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16. Abstract

This research intends to develop techniques for estimating and forecasting three critical mobile source emission related travel indicators: vehicle age distribution, mileage accumulation rates by vehicle type, and VMT mix. As for modeling the vehicle age distribution, two model types were used; each of which contains the linear model, nonlinear model and time series model. Age distributions for the 8 counties in HGAC area in Texas were used for validating model structures and parameters. The differences between the emission factors generated by MOBILE based on the default values and the forecasted values were compared. The developed computer program can be used in the Texas cities. As for modeling the mileage accumulation rate, a correcting process was developed. The real mileage accumulation rates by some vehicle types in Houston were collected, the correcting factor and estimated mileage accumulation rates were generated. As for VMT mix, extensive efforts were made on collecting information on VMT mix estimation. A national-wide survey through e-mail was conducted to ascertain what kinds of methodologies were being used by the other states. The evaluations of VMT mix estimation methodologies and the proposed improvements are on-going works, which will be summarized in the final report.

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Forecasting Traffic Characteristics for Air Quality Analyses

By

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Summary

Accurate and reliable quantification of mobile source emissions is very important in the conformity determination process. In order for each state to determine conformity in a consistent manner, the U.S. Environmental Protection Agency (EPA) requires that all states employ MOBILE (the previous version is MOBILE5 and the newest version is MOBILE6) emission factor model (EMFAC in California). MOBILE is a computer program that estimates hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x) emission factors for gasoline-fueled and diesel highway motor vehicles, and for certain specialized vehicles such as natural gas fueled or electric vehicles that may replace them (Environmental Protection Agency, 2001a).

MOBILE6 calculates emission factors for 28 individual vehicle types in low- and high-altitude regions of the United States. MOBILE estimates emission factors for any calendar year between 1952 and 2050, inclusive. Vehicles from the 25 most recent model years are considered to be in operation in each calendar year.

MOBILE6 emission factor estimates require inputs of various conditions such as ambient temperatures, travel speeds, operating modes, fuel volatility, and mileage accrual rates.

A crucial part in using MOBILE is the input of reliable mobile source emission related travel indicators, such as the vehicle age distribution, mileage accumulation rates by vehicle type, vehicle miles traveled (VMT) mix, compositions of traffic, average speeds, and etc.

This research intends to develop techniques for estimating and forecasting the three critical mobile source emission related travel indicators: vehicle age distribution, mileage accumulation rates by vehicle type, and VMT.

As for estimating vehicle age distribution, two types of models were developed. Model Type I (**MT I**) models the number of vehicles for the particular vehicle type in particular age, and then transfers the results to project the future age distribution. Model Type II (**MT II**) models the future age distribution directly. Both model types contain a family of linear models, nonlinear models and time series models. Based on a certain kind of criteria, the "best" model can be chosen from the two model families. To illustrate the proposed models and corresponding computer program (MOFAD), examples for the eight counties in Houston-Galveston Area Council (HGAC) area are presented. In addition, the differences between the emission factors generated by MOBILE based on the default age distribution values and the forecasted values by the proposed model are compared. Results show that the differences are big, which implies that the proposed model should be used to generate locality-specific MOBILE emission factors.

As for mileage accumulation rates, extensive efforts were made to collect vehicle mileage accumulation data in the Houston area and El Paso area. The survey results were used for building the site-specific model for estimating vehicle mileage accumulation rates in the corresponding local area.

The modeling of the correcting process for mileage accumulation was developed mathematically in this report. The corrected local mileage accumulation can be obtained by the combined use of the real survey data and the default national wide data. To illustrate this process, the correcting factor as well as the final corrected mileage accumulation for Houston area was

calculated. From the results, the real mileage accumulation in Houston area is 1.85 times higher than the national-wide default data.

As for VMT mix, according to the information collected, there are several methodologies on VMT mix estimation. EPA gives a guidance involving the development and application of methods to estimate detailed national wide VMT related variables. The results serve as the national default values. Bhat and Nair (2000) formulate and estimate a fractional split model. In develop the methodology used for the Houston-Galveston Nonttainment Counties gridded mobile source emissions inventories for FY 2007, the 24-hour traffic assignment are used in the analysis to obtain the VMT mix, which can be used as the input of MOBILE5. For the practices in the other states, some use the MOBILE defaults, some use the HPMS traffic count data, some estimate according to the percentage of vehicles registered within the state, some use the fuel consumption based finance method, the policy procedure, etc.

The on-going work will be focused on evaluating VMT mix estimation methodologies and propose improvements; the collection of vehicle classification-based traffic counts for VMT mix; the test and validate developed techniques/models; and the final report summarizing research findings.

Since after the start of the project, there are a lot of changes in the new version of MOVILE6, especially on VMT related variables, efforts will be focused on the programming and validating of the improvements for estimating VMT related variables.

CHAPTER 1 INTRODUCTION

1.1 Background of Research

A number of Texas cities have been designated as non-attainment areas in the past years, because of the stringent air quality set by the Environmental Protection Agency (EPA) and federal regulations. These designations are accompanied by a set of planning requirements, a State Implementation Plan (SIP) mandate, and potential retributions for failure to comply with the conditions. TxDOT and State MPOs must work with TNRCC to assess trade-offs between mobile- and other-source-emission reduction programs and adopt a specific set of SIP strategies that are feasible and achievable to reach air quality attainment status. If unrealistically large emission reduction targets are assigned to mobile sources and included in the SIP, conformity demonstrations will be difficult to make. Therefore, accurate and reliable quantification of mobile source emissions is very important in the conformity determination process. In order for each state to determine conformity in a consistent manner, EPA requires that all states employ MOBILE emission factor model (EMFAC in California) to generate mobile source emission factors for different vehicle types.

A crucial part in appropriately running MOBILE, or some of other emission models, is the availability of reliable mobile source emissions related travel indicators, such as the vehicle age distribution, mileage accumulation rates by vehicle type, vehicle miles traveled (VMT) mix, compositions of traffic, average speeds, ambient temperature, etc. MOBILE is used to generate emission factors for each emission species, which will be interfaced with travel demand models to calculate the mobile source emissions estimates. Specifically, MOBILE calculates the emissions such as HC, CO, and NOx in grams per mile, a travel demand model supplies an estimate of Vehicle Miles Traveled (VMT), and the total grams of pollutants emitted by vehicles can be produced by multiplying the emission factors by the VMT.

In practice, the level of detail at which the emissions analysis is conducted varies quite substantially among metropolitan regions. But the EPA requires that metropolitan planning areas related as serious or higher in non-attainment designation for ozone and CO estimate their mobile source emissions using network-based transportation models. The planning organizations in these areas, in general, conduct their emissions analysis at an individual link level. This involves the estimation of volumes and speeds on each network link in the metropolitan area from travel demand models such as EMME/2 and TRANSPLAN, followed by the computation of link-specific emissions factors based on a) link VMT, b) vehicle speed on the link, c) the vehicle class-specific emissions factors, and d) VMT mix fractions in the eight vehicle classes. Of all of these, the link VMT and link speeds are obtained directly from the network-based travel demand models. The vehicle class-specific emissions factors are obtained from the emissions factor models based on the various inputs listed earlier. The VMT mix is a supplementary travel indicator that is to be proved by the analyst.

1.2 Objectives of Research

This research intends to develop techniques for estimating and forecasting three critical mobile source emission related travel indicators: vehicle age distribution, mileage accumulation rates by vehicle type, and VMT mix.

As a final product, the study will develop a guidebook containing techniques and models for estimating and forecasting mobile source emissions related travel indicators.

1.3 Outline of This Report

The next chapter of this report will present the extensive review of the state-of-the-art/practice of the modeling and forecasting of the three source emissions related travel indicators. Chapter 3 will then describe the modeling process and computer programming for estimating vehicle age distribution, as well as the real case study in the Houston-Galveston Council Area (HGAC). Chapter 4 will subsequently introduce the survey process of mileage accumulation rate in Houston area, and also will describe the mathematical modeling of the correcting process for mileage accumulation. Chapter 5 will present the information collected on VMT estimation within and outside Texas. Finally, Chapter 6 will give the conclusions and on-going works for this project.

CHAPTER 2 REVIEW STATE-OF-THE-ART AND STATE-OF-THE-PRACTICE

This chapter intends to explore state-of-the art/practice on the estimation of vehicle age distribution, mileage accumulation rates and VMT. A review has demonstrated, however, that reliable and consistent techniques for estimating the necessary travel indicators either do not exist or need to be substantially improved.

2.1 Vehicle Age Distribution

MOBILE's emission factor calculations rely in part on travel fractions for vehicles of each given age and type, which in turn are based on estimates of the average annual mileage accumulation by age (first year to 25th - and - greater years of operation) for each of the eight vehicle types, and the registration distribution by age (age 0 - 1 to age 24 - 25+) for each vehicle types, except motorcycles, for which annual mileage accumulation rates and registration distribution are only provided for the 12th - and - later years of operation (age 0 - 1 to 11 - 12+). MOBILE uses national average annual mileage accumulation rates and registration distributions by age, and has provisions allowing the input of alternate data for either or both of these. The national annual mileage accumulation rates are based on analyses of information developed over a long period of time, and the registration distributions are based on analysis of calendar year 1990 registration. Besides using the national average values for vehicle age distribution and mileage accumulation rates, there exist no generic models/techniques for estimating geographical area specific values for any specific years.

2.2 Mileage accumulation

The MOBILE6 emission model, currently under development, uses mileage accumulation rates that assume that the average 25-year-old car has been driven more than 210,000 miles, and that the average 25-year-old pickup truck has been driven over 250,000 miles (United States Environmental Protection Agency, 1998, 1999a). Cumulative mileage is used in the model to calculate emission factors that increase with mileage due to air pollution control device "deterioration" Odometer readings taken in previous EPA studies (United States Environmental Protection Agency 1999b) and data reported herein indicate that average mileage accumulations may be much less (i.e. 125,000 miles) than those used in the MOBILE6 model. This has the effort of over-estimating emissions from older vehicles. A simple model is presented by Miller et al. (2001) which accounts for scrappage of old vehicles as a function cumulative mileage. This model predicts average cumulative mileage that is much closer to actual odometer readings (taken in Nashville, TN) than the default values used in MOILE6. The use of more accurate cumulative mileage values for older vehicles should provide improvements to the estimation of emissions from the vehicle fleet.

2.3 VMT mix estimation

The vehicle miles traveled (VMT) mix specifies the fraction of total highway VMT that is accumulated by each of the vehicle types. The VMT mix is used only to calculate the composite (all vehicle, or fleet wide) emission factors. MOBILE calculates a typical urban area

VMT mix based on national data characterizing registration distributions and annual mileage accumulation rates by age for each vehicle type, the fraction of travel by each vehicle type that is typical of urban areas, and total vehicle counts (fleet size) by vehicle type.

The emissions factors for each of the three pollutants CO, VOC, and NOx vary quite widely among the different vehicle class. Consequently, the emissions analysis is very sensitive to VMT mix. For example, at high temperatures, a 2.8% change in the heavy duty gas vehicle (HDGV) mix causes about a 10% change in the CO emissions rate, and a 4.8% change in the HDGV mix leads to about a 10% shift in the VOC emissions rate. It is, therefore, important to provide accurate VMT mix values.

Instead of using MOBILE default values, an alternative approach adopted by some metropolitan agencies is to use 24-hour local vehicle classification-counts to determine VMT mix, followed by the application of factors to convert vehicle types in traffic counts to the MOBILE vehicle classes. EPA recommends that local agencies adopt this approach because the MOBILE default values may not be reflective of the local traffic vehicle mix. In this local vehicle count-based approach, the VMT mix is typically stratified by the function classification of roadways to accommodate variations across roadway classes. However, since most counts are conducted only on higher roadway classes (such as interstates and major arterials), there is inadequate information to comprehensively capture variations in VMT mix by roadway class. Values of VMT mix obtained for the higher roadway classes are applied (sometimes after ad hoc adjustments based on judgment) to the lower roadway classes (such as minor arterials, collectors, and local roads).

There are some other dimensions in estimating of VMT mix. Some examples are listed as follows:

- VMT mix can be estimated by functional class using the Highway Performance Monitoring System (HPMS) methodology based on traffic count;
- VMT mix can be estimated for all state owned highways by county;
- VMT mix can be estimated based on fuel consumption records;
- VMT mix can be estimated for the Cost Responsibility Study based on fuel tax and motor carrier tax records; and so on.

HPMS is a FHWA program, which was introduced in 1978 to strengthen the methods used by the states for collecting, estimating and reporting traffic count data, and to help reduce the effort involved in providing the federal government with necessary traffic data. Based on traffic counts in this program that are distributed over the national highway system, FHWA requires each state to report total state VMT by functional class. The cost of HPMS VMT estimation for the states is significant and because of cost, a sample design for traffic counts is used to develop annual VMT estimates by FHWA functional class and vehicle category for all highways in the state.

Therefore, efforts in improving the accuracy of VMT mix estimation have been made. At a national level, a review of the literature indicates several successful and relatively low-cost approaches for improved VMT mix estimates. Studies in Oregon and Virginia used 24-hour vehicle classification based traffic counts and a mapping approach that improved the seasonal and day-of-week factors used to convert raw counts into VMT mix estimates without requiring the collection of addition data. In addition, some other studies have used simulation models or have modestly increased sample sizes to improve reliability of estimates.

A problem with the state-of-the-art/practice discussed above for VMT mix determination is that they apply aggregate-level values across links in the road network in a region. It was found, in an analysis of VMT mix from 477 different count sites in the U.S., that substantial variations exist in VMT mix across the sites, emphasizing the need for local determination of VMT mix values (rather than using MOBIL default values). The same study also indicates substantial variation in VMT mix even after controlling for roadway class at any given site, underscoring the need to consider explanatory factors other than roadway class in local VMT mix analysis.

Procedures used by the Texas Transportation Institute (TTI) are documented in developing the Houston-Galveston Nonattainment Counties Mobile Source Emissions Inventories for FY2007 (George *et al.* 2000). The time-of-day VMT and speed estimates for the Houston-Galveston region were developed using the PREPIN2 program. PREPIN2 is one of a series of programs developed by TTI to facilitate the application of EPA's MOBILE5a Hybrid program in estimating mobile source emissions. The PREPIN2 program was developed for use in urban areas that do not have time-of-day assignment and speeds available for air quality analyses. The program inputs a 24-hour assignment and applies the needed seasonal adjustment factors. The time-of-day factors are applied to the seasonally adjusted 24-hour assignment results to estimate the directional time-of-day travel. A simplified version of the HGAC speed model was used to estimate the operational time-of-day speeds for intrazonal trips. These VMT and speeds by link are subsequently input to the IMPSUMA program for the application of MOBILE5a Hybrid emissions rates.

Lee-Gosselin and Richardson (1988) reported a study that looked into the problem of VMT estimation in Canada. They looked at the VMT estimation from different viewpoints and levels, as in this paper (regional VMT and VMT of different road categories, for instance). However, clear mathematical descriptions are not provided by Lee-Gosselin and Richardson. Hoang and Poteat (1980) also applied stratified sampling by stratifying the highway links by volume, area, and facility type. The difference between the approach of Hoang and Poteat and our approach is mainly that Hoang and Poteat calculated required sample sizes for each stratum.

As far as we know, the VMT estimation problem is not fully covered by any standard or guideline concerning traffic counting. The American Association of State Highway and Transportation Officials' Guidelines for Traffic Data Programs ("AASHTO", 1992) provided very little insight into the strategic planning of counting site network, though it gave numerous recommendations of how to carry out counting operations. The same applies to the ASTM Standard Practice for Highway-Traffic Monitoring ("Standard", 1994). All that was basically said is that the gathered data is finally aggregated as the national or regional VMT. This may be sufficient if the total counting site network covers the whole road network well. But there is also a risk that counting sites are distributed to mainly cover important main links and urban areas, and thus the system may give a biased estimate of the total VMT (or at least the less important areas and roads receive less attention and counting effort than they perhaps should).

Räty and Leviäkangäs (1999) showed how the VMT could be estimated by means of stratified probability proportional to size (PPS) cluster sampling. This approach is strategic, showing how the PPS method can be used as a tool to determine the approximate number of counting sites required, rather than operational, which is the next phase of network planning. It calculated the needed total sample size and allocated it optimally to each stratum.

CHAPTER 3 COLLECTION OF AGE DISTRIBUTION DATA AND THE DEVELOPMENT OF MODELS FOR ESTIMATING VEHICLE AGE DISTRIBUTION

3.1 Age Distribution and Its Impact to the Emission Estimation of MOBILE

MOBILE's emission factor calculations rely in part on travel fractions for vehicles of each given age and type, which in turn are based on estimates of the registration distribution by age (age 0 - 1 to age 24 - 25^+) for each vehicle types, except motorcycles, for which registration distribution are only provided for the 12^{th} - and - later years of operation (age 0 - 1 to 11 - 12^+).

MOBILE6 users may specify vehicle registration data for 25 vehicle ages for one or more of the 16 composite vehicle types listed in TABLE 3-1.

