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16. Abstract
The EPA recently released the latest version MOBILE6, its first major update to the MOBILE series since 1996. This model will soon become the required standard for air quality conformity analysis transportation conformity measure (TCM) effectiveness analysis. A brief review of the input requirements of the MOBILE6 emissions factor model is presented which is followed by a more detailed discussion of the traffic-related input needs of the model. In particular, the various issues involved in the modeling of vehicle registration distribution and the VMT distribution, the methodology adopted, data acquisition and analysis, and the modeling results are discussed. The report also briefly describes the GIS-based software application developed to facilitate TCM analysis. Some simple TCM scenarios that were analyzed as part of the study are also presented to better explain the application of the software to perform TCM analyses.

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GIS-Integrated Traffic Input Models for Mobile-Source Emissions Analysis

by

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Research Project 0-4377
Develop GIS-Integrated Traffic Models for MOBILE6-Based
Air Quality Conformity and TCM Analysis

Conducted for the

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1. BACKGROUND AND SIGNIFICANCE OF WORK

Atmospheric emissions may be classified into three categories: mobile, stationary, and area sources. Among these, mobile source emissions contribute significantly to the ozone and CO pollutants. Approximately 50 percent of ozone precursor emissions (volatile organic compounds-VOCs and oxides of nitrogen-NOx) originate from mobile-source emissions, and about 90 percent of CO emissions come from mobile-source emissions.

The significant contribution of mobile-source emissions to air pollution, combined with the deteriorating air quality in many metropolitan areas, has resulted in a need to determine current and projected emissions inventories, and to establish the relative emissions contributions of mobile and other sources. These have to be included in the State Air Quality Implementation Plan (SIP) for achieving clean air levels consistent with National Ambient Air Quality Standards (NAAQS). In addition, an emissions reduction budget is assigned to each emission source for achieving reasonable further progress (RFP) toward attainment. For the mobile source category, the emissions reduction budget is further refined into a regulatory limit on emissions, referred to as emissions budget. The emissions budget in the SIP represents the highest level of emissions allowed from all projects included in the 20-year Regional Transportation Plan and Transportation Improvement Plan of constituent Metropolitan Planning Organizations (MPOs).

The integration of transportation planning and air quality planning is important for mobile source emissions estimation and for establishing conformity of mobile source emissions to the emissions budgets and emissions reduction budgets in the SIP. The transportation conformity rule establishes the criteria and procedures by which the Federal Highway Administration (FHWA), the Federal Transit Authority (FTA), and state agencies/MPOs determine the conformity of federally funded or approved projects to SIPs. The final conformity rule (effective September 15, 1997) states that "transportation plans, programs, and projects must conform to the mobile source emissions budget in the latest submitted or EPA-approved SIP, and must be found not to lead to new NAAQS violations, exacerbate existing violations, or delay timely attainment of any interim milestone." Further, transportation plans and programs can be found to conform only if they provide for timely implementation of SIP-adopted Transportation Control Measures (TCMs).

Conformity determinations must be made at least every three years in non-attainment areas or whenever modifications are made to plans, TIPs, or projects. Certain events, such as SIP revisions that establish/revise transportation-related emissions budgets or add/delete TCMs, might also trigger a necessity for fresh conformity determination.

There is a strong incentive for various Texas agencies (MPO staff, TxDOT, and TNRCC) to assess trade-offs between mobile and other source emission reduction programs and to adopt a specific set of SIP strategies that are feasible and achievable to reach attainment. If unrealistically large emission reduction targets are assigned to mobile sources and are included in the SIP, it will be difficult to demonstrate conformity. Therefore, it is critical for MPOs to develop reliable projections of mobile-source emissions-related traffic indicators. Over-predictions of these indicators will result in overestimation of the need for emissions controls. Under-predictions, on the other hand, could result in the need, when problems become apparent, to apply drastic emissions control measures that are more expensive than what additional controls would have entailed at the outset if potential problems had been correctly anticipated.

