, the ozone season VMT for each county by time of day and functional class of roadway (and thus on each link of the network) is obtained. This VMT is validated against observed traffic counts taken in the Dallas-Fort Worth area during the months of September, October, March, April, and May 1990.

The base VMT is then increased by 5% for freeways and by 3% for arterial streets in order to replicate summer ozone conditions. The loaded link speeds reflect this increase in the VMT as this modification is conducted within the model run of the DFWRTM.

The NCTCOG's transportation study area (TSA) does not encompass the entire D-FW nonattainment area, omitting as it does some rural areas of Collin and Denton Counties. Expansion factors based on population are used to expand the VMT for these rural areas. The populations of Collin and Denton Counties inside the TSA are, respectively, 92% and 90% of the total county populations. Therefore, the VMT for Collin and Denton Counties is expanded by 8% and 10%, respectively.

The VMT mix (by vehicle type for freeways and arterials) is then multiplied by the VMT on each link to obtain a disaggregate estimate of the VMT accrued by each vehicle type on each roadway segment in the DFWRTM network for each time-of-day. This process is illustrated in Figure 1.

3.2. Determination of Base Emissions by County and Functional Class

The MOBILE5 model is executed separately to provide emission factors for urban and rural counties and for five time-of-day periods (12 a.m.– 6 a.m., 6 a.m.– 9 a.m., 9 a.m.– 3 p.m., 3 p.m.–7 p.m., and 7 p.m.–12 a.m.). The emission factors developed do not vary by functional class of roadways. However, the VMT mix applied to the VMT to get VMT by vehicle type is different for freeways and arterials.

Ozone Season Weekday VMT

```
┌─────────────┐      ┌──────────────────────────┐
│   DFWRTM    │─────▶│  Daily traffic volumes on each │
│             │      │       Network link         │
└─────────────┘      └──────────────────────────┘
                                  │
                                  ▼
                     ┌──────────────────────────┐
                     │ Factor into five times of day based on │
                     │   observed VMT distribution │
                     └──────────────────────────┘
                                  │
                                  ▼
                     ┌──────────────────────────┐
                     │  Obtain VMT by time of day on each │
                     │        network link        │
                     └──────────────────────────┘
                                  │
                                  ▼
                     ┌──────────────────────────┐
                     │ Adjust VMT to replicate summer ozone │
                     │        conditions          │
                     └──────────────────────────┘
                                  │
                                  ▼
                     ┌──────────────────────────┐
                     │ Adjust VMT for Collin and Denton using │
                     │ population-based expansion factors │
                     └──────────────────────────┘
                                  │
                                  ▼
    ┌────────────────────────┐      ┌──────────────────────────┐
    │ Apply appropriate VMT mix │────▶│ VMT by time of day and vehicle type │
    │                        │      │    on each network link    │
    └────────────────────────┘      └──────────────────────────┘
```