TABLE 3-1 Composite Vehicle Classes for Vehicle Registration Data

Number	Abbreviation	Description
1	LDV	Light-Duty Vehicles (Passenger Cars)
2	LDT1	Light Duty Trucks 1 (0-6,000 lbs. GVWR, 3751-5750 lbs. LVW)
3	LDT2	Light Duty Trucks 2 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
4	LDT3	Light Duty Trucks 3 (6,001-8,500 lbs. GVWR, 0-3750 lbs. LVW)
5	LDT4	Light Duty Trucks 4 (6,001-8,500 lbs. GVWR, 3751-5750 lbs. LVW)
6	HDV2B	Class 2b Heavy Duty Vehicles (8,501-10,000 lbs. GVWR)
7	HDB3	Class 3 Heavy Duty Vehicles (10,001-14,000 lbs. GVWR)
8	HDV4	Class 4 Heavy Duty Vehicles (14,001-16,000 lbs. GVWR)
9	HDV5	Class 5 Heavy Duty Vehicles (16,001-19,500 lbs. GVWR)
10	HDV6	Class 6 Heavy Duty Vehicles (19,501-26,000 lbs. GVWR)
11	HDV7	Class 7 Heavy Duty Vehicles (26,001-33,000 lbs. GVWR)
12	HDV8A	Class 8a Heavy Duty Vehicles (33,001-60,000 lbs. GVWR)
13	HDV8B	Class 8b Heavy Duty Vehicles (>60,000 lbs. GVWR)
14	HDBS	School Buses
15	HDBT	Transit and Urban Buses
16	MC	Motorcycles (All)

Note: The above table is copied from Environmental Protection Agency (2001b), where LVW is *loaded vehicle weight* rating, and GVWR is *gross vehicle weight ratings.*

In the input file for MOBILE6, vehicle age fractions are represented by decimals (0.000 through 1.000) for each of the 25 model years and older in the fleet being modeled. MOBILE uses national average annual registration distributions by age, and has provisions allowing the input of alternate data. EPA provides an estimate of the number of vehicles of various ages in operation in the United States as of July 1, 1996 for eighteen GVWR-based vehicle categories, which are listed in TABLE 3-1. So the national annual registration distribution data are based on the analysis of calendar year 1996 registration. Using the default values assumes that the national distribution of vehicles registered by age is the same as the distribution in specific localities. Using national average default values to model specific areas would tend to produce inaccurate emission factors.

Besides using the national average values for vehicle age distribution, there exist no generic models/techniques for estimating geographical area specific values for any specific years. This is a new research and is unique at this moment. EPA encourages local areas to use their local age distributions estimating emission inventories (Cambridge Systematics Inc. and etc. 1996). In the real applications, someone uses the local vehicle registration data for a particular year as input into MOBILE. For example, in developing the Houston-Galveston nonattainment counties gridded mobile source emissions inventories for FY 2007, the 1993 vehicle registration data for the 8 counties were used to run MOBILE5a (Dresser and Bell, 1998).

Vehicle age distribution has an important impact on the MOBILE emission factors (HC, CO and NO_x). For example, Figure 3-1 and 3-2 show the plots of the change of emission factors with the percentage of age 1 vehicles for vehicle type LDDT (Light Duty Diesel Vehicle) and HDDV (Heavy Duty Diesel Vehicle), which were generated by MOBILE5a. From the two Figures it is shown that the increase of the age distribution (for vehicle age=1, *i.e.* the new vehicle) will reduce the overall vehicle class emission inventory. So the proper estimation of vehicle age distribution is very important to the accurate estimation of vehicle emission factors.

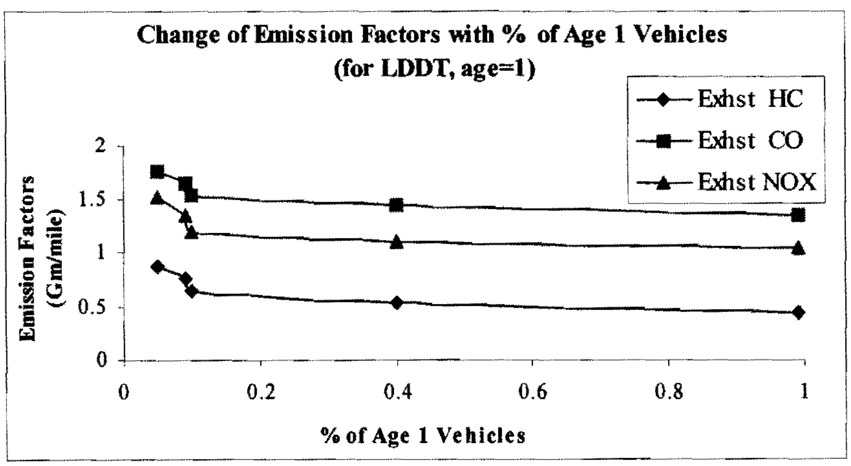


Figure 3-1 Change of emission factors with % of age 1 vehicles distribution (for vehicle type LDDT and age 1)

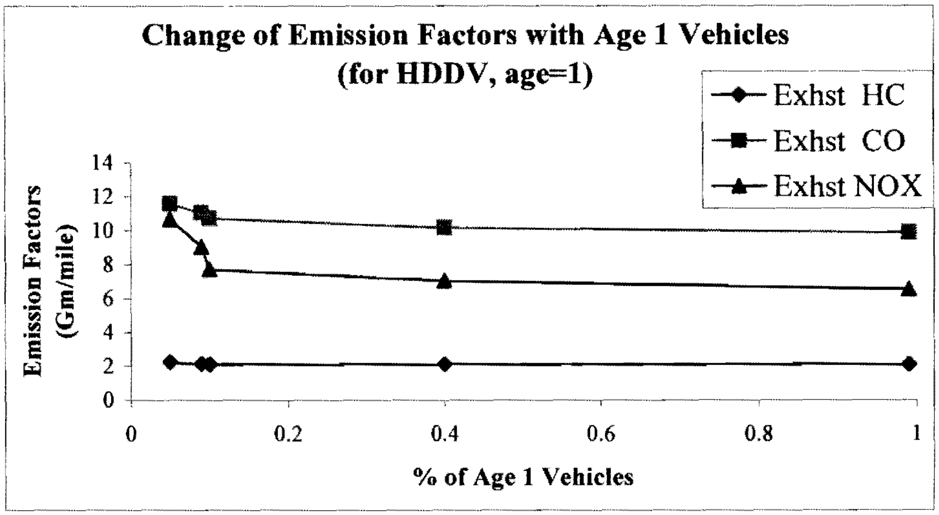


Figure 3-2 Changes of emission factors with age distribution (for vehicle type HDDV and age 1)

3.2 Model Design for Estimating Vehicle Age Distribution

Vehicle age distribution modeling system is an object in which variables of different kinds interact and produce observable signals (vehicle age distribution), which are usually called *outputs*. Figure 3-3 is the illustration of this system, where vehicle age distribution, as well as the absolute number of vehicles for a particular vehicle type with a particular age in a certain area, can be regarded as the function of some kinds of *inputs*. These input variables could be either the predictable socioeconomic factors, or the complex unpredictable or immeasurable inputs. The predictable socioeconomic indices may include population, average income, household, population density and etc. If the variables are unpredictable or immeasurable, the chronological series can be used as the input of the function.

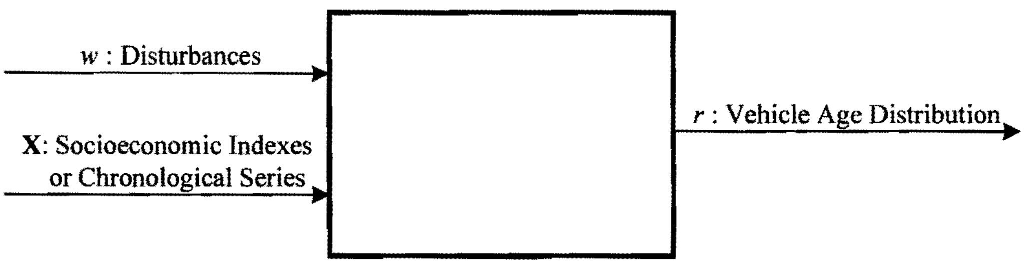


Figure 3-3 The vehicle age distribution modeling system

According to the theory of system identification, we shall call the assumed relationship among observed input/output variables a *model* of the system. (Ljung, 1999). The models should contain some parameters that need to be calibrated by the real world collected data. The calibration of parameters can be based on the algorithms like Least Square (Ljung 1999, Crooper and McGillem, 1999). The projection of the age distribution for the target year can be obtained when the input variables for the target year are supplied.

According to whether the age distribution is modeled directly, two types of models are developed for the projection of the future vehicle age distribution. Model Type I (**MT I**) models the number of vehicles for the particular vehicle type in particular age, and then transfers the results to project the future age distribution. Model Type II (**MT II**) models the future age distribution directly. The modeling processes are described next.

MT I:

Suppose v_{kg} is the number of vehicles with type k $(k = 1, 2, ..., n_k)$ and age g $(g = 1, 2, ..., n_g)$, n_k is the number of total vehicle types, and n_g is the maximum number of vehicle age. Let $\hat{v}_{kg}$ be the estimated value of v_{kg} by a certain model, then the entire system objective can be represented as:

$$\min \sum_{k=1}^{n_k} \sum_{g=1}^{n_g} (v_{kg} - \hat{v}_{kg})^2 \tag{3-1}$$

Since $(v_{kg} - \hat{v}_{kg})^2 \geq 0$, so the system objective (3-1) can be decomposed into various sub-system objectives as:

$$\min(v_{kg} - \hat{v}_{kg})^2 \qquad \forall k = 1, \dots n_k, g = 1, \dots, n_g \tag{3-2}$$

where, each v_{kg} is a function of the vector of inputs $\mathbf{x} = \{x_1, x_2, ..., x_{n_x}\}$ (n_x is the total number of inputs).

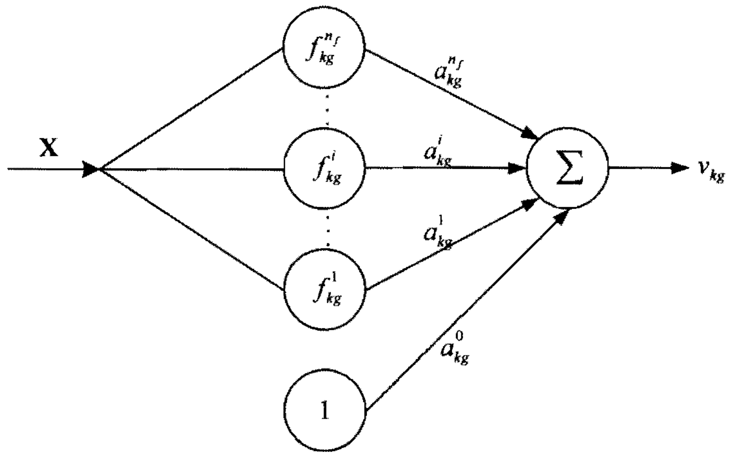
There are many factors that can affect vehicle age distribution, and the relationship between these factors and age distributions are very complex. Until now no one can build a physical model that can describe this kind of relationship. Since it is very difficult to build a model that can physically represent the relationships between the various inputs (in vector **x**) and the system output v_{kg}, it is reasonable to regard the system as a *black box*. In practical application, it may be necessary to use models that describe the relationships among the system variables in terms of mathematical expressions. From the theory of system identification, the mapping from the input vector **x** to the output v_{kg} can have the following parameterized function form:

$$v_{kg} = a_{kg}^0 + \sum_{i=1}^{n_f} a_{kg}^i f_{kg}^i \left(\mathbf{x} \middle| c_{kg}^{i0}, c_{kg}^{i1}, ..., c_{kg}^{in_f}\right) \tag{3-3}$$

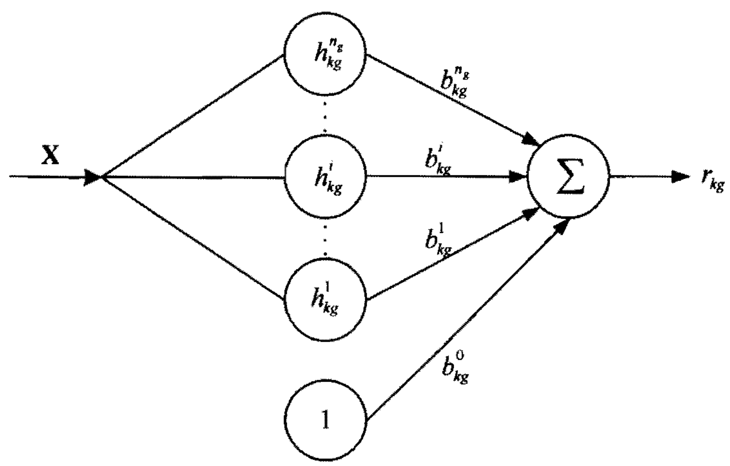
where, the parametric matrix $\theta_{kg} = \left[a_{kg}^0, a_{kg}^1, \dots, a_{kg}^{n_f}; c_{kg}^{10} c_{kg}^{11}, c_{kg}^{12}, \dots, c_{kg}^{1n_f}; \dots; c_{kg}^{n_f 0}, c_{kg}^{n_f 1}, c_{kg}^{n_f 2}, \dots, c_{kg}^{n_f n_f}\right]$ is to be calibrated; f_{kg}^i is regarded as the basic function; and n_f is the total number of the basic functions f_{kg}. The basic function f_{kg}, however, can have different forms. The simplest basic function is the linear one that can be expressed as:

$$f_{kg}^i(\mathbf{x}) = x_i, \qquad \forall\, i = 1, 2, ..., n_f = n_x \tag{3-4}$$

which is a linear function of the scalar variable x_i. This kind of relationship is also illustrated in Figure 3-4(a).



(a) MT I



(b) MT II

Figure 3-4 The mapping from input X to the output

The structured model in (3-3) is parameterized with the parameter vector $\theta_{kg} = \left[a_{kg}^{0}, a_{kg}^{1}, \dots, a_{kg}^{n_f}; c_{kg}^{01}, c_{kg}^{11}, \dots, c_{kg}^{1n_f}; \dots; c_{kg}^{n_f 0}, c_{kg}^{n_f 1}, \dots, c_{kg}^{n_f n_f}\right]$. The search for the best model then becomes a problem of determining or estimating θ_{kg}. Our objective now is to determine a mapping from data sets $Z_v^N = \left(v_{kg}^N, \mathbf{x}^N\right)$ (where, N is the total number of recorded input-output pairs over a time period $1 \le t \le N$), to a series of possible parameters $\hat{\theta}_{kg} = \left[\hat{a}_{kg}^{0}, \hat{a}_{kg}^{1}, \dots, \hat{a}_{kg}^{n_f}; \hat{c}_{kg}^{10}, \hat{c}_{kg}^{11}, \dots, \hat{c}_{kg}^{1n_f}; \dots; \hat{c}_{kg}^{n_f 0}, \hat{c}_{kg}^{n_f 1}, \dots, \hat{c}_{kg}^{n_f n_f}\right]$, so that the model produces the prediction that is close to the target output. An obvious approach is then to select $\hat{\theta}_{kg}$ so as to fit the calculated values $\hat{v}_{kg}\left(t \middle| \hat{\theta}_{kg}\right)$ as well as possible to the measured inputs by least squares method.

So the *best* value of θ_{kg} is determined from the input-output data set by:

$$\hat{\theta}_{kg} = \arg\min \sum_{t=1}^{N} \left| v_{kg} - \left(\hat{a}_{kg}^{0} + \sum_{i=1}^{n_f} \hat{a}_{kg}^{i} f_{kg}^{i} \left(\mathbf{x} \middle| \hat{c}_{kg}^{i0}, \hat{c}_{kg}^{i1}, \ldots, \hat{c}_{kg}^{in_f} \right) \right) \right|^2 \tag{3-5}$$

The model output, which is the number of the vehicles for type k with age g, will be:

$$\hat{v}_{kg} = \hat{a}_{kg}^{0} + \sum_{i=1}^{n_f} \hat{a}_{kg}^{i} f_{kg}^{i} \left(\mathbf{x} \middle| \hat{c}_{kg}^{i0}, \ldots, \hat{c}_{kg}^{in_f} \right) \tag{3-6}$$

The age distribution r_{kg} can then be calculated by:

$$r_{kg} = \frac{v_{kg}}{\sum_{g=1}^{n_g} v_{kg}} \tag{3-7}$$

MT II:

Model Type II (**MT II**) models the future age distribution r_{kg} directly. Similarly, the entire system objective can be represented as:

$$\min \sum_{k=1}^{n_k} \sum_{g=1}^{n_g} \left(r_{kg} - \hat{r}_{kg} \right)^2 \tag{3-8}$$

$$s.t. \quad \sum_{g=1}^{n_g} r_{kg} = 1 \qquad \forall k = 1, 2, \ldots, n_k \tag{3-9}$$

In (3-8) and (3-9), r_{kg} is the age distribution for vehicle type k with age g, $\hat{r}_{kg}$ is the estimated value of r_{kg} by model, and n_k and n_g are the same as defined before. The constraint $\sum_{g=1}^{n_g} r_{kg} = 1$ is necessary here in order to ensure the sum of the age distribution for a particular vehicle type k is equal to 100%.