The North Central Texas Council of Governments (NCTCOG), the metropolitan planning organization of the Dallas Fort Worth (D-FW) area, is responsible for developing and maintaining the mobile-source emissions inventories in the area. The U.S. EPA designates the counties of Collin, Dallas, Denton, and Tarrant within the D-FW planning area as serious non-attainment areas. The NCTCOG models the mobile-source emissions for this area using the version MOBILE5 of the MOBILE Emissions Factor model.

In January 2002, the EPA released an updated version of its mobile-sources emissions model, MOBILE6. The latest of the MOBILE series is a software application program that provides estimates of current and future emissions from highway motor vehicles. MOBILE6 calculates average in-use fleet emission factors for the three criteria pollutants: hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). These pollutants are calculated for gas, diesel, and natural gas fueled vehicles for calendar years 1952 to 2050. Users can provide "optional" input data for the model that reflect their local conditions. If no optional input data is provided, MOBILE uses its default values, which are derived from national average data.

The accuracy of the MOBILE output is largely dependent on the accuracy of the input data. Different regions have characteristics unique to them; hence the use of nationwide averages may not be appropriate for all inputs. Using these national default values in most cases underutilizes the capabilities of the MOBILE6 model, and therefore the EPA and the U.S. Department of Transportation (DOT) advise non-attainment areas to use local data in their emissions modeling procedure, if possible. MOBILE6 has a greatly expanded vehicle classification scheme and provides a greater number of optional inputs than previous models. These changes enable the user to enter inputs at a finer spatio-temporal scale and ultimately derive more accurate emissions estimates. Unfortunately, the input requirements for the MOBILE6 model are vastly different from those for the MOBLE5 model. The main differences are in the following areas:

- Emissions, fleet, and activity data:
  - Basic exhaust emissions: There have been changes to the basic exhaust emissions with updates to the in-use deterioration estimates for light-duty and heavy-duty cars and trucks. Also the basic exhaust emissions must conform to the new emission standards for light-duty and heavy-duty vehicles.
  - Speed and off-cycle effects for light-duty vehicles: For light-duty vehicles, facility-based speed corrections, the effects of the supplemental Federal Test Procedure (FTP) rule, and the effects of air conditioning on the exhaust emissions have been included.
  - Heavy-duty emissions: For heavy-duty vehicles, the impact of new emission standards has been accounted for and the emissions have been adjusted for an excess of nitrogen oxides.
  - Effects of fuel composition: The effects of oxygenated fuels on the carbon monoxide (CO) emissions and the explicit effects of sulfur on exhaust emissions have been accounted for. The emissions of natural gas vehicles are modeled explicitly.

- Changes to evaporative hydrocarbon emissions: Diurnals and resting loss emissions are based on new real-time and multi-day data. Liquid leaker emissions are added to hot-soak, diurnal, running, and resting losses. For hot soak emission calculation, new data have to be provided for fuel Reid Vapor Pressure less than 9.0 psi. A new method has been included for evaporative I/M calculations.
- Fleet characterization: New estimates are used for national average mileage accumulation, vehicle registration (age) distribution, and vehicle class counts.
- Vehicle activity: For MOBILE6, the following new activity data has to be specified. (1) new trip- length estimates, (2) engine start soak time distribution, (3) diurnal soak time distributions, (4) trip starts and trip ends, (5) vehicle miles traveled (VMT) by hour of day, facility, and speed.

▪ Structural changes: Running and start emissions are separated in MOBILE6. Start emissions are those that occur in the first hour of the trip. They depend on the soak duration prior to the trip, the environmental conditions prevailing during the trip start, and vehicle characteristics such as type, age, and mileage. Running emissions are those that occur during hot-stabilized operation. Aggregate running emissions depend on vehicle speeds; environmental conditions during the trip; the hour of day; distribution of vehicle characteristics such as age, mileage, and type; VMT mix; and the implementation of inspection/maintenance programs. In MOBILE6, the calculation of emissions is carried out by the hour. The vehicle classification has been expanded with the inclusion of the following subclasses: LDDV, LDGV, LDGT 1-4, LDDT 12, 34, HDGV 2b-8b, HDDV 2b-8b, MC, HDGB, HDDB-S, and HDDB-T (refer to Table 1.1 of Appendix I).