Figure 1: Determination of Ozone-Season Weekday VMT

An average loaded speed is determined for each link in the network for each time-of-day as a function of the traffic volume and the capacity of the link. For each time period, the emission calculations are conducted on a link-by-link basis by multiplying the VMT accrued by each vehicle type on the link by the appropriate emissions factor for that vehicle type, area type, and link average speed. The link emissions are aggregated across all times of day to obtain the 24-hour base emissions for each pollutant for each county, as a function of road functional classification and vehicle type. Figure 2 provides a comprehensive illustration of this process.

```
┌─────────────────────┐      ┌──────────────┐          ┌──────────────────────────────────┐
│ Daily traffic volumes│ ◄──  │    DFWRTM    │          │  Vehicle Registration Distribution │
│ on each Network link │      └──────────────┘          └──────────────────────────────────┘
└─────────────────────┘                                 ┌──────────────────────────────────┐
          │                                              │   Hourly Operating Mode fractions  │
          ▼                                              └──────────────────────────────────┘
┌─────────────────────┐                                 ┌──────────────────────────────────┐
│ Factor into five times│                               │      Trip Length Distribution      │
│ of day based on      │                                 └──────────────────────────────────┘
│ observed VMT         │                                 ┌──────────────────────────────────┐
│ distribution         │                                 │       Local Area Parameters        │
└─────────────────────┘                                 └──────────────────────────────────┘
          │                                              ┌──────────────────────────────────┐
          ▼                                              │        I/M program credits         │
┌─────────────────────┐                                 └──────────────────────────────────┘
│       NETSUM         │                                 ┌──────────────────────────────────┐
└─────────────────────┘                                 │        Antitampering rates         │
          │                                              └──────────────────────────────────┘
          ▼
┌─────────────────────┐             ┌──────────────────────────────────────┐
│   Average loaded     │             │  Emission factors for each pollutant  │
│ speeds by time of day│  Mobile5a   │  by time of day, location, and        │
│ for each network link│             │  vehicle type for 1-mile speed        │
└─────────────────────┘             │  increments from 3-65 mph             │
          │                          └──────────────────────────────────────┘
          ▼
┌─────────────────────┐      ┌──────────────────────────┐
│  VMT by time of day  │ ──►  │    Emission factors by    │
│ and vehicle type on  │      │ time of day and vehicle type│
│  each network link   │      │   on each network link    │
└─────────────────────┘      └──────────────────────────┘
                                          │
                                          ▼
                             ┌──────────────────────────┐
                             │  Base emissions by county  │
                             │  and functional class of   │
                             │         roadway            │
                             └──────────────────────────┘
```
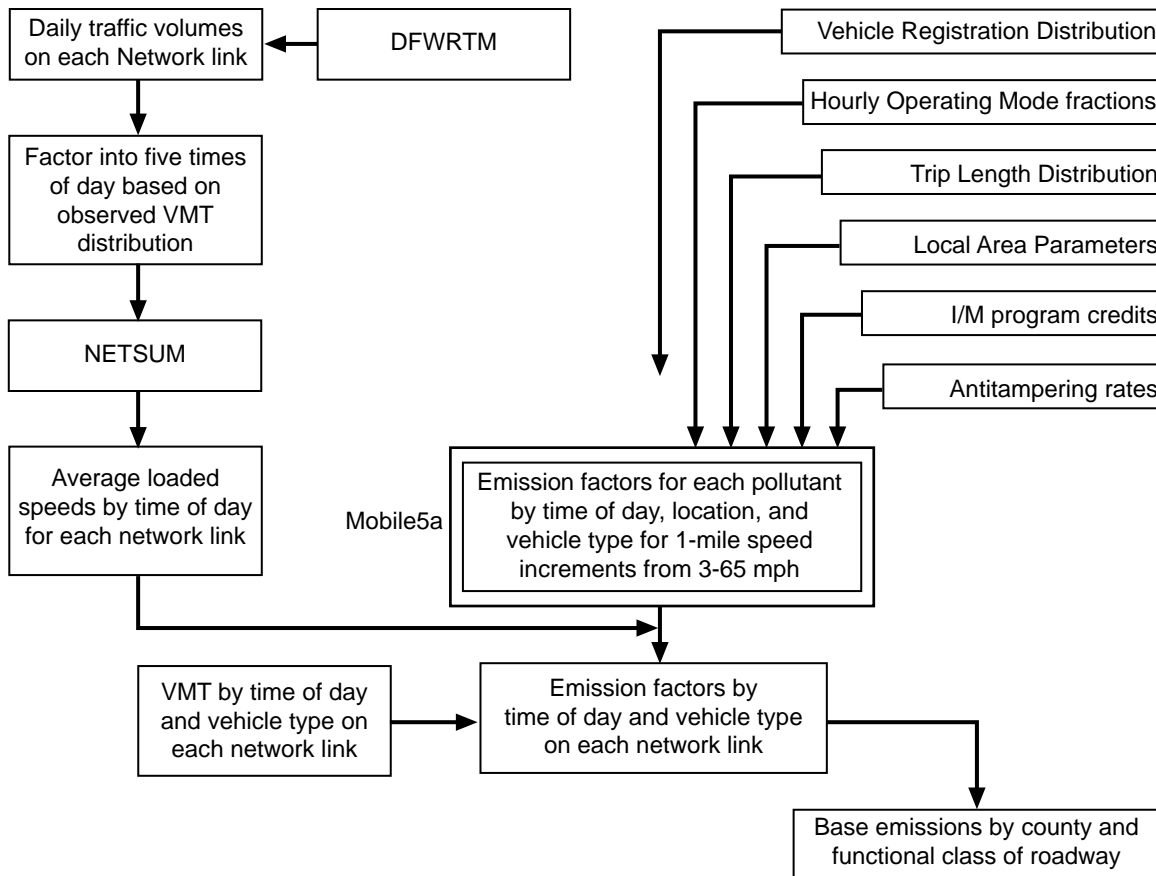
Figure 2: Determination of Base Emissions