Since $\left(r_{kg} - \hat{r}_{kg} \right)^2 \geq 0$, the entire system objective can be decomposed into various sub-system objectives as:

$$\min \left(r_{kg} - \hat{r}_{kg} \right)^2 \qquad \forall k = 1, \ldots n_k, g = 1, \ldots, n_g \tag{3-10}$$

$$s.t. \quad \sum_{g=1}^{n_g} r_{kg} = 1 \qquad \forall k = 1, 2, ..., n_k \tag{3-11}$$

where, each r_{kg} is a function of the vector of inputs $\mathbf{x} = \{x_1, x_2, ..., x_{n_x}\}$ (n_x is the total number of inputs).

In the same way as for v_{kg}, the mapping from the input vector $\mathbf{x}$ to the output r_{kg} can have the following parameterized function form:

$$r_{kg} = b_{kg}^0 + \sum_{i=1}^{n_g} b_{kg}^i h_{kg}^i \left(\mathbf{x} \middle| d_{kg}^{i0}, ..., d_{kg}^{in_g}\right) \tag{3-12}$$

where, $\phi_{kg} = \left[b_{kg}^0, b_{kg}^1, ..., b_{kg}^{n_f}; d_{kg}^{10}, d_{kg}^{11}, ...d_{kg}^{1n_g}; ...; d_{kg}^{n_g 0}, ...d_{kg}^{n_g n_g}\right]$ is the parametric matrix to be calibrated; h_{kg}^i is regarded as the basic function; and n_f is the total number of the basic functions h_{kg}. The basic function h_{kg}, however, can have different forms. The simplest one is the linear one that can be expressed as:

$$h_{kg}^i(\mathbf{x}) = x_i \qquad \forall\, i = 1,2,...,n_f = n_x \tag{3-13}$$

which is a linear function of the scalar variable x_i. This kind of relationship is also illustrated in Figure 3-4(b).

The structured model in (3-12) is parameterized with the vector $\phi_{kg} = \left[b_{kg}^0, b_{kg}^1, ..., b_{kg}^{n_f}; d_{kg}^{10}, d_{kg}^{11}, ...d_{kg}^{1n_g}; ...; d_{kg}^{n_g 0}, ...d_{kg}^{n_g n_g}\right]$. The search for the best model then becomes a problem of determining or estimating ϕ_{kg}. Our objective now is to determine a mapping from data sets $Z_r^N = \left(r_{kg}^N, \mathbf{x}^N\right)$ (where, N is the total number of recorded input-output pairs over a time period $1 \le t \le N$), to a series of possible parameters $\hat{\phi}_{kg} = \left[\hat{b}_{kg}^0, \hat{b}_{kg}^1, ..., \hat{b}_{kg}^{n_f}; \hat{d}_{kg}^{10}, \hat{d}_{kg}^{11}, ...\hat{d}_{kg}^{1n_g}; ...; \hat{d}_{kg}^{n_g 0}, ...\hat{d}_{kg}^{n_g n_g}\right]$, so that the network produces the prediction that is close to the target output. One of the measurements of closeness may be on a mean square error criterion.

So, the *best* value of θ_{kg} is determined from the data input-output set by:

$$\hat{\phi}_{kg} = \arg\min \sum_{t=1}^{N} \left| v_{kg} - \left(\hat{b}_{kg}^0 + \sum_{i=1}^{n_f} \hat{b}_{kg}^i h_{kg}^i \left(\mathbf{x} \middle| \hat{d}_{kg}^{i1}, ..., \hat{d}_{kg}^{in_g}\right) \right) \right|^2 \tag{3-14}$$

The model output, that is vehicle age distribution for type k with age g (with no constraint (3-11), will be:

$$r_{kg}^e = \hat{b}_{kg}^0 + \sum_{i=1}^{n_f} \hat{b}_{kg}^i h_{kg}^i \left(\mathbf{x} \middle| \hat{d}_{kg}^{i1}, ..., \hat{d}_{kg}^{in_g}\right) \tag{3-15}$$

To meet the constraint (3-11), the resulting age distribution r_{kg} can be calculated by:

$$r_{kg} = \frac{r_{kg}^{e}}{\sum_{g=1}^{n_g} r_{kg}^{e}} \tag{3-16}$$

3.3 Model Implementation for Estimating Vehicle Age Distribution

The whole process of the projection of vehicle age distribution includes the calibration of parameters for each model, the examination of the significance test for input indices (if the input indices are predictable), the choice of model types and structures, and the projection of vehicle age for the target year.

Possible data needed for modeling and projection include the socioeconomic indices in the corresponding area in the past years, the age distribution or number of vehicles for all kinds of vehicle types at different vehicle age, socioeconomic indices in the past years for projection, and other necessary background information and user defined requirements.

The socio-economic data may include: population (total, for different age groups…), number of employees, incomes and production of industries (total, agricultural services, construction, manufacturing, transportation and public utilities, etc.), or even the price of oils, etc. A specific jurisdiction can input as many as the possible socio-economic data they may have. The software MOFAD have the ability to select several most suitable ones to build the model.

Parameter calibration is implemented by the linear square regression approach. The calibration of the parameters includes parameter estimations and interval estimations. The significance test for each index can be conducted by using the result of corresponding parameter estimation and interval estimation. The suitable model type and structure is determined such that the final model meets the requirements of the objective functions in (3-1) and (3-8). The projection of age distribution for the target year can be obtained if all the input socioeconomic indices for the target year are available.

The FORTRAN program with the name MOFAD (**MO**deling and **F**orecasting **A**ge **D**istribution) implements the whole modeling process. The program is organized in different subroutines; each one of which represents different functions. Figure 3-5 illustrates the flowchart of the program and Figure 3-6 illustrates the organization map of the program MOFAD.

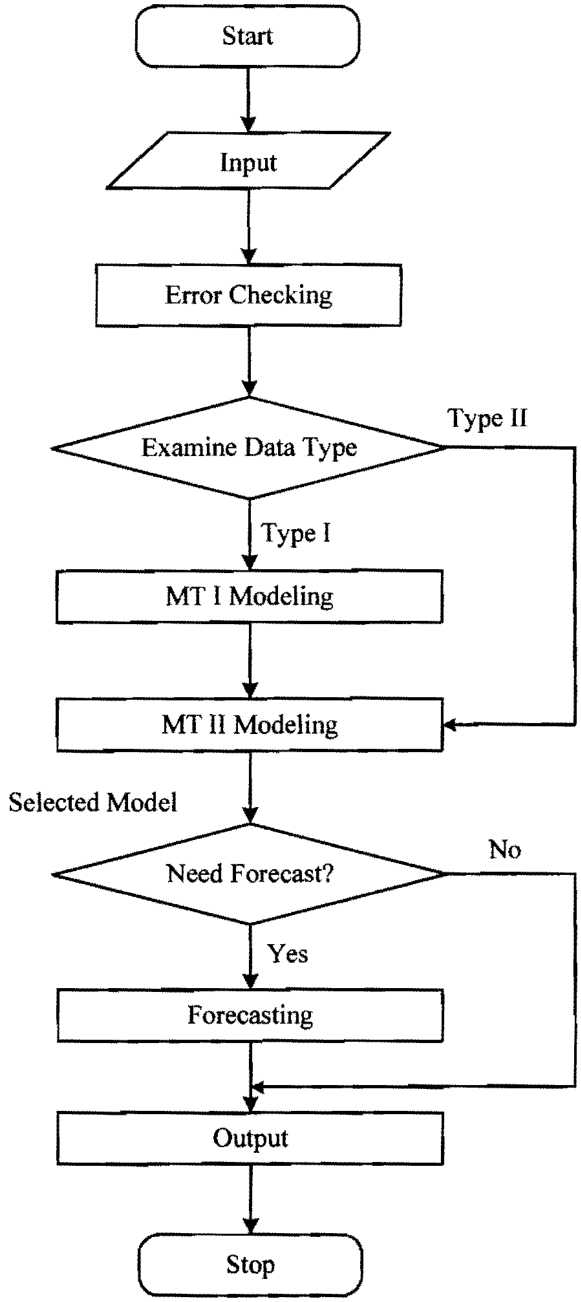


Figure 3-5 Flowchart of the program MOFAD

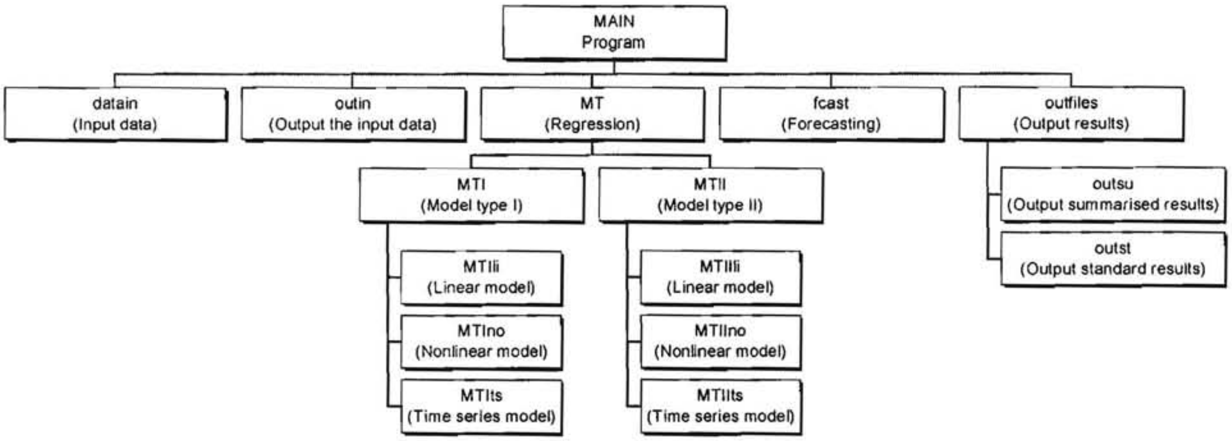


Figure 3-6 Organization map for the subroutines of program MOFAD

A master file that contains the main information of the input / output files is needed and several input files are necessary. The input files include the files containing the socioeconomic indices in the past model years, and the socioeconomic indices for the future years. The program can generate 4 types of output files that will meet the various needs of the users. It can provide the detailed modeling information in one of the output file, and give the summarized output in another file. It can also produce the standard output files that can be directly used as one of the input file for MOBILE. The model software MOFAD is during the finalizing stage and will be available for the users soon.

3.4 Model Application for Estimating Vehicle Age Distribution

To validate the proposed model as well as the corresponding computer program, the real application was conducted in the 8 counties in HGAC (Houston-Galveston Area Council, Figure 3-7): Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery and Waller. Socioeconomic data were obtained from the web address of government information sharing project (Information Services in Oregon State University, 2001), the US census bureau (US Census Bureau 2001), etc. Age distribution data were obtained from the Texas Department of Transportation, HGAC, etc., which contain vehicle age registration information from 1994 to 2000, and were used for model calibrations and selections.

Figure 3-7 Map of the 8 counties in HGAC

Since for MOBILE6, vehicle age distribution with 25 ages for 16 vehicle types needs to be modeled and forecasted, a total of 400 models were to be built. For each model, we had two model types, and for each model type, we tested five kinds of candidate models. The five candidate models included one linear regression model, three nonlinear models and one pure time series model. The linear regression model has been described in (3-4) and (3-13), while for the time series model the input was the chronological series (*i.e.* the sequence of year) instead of the socioeconomic indices. The three nonlinear models chosen here were all log-linear models listed in the following:

For MT I:
$$v_{kg} = \exp\left(c_{kg}^{0} + c_{kg}^{1}\log x_1 + \ldots + c_{kg}^{n}\log x_n\right) \tag{3-17}$$

$$v_{kg} = \exp\left(c_{kg}^{0} + c_{kg}^{1}x_1 + \ldots + c_{kg}^{n}x_n\right) \tag{3-18}$$

$$v_{kg} = c_{kg}^{0} + c_{kg}^{1}\log x_1 + \ldots + c_{kg}^{n}\log x_n \tag{3-19}$$

For MT II:
$$r_{kg} = \exp\left(d_{kg}^{0} + d_{kg}^{1}\log x_1 + \ldots + d_{kg}^{n}\log x_n\right) \tag{3-20}$$

$$r_{kg} = \exp\left(d_{kg}^{0} + d_{kg}^{1}x_1 + \ldots + d_{kg}^{n}x_n\right) \tag{3-21}$$

$$r_{kg} = d_{kg}^{0} + d_{kg}^{1}\log x_1 + \ldots + d_{kg}^{n}\log x_n \tag{3-22}$$

Therefore, in running the program for each county, a total of 4000 candidate models (=25 ages * 16 vehicle types * 2 model types * 5 linear or nonlinear models) were to be prepared. The selected model from the 4000 candidate was the one that can meet the requirement of the objective functions (3-2) and (3-10), *i.e.* the one that had the minimum modeling errors.

TABLE 3-2 shows the number of different models used in modeling age distribution for 8 HGAC counties. From TABLE 3-2 it is shown that for MT I, the selected models came from different five model families (linear model, 3 types of nonlinear models and time series models). Most of them were taken from the linear model and the third nonlinear model (3-19). Only under a few cases the best model for MT I were taken from time series model. For MT II, the results are very interesting. All the selected models were taken from the time series model and the third nonlinear model (3-22), and none were taken from the first nonlinear model (3-20) and the second nonlinear model (3-21). TABLE 3-3 lists the number of models taken from MT I and taken from MT II. About 41.4% of the final models were taken from MT I, while 58.6% taken from MT II.

TABLE 3-2 Number of Different Models Used in Modeling Age Distribution for 8 HGAC Counties

	Linear	Nonlinear1	Nonlinear2	Nonlinear3	Time Series	Total
	MT I					
Brazoria	112	69	38	181	0	400
Chambers	15	36	81	268	0	400
Fort Bend	202	30	57	108	3	400
Galveston	158	28	57	156	1	400
Harris	160	52	64	124	0	400
Liberty	153	18	80	149	0	400
Montgomery	264	39	17	80	0	400
Waller	166	37	50	147	0	400
	MT II					
Brazoria	248	0	0	152	0	400
Chambers	225	0	0	175	0	400
Fort Bend	254	0	0	146	0	400
Galveston	182	0	0	215	3	400
Harris	301	0	0	99	0	400
Liberty	238	0	0	161	1	400
Montgomery	272	0	0	128	0	400
Waller	257	0	0	143	0	400

TABLE 3-3 Number and Percentage of Selected Models from MT I and MT II

	MT I		**MT II**	
Brazoria	150	37.5%	250	62.5%
Chambers	100	25.0%	300	75.0%
Fort Bend	154	38.5%	246	61.5%
Galveston	186	46.5%	214	53.5%
Harris	164	41.0%	236	59.0%
Liberty	213	53.3%	187	46.8%
Montgomery	178	44.5%	222	55.5%
Waller	179	44.8%	221	55.3%
Average	165.5	41.4%	234.5	58.6%

Figure 3-8 shows the average relative modeling errors for the 8 HGAC counties. Each data was the average value of relative errors for the corresponding 4000 candidate models. From Figure 3-8 we know that the overall average relative errors for the 8 HGAC counties vary from 8.03% to 9.74% with an average value of 8.75%. Since these average relative errors are all less than 10%, they are acceptable.