▪ Changes in the input and output formats: Control flags have been eliminated in MOBILE6. There is a more extensive use of user-supplied comments. External files are required for registration distributions, in-use program descriptions, and local activity data.

2. INPUT REQUIREMENTS FOR MOBILE6 EMISSION FACTOR MODEL

2.1 Introduction

MOBILE6 utilizes an input file that provides program control information and data describing the scenarios for which emission factors are to be estimated for calculating pollutant-specific emissions. The input file is divided into three different sections-namely, the Control section, the One-time Data section, and the Scenario section.

The Control section manages the input, output, and execution of the program. The One-time Data section allows the user to input emission-related parameters that differ from the internal default values of MOBILE6. The values of these parameters are applied collectively to all scenarios each time the program is run. The Scenario section provides information on the individual scenarios for which emission factors are to be calculated. Each run of MOBILE6 can include many different scenarios, and each scenario can include different scenario parameters.

Because the Control section does not pertain to the traffic-related inputs, our discussion will be restricted to the One-Time Data and Scenario selection sections. As was discussed earlier, MOBILE6 includes default values for a wide range of parameters that affect emissions. These defaults are calculated to represent “national average” input data values. Substituting default values with information related to local conditions will result in more precise estimates of local emissions. The following subsections discuss default values and input data required by the user for each of the inputs included in the One-Time Data and Scenario selection sections.

2.2 One-Time Data

The One-Time Data section includes information that is input only once in a given MOBILE6 input file. These inputs are used to alter MOBILE6 default values to reflect locality-specific data when such information is available to the user. Figure 2.1 shows the one-time data inputs and the corresponding command type. Each of these inputs is discussed briefly in the following subsections. A more detailed discussion can be obtained from Bhat et al [2].