3.3. Local Street Emissions

Because the DFWRTM roadway network does not include local streets in the Dallas-Fort Worth area. the DFWRTM cannot estimate the VMT on local streets. Nevertheless, the VMT on local roads contributes substantially to mobile source emissions. The NCTCOG estimates this VMT by developing an intrazonal trip length parameter for each TSZ (Traffic Survey Zone) as a function of its area. The VMT on all local roads within each TSZ is then calculated by multiplying the trip-length parameter for each zone by the total number of intrazonal trip interchanges within that zone (obtained from the trip distribution step) and then adding the VMT from the zone centroid connectors. For each time period, the local

street VMT is estimated based on the same distribution used for nonlocal streets. A speed of 20 mph is assumed for all such roads. This process is illustrated in Figure 3 below.
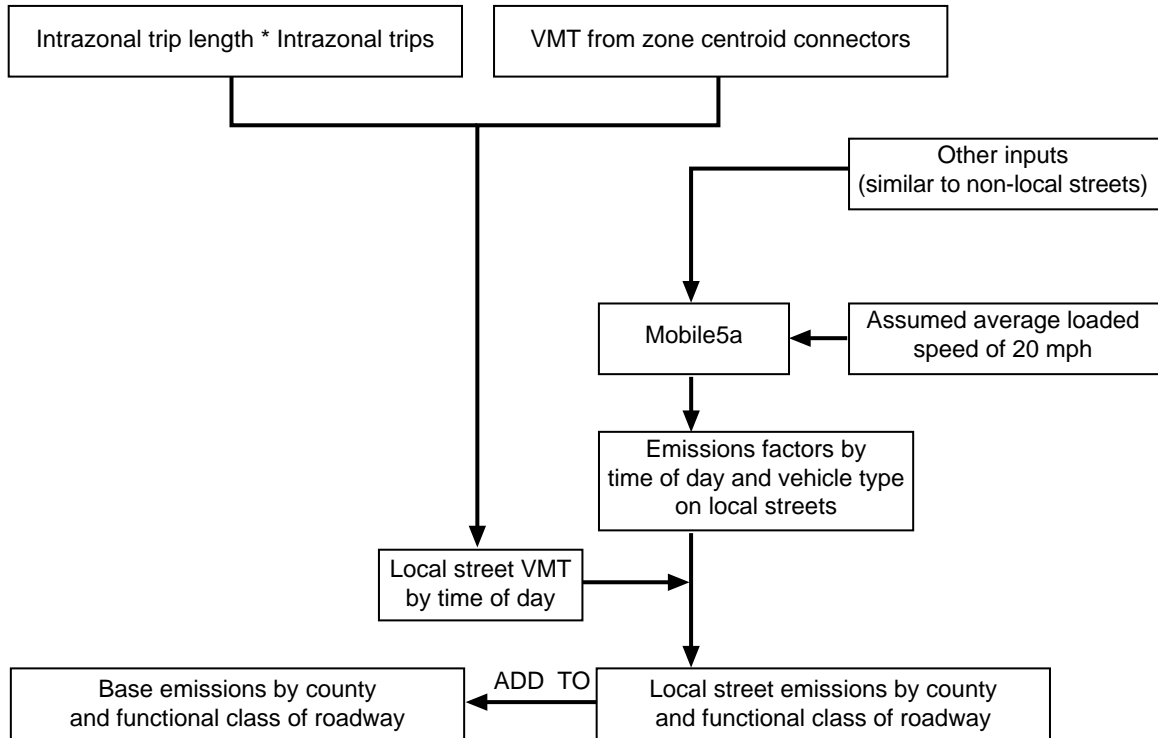