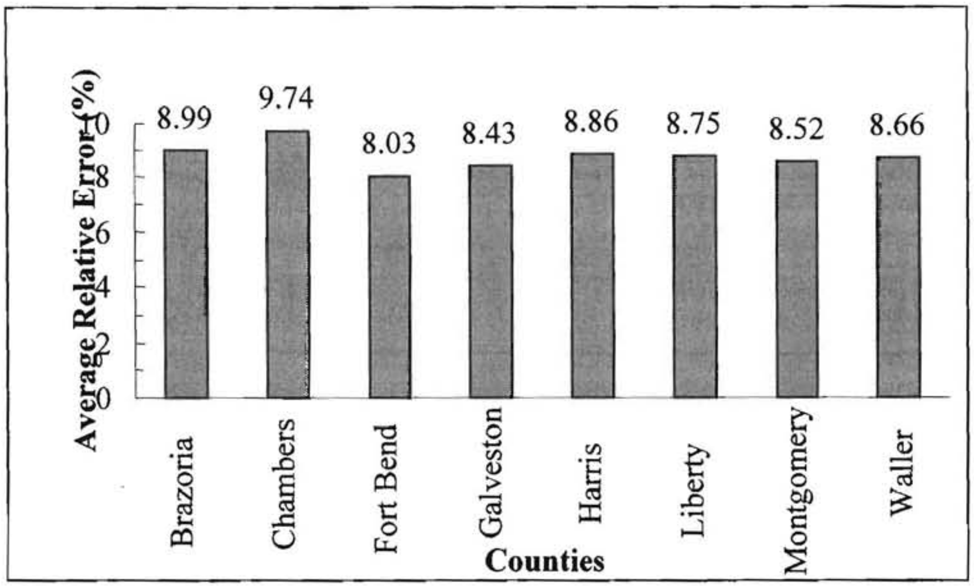


Figure 3-8 Average relative modeling errors for the 8 HGAC counties

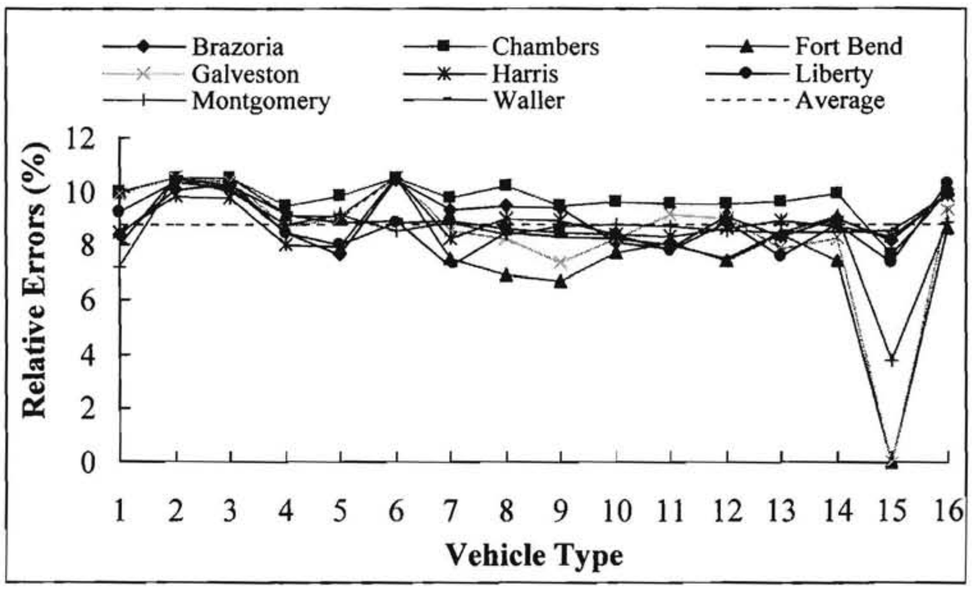
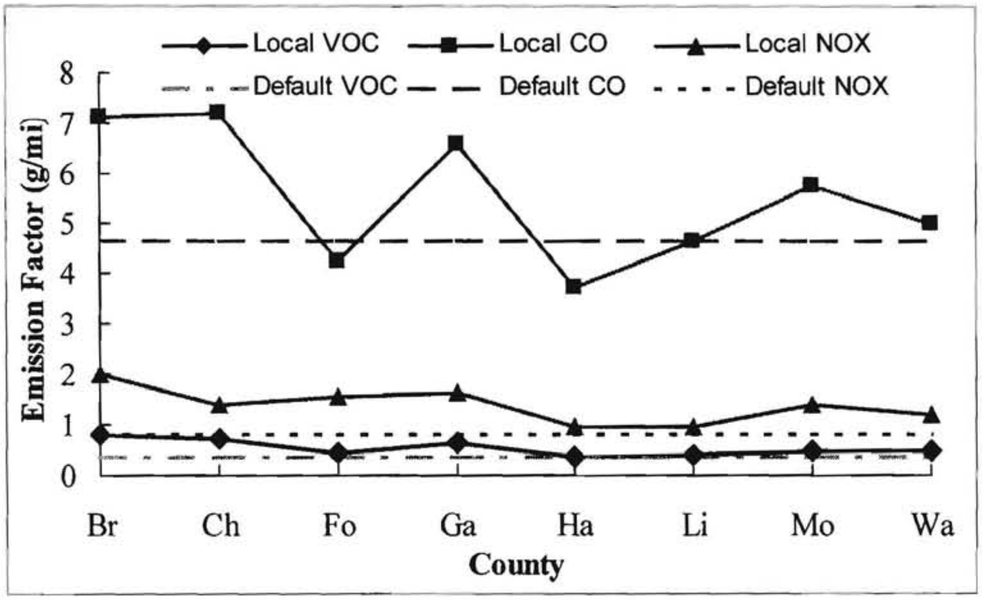


Figure 3-9 Average relative modeling errors for the 16 vehicle types among the 8 HGAC counties

In Figure 3-9, the average relative errors for 16 vehicle types among the 8 HGAC counties are plotted. The cords of vehicle type in Figure 3-9 are the same as listed in TABLE 3-1. The *x*-axis in this Figure is purely a categorical classification. Apparently, the average relative errors can vary with the vehicle types. Some vehicle types always have the smaller errors while some others have the relatively higher errors. Among the 16 vehicle types, vehicle type 2 (LDT1) has the highest average relative error (10.32%), while vehicle type 15 (HDBT) has the least average relative error (5.47%).

The calibrated models are also used for forecasting of vehicle age distribution for the 8 counties in HGAC for 2001. The forecasted results are input to MOBILE. Figure 3-10 presents the produced three emission factors (VOC, CO and NO_x) by the default age distributions and by the forecasted local ones from our program MOFAD in 2001 for the 8 counties. Also, the *x*-axis in this Figure is purely a categorical classification. From the results we can see that there are big differences between them, especially for CO. In most of the 8 HGAC counties, the emission factors (especially for CO) are larger than the ones that are generated by the default age distributions. The only exception is the county Liberty, where the local emission factors are almost the same as the default ones.



Br: Brazoria	Ch: Chambers
Fo: Fort Bend	Ga: Galveston
Ha: Harris	Li: Liberty
Mo: Montgomery	WA: Waller

Figure 3-10 Comparison of emission factors by default and forecasted vehicle age distributions for 8 HGAC counties in the year 2001

CHAPTER 4 SURVEY VEHICLE USERS BASED ON CLASSES FOR MILEAGE ACCUMULATION RATES BY VEHICLE TYPE

4.1 Mileage accumulation and its impact on the emission estimation of MOBILE

The mileage accumulation rate represents the total travel accumulated per vehicle of a given age and individual vehicle category. Mileage accumulation rates used in the MOBILE model are estimates of the mileage driven each year by each vehicle age group. The model allows the user to input mileage accumulation rates or utilize default values in the model. In generating the default values, the non-bus estimates were generated from data contained on two travel behavior surveys, namely the Department of Transportation's "1995 Nationwide Personal Transportation Survey" for light duty vehicles and the U.S. Bureau of the Census' 1992 Truck Inventory and Use Survey." Mileage data for school buses and transit buses were obtained from Bobit Publication's "School Bus Fleet Book Issue" and a data file provided by the Federal Transportation Administration. The data from these sources were evaluated on a line-by-line basis by eliminating any data records that were incomplete. Those records that were retained were entered into a database, sorted into gross vehicle weight rating categories, plotted graphically and the results were smoothed using linear and exponential best-fit curve analyses. The equations for the curves are listed in Appendix A. The curve-fit average annual mileage accumulation rates are reproduced in Appendix B. These age-specific average annual mileage accumulation rates represent that for the 1996 calendar year; in MOBILE6, these default rates will be applied to appropriate vehicle categories, and will be used for all past, present and future calendar years unless the model user provides their own data. Note that motorcycle mileage accumulation rates in MOBILE6 are from MOBILE5, which are listed in Appendix C.

Mileage accumulation rates are used in the MOBILE6 model for two purposes: (a) to weight the VMT (vehicles mileage of travel) by vehicle age and (b) to calculate the total mileage accumulation by vehicle age to be used to calculate the emission factors for each vehicle age taking into account the "deterioration" of air pollution control devices.

Generally, older cars have higher emission rates, but are driven fewer miles per year than new vehicles. Deterioration rates, used to calculate emission factors for each age group, are linear functions of cumulative mileage. Emission factors are calculated with a ZML (zero mile level) grams per mile emission rate, plus a DET (deterioration rate factor) in grams per mile per 1000 miles of accumulated travel.

A typical ZML for CO from a 20-year-old 1980 model LDGV's is 6.0 g/mile, with a typical deterioration rate of 0.07 g/mile per 1000 miles. This means that the CO emission rate is 6.0 g/mile when the vehicle is new, but 20.0 g/mile when the vehicle has accumulated 200,000 miles. If the average 20-year old LDGV only accumulates 125,000 miles, then the CO emission factor would be 25% less (i.e. 15 g/mile vs. 20 g/mile).

The vehicle mileage accumulation rate has an important impact on the final emission factors (HC, CO and NOX). Figure 4-1 and 4-2 show the plots of the change of emission factors with the percentage change of vehicle mileage accumulation rate for vehicle type LDGV and HDGV, which were derived from MOBILE5a. From the two Figures we can see that the increase of the percentage of vehicle mileage accumulation rate will increase the values of emission factors. The percentage changes of emission factors increase almost linearly with the percentage changes of vehicle mileage accumulation. For vehicle type LDGV, HC has the highest slop while NO_x has the lowest one. For vehicle type HDGV, CO has the highest slop while NO_x has the lowest one. Therefore, the proper estimation of vehicle accumulation rate is very important to the accurate estimation of vehicle emission factors.

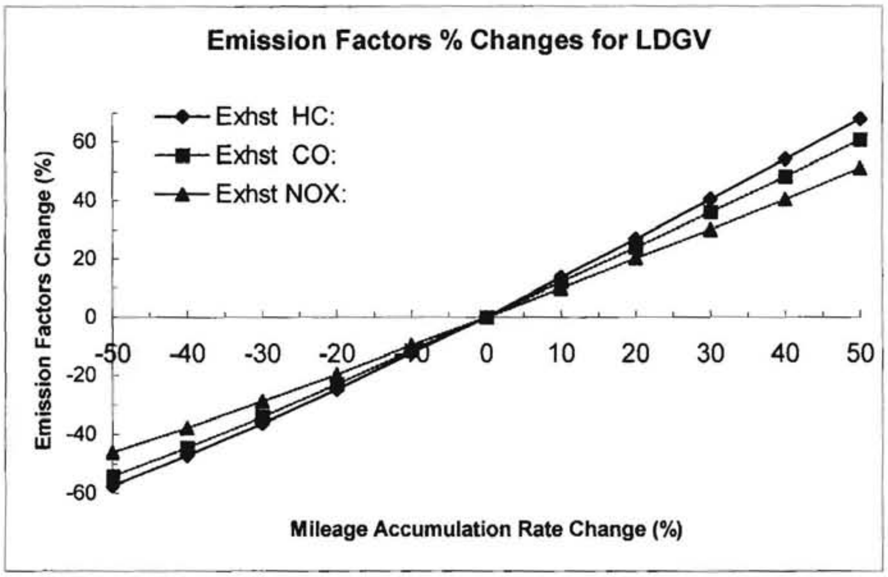


Figure 4-1 Percentage Changes of Emission Factors with Percentage Changes of Mileage Accumulation Rate for LDGV

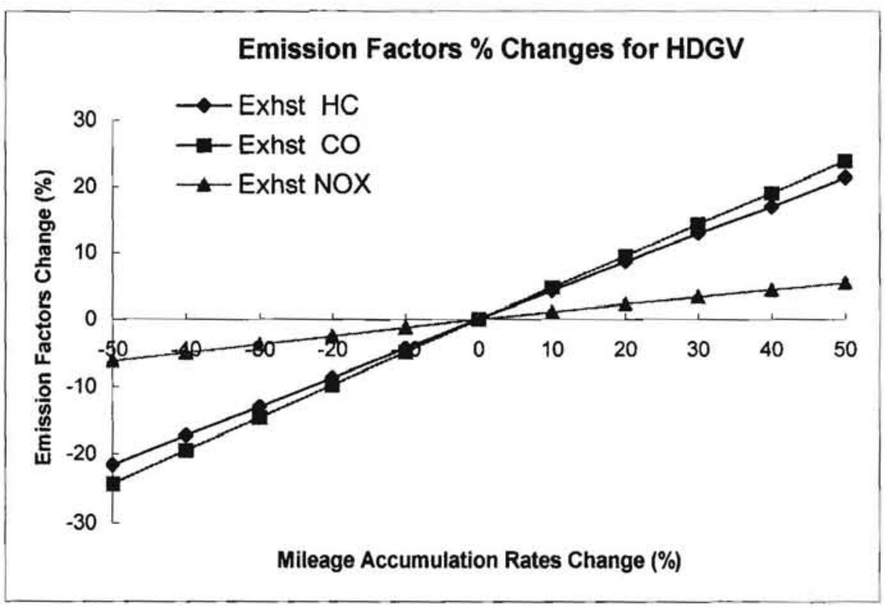


Figure 4-2 Percentage Changes of Emission Factors with Percentage Changes of Mileage Accumulation Rate for HDGV

Since the default values are based on the national-wide estimation, it's better to get the mileage accumulation rates on the basis of locality-specific data as suggested by MOBILE6.

4.2 Survey process and data collection of vehicle mileage

To test and validate the models, extensive efforts were made to collect vehicle mileage accumulation data in the Houston area and El Paso area.

The purpose of this survey is to investigate selected vehicle users based on the vehicle classes and vehicle ages regarding the annual total mileage traveled. The survey results will be used for building the site-specific model for estimating vehicle mileage accumulation rates in the corresponding local area.

A survey instrument was designed as illustrated in Appendix D. The vehicle types surveyed include the car, van, truck, etc. The vehicle make year, model and vehicle weight are also surveyed. More importantly, the number of miles for the vehicle driven in year 2000 and the total mileage on the odometer are recorded. Simultaneously, the background information such as the vehicle owners' age group, ethnic group, sex, number of household members, average household income, residential area, etc., are collected.

Four graduate students/research assistants (in Houston area) and two research assistants (in El Paso area) were assigned to conduct the survey in different locations such as Department of Public Safety, inspection and maintenance stores, oil stations, etc. The survey period lasts for four months starting from the beginning of February 2001.

Until the moment when this memorandum is prepared, a total of 902 survey forms have been returned (805 in Houston area and 97 in El Paso area), with about 1216 vehicles (1076 in Houston area and 140 in El Paso area) were surveyed.

4.3 Algorithm for Correcting Vehicle Mileage Accumulation

Normally, the real mileage accumulation (MA) is not surveyed in the same vehicle types as what is required by MOBILE. For example in our survey in Houston, vehicles were divided into four types: Car, Suv, Van and Truck, while in MOBILE6 totally 28 vehicle types are needed. So one of the important things is to convert this kind of vehicle types into MOBILE vehicle types. With the help of the existing national default value of MA, the estimated MA for all the 28 vehicle types can be estimated by some kind of correcting process. Then, the initial correcting factors for all vehicle types and vehicle ages can be obtained. By taking the average of all those correcting factors, the final correcting factor for the whole MA in the particular local area can be calculated. Therefore, by applying the final correcting factor to the national-wide default MA values, the local MA values can be estimated. Figure 4-3 illustrates the whole modeling process.

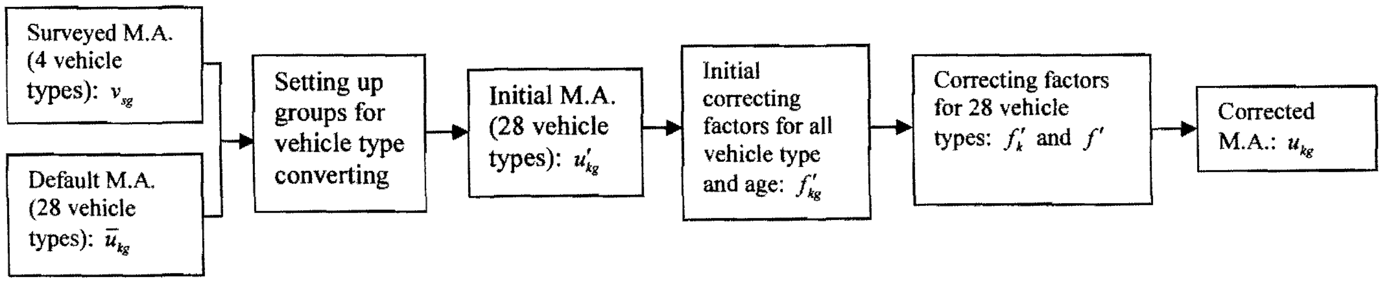


Figure 4-3 Diagram of the modeling process

Let u_{kg} be the value of vehicle mileage accumulation rate with vehicle type k and age g, where, k is the vehicle type required by MOBILE6, $k = 1, 2, ..., n_k$. n_k is the total vehicle type required by MOBILE6; g is the vehicle age, $g = 1, 2, ..., n_g$; n_g is the total vehicle age required by MOBILE6; s is the surveyed vehicle type, $s = 1, 2, ..., n_s$; n_s is the total surveyed vehicle type (In our survey, $n_s = 4$. $s = 1,2,3,4$ represents Car, Suv, Van and Truck).

Now let's set up the groups of converting vehicle types for survey to vehicle types for MOBILE6. Suppose s_p^i is the $i^{\text{-th}}$ vehicle type for survey in group p; m_p^i is the $i^{\text{-th}}$ vehicle type for MOBILE6 in group p; p is the group number (p=1, 2, ...P), P is the total number of groups, then the corresponding groups can be formed as listed in TABLE 4-1.