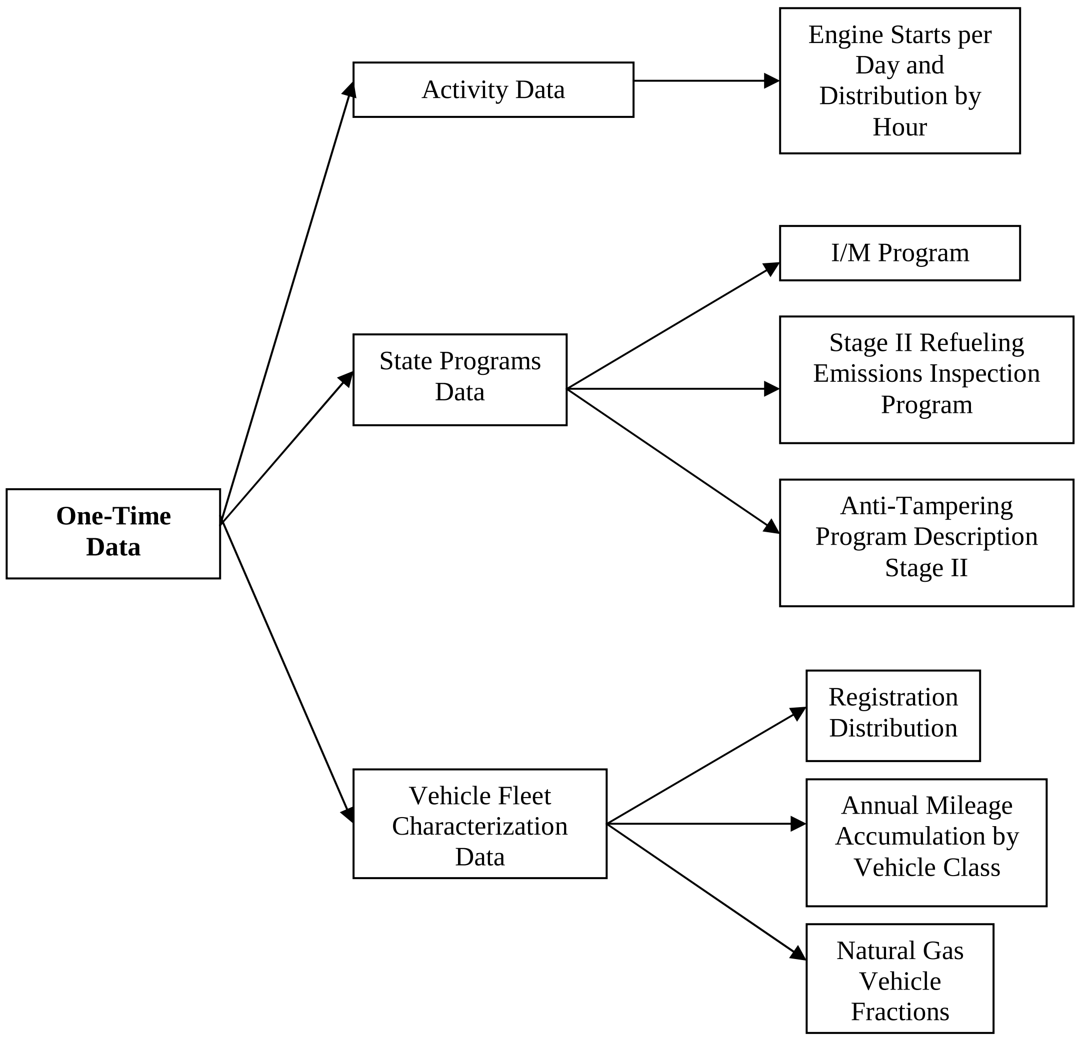

Figure 2.1. One-Time Data

2.2.1 Engine starts per day and distribution by hour

The number of starts per day affects engine exhaust start emission estimates for light-duty gasoline cars, diesel passenger cars, trucks, and motorcycles. It also affects the evaporative hot soak losses (which occur at trip ends) on all gasoline-fueled vehicles, including heavy-duty vehicles and buses. The number of starts per day is used to calculate the number of trips and trip ends per day. This command does not affect the emission estimates for heavy-duty diesel-fueled vehicles and buses. MOBILE6 assigns a separate default value for the number of engine starts per day to each of the twenty-five individual vehicle classes at each of twenty-five vehicle age categories. These default values differ for weekdays and weekends, though the same default value is used for all ages within a vehicle class.

Input data required from the user:

- Engine starts per day values for all vehicle classes affected by the Starts Per Day command (see Table 1.4 in Appendix I for affected vehicle classes) for the twenty-five vehicle ages included in each day type.
- Average fraction of all engine starts that occur in each hour of a 24-hour day, for both weekdays and weekends.

2.2.2 I/M program

The user can direct MOBILE6 to model an I/M program and define basic information about the program to be modeled using the I/M Program command. If the user chooses not to use this command, MOBILE6 assumes no I/M program is in place.

Input data required from the user:

- The number of I/M programs that will be used in the run.
- Calendar year that the program began (1960-2051).
- Calendar year that the program ended (1960-2051).
- Frequency of inspection (biennial or annual).
- I/M program type.
- I/M inspection type.

In order to specify the first and last model years that will be covered by the I/M program to be modeled, the user is required to use the I/M Model Years command. The I/M Vehicles command identifies which vehicle types are included in the I/M program to be modeled. The I/M Stringency command is required when an exhaust I/M program is being modeled. Using this command, the user is able to define the expected exhaust inspection failure rate for pre-1981 model year vehicles included in the I/M program being modeled.

The I/M Compliance command lets the user specify the percentage of vehicles in the fleet that complete the I/M program and receive either a certificate of compliance or a waiver. The I/M Waiver Rates command allows the user to specify the number of vehicles that fail an initial I/M test and receive a certificate of compliance after failing the retest.

The I/M Exemption Age command allows the user to specify the age at which the vehicles become exempt from the I/M program that is being modeled. The age at which vehicles first become subject to I/M testing is specified using the I/M Grace Period command. This input gives the user the ability to model programs that exempt the newest vehicles from the requirements.