Figure 3: Local Street Emissions

3.4. Emissions from Nonrecurring Congestion

Congestion resulting from incidents — also known as *nonrecurring congestion* — results in emissions that are not included in VMT-based estimates. To account for these effects, the delay owing to nonrecurring congestion is added to the freeway travel time and congestion delay resulting from bottlenecks. This congestion results in increased freeway travel times that can translate into reduced speeds on freeway facilities. Arterial street emissions are not significantly affected by incidents because alternate routes on the arterial system are generally available. Figure 4 illustrates the process of estimating emissions from nonrecurring congestion.
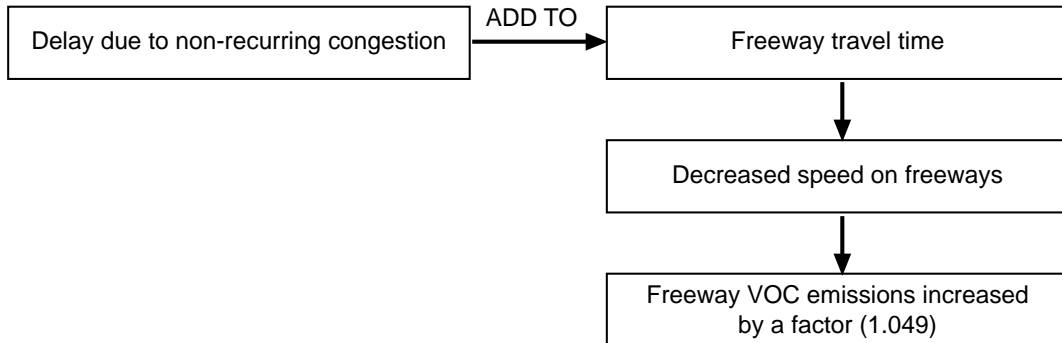
Figure 4: Emissions from Nonrecurring Congestion

3.5. Diurnal Emissions

The MOBILE5 model cannot adequately distribute diurnal emissions using a time-of-day analysis. Therefore, diurnal emissions are processed separately from the base emissions. For LDGVs, LDGT1s, LDGT2s and HDGVs, MOBILE5 provides factors that enable splitting between regular and multiple diurnals. By multiplying the number of vehicles with multiple diurnals by the multiple diurnal emission factor and the number of vehicles with regular diurnals by the regular diurnal emission factor, the diurnal emissions are obtained. These emissions are added to the VOC emissions on the basis of the VOC emission distributions for the LDGV, LDGT1, LDGT2, HDGV, and MC categories.

REFERENCES

1. Bhat, C. R., and Nair, H. S., VMT Mix Modeling for Mobile Source Emissions Forecasting: Formulation and Empirical Application, Working Paper, 1999, The University of Texas at Austin.

2. Ellis, George W., *The Determination of Vehicular Cold and Hot Operating Fractions for Estimating Highway Emission,* 1978.

3. NCHRP Report 394, "Improving Transportation Data for Mobile Source Emission Estimates."

4. NCTCOG, "Final 1990 Base Year On-Road Mobile Source Emission Inventory for the Dallas-Fort Worth Ozone Nonattainment Area," Transportation Department, NCTCOG.

5. *MOBILE5 User's Guide,* U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Mobile Sources, Emission Planning and Strategies Division, Air Quality Analysis Branch, May 1994.