TABLE 4-1 Groups setting for converting vehicle types for survey to that for MOBILE6

Group number	Vehicle type for MOBILE6	Vehicle type for survey
1	$m_1^1, m_1^2, ..., m_1^{n_{m1}}$	$s_1^1, s_1^2, ..., s_1^{n_{s1}}$
2	$m_2^1, m_2^2, ..., m_2^{n_{m2}}$	$s_2^1, s_2^2, ..., s_2^{n_{s2}}$
...	...	...
P	$m_P^1, m_P^2, ..., m_P^{n_{mP}}$	$s_P^1, s_P^2, ..., s_P^{n_{sP}}$

In the above table, n_{sp} is the total number of vehicle types for survey in the $p^{\text{-th}}$ group; n_{mp} is the total number of vehicle types for MOBILE6 in the $p^{\text{-th}}$ group. $m_1^1, m_1^2, ..., m_1^{n_{m1}}$, $m_2^1, m_2^2, ..., m_2^{n_{m2}}$, ... $m_P^1, m_P^2, ..., m_P^{n_{mP}}$ should cover all the 28 vehicle types for MOBILE6. $s_1^1, s_1^2, ..., s_1^{n_{s1}}$, $s_2^1, s_2^2, ..., s_2^{n_{s2}}$, ... $s_P^1, s_P^2, ..., s_P^{n_{sP}}$ come from the vehicle types for survey.

So the initial mileage accumulation for 28 vehicle types can be calculated according to the following formula:

$$u'_{m_p^i,g} = \begin{cases} \bar{u}_{r_p^i,g} + \underset{j=1,2,...,n_{sp}}{average}\{v_{s_p^j,g}\} - \underset{j=1,2,...,n_{mp}}{average}\{\bar{u}_{m_p^j,g}\} & \forall \text{not all } v_{s_p^j,g} = 0, (j = 1,2,...,n_{sp}) \\ 0 & \forall \text{ all } v_{s_p^j,g} = 0,, (j = 1,2,...,n_{sp}) \end{cases}$$

$$\forall i = 1, 2, ..., n_{mp};\ p = 1, 2, ..., P \qquad (4\text{-}1)$$

In this formula, $\bar{u}_{r_p^i,g}$ is the default value of vehicle mileage accumulation rate with vehicle type r_p^i and age g; $u'_{m_p^i,g}$ is the initial corrected mileage accumulation rate for vehicle type m_p^i and age g; v_{sg} is the surveyed vehicle mileage accumulation rate for vehicle type s and age g. The term *average* here means only average those who have the value not equal to 0.

Initial correcting factors for vehicle type *k* and age *g* can be gotten by the following formula:

$$f'_{kg} = \frac{u'_{kg}}{u_{kg}}, \quad \forall u'_{kg} > 0 \qquad (4\text{-}2)$$

where, f'_{kg} is the initial correcting factor for vehicle type *k* and age *g*.

So the initial correcting factor for vehicle type k is:

$$f'_k = \underset{g}{average}\{f'_{kg}\}, \quad \forall f'_{kg} > 0 \qquad (4\text{-}3)$$

where, f'_k is the initial correcting factor for vehicle type *k*.

By averaging the initial correcting factors for all vehicle types, the initial total correcting factors can be calculated as:

$$f' = \underset{k}{average}\{f'_k\}, \quad \forall f'_k > 0 \qquad (4\text{-}4)$$

where, f' is the initial total correcting factors.

By combining the results from (4-3) and (4-4), we can get the correcting factors for all vehicle types as:

$$f_k = \begin{cases} f'_k & \text{if } f'_k > 0 \\ f' & \text{if } f'_k > 0 \end{cases} \qquad (4\text{-}5)$$

f_k is the correcting factor for vehicle type *k*.

After getting the finial-correcting factor for each vehicle type, the value of vehicle mileage accumulation rate with vehicle type *k* and age *g* can be estimated as:

$$u_{kg} = f_k \cdot \bar{u}_{kg}, \quad \forall g = 1, 2, ..., n_g \quad k = 1, 2, ..., n_k \qquad (4\text{-}6)$$

Application to the survey analysis of mileage accumulation in Houston

For the application of the real survey in Houston, four vehicle types were surveyed: Car, Suv, Van and Truck.

According to the requirement by MOBIILE6, a total of 28 vehicle types are needed. So after the surveyed data were obtained, the four vehicle types for survey were converted to the 28 MOBILE6 vehicle types. Finally, a total of 5 groups were set up as shown in TABLE 4-2:

TABLE 4-2 Groups setting for converting vehicle types for survey to that for MOBILE6 in Houston area

Groups	Vehicle types in MOBILE6	Vehicle types in survey
1	1, 14	Car
2	2	Suv
3	3 ~ 5, 15, 28	Suv, Van
4	6 ~ 11, 16, 17 ~ 21	Truck
5	12, 13, 22 ~ 27	None

By applying the formulas in mentioned above, the mileage accumulation rate in Houston area can be estimated. TABLE 4-3 is the result of the correcting factors for different vehicle types.

TABLE 4-3 Correcting factors of Mileage accumulation for Houston area

VT	1	2	3	4	5	6	7
CF	1.850949	1.426011	1.312714	1.29849	1.29849	1.991038	1.991038
VT	8	9	10	11	12	13	14
CF	2.330758	2.330758	2.330758	2.330758	1.845634	1.845634	1.850949
VT	15	16	17	18	19	20	21
CF	1.350896	2.156872	2.725611	1.690655	1.690655	1.910357	1.910357
VT	22	23	24	25	26	27	28
CF	1.845634	1.845634	1.845634	1.845634	1.845634	1.845634	1.134574

CF: correcting factor

VT: vehicle type

Figure 4-4 shows the national-wide mileage accumulation rate, while Figure 4-5 shows the corrected local mileage accumulation rate for Houston area.

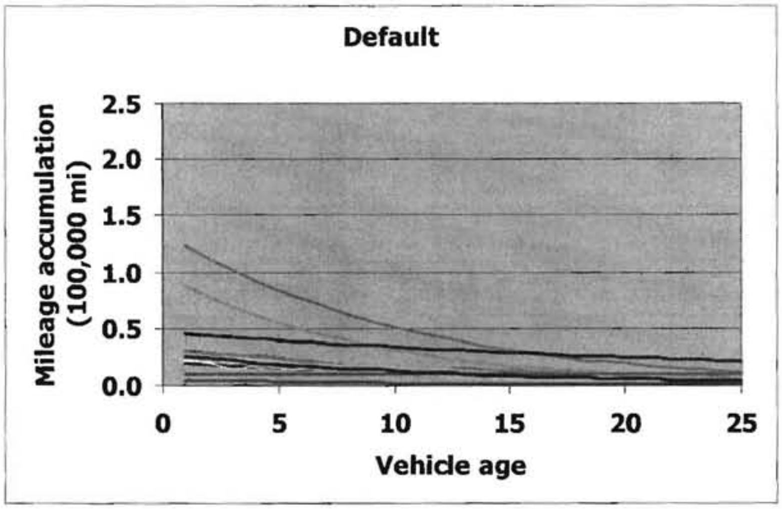


Figure 4-4 Default national-wide mileage accumulation rate

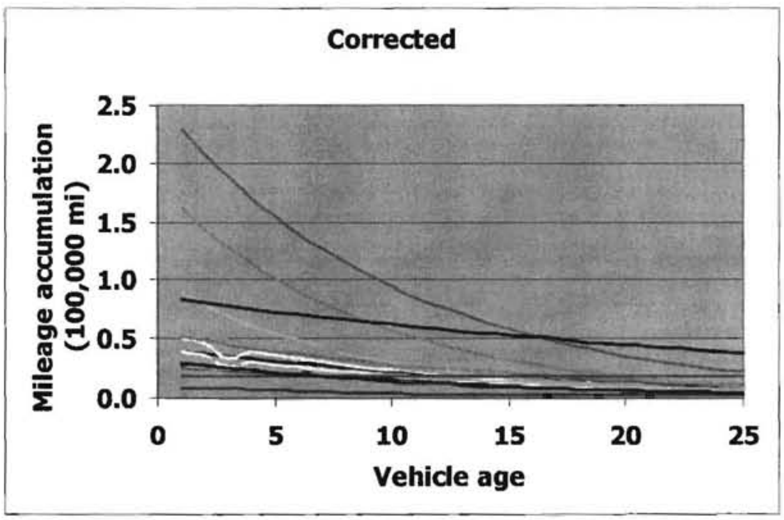


Figure 4-5 Corrected local mileage accumulation rate for Houston area

From the above two Figures we can see that the corrected local mileage accumulation rate in Houston area is higher than the national-wide default values. The average correcting factors is 1.85. That means in Houston, the vehicle mileage accumulation rate is 1.85 times of the default one in an average.

CHAPTER 5 COLLECT INFORMATION ON VMT MIX ESTIMATION

5.1 Requirements in MOBILE5 &6 on VMT & mix

5.1.1 Definition of VMT and VMT mix

VMT (vehicle miles traveled or vehicle miles of travel) is a unit to measure vehicle travel made by a vehicle, such as an automobile, van, pickup truck, or motorcycle. Each mile traveled is counted as one vehicle mile regardless of the number of persons in the vehicle.

The vehicle mile traveled (VMT) mix specifies the fraction of total highway VMT that is accumulated by each of the different vehicle types.

VMT & mix are important travel indexes in the emission estimation model MOBILE. Emissions analysis is very sensitive to VMT mix. For example, for MOBILE5 at high temperature, a 2.8% change in HDGV mix causes about a 10% change in the CO rate; at high temperature, a 4.8% change in HDGV mix leads to about a 10% shift in the VOC rate.

5.1.2 Requirement in MOBILE5 on VMT mix

The VMT mix is used in MOBILE5 only to calculate the composite (all vehicle, or fleetwide) emission factor for a given scenario on the basis of the eight vehicle class-specific emission factors.

In MOBIEL5, the users can choose between the use of the MOBILE5 national VMT mix (VMFLAG=1), the input of one alternate VMT mix (in One-time Data) for use in all scenarios of a given MOBILE5 run (VMFLAG=3), or the input of a different alternate VMT mix (in Scenario data) for each scenario (VMFLAG=2).

In MOBILE5, VMT mix is the fraction of total highway VMT that is accumulated by each of the 8 vehicle types. Each VMT mix supplied as input must consist of a set of eight fractional values, representing the fraction of total highway VMT accumulated by each of the eight vehicle types. All values must be between zero and one, and the eight values must sum to 1.0 (MOBILE5 produces an error message and does not execute the run if these constrains are not meet).

The format of the VMT mix record(s) is **8F4.3**. The values correspond to the eight vehicle types in this order: LDGV, LDGT1, LDGT2, HDGV, LDDV, LDDT, HDDV, and MC. An example of a VMT mix record specifying that 65% of all VMT is accumulated by LDGVs and that each of the other seven vehicle types accounts for 5% of all VMT is shown below. Note that this format does not include leading zeros or blanks between the individual values.

.650.050.050.050.050.050.050.050

5.1.3 New version of MOBILE and changes on VMT and VMT mix

The present version of MOBILE used in Texas and other states is MOBILE5. However, the new version MOBILE6 will be fully released soon. In the summer of 2001, the trial version of MOBILE6 has already been sent to all the states' DOT. Therefore, in estimating the VMT mix, it is practical to consider all the requirements in the new version (MOBILE6), instead of only in the old version (MOBILE5) as required in the project proposal.

In MOBILE5 environment, VMT information was used outside of the MOBILE5. VMT information is not needed to run the model. VMT was used to estimate emission inventory. In MOBILE6 environment, local VMT data or the national default is required when to model local conditions.

In MOBLIE6, there are a lot of changes on VMT related functions, which are different from that in MOBILE5. TABLE 5-1 lists the names and functions of VMT related commands and their corresponding functions. TABLE 5-2 lists the difference of the VMT related commands and functions between MOBILE5 and MOBILE6.

TABLE 5-1 Name and functions of VMT related Commands in MOBILE6

Command and Name	Command and Function
VMT FRACTIONS	Allows user to apply alternate VMT factions by each of 16 combined vehicle types
VMT BY FACILITY	Allows user to supply alternate VMT distributions by facility type that override M6 defaults for each scenario. 4 Road Types * 24 Hours = 96 VMT Fractions (freeway, arterial, local and ramp)*(6 AM ~5 AM)
VMT BY HOUR	Allows user to apply alternate hourly distributions of VMT that override M6 defaults for each scenario. 24 Hours; all facility types (24 values must added to 1)
SPEED VMT	Allows user to enter VMT distribution across 14 preselected speed ranges for each of the 24 hours of the day for each scenario.

TABLE 5-2 VMT related MOBILE6 commands and the difference between MOBILE5 and MOBILE6

M6 Command	Difference Between M5 and M6
VMT FRACTIONS	In M5, only 8 VMT fractions instead of the 28 fractions needed for M6.
VMT BY FACILITY	New features, no precedent in M5.
VMT BY HOUR	New features, no precedent in M5.
SPEED VMT	In M5, a single average speed could be specified for all or for 8 individual vehicle types. M6 requires speed distributions for each hour.

From TABLE 5-1 & 5-2, we can see that there are many new features in MOBILE6. The format and part of the default VMT related variables in MOBILE6 are listed in Appendix E, F, G, and H.

5.1.4 Converting of MOBILE5 vehicle classes into MOBILE6 vehicle classes

For MOBILE5, the emission factor models require the VMT split by eight vehicle classes. The vehicle classes are based on the size and weight of vehicles as well as the type of fuel used. The eight vehicle classes are: light-duty gasoline vehicle (LDGV), light-duty gasoline truck type 1 (LDGT1), light-duty gasoline truck type 2 (LDGV2), heavy duty gasoline vehicle (HDGV), light duty diesel vehicle (LDDV), light duty diesel truck (LDDT), heavy duty diesel vehicle (HDDV), and motorcycle (MC).

So MOBILE5 accounted for only eight vehicle classes, but MOBILE6 has greatly expanded the number of individual vehicle classes to 28 as listed in Appendix I. In some contexts, MOBILE6 input is provided in terms of 16 combined vehicle classes as listed in Appendix J. The difference between the 28 vehicle classes and the 16 vehicle classes is that the 28 vehicle classes divide vehicle types also according to whether the vehicle use gasoline or diesel, while the 16 vehicle classes do not have this kind of division. In some ceases, aggregated user-supplied MOBILE5data will be used for each of the vehicle classes in MOBILE6. In other cases, such as distributions, the MOBILE5 values must be split by vehicle class for use in MOBILE6.

Because of the unequal growth that occurs in various vehicle classes, the VMT distribution by vehicle class becomes a function of calendar year. MOBILE5 allows the user to enter eight VMT values, corresponding to the eight vehicle classes represented in the MOBILE5 output. MOBILE6 allows the user to enter 16 VMT values by combined vehicle class.

Whereas MOBILE5 allowed the user to enter separate VMT for diesel-and gasoline-fueled vehicle classes, MOBILE6 requires that VMT by vehicle class be supplied in terms of the 16 combined gasoline and diesel-fuel categories. In MOBILE6, the VMT by vehicle class is split internally – accounting for the diesel sales fractions and annual mileage accumulation rates – in order to ensure that all of the fleet descriptions and activity values are consistent with one another. The first step in converting MOBILE5 to MOBILE6 VMT fractions is to combine the VMT fractions for gasoline and diesel categories into five composite gasoline/diesel groupings:

- LDV Group = LDGV + LDDV
- LDT Group 1 = LDGT1 + LDDT
- LDT Group 2 = LDGT2
- HDV Group = HDGV + HDDV
- MC Group = MC

The sum of the VMT fractions from the five groups should still equal 1. These fractions are then adjusted using factors calculated from the default distributions of VMT from MOBILE6 for the appropriate calendar year. When the adjustments are completed properly, the sum of the 16 MOBILE6 VMT fractions will be 1.

TABLE 5-3 Converting MOBILE5 vehicle classes into MOBILE6 vehicle classes

16 Combine MOBILE6 Vehicle Classes	VMT Fraction Calculation
LDV	LDV Group
LDT1	LDT Group 1 * A
LDT2	LDT Group 1 * B
LDT3	LDT Group 2 * C
LDT4	LDT Group 2 * D
HDV2b	HDV Group * E
HDV3	HDV Group * F
HDV4	HDV Group * G
HDV5	HDV Group * H
HDV6	HDV Group * I
HDV7	HDV Group * J
HDV8a	HDV Group * K
HDV8b	HDV Group * L
HDBS	HDV Group * M
HDBT	HDV Group * N
MC	MC Group

The values A through N are taken for the appropriate calendar year. They are calculated from the default MOBILE6 VMT fractions for that calendar year. The terms A and B, C and D, and E through N should each add up to 1. The resulting 16 VMT fractions are supplied to MOBILE6 using the VMT FRACTIONS command.

5.2 Information on VMT mix estimation

5.2.1 Sources of Information Collected

Information collected includes the reports from US EPA (United States Environmental Protection Agency), papers and reports from relevant Journals, conference proceedings and government websites. A survey through e-mail was conducted to obtain more information on what kind of methodologies are using by the other states.

5.2.1.1 EPA documents

EPA provides a guidance to assist users of the MOBILE6 highway vehicle emission factor model in the preparation of traffic activity inputs. It offers the recommendations on how to develop national wide distributions of vehicle miles traveled (VMT) by time of day, facility type and average speed.

5.2.1.2 Other literatures

Other literatures include the reports from other government agencies, papers on Journals, conference proceedings, etc. From these literatures the information of VMT estimation in the following states are obtained: Oregon, California, Florida, Idaho, Washington and Wisconsin.