The I/M Effectiveness command is used to enter separate effectiveness values for each of the three pollutants–hydrocarbons, carbon monoxide, and nitrogen oxides. This command is used as a correction factor that reduces the exhaust I/M credit for test and repair programs by the percentage input by the user.

2.2.3 Stage II refueling emissions inspection program

The Effects of Stage II on Refueling Emissions command permits the user to model the impact of refueling emissions required by a Stage II vapor recovery system. There is no default calculation of impact of a Stage II program.

Input data required from the user:

- Calendar year (1989-2050).
- Number of phase-in years of the program (1-9 years).
- The percent efficiency for the light-duty gasoline vehicles (LDGVs) and the light-duty gasoline trucks (LDGTs) in the program (0%-100%).
- The percent efficiency for the heavy-duty gasoline vehicles (HDGVs) in the program (0%-100%).

2.2.4 Stage II Anti-Tampering program description

The user has the option to model the impact of an anti-tampering program using the Anti-Tampering Programs command, but no default values are supplied.

Input data required from the user:

- Calendar year that the program began (1960-2050).
- The earliest model year to be covered by the program (1960-2050).

- The final model year to be covered by the program (1960-2050).
- Knowledge of which vehicle class is included in the program; vehicles included are light-duty and heavy-duty gasoline vehicles and gasoline buses.
- Frequency of inspection (annual or biennial).
- Compliance rate for the anti-tampering program (0%-100 %).
- Knowledge of which vehicle components will be inspected; components include air pump system disablement, catalyst removal, fuel inlet restrictor disablement, fuel inlet restrictor disablement, tailpipe lead deposit test, EGR disablement, evaporative system disablement, PCV system disablement, and missing gas cap.

2.2.5 Vehicle registration distribution

The Distribution of Vehicle Registration command allows the user to supply vehicle registration distributions by vehicle age for any of the sixteen composite (combined gas and diesel) vehicle types. A list of these vehicle types can be found in Appendix I, Table 1.2. Vehicle age involves a 25-year range, with vehicles 25 years and older grouped together.

Input data required from the user:

- Vehicle registration data for each of the twenty-five vehicle ages for one or more of the sixteen composite vehicle types.
- Each composite vehicle type requires twenty-five age fractions, representing the fraction of vehicles of that age in that composite vehicle class in July.

2.2.6 Annual mileage accumulation by vehicle class

The Annual Mileage Accumulation Rates command allows the user to input the annual mileage accumulation rates by vehicle age for any of the twenty-eight individual vehicle types. A list of these vehicle types can be found in Appendix I, Table 1.1. As mentioned above, vehicle age involves a 25-year range, with vehicles 25 years and older grouped together.

Input data required from the user:

- The total annual travel miles accumulated per vehicle of a given age for the twenty-eight vehicle categories.

2.2.7 Natural gas vehicle fractions

The Natural Gas Vehicles Fraction command allows the user to give the percentage of vehicles in the fleet that are certified to operate on either compressed or liquefied natural gas in each of the twenty-eight individual classes (Appendix I, Table 1.1) beginning with the 1994 model year. The default fraction of NGV vehicles in the fleet is equal to zero.

Input data required from the user:

- Number of vehicles that are NGV for the twenty-eight individual classes for the years 1994-2050.

2.3 Scenario Selection

The Scenario data are used to assign values to those variables that specifically define each of the scenarios to be evaluated. Figure 2.2 shows the scenario inputs and the corresponding command type. Each of these inputs is discussed briefly in the following subsections. A more detailed discussion can be obtained from Bhat et al [2].

2.3.1 Diesel sales fraction

The user can input locality-specific diesel fractions for fourteen of the sixteen composite vehicle categories (see Appendix I, Table 1.3) by vehicle age by using the Diesel Sales Fraction command. The two vehicles included are urban/transit buses and motorcycles, all of which are assumed to be diesel fueled.

Input data required from the user:

- Diesel fractions by age (1-25 years) of vehicle for each of the fourteen vehicle types to come up with 350 separate diesel fractions.

2.3.2 Distribution of vehicle miles traveled by vehicle class

The Vehicle Miles Traveled Fraction (VMT) command permits the user to assign VMT to specific vehicle types. VMT mix inputs must consist of a set of sixteen fractional values, representing the fraction of total highway VMT accumulated by each of the sixteen combined vehicle types (see Appendix I, Table 1.2).

Input data required from the user:

- Calendar year of evaluation.
- Vehicle population data for the sixteen composite vehicle classes.
- Vehicle registration by age distribution.
- Mileage accumulation data.

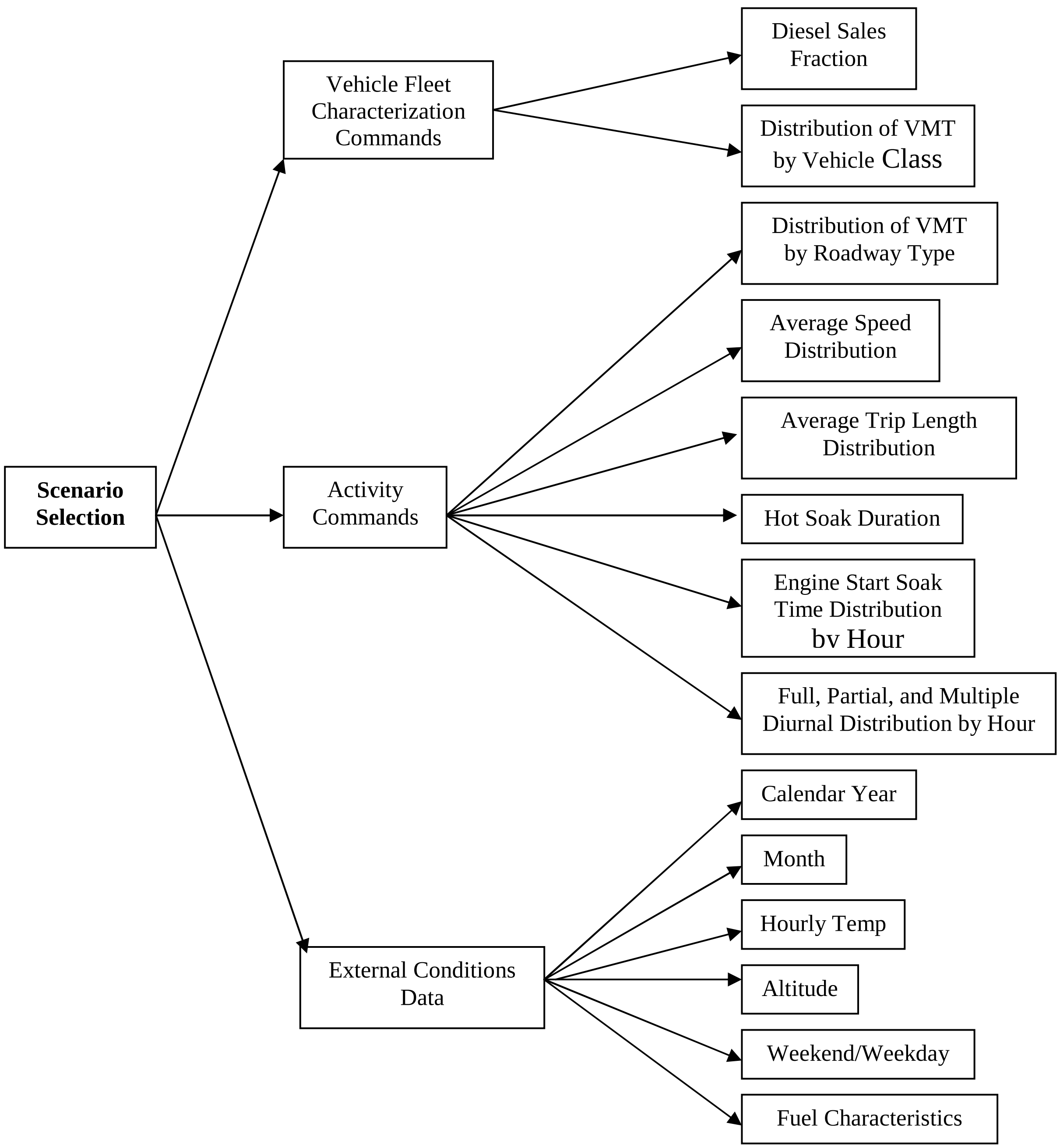

Figure 2.2. Scenario Selection

2.3.3 Distribution of vehicle miles traveled by roadway type, speed, and hour

The VMT by Facility command involves computing VMT on various roadway or facility types by vehicle class. The user may enter VMT distributions for each of the twenty-eight vehicle classes (see Appendix I, Table 1.1) across the four roadway types for each of the 24 hours of the day. The four roadway types include freeway, arterial, local, and ramp.

Input data required from the user:

- Fractional values for the four roadway types at each of the 24 hours of the day for a given vehicle class.
- The distributions for each hour must add up to one.

If the VMT by Facility cannot be obtained or is not needed, the user can instead assign a fraction of VMT occurring at each hour of the day that is independent of facility type using the VMT by Hour command. Total VMT is allocated among the 24 hours of each day.

Input data required from the user:

- Total VMT for the 24 hours of the day.

The Speed VMT command allows the user to allocate VMT by average speed on freeways and arterial roads. The VMT distribution over fourteen pre-selected average speed ranges is used. MOBILE6 then calculates these distributions for each of the 24 hours of the day and for freeways and arterials.

Input data required from the user:

- VMT distribution.
- Average speeds.

2.3.4 Average speed distribution by hour and roadway type

The Average Speed command permits the user to designate a single average speed to use for all the freeways and/or arterial/collectors for the entire 24 hours of the day. The user can enter a single value instead of a distribution, as in the case of the Speed VMT command.