5.2.1.3 Survey by E-mail

To better obtaining the current practice of the VMT & mix estimation approaches in the other states and agencies, a survey by e-mail was conducted. The persons surveyed are those who attended the *TRB Technical Meeting and Workshop - Impacts of Recent Transportation Air Quality Modeling Improvements: Emphasis on MOBILE6 and EMFAC2000*, held on June 3-5, 2001 at Irvine California. That workshop was sponsored by the Transportation Research Board's Transportation/Air Quality Committee (A1F03), and addressed the new EPA and California mobile source emission factor models and their use in the transportation community. It attracted national-wide persons who apply, develop, or use the result of mobile source emissions models, or are involved in regional transportation and air quality planning. In this e-mail survey, 4 questions were designed as listed in the following:

1. What's the current approach they are using now in estimating VMT mix for MOBILE5 input?
2. What kinds of approaches they are going to use when MOBILE6 is released?
3. Do they have any project/planning in setting up new algorithm(s) in estimating the VMT related parameters for MOBILE6?
4. Any other information on this matter they may provide.

The e-mail was sent out on Oct. 10, 2001 and Oct. 16, 2001, and the replies were received soon. Totally 133 persons were surveyed with 15 responded. For some important valuable replies, the follow-up e-mails were sent to the relevant persons to get more specific detailed information. Appendix K lists the name of persons and agencies/companies that responded the survey through e-mail. The responded ones include those from FHWA, different states (Colorado, Georgia, Florida, New York State, California); some regional councils and national laboratories planning (North Center TX Council of Governments, Wasatch Front Regional Council; Lawrence Berkeley National Laboratory); and some companies (Cambridge Systematics, Inc., Stan COG, ENVIRON International Corp).

5.2.2 Current Methodologies on VMT mix estimation

According to the information collected, there are several methodologies on VMT mix estimation. EPA gives a guidance involving the development and application of methods to estimate detailed national wide VMT related variables. The results serve as the national default values. It uses the traffic count data and the travel demand model to estimate the VMT related variables for five selected urban areas and estimated national time-of-day and speed distributions of urban VMT derived by extrapolation of results for four of the five selected urban areas.

Bhat and Nair (2000) formulate and estimate a fractional split model that determines the VMT mix ratio as a function of several informative variables, including physical attributes of links, the operating characteristics of links, aggregate area type characterizations of the traffic survey zone in which the link lies, and the land use attributes of the zone. This model is currently being embedded within a GIS platform to predict the VMT mix on all links of the Dallas Fort Worth metropolitan region.

In develop the methodology used for the Houston-Galveston Nonttainment Counties gridded mobile source emissions inventories for FY 2007, the 24-hour traffic assignment are used in the analysis to obtain the VMT mix, which can be used as the input of MOBILE5.

For the practices in the other states, some use the MOBILE defaults, some use the HPMS traffic count data, some estimate according to the percentage of vehicles registered within the state, some use the fuel consumption based finance method, the policy procedure, etc.

5.2.3 Guidance by EPA

The EPA report *EPA420-P-99-006* (entitled as "*Development of Methodology for Estimating VMT Weighting by Facility Type*") summarizes the results of work conducted for the involving the development and application of methods to estimate certain aspects of on-road vehicle activity. In particular, this work was designed to estimate VMT on different classes of roadways by time of day and speed, and to investigate other vehicle activity characteristics.

Two methods are developed for development of VMT distributions by facility class and speed. The first one works directly from vehicle count data. The second requires processing of regional travel demand model outputs. These two methods use data, which are most likely to be available to local and state agencies, and neither method relies on databases of observed speeds. In these methods, speeds are estimated using facility characteristics and level of traffic congestion. Actual speed data can and should address the efforts of local characteristics that influence driver behavior and speeds, such as roadway lay-out (curves, hills, visibility, and distances between intersections) and signal coordination.

5.2.3.1 Method 1 – Working with traffic count data

It is relatively straightforward to estimate total VMT from vehicle count databases, although as noted later in this section, there are a number of ways in which biases can enter the calculation. Most regions use similar methods to estimate total VMT by functional class. Area type is available and used in many areas. The VMT estimation procedure is:

1. Calculate the sum of counts in each functional class (by area type if possible)
2. Determine the sample size in each functional class (the number of counters)
3. Determine the average volume by dividing total count by sample size
4. Obtain miles of facility in each class (available from DOT or GIS databases)
5. Calculate VMT by class as average volume multiplied by the number of miles of facility

Several key issues are immediately apparent if the VMT estimates are intended to be used in emission calculations. First, the classification of roadways must be matched to the four functional classes used in MOBILE6. Thus data for major and minor arterials and collectors may nee to be merged into the MOBILE "arterial" class. The MOBILE "freeway" class might include data reported for "interstate" and "expressway" classes as well.

Frequently, counts will not be available for ramps. However, in the absence of actual count data, ramp VMT can be estimated as a fraction of freeway VMT, possibly by area type, based upon VMT estimates from a regional travel demand model. Rapid acceleration events on on-ramps can be significant contributions to total emissions, so realistic estimation of ramp VMT is important.

Common problems with count data include biases arising from the selection of roadways that are sampled or from idiosyncrasies of the counting device. For example, area using road tube counters may have undercounts on multilane facilities, especially during peak traffic periods. These result from two cars crossing the tube at the same time. (On freeways, this problem can be corrected by switching to ramp on/off counts). Also, sometimes data are combined without correcting for underlying differences in the collection method.

Another problem that can occur is having too little count data for a particular facility type (or facility/area type combination). In these cases, one can combine two similar classes or extrapolate data from another, similar class. The overall result, however, is an increase in the associated uncertainty of these estimates.

Addressing the speed dependence of emission rates in MOBILE6 requires that VMT for arterials and freeways be further disaggregated by either speed or LOS. Since characterizing traffic behavior using speed estimates provides better precision and sensitivity than would the relatively coarse LOS classes, they focus on deriving speed distributions rather than LOS.

There are generally two methods available for estimating speeds. The first uses procedures from the Highway Capacity Manual (HCM). The second uses volume/capacity relationships expressed in the Bureau of Public Roads (BPR) curves (or modified BPR curves). The accuracy of both methods falls substantially when applied to arterials, due to the complications caused by controls (signalization).

5.2.3.2 Method 2 – Working with travel demand models

Travel demand models (TDMs) provide another source of estimates of vehicle activity by function class, time of day, and speed. The modeling process assigns trips (defined by an origin and a destination within the roadway network) to roadway segments. To the extent that model inputs capture all trips within a region, TDMs provide comprehensive regional VMT estimates and avoid the uncertainties associated with extrapolation of traffic volumes from count data at selected locations. They provide less detail, however, regarding volume fluctuation by time of day, vehicle type, and speeds than can be obtained from measurements, except to the extent that available data are used to provide such detail in model output.

Because of the difficulties that can arise in achieving both accurate assignments and accurate speeds in TDMs, it may be preferable to calculate speed externally. Post-processing software is available that uses HCM procedures and BPR curves to calculate hourly congested speeds and produce summaries of regional VMT distributions. The general speed post-processing algorithm operates on hourly link volumes (even if the TDM outputs are multiple hour or daily assignments) as follows:

1. Distribute link-level volumes by hour of day using user-provided or default temporal distributions (usually from count data sets).
2. Calculate hourly VMT by multiplying link distance by hourly volume.
3. Calculate the v/c ratio using either link-specific capacities or lookup tables.
4. Apply the BPR curve, using link-specific free flow speeds or lookup tables, to arrive at hourly congested speeds.

There are several areas in which TDMs may fail to provide comprehensive VMT estimates. These relate to both the preparation of inputs used in modeling and in the level of detail incorporated in trip and network inputs.

Information on travel by vehicle class is typically not available directly in TDMs. The "trip table" inputs that identify the number of trips for each purpose (e.g., home-based work trips) between each pair of spatially defined zones in the model, and this information can be used if data exist on fleet composition for different trip purposes. However, as TDMs focus primarily on travel by individuals rather than goods movement, this approach provides little value for identifying medium and heavy truck activity. Goods movement models are under development, but at present, simple adjustment factors are more commonly used to estimate incremental freight-related VMT to be added to modeled volumes. Time of day, day of week, and seasonal variation of freight travel should be evaluated separately, based on local data.

5.2.3.3 Development of national default VMT and speed distributions

Vehicle activity estimates derived from both traffic counts and travel demand models were used to develop distributions of VMT by functional class, speed, and time of day for five urban areas. The data were merged to the four functional classes in MOBILE6: freeways; arterials; local roads; and ramps. The five example urban areas were: Chicago, IL; Houston, TX; Charlotte, NC; Ada County ID (Boise region); and New York NY.

Results for Chicago, Houston, and Boise were obtained using travel demand model outputs and the Caltrans Direct Travel Impact Model (DTIM2). Results for Charlotte and New York were based on traffic count data and a FORTRAN program developed for this purpose. Both methods produce hourly speed estimates based on the level of congestion (ratio of volume to capacity), roadway type, and free flow speed. In addition to these five areas, VMT and speed statistics by functional class were also obtained for three additional cities from chase car data collected by EPA and CARB, (Sierra Research, 1997). These cities were: Baltimore, MD; Spokane WA; and Los Angeles CA.

To develop national default distributions, the area-specific results are extrapolated, using the assumption that the cities for which distributions are available can be used as surrogates or prototypes for other urban areas. The distributions for these eight areas, along with Highway Performance Monitoring System VMT data (HPMS, 1995), provided a basis for calculating a national default VMT weighting. Although the data from all eight cities are summarized, it was not possible to use data for all cities in developing national defaults because of insufficient data to determine both functional class and temporal dependence of volume and speed.

In order to develop estimates of national class, time of day, and speed, the characteristics identifies for the four cities (Chicago, IL; Houston, TX; Charlotte, NC; and New York NY) for which hourly speeds could be obtained were assigned to urban area throughout the country. Urbanized area 1995 daily VMT by functional class were obtained from HPMS (1995). A "best-fit" procedure was used to select which of the four cities' characteristic temporal and speed profiles would be assigned to each urban area.

HPMS interstate and freeway/expressway classes were combined, as were arterial and collector classes to provide VMT values corresponding to the MOBILE6 functional classes. Ramp VMT was assumed to be 8.7 percent of freeway VMT. Fractional VMT for the four functional classes was then calculated for each urban area.

The temporal variation and speed distributions of VMT by functional class for either Chicago, Houston, Charlotte, or New York were assigned to each HPMS urban area based on which had a functional class VMT distribution that was most similar. Similarity was determined by a "distance" calculation based on the sum of squares of the differences between fractional VMT for each functional class. The sum of HPMS functional class VMT values for all urban areas assigned to a particular prototype city was determined and was used as the prototype city's weight in calculating national VMT distributions. The following equation was used to calculate "distances" between the prototype cities and HPMS urban areas:

"Distance" from HPMS urban area to prototype city

$=((\text{fracVMT\_freeway}_{HPMS})-(\text{fracVMT\_freeway}_{proto\text{-}hpms}))^2$

$+((\text{fracVMT\_art/col}_{HPMS})-(\text{fracVMT\_art/col}_{proto\text{-}hpms}))^2$

$+((\text{fracVMT\_local}_{HPMS})-(\text{fracVMT\_local}_{proto\text{-}hpms}))^2$

$+((\text{fracVMT\_ramp}_{HPMS})-(\text{fracVMT\_ramp}_{proto\text{-}hpms}))^2$

The assignment of HPMS functional class VMT to the four prototype cities is shown in TABLE 5-4. Approximately, 50 percent of total VMT occurs on arterial and collectors, 34 percent on freeways, and 13 percent on local roads. Ramp VMT is estimated as a percentage of freeway VMT. HPMS data include VMT accumulated by all vehicle types. National summary data from HPMS (HPMS, 1995) show approximately 7.8 percent of urban interstate VMT to be accumulated by buses, combination trucks, and single unit 6-tire or more trucks, and approximately 4.1 percent of other urban VMT to be attributable to these classes.

TABLE 5-4 Total HPMS VMT assigned to each prototype city (thousands)

	Freeways	Arterials & Collectors	Locals	Ramps	Total
Charlotte	87631	127404	72689	7623	295348
Chicago	291757	749362	165148	25382	1231650
Houston	395167	358956	107253	34379	895756
New York	504841	626451	142653	43921	1317866
Total	1279396	1862173	487743	111307	3740620

For emission calculations using MOBILE6, both the freeway and arterial/collector functional classes are speed dependent, and default values for temporal distribution of travel may be needed to estimate congestion and speeds in urban areas. In addition, distribution of vehicle activity by time of day for all facility types is obviously needed for the preparation of hourly emission estimates, and also if diurnal temperature variations are to be used in estimating emissions. TABLE 5-5 shows the hourly distributions, using the assigned HPMS VMT values as a weighted average of the four prototype city distributions, using the assigned HPMS VMT values as weights. Since no hourly ramp data were available for any of the cities, it is reasonable to assume that hourly ramp distributions are similar to those for freeways. The distributions can be used in conjunction with the methods to estimate hourly VMT and speed distributions based on daily traffic volumes from either travel demand models or traffic count data. For national urban emissions estimation, the national VMT totals by facility type can be multiplied by the corresponding hourly fractions to obtain hourly VMT by facility type.

TABLE 5-5 Hourly distribution of national VMT by functional class

Hour	Freeways	Arterials & Collectors	Locals
1	0.0135	0.0091	0.0098
2	0.0112	0.0070	0.0076
3	0.0108	0.0064	0.0068
4	0.0108	0.0063	0.0066
5	0.0130	0.0079	0.0081
6	0.0227	0.0162	0.0159
7	0.0652	0.0523	0.0509
8	0.0744	0.0739	0.0733
9	0.0648	0.0655	0.0679
10	0.0566	0.0549	0.0548
11	0.0546	0.0540	0.0526
12	0.0567	0.0595	0.0577
13	0.0576	0.0631	0.0614
14	0.0557	0.0580	0.0573
15	0.0584	0.0608	0.0603
16	0.0594	0.0662	0.0653
17	0.0750	0.0790	0.0804
18	0.0666	0.0764	0.0782
19	0.0432	0.0541	0.0542
20	0.0352	0.0411	0.0407
21	0.0296	0.0315	0.0313
22	0.0264	0.0263	0.0264
23	0.0216	0.0179	0.0187
24	0.0171	0.0126	0.0136

5.2.4 Fractional Split Model

Bhat and Nair (2000) proposes and implements a fractional split model that predicts the VMT mix on links as a function of the functional roadway classification of the link, the physical attributes of the link, the operating conditions on the link, and the attributes of the traffic analysis zone in which the link lies.

Several data sources are used in the analysis. These include: a) vehicle classification counts conducted in the Dallas-Fort Worth area by the Texas Department of Transportation's (TxDOT) Regional Planning Organization (R.P.O.) and the Division 10 of TxDOT, b) 1996 GIS-based road network file for the Dallas-Fort Worth area, c) Zonal level land use characteristics file of the Dallas-Fort Worth area, and d) 1996 GIS-based Dallas-Fort Worth zonal coverage file. The latter three data files were obtained from the North Central Texas Council of Governments (NCTCOG).

The model results can be applied in forecasting mode to determine the VMT mix in the six vehicle types: autos, PUVs, SUVs, trucks, buses, and motorcycles/two wheelers. The model-predicted VMT mix in the six vehicle types has to be converted into the eight-class EPA vehicle classification for input into the MOBILE5 emissions factor model. However, variations in VMT mix across different times of the day are not captured in the model. And seasonal variations in VMT mix are also not incorporated in the model. Since the fractional model is for getting VMT mix as the input of MOBILE5, it is not well ready for getting the VMT related inputs of MOBILE6.

5.2.5 HGAC practice: 24 hour assignment

The time-of-day VMT and speed estimates for the Houston-Galveston region were developed using a program called PREPIN2. PREPIN2 is one of a series of programs developed by TTI to facilitate the application of EPA's MOBILE5a Hybrid program in estimating mobile source emissions. The PREPIN2 program was developed for use in urban areas that do not have time-of-day assignments and speeds available for air quality analyses. The program inputs a 24-hour assignment and applies the needed seasonal adjustment factors. The time-of-day factors are applied to the seasonally adjusted 24-hour assignment results to estimate the directional time-of-day travel. The HGAC speed models are used to estimate the operational time-of-day speeds by direction on the links. Special intra-zonal links are defined and the VMT and speeds for intra-zonal trips are estimated. These VMT and speeds by link are subsequently input to a program called IMPSUMA for the application of MOBILE5a Hybrid emissions rates.

For the development of girded emissions, the HGAC 24-hour assignment was used as input to the PREPIN2 program. For a given application, 24 applications of PREPIN2 are run to estimate the directional VMT and speeds for each of the 24 one-hour time periods comprising the 24-hour period.

The primary output of PREPIN2 is a data set for the subject time period containing two records for each link. One record specifying the estimated time-of-day VMT and speed in the peak, or principal, direction and the second record specifying the estimated VMT and speed in the opposite direction. This data set is subsequently input to the IMPSUMA program, which applies the MOBILE5a Hybrid missions rates to estimate the mobile source emissions for each link. The program VMTSUM calculates the VMT by time period for input into IMPSUMA to incorporate the diurnal emissions into the appropriate time period. Finally, a program SUMALL combines the time-of-day emissions estimates to obtain 24-hour girded emissions.

5.2.6 Practices in other states

From the information collected, there appear to be several general approaches taken by other states in developing the VMT distribution:

1. MOBILE defaults are used. The "default" VMT distribution in MOBILE is not actually fixed, but is a function of the user-input registration (age) distribution and the MOBILE default mileage accumulation rates by vehicle type. Georgia and Massachusetts use this approach. California's approach is similar in that state-specific registration distribution data and mileage accumulation rates (from I/M data) are used to produce a VMT mix.

2. HPMS data are used to obtain light-duty vs. heavy-duty VMT percentages. EPA data (contained in the guidance document Use of Locality-Specific Transportation Data for the Development of Mobile Source Emission Inventories, and consistent with MOBILE defaults) are then used to allocate the HPMS data to MOBILE vehicle classes. Connecticut and Texas have taken this approach. Georgia has also explored the use of HPMS data and found that it gave them roughly five percent lower emissions compared to the use of MOBILE defaults. Maryland used "old state highway count" data to allocate light vs. heavy duty VMT.

3. State vehicle registration data are used to develop all categories; i.e., VMT is split according to the percentage of vehicles registered within the state. New York and Delaware indicated that they used this approach. They acknowledged that this does not reflect the fact that mileage accumulation rates between heavy-duty and light-duty vehicles may differ. The state analyzes the vehicle registration database to count the number of vehicles registered by MOBILE5 vehicle type (8 categories). This provides info for the vehicle age distribution data input to MOBILE5. Then they assume that the VMT in the state is proportional to the % of vehicles registered by vehicle type.

4. Other approaches such as the fuel consumption based Finance method, the policy procedure, and etc. are also be used in some of the other states.

Following are descriptions of the VMT estimation in some states including Colorado State, Oregon State and Wisconsin State.

5.2.6.1 Colorado Practice

Colorado has been using local VMT mix information that was collected (actual on-board counts) in Denver in the late in the late 1908's. Several small scale counting efforts during the 90's has confirmed that this late 80's information remains relatively representative of the distribution of VMT over the fleet. Over the next six months, this information will be updated with a new study that will take place in the major metropolitan areas of the state. They are doing "cluster counting" - a system of counting vehicles at intersections multiple times and a multiple locations within the intersection. This system was devised by their Department of Transportation for VMT counting needs. They believe it will be an appropriate methodology for the needs to update VMT by MOBILE6 model vehicle types. Until this new information is available, they will probably use the Mobile6 default VMT mix distributions.

5.2.6.2 Oregon practice

On July 2000, David Evans and Associates, Inc. (EDA) and Cambridge Systematics, Inc. (CS), consultants, evaluated the Oregon Department of Transportation's (ODOT's) existing procedures for estimating statewide VMT and to bring each of these procedures into closer alignment, with the possibility of identifying a single, effective method for estimating statewide VMT.

Three different statewide VMT estimation procedures have been developed and are utilized by ODOT for different purposes: Traffic data; Finance and Policy.

- Traffic Data procedure. The ODOT Transportation Data Section has two methods for estimating VMT based on traffic count data. The first method is the Highway Performance Monitoring System (HPMS) developed by the Federal Highway Administration (FHWA). The second method is based on the Mileage Control File (MCF) database, which provides VMT estimates for all highways on the State Highway System (SHS) as part of Oregon's Traffic Monitoring System (TMS) for Highways. ODOT did not use the MCF to estimate statewide VMT. The combination of the HPMA and MCF) methods used by ODOT were referenced as the "Traffic Data procedure".
- The ODOT Financial and Economic Analysis Section estimate VMT based on fuel consumption records. This procedure is cited as the "Finance method".
- The ODOT Policy Section has historically developed statewide VMT estimates for Oregon's Highway Cost Allocation Studies (HCAS). These estimates are primarily based on developing an accurate factor for expanding SHS VMT into statewide VMT. This ODOT procedure is cited as the "Policy method".

TABLE 5-6 provides a summary of key advantages (Pros) and disadvantages (Cons) of each of the three existing statewide VMT estimation procedures used by ODOT. These pros and cons were identifies through a coordinated effort between the consultants and ODOT.

TABLE 5-6 Key advantages (Pros) and disadvantages (Cons) of existing ODOT statewide VMT estimation procedures

Traffic Data Procedure	Finance Procedure	Policy Procedure
Pros • Used in FHWA's Highway Statistics Report and other national publications • Based on actual traffic data • Allows consistent comparison between states • HPMS is only method that procedures data by roadway functional class and area type • HPMS has info. For non-SHS • Used for other purposes in addition to statewide VMT	*Pros* • Consistent with ODOT revenue estimates • Requires relatively few data inputs • Heavy vehicle VMT based on actual reported mileage • Effective method for long-range forecasts and consistent with forecast revenues	*Pros* • Same SHS VMT estimate as MCF • Provides info. by jurisdictional class and estimated and projected VMT by vehicle type
Cons • Complex, data-intensive and resource-intensive methods • Counts are only taken once every three years • HPMS provides limited data for Rural Minor Collectors, and Urban and Rural Local roads	*Cons* • Does not allow for consistent comparison between states • Does not procedure data by roadway functional class, jurisdictional class, or vehicle type • Fuel economy for medium-heavy vehicles based on 1992 data • Relies on several assumptions and data collected from other agencies	*Cons* • Does not allow for consistent comparison between states • Dependent upon increasingly outdated data • Continued use of fitted statewide VMT to SHS VMT ratio will lead to decreased SHS % of statewide VMT • Does not provide info. by roadway functional class

5.2.6.3 Wisconsin practice

WisDOT develops estimates of statewide VMT based on three independent approaches:

1. A fuel-based approach that provides a direct estimate of statewide VMT based on gasoline and diesel fuel consumption in the state multiplied by auto and truck fleet fuel efficiency (MPG) estimates. WisDOT uses the statewide VMT total from this fuel-based method as their control total.
2. A traffic count-based method that uses the traffic count information available from automatic traffic recorders (ATRs) located around the state to estimate the percent change in AADT weighted by functional classification (except for Locals and Rural Minor Collectors). WisDOT currently has a lot of 146 ATRs located throughout the state, including nine on non-state highways. Of these 146 ATRs, WisDOT typically ends up with complete data (without the effects of highway construction or detours or equipment-related problems) from approximately 100 of the ATRs to get a percent change comparison over two years. They compare the changes in AADT levels at these ATRs, summed at an aggregate functional class (at least 10 and hopefully 30 or more), weight the functional classification levels by the proportion of VMT they carry (from the previous year's HPMS results), and arrive at a statewide weighted percent change estimate from the previous year. Since WisDOT has very few ATRs located on the lower functionally classified highways, however, they have little information about VMT changes on local roads.
3. A second count-based approach uses the annual change shown for the interstate, freeway, arterial and collector highways in the state from the annual HPMS VMT estimates. Since they take 48-hour coverage traffic counts on virtually every segment of state highway on a three-year cycle, WisDOT uses the HPMS Universe rather than the HPMS Sample Segments. With only one-third of the counts current, however, the other two-thirds get growth factored up to the current year.

WisDOT estimates total VMT for all Rural Minor Collectors (also not required for HPMS) directly from the local roads files that contain AADT estimates for each segment.

CHAPTER 6 CONCLUSION AND ON-GOING WORKS

6.1 Conclusions

In this interim report, the state-of-the-art and the state-of-the-practice of the project were conducted and a large amount of literatures were reviewed. According to the work plan, the data collecting and modeling of for vehicle registrations and for mileage accumulation were made. The collection of information on VMT mix estimation was also carried out to form the bases for the improvements of VMT mix estimation methodologies.

As for modeling the vehicle age distribution, two model types were used; each of which contains the linear model, nonlinear model and time series model. Age distributions for the 8 counties in HGAC area in Texas were used for the validation of the model structures and parameters. The differences between the emission factors generated by MOBILE based on the default age distribution values and the forecasted values by the proposed model are compared. Results show that the differences are significant especially for CO, which implies that in using MOBLE to estimate emission factors, the proposed model should be used to generate age distribution inputs for MOBILE. The developed computer program will serve as the standard software for the Texas cities to generate the age distribution input for MOBILE.

It should be noted that the prediction of age distribution by our model contains more information, including socioeconomic indexes and local distribution in the recent years. It is not based on the simple expending of the current trends of vehicle age distribution. The basic idea is to build the relationship between the socioeconomic indexes and vehicle age distribution. In the future years, vehicle age distribution can be properly predicted providing the socioeconomic indexes are provided. This is the only modeling effort of this type of problem till now.

The modeling of the correcting process for mileage accumulation was developed mathematically in this report. The corrected local mileage accumulation can be obtained by the combined uses of the real survey data and the default national wide data. To illustrate this process, the real mileage accumulation rate in Houston was collected and the correcting factor as well as the final corrected mileage accumulation for Houston area was obtained. From the results, the real mileage accumulation in Houston area is 1.85 times higher than the national-wide default data.

According to the information collected, there are several methodologies on VMT mix estimation. EPA gives a guidance involving the development and application of methods to estimate detailed national wide VMT related variables. The results serve as the national default values. Bhat and Nair (2000) formulate and estimate a fractional split model. In develop the methodology used for the Houston-Galveston Nonttainment Counties gridded mobile source emissions inventories for FY 2007, the 24-hour traffic assignment are used in the analysis to obtain the VMT mix, which can be used as the input of MOBILE5. For the practices in the other states, some use the MOBILE defaults, some use the HPMS traffic count data, some estimate according to the percentage of vehicles registered within the state, some use the fuel consumption based finance method, the policy procedure, and etc.

6.2 On-going works

The on-going work will focus on the several steps according to the work plan of the project:

- Evaluate VMT mix estimation methodologies and propose improvements;
- Collect vehicle classification-based traffic counts for VMT mix;
- Test and validate developed techniques/models;
- Document research findings.

Since there is a lot of changes in the new version of MOVILE6, especially on VMT related variables, efforts will be focused on the proposing of the improvements for estimating VMT related variables and its realization.

All the proposed models and compiled programs in this report will be further tested, validated and perfected with more real data. The models for vehicle age distribution will be further tested using the data from El Palso. Guidance for survey and correcting the local mileage accumulation will be documented based on the practice in Houston area. Practical computer programs for estimating VMT related variables will be complied and will be validated by using the real survey data in HGAC area.

Finally, research report documenting research performed, findings and recommendations will be given.

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Appendix A Annual mileage accumulation curve fit equations

Vehicle Class	Equation
LDGV	$y = 15684e^{-0.0506x}$
LDDV	$y = 15684e^{-0.0506x}$
LDGT1	$y = 17.472x^2 - 1163.7x + 20642$
LDGT2	$y = 22905e^{-0.0712x}$
LDDT1	$y = 30028e^{-0.104x}$
LDDT2	$y = 28231e^{-0.0808x}$
HDGV (2B-3)	$y = 21250e^{-0.0618x}$
HDGV (4-8)	$y = 23243e^{-0.0829x}$
HDGSB	$y = 9939$
HDGTB	$y = 38654e^{-0.0958x}$
HDDV (2B)	$y = 29657e^{-0.0888x}$
HDDV (3)	$y = 37008e^{-0.1222x}$
HDDV (4-5)	$y = 32625e^{-0.0656x}$
HDDV (6-7)	$y = 44883e^{-0.0983x}$
HDDV (8A)	$y = 98554e^{-0.1153x}$
HDDV (8B)	$y = 137024e^{-0.0982x}$
HDDSB	$y = 9939$
HDDTB	$y = 46659e^{-0.0324x}$

X=model year – 1990

Y=Annual mileage (miles)

Appendix B Average Annual Mileage Accumulation (Curve Fit Data)

U.S. Levels
(12 months estimate)

	LDV		LDGT		LDDT		HDGV		HDGB	
Vehicle Age	**LDGV**	**LDDV**	**LDGT** 0-6000	**LDGT** 6001-8500	**LDDT** 0-6000	**LDDT** 6001-8500	**2B-3** 8501-14000	**4-8** >14000	**S.BUS ANY WGT.**	**T.BUS ANY WGT.**
1	14910	14910	19496	21331	27059	26040	19977	21394	(a)	35123
2	14174	14174	18284	19565	24384	24018	18779	19692		31914
3	13475	13475	17308	18500	21973	22154	17654	18125		28999
4	12810	12810	16267	17228	19801	20434	16596	16683		26350
5	12178	12178	15260	16044	17843	18848	15601	15356		23942
6	11577	11577	14289	14942	16079	17385	14666	14134		21755
7	11006	11006	13352	13915	14490	16036	13787	13010		19768
8	10463	10463	12451	12959	13057	14791	12961	11975		17962
9	9947	9947	11584	12068	11766	13643	12184	11022		16321
10	9456	9456	10752	11239	10603	12584	11454	10145		14830
11	8989	8989	9955	10466	9555	11607	10768	9338		13475
12	8546	8546	9194	9747	8610	10706	10122	8595		12244
13	8124	8124	8467	9077	7759	9875	9516	7911		11126
14	7723	7723	7775	8453	6992	9109	8946	7282		10109
15	7342	7342	7118	7872	6301	8402	8409	6703		9186
16	6980	6980	6496	7331	5678	7749	7905	6169		8347
17	6636	6636	5909	6827	5116	7148	7432	5679		7584
18	6308	6308	5356	6358	4610	6593	6986	5227		6891
19	5997	5997	4839	5921	4155	6081	6568	4811		6262
20	5701	5701	4357	5514	3744	5909	6174	4428		5690
21	5420	5420	3909	5135	3374	5174	5804	4076		5170
22	5152	5152	3497	4782	3040	4772	5456	3752		4698
23	4898	4898	3120	4454	2740	4402	5129	3453		4268
24	4656	4656	2777	4148	2469	4060	4822	3178		3879
25	4427	4427	2470	3863	2225	3745	4533	2926		3524
26	4208	4208	2197	3597	2005	3454	4261	2693		3202
27	4001	4001	1959	3350	1807	3186	4006	2479		2910
28	3803	3803	1756	3120	1628	2939	3766	2281		2644
29	3616	3616	1589	2905	1467	2711	3540	2100		2402
30	3437	3437	1456	2706	1322	2500	3328	1933		2183

LDV Light duty vehicle

LDGV Light duty gasoline vehicle

LDDV Light duty diesel vehicle

LDGT Light duty gasoline truck

(a) Average school bus mileage for all ages = 9,939

LDDT Light duty diesel truck

HDGV Heavy duty gasoline vehicle

HDGV Heavy duty gasoline vehicle

HDGB Heavy duty gasoline bus

Annual Mileage Accumulation (Curve Fit Data)

(12 months estimate)

(Continued)

U.S. Levels

Vehicle Age	HDDV						HDDB	
	2B 8501-10000	**3** 14001-19500	**4-5** 14001-19500	**6-7** 19501-33000	**8A** 33001-60000	**8B** >60000	**S.Bus** Any WGT.	**T. Bus** Any WGT.
1	27137	32751	30653	40681	87821	124208	(a)	45171
2	24831	28984	28622	36872	78257	112590		43731
3	22721	25650	26805	33420	69735	102060		42337
4	20791	22699	25103	30291	62141	92514		40987
5	19024	20088	23509	27455	55374	83861		39681
6	17407	17778	22016	24885	49343	76017		38416
7	15928	15733	20618	22555	43970	68907		37191
8	14575	13923	19309	20443	39181	62462		36005
9	13336	12321	18083	18529	34915	56620		34857
10	12203	10904	16935	16795	31112	51324		33746
11	11166	9650	15860	15222	27724	46523		32670
12	10217	8540	14853	13797	24705	42172		31629
13	9349	7557	13910	12505	22015	38228		30620
14	8555	6688	13026	11335	19617	34652		29644
15	7828	5919	12199	10273	17481	31411		28699
16	7163	5238	11425	9312	15577	28473		27784
17	6554	4635	10699	8440	13881	25810		26898
18	5997	4102	10020	7650	12369	23396		26041
19	5488	3630	9384	6933	11022	21208		25211
20	5021	3213	8788	6284	9822	19224		24407
21	4995	2843	8230	5696	8752	17426		23629
22	4204	2516	7707	5163	7799	15796		22875
23	3847	2227	7218	4679	6950	14319		22146
24	3520	1971	6760	4241	6193	12979		21440
25	3221	1744	6331	3844	5518	11765		20757
26	2947	1543	5929	3484	4918	10665		20095
27	2697	1366	5552	3158	4382	9667		19454
28	2468	1209	5200	2862	3905	8763		18834
29	2258	1070	4869	2594	3480	7944		18234
30	2066	947	4560	2352	3101	7201		17652

HDDV Heavy duty diesel vehicle

HDDB Heavy duty diesel bus

(a) Average school bus mileage for all ages = 9,939

Appendix C Motorcycle Age Distribution and Mileage Accumulation Rates for Use in MOBILE6

Age	Registration Distribution	Mileage Accumulation Rates
1	0.144	4,786
2	0.168	4,475
3	0.135	4,164
4	0.109	3,853
5	0.088	3,543
6	0.07	3,232
7	0.056	2,921
8	0.045	2,611
9	0.036	2,300
10	0.029	1,989
11	0.023	1,678
12+	0.097	1,368

Note: Motorcycle vehicle count is 4,219,000 for all years, pre-1982 through 2050.