Input data required from the user:

- Average speed value ranging from 2.5 to 65 mph.
- The roadway scenario the user wants to model; choices include the following.
  - Non-ramps: all VMT occurring on freeways, not including ramps.
  - Freeway: all VMT occurring on freeways, including ramps.
  - Arterial: all VMT occurring on arterial/collector roadways.
  - Area wide: VMT occurring on all roadway types as determined by the VMT by Facility command.

2.3.5 Average trip-length distribution

Trip-length activity estimates are used to calculate running loss emissions. Running loss emissions are evaporative emissions that is, emissions that have escaped from a vehicle while the engine is operating. The rate of running emissions is assumed to continually increase as a function of trip length until it reaches a plateau at a trip length of about 50 to 60 minutes. The 24-hour day was divided into fourteen different hourly groups. The hourly intervals are shown in Table 2.2 in Appendix II.

Input data required from the user:

- Trips per vehicle per day for cars and trucks.
- Distribution of vehicle trips by hourly groups on the basis of VMT.
- Knowledge of whether trips occur during weekend or on a weekday.
- Trip length of vehicle trip (see Appendix III, Table 3.1 for trip duration categories).

2.3.6 Hot soak duration

Hot soak emissions occur when fuel vapors escape from a hot vehicle that has just been turned off. The emissions are highest immediately after the engine is shut down and decrease over time, reaching a baseline level in about an hour. Hot soak emissions are truncated if the engine is turned on again before the baseline has been reached (before an hour has elapsed). MOBILE6 assumes that hot soak durations range from 1 minute at minimum to a maximum of 60 minutes. The hot soak time distributions reflect the number of vehicles experiencing a hot soak of a given duration (1 to 60 minutes) at each hour of the day. MOBILE6 divides the day into fourteen time periods, one for each hour between 6 a.m. and 7 p.m., plus one for the hours from 7 p.m. through 5 a.m. the next day. MOBILE6 computes hot soak emissions for each minute of each hour and weights these emissions by the fraction of vehicles experiencing a hot soak at that time.