Source: 1987 Motorcycle Statistical Annual, Motorcycle Industry Council, Inc.

Appendix D Vehicle Mileage Survey Form

Circle the correct multiple choice answer that applies in Part I. and Part II. Fill in the TABLE Chart in Part III.

I. Background Information:

1.What age group do you fall under?
   a. 17 yr. and below b. 18-24 yr. c. 25-31 yr. d. 32-38 yr.
   e. 39-45 yr. f. 46-52 yr. g. 52 yr. and above

2. What is your ethnic group?
   a. Hispanic b. Caucasian c. African- American d. Pacific- Asian e. Native American
   f. Other

3. What is your sex?
   a. Male b. Female

II. Household Information:

4. How many members are in your household?
   a. 1-3 b. 4-6 c. 7-9 d. 10 and above

5. What is the average household income? (Optional)
   a. 16,000 or below b. 17,000- 24,000 c. 25- 32,000 d. 33,00- 40,000 e. 41,000- 48,000
   f. 49,000- 55,000 g. 55,000 and above

6. What area of the city do you reside at?
   a. North b. Northeast c. South d. Southeast e. Southwest f. Downtown- Central
   g. Other (specify):

III. Please fill in the TABLE Chart for all the vehicles you own.

Number Of Vehicles	Vehicle Type (Car, Van, Truck, etc)	Make and Model / Vehicle Weight	Year of Make	Number of Miles driven in Yr. 2000	Total Mileage on the Odometer	County You Reside
1						
2						
3						

Appendix E Default VMT mix in MOBILE6

```
* The sixteen vehicle classes are:
*
*  1  LDV    Light-Duty Vehicles (Passenger Cars)
*  2  LDT1   Light-Duty Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
*  3  LDT2   Light Duty Trucks 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
*  4  LDT3   Light Duty Trucks 3 (6,001-8500 lbs. GVWR, 0-3750 lbs. LVW)
*  5  LDT4   Light Duty Trucks 4 (6,001-8500 lbs. GVWR, 3751-5750 lbs. LVW)
*  6  HDV2B  Class 2b Heavy Duty Vehicles (8501-10,000 lbs. GVWR)
*  7  HDV3   Class 3 Heavy Duty Vehicles (10,001-14,000 lbs. GVWR)
*  8  HDV4   Class 4 Heavy Duty Vehicles (14,001-16,000 lbs. GVWR)
*  9  HDV5   Class 5 Heavy Duty Vehicles (16,001-19,500 lbs. GVWR)
* 10  HDV6   Class 6 Heavy Duty Vehicles (19,501-26,000 lbs. GVWR)
* 11  HDV7   Class 7 Heavy Duty Vehicles (26,001-33,000 lbs. GVWR)
* 12  HDV8A  Class 8a Heavy Duty Vehicles (33,001-60,000 lbs. GVWR)
* 13  HDV8B  Class 8b Heavy Duty Vehicles (>60,000 lbs. GVWR)
* 14  HDBS   School Busses
* 15  HDBT   Transit and Urban Busses
* 16  MC     Motorcycles (All)
*
* All values must be less than or equal to 1 and greater than or equal to
* zero.  The sum of all 16 values must be exactly equal to 1, otherwise
* the model will normalize the values so that they equal 1. All 16 values
* must be entered each time the VMT MIX label is used.
*
* The default value for VMT mix varies by calendar year, based on the
* value of vehicle counts in the model.  Vehicle count by calendar year
* is not a user input.  The following values are for the 2010 calendar
* year.
*
VMT MIX             :
0.354  0.089  0.297  0.092  0.041  0.040  0.004  0.003
0.002  0.008  0.010  0.012  0.040  0.002  0.001  0.005
```

Appendix F Default VMT BY HOUR in MOBILE6

```
VMT BY HOUR
*
*  Fraction of all vehicle miles traveled by hour of the day.
*  First hour is 6 a.m.
*
      0.0569  0.0740  0.0656  0.0555  0.0540  0.0582
      0.0608  0.0571  0.0598  0.0636  0.0777  0.0730
      0.0501  0.0389  0.0308  0.0264  0.0194  0.0144
      0.0108  0.0086  0.0081  0.0080  0.0098  0.0186
```

Appendix G Default VMT BY FACILITY in MOBILE6

```
VMT BY FACILITY
* VMT fractions are listed for 28 vehicle classes.
* For each class, 24 sets of values represent the hours of the day.
* For each class and hour, 4 values represent the VMT distribution on
* freeway, arterial, local and ramps--in that order.
   1 0.392  0.457  0.117  0.034
     0.344  0.497  0.129  0.030
     0.338  0.497  0.135  0.029
     0.349  0.492  0.129  0.030
     0.346  0.497  0.127  0.030
     0.333  0.509  0.129  0.029
     0.324  0.516  0.132  0.028
     0.334  0.506  0.131  0.029
     0.334  0.506  0.131  0.029
     0.320  0.519  0.134  0.028
     0.330  0.506  0.135  0.029
     0.312  0.521  0.140  0.027
     0.295  0.538  0.141  0.026
     0.310  0.527  0.137  0.027
     0.329  0.510  0.133  0.029
     0.343  0.497  0.131  0.030
     0.381  0.460  0.126  0.033
     0.405  0.437  0.123  0.035
     0.426  0.418  0.118  0.037
     0.443  0.403  0.115  0.039
     0.457  0.394  0.110  0.040
     0.461  0.391  0.107  0.040
     0.453  0.400  0.108  0.039
     0.418  0.434  0.112  0.036
   2 0.392  0.457  0.117  0.034
     0.344  0.497  0.129  0.030
     0.338  0.497  0.135  0.029
     0.349  0.492  0.129  0.030
     0.346  0.497  0.127  0.030
     0.333  0.509  0.129  0.029
     0.324  0.516  0.132  0.028
```

Appendix H Default VMT BY FACILITY in MOBILE6

SPEED VMT												
1	1	0.0083	0.0272	0.0210	0.0224	0.0217	0.0381	0.0344	0.0536	0.0614	0.0700	0.
1	2	0.0260	0.0066	0.0076	0.0156	0.0282	0.0326	0.0344	0.0361	0.0360	0.0435	0.
1	3	0.0259	0.0033	0.0064	0.0057	0.0126	0.0281	0.0342	0.0349	0.0407	0.0369	0.
1	4	0.0145	0.0096	0.0021	0.0022	0.0041	0.0166	0.0232	0.0373	0.0418	0.0449	0.
1	5	0.0083	0.0086	0.0052	0.0032	0.0040	0.0163	0.0232	0.0364	0.0375	0.0420	0.
1	6	0.0072	0.0034	0.0042	0.0098	0.0121	0.0244	0.0289	0.0327	0.0401	0.0392	0.
1	7	0.0103	0.0023	0.0064	0.0087	0.0147	0.0281	0.0335	0.0328	0.0345	0.0354	0.
1	8	0.0083	0.0075	0.0052	0.0043	0.0054	0.0182	0.0257	0.0381	0.0380	0.0421	0.
1	9	0.0113	0.0065	0.0052	0.0023	0.0039	0.0206	0.0279	0.0358	0.0383	0.0517	0.
1	10	0.0155	0.0075	0.0034	0.0042	0.0081	0.0272	0.0324	0.0363	0.0315	0.0390	0.
1	11	0.0156	0.0411	0.0225	0.0199	0.0284	0.0316	0.0500	0.0488	0.0446	0.0555	0.
1	12	0.0186	0.0113	0.0046	0.0110	0.0183	0.0261	0.0488	0.0383	0.0314	0.0534	0.
1	13	0.0176	0.0064	0.0010	0.0024	0.0034	0.0155	0.0191	0.0315	0.0357	0.0515	0.
1	14	0.0135	0.0043	0.0031	0.0010	0.0012	0.0094	0.0177	0.0258	0.0264	0.0550	0.
1	15	0.0094	0.0031	0.0025	0.0007	0.0012	0.0069	0.0166	0.0216	0.0257	0.0476	0.
1	16	0.0054	0.0018	0.0018	0.0004	0.0011	0.0045	0.0155	0.0175	0.0250	0.0401	0.
1	17	0.0027	0.0010	0.0014	0.0002	0.0011	0.0028	0.0147	0.0147	0.0245	0.0352	0.
1	18	0.0013	0.0006	0.0012	0.0001	0.0011	0.0020	0.0144	0.0133	0.0242	0.0327	0.
1	19	0.0000	0.0001	0.0010	0.0000	0.0011	0.0012	0.0140	0.0119	0.0240	0.0302	0.
1	20	0.0000	0.0013	0.0000	0.0000	0.0000	0.0010	0.0115	0.0097	0.0200	0.0241	0.
1	21	0.0000	0.0003	0.0010	0.0000	0.0000	0.0008	0.0103	0.0086	0.0181	0.0206	0.
1	22	0.0000	0.0013	0.0000	0.0000	0.0000	0.0008	0.0107	0.0081	0.0170	0.0199	0.
1	23	0.0021	0.0003	0.0000	0.0010	0.0000	0.0010	0.0118	0.0100	0.0205	0.0224	0.
1	24	0.0031	0.0003	0.0000	0.0010	0.0001	0.0011	0.0134	0.0124	0.0240	0.0267	0.
2	1	0.0004	0.0052	0.0061	0.0053	0.0158	0.0854	0.3210	0.1382	0.2804	0.0595	0.
2	2	0.0036	0.0029	0.0059	0.0234	0.0735	0.1114	0.2842	0.0950	0.2633	0.0396	0.
2	3	0.0033	0.0021	0.0032	0.0085	0.0436	0.1130	0.2914	0.1076	0.2835	0.0424	0.
2	4	0.0030	0.0015	0.0011	0.0015	0.0183	0.1001	0.2910	0.1246	0.3013	0.0535	0.
2	5	0.0030	0.0014	0.0005	0.0017	0.0181	0.1008	0.2898	0.1246	0.3015	0.0537	0.
2	6	0.0034	0.0017	0.0021	0.0049	0.0344	0.1091	0.2894	0.1125	0.2932	0.0460	0.
2	7	0.0040	0.0021	0.0027	0.0078	0.0427	0.1134	0.2857	0.1083	0.2886	0.0427	0.
2	8	0.0038	0.0025	0.0020	0.0022	0.0216	0.1034	0.2834	0.1243	0.3020	0.0515	0.
2	9	0.0041	0.0024	0.0020	0.0034	0.0249	0.1049	0.2844	0.1215	0.2986	0.0489	0.
2	10	0.0052	0.0027	0.0032	0.0085	0.0450	0.1151	0.2822	0.1024	0.2835	0.0419	0.
2	11	0.0049	0.0165	0.0087	0.0224	0.0652	0.1222	0.2809	0.0959	0.2557	0.0405	0.
2	12	0.0055	0.0071	0.0082	0.0219	0.0675	0.1169	0.2771	0.0915	0.2637	0.0394	0.
2	13	0.0043	0.0024	0.0016	0.0038	0.0255	0.1005	0.2849	0.1205	0.2996	0.0497	0.
2	14	0.0038	0.0021	0.0018	0.0015	0.0115	0.0734	0.2923	0.1219	0.3170	0.0641	0.
2	15	0.0037	0.0017	0.0012	0.0019	0.0103	0.0558	0.3040	0.1067	0.3309	0.0702	0.

Appendix I Composite MOBILE6 Vehicle Classifications (STARTS PER DAY Command)

Number	Abbreviation	Description
1	LDGV	Light-duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-duty Gasoline Tracks 1 (0-6,000lbs. GVWR, 0-3750lbs.LVW)
3	LDGT2	Light-duty Gasoline Tracks 2 (0-6,001lbs. GVWR, 3751-5750lbs.LVW)
4	LDGT3	Light-duty Gasoline Tracks 3 (6,001-8500lbs. GVWR, 0-3750lbs.LVW)
5	LDGT4	Light-duty Gasoline Tracks 4 (6,001-8500lbs. GVWR, 3751-5750lbs.LVW)
6	HDGV2B	Class 2b Heavy Duty Gasoline Vehicles (8501-10,000lbs. GVWR)
7	HDGV3	Class 3 Heavy Duty Gasoline Vehicles (10,001-14,000lbs. GVWR)
8	HDGV4	Class 4 Heavy Duty Gasoline Vehicles (14,001-16,000lbs. GVWR)
9	HDGV5	Class 5 Heavy Duty Gasoline Vehicles (16,001-19,500lbs. GVWR)
10	HDGV6	Class 6 Heavy Duty Gasoline Vehicles (19,501-26,000lbs. GVWR)
11	HDGV7	Class 7 Heavy Duty Gasoline Vehicles (26,001-33,000lbs. GVWR)
12	HDGV8A	Class 8a Heavy Duty Gasoline Vehicles (33,000-60,000lbs. GVWR)
13	HDGV8B	Class 8b Heavy Duty Gasoline Vehicles (>60,000lbs. GVWR)
14	LDDV	Light Duty Diesel Vehicles (Passenger cars)
15	LDDT12	Light Duty Diesel trucks 1 and 2 (0-6,000lbs. GVWR)
16	HDDV2B	Class 2b Heavy Duty Diesel Vehicles (8501-10,000lbs. GVWR)
17	HDDV3	Class 3 Heavy Duty Diesel Vehicles (10,001-14,000lbs. GVWR)
18	HDDV4	Class 4 Heavy Duty Diesel Vehicles (14,001-16,000lbs. GVWR)
19	HDDV5	Class 5 Heavy Duty Diesel Vehicles (16,001-19,500lbs. GVWR)
20	HDDV6	Class 6 Heavy Duty Diesel Vehicles (19,501-26,000lbs. GVWR)
21	HDDV7	Class 7 Heavy Duty Diesel Vehicles (26,001-33,000lbs. GVWR)
22	HDDV8B	Class 8a Heavy Duty Diesel Vehicles (33,000-60,000lbs. GVWR)
23	HDDV8B	Class 8b Heavy Duty Diesel Vehicles (>60,000lbs. GVWR)
24	MC	Motorcycles (Gasoline)
25	HDGB	Gasoline Buses (School, Transit and Urban)
26	HDDBT	Diesel Transit and Urban Buses

27	HDDBS	Diesel School Buses
28	LDDT34	Light Duty Truck 3 and 4 (6,001-8500lbs.GVWR)

Appendix J Composite MOBILE6 Vehicle Classifications for Registration Data and Vehicle Miles (RED DIST and VMT FRACTIONS Commands)

Number	Abbreviation	Description
1	LDV	Light-duty Vehicles (Passenger Cars)
2	LDT1	Light-duty Tracks 1 (0-6,000lbs. GVWR, 0-3750lbs.LVW)
3	LDT2	Light-duty Tracks 2 (0-6,001lbs. GVWR, 3751-5750lbs.LVW)
4	LDT3	Light-duty Tracks 3 (6,001-8500lbs. GVWR, 0-3750lbs.LVW)
5	LDT4	Light-duty Tracks 4 (6,001-8500lbs. GVWR, 3751-5750lbs.LVW)
6	HDV2B	Class 2b Heavy Duty Vehicles (8501-10,000lbs. GVWR)
7	HDV3	Class 3 Heavy Duty Vehicles (10,001-14,000lbs. GVWR)
8	HDV4	Class 4 Heavy Duty Vehicles (14,001-16,000lbs. GVWR)
9	HDV5	Class 5 Heavy Duty Vehicles (16,001-19,500lbs. GVWR)
10	HDV6	Class 6 Heavy Duty Vehicles (19,501-26,000lbs. GVWR)
11	HDV7	Class 7 Heavy Duty Vehicles (26,001-33,000lbs. GVWR)
12	HDV8A	Class 8a Heavy Duty Vehicles (33,000-60,000lbs. GVWR)
13	HDV8B	Class 8b Heavy Duty Vehicles (>60,000lbs. GVWR)
14	HDBS	School Buses
15	HDBT	Transit and Urban Buses
16	MC	Motorcycles (All)

Appendix K Names of Persons and Agencies/Companies for Responded E-mail Survey on VMT Approaches

Name of Persons	Name of Agencies/Companies
Alison K. Pollack	ENVIRON International Corp.
Andrew Edwards	Air Quality Specialist Southern Resource Center - FHWA
Barbara MacRae	Colorado Department of Public Health and Environment Air Pollution Control Division
Christopher Porter	Cambridge Systematics, Inc.
Dawn Wills	Transportation Planner North Center TX Council of Governments
JIM Dileo	Colorado Department of Public Health and Environment Air Pollution Control Division
Jonathan Morton	Georgia Department of Natural Resources
Joon Byun	Air Quality Modeling Specialist Eastern Resource Center, FHWA
Kevin N. Black	FHWA
Kip Billings	Wasatch Front Regional Council
Lark Downs	Stan COG
Richard McElveen	Florida Department of Environmental Protection
Tom Wenzel	Lawrence Berkeley National Laboratory
Walter Pienta	NYS Department of Environmental Conservation
Wayne Luney	California DOT