Input data required from the user:

- Hot soak activity values representing the fraction of vehicles experiencing a hot soak of each duration (1 to 60 minutes) at each of the fourteen time periods of the day (see Appendix III, Table 3.2 for fourteen time periods).

2.3.7 Engine start soak time distribution by hour

A vehicle is defined to be "soaking" if its engine is not running. Soak time is the time interval between when an engine is turned off and the next time it is started. The MOBILE6 model contains a soak length distribution for each of the fourteen hourly groups for weekdays and weekends (refer to Appendix II, Table 2.1). Each of these distributions contains seventy values representing a range of soak durations varying from 0 to over 720 minutes. From the soak time data, the model computes the percentage of vehicles that have been soaking for a given amount of time prior to an engine start for each hour of the day. This, in turn, affects start emissions, which depend on the length of soak time. The *same* soak time distributions are applied to all vehicle classes and all vehicle ages.

Input data required from the user:

- Values for each of the seventy soak durations for each of the 24 hours of the day for week and weekend days (3,360 values).
- The seventy values representing the percentage of soaks with a particular range of soak length occurring in a particular hour of the day.

2.3.8 Full, partial, and multiple diurnal distribution by hour

Diurnal emissions are much like evaporative emissions, excluding those that occur during vehicle running, starting, or hot soak operation. They generally occur over a period of several hours and have to be distributed across different hourly groups. In the

MOBILE6 model framework, three types of diurnals are defined. The first type is the multi-day diurnal. This type occurs if a vehicle is operated and then "soaks" (is parked) for two or more days, during which it experiences two or more cycles of thermal gradients sufficiently large enough to raise fuel tank temperatures past a threshold value. The second type is the full or one-day diurnal. This type of diurnal starts prior to the beginning of the temperature rise (i.e., prior to 6 a.m.) and can last for up to 24 hours. The third type is the interrupted diurnal. This type is similar to the previous ones, except that the soak periods range from a minimum of one hour up to 24 hours, and they start later in the day (i.e., the vehicle is operated during the morning so that the early morning heat build, beginning at 6 a.m., is interrupted). The diurnals, which range from 25 hours to 48 hours, are a combination of a one-day diurnal and an interrupted multi-day diurnal, depending on when they start.

Input data required from the user:

- Values representing the fraction of vehicles that experience a diurnal of each duration (72) at each time period of the day (18) (1,296 values total).
- MOBILE6 assumes that diurnal soak times range from 1 hour at a minimum to a maximum of 72 hours.
- Diurnal emissions are calculated to be zero from 12 a.m. to 6 a.m., because temperatures fall during the night (hence, 18 time periods in the day).

2.3.9 Calendar year

The calendar year command allows the user to specify a four-digit value for the calendar year for which the emission factors are to be calculated, known as the calendar year of evaluation. There is no default value for the calendar year.

Input data required by user:

- Calendar year between 1952 and 2050.

2.3.10 Month

Using the Month command, the user is required to specify either January 1 or July 1 as the date of calculation of the emission factors. January 1 is the default value. The specified month will affect emission computations in the following ways.

- Change in the composition of the fleet (July will include an additional 6 months of fleet turnover).
- Change in the way reformulated gasoline effects are modeled. If January is selected, winter rules for RFG are applied, and if July is selected, summer rules for RFG are applied.

Input data required from the user:

- Knowledge on which season's rules are applied for reformulated gasoline effects.

2.3.11 Hourly temperature

In the specification of temperatures, the user has two options. The first option is to specify the daily minimum and maximum temperatures, as in previous versions of the MOBILE model. The second option is to specify the 24 hourly temperatures. There are no default values for this command. MOBILE6 uses the maximum and minimum daily temperatures to perform temperature corrections to exhaust HC, CO, and NO_x; diurnal, hot soak, running loss, and resting loss portions of evaporative HC; and temperature of dispensed fuel to calculate refueling emissions.

Input data required by user:

- Daily minimum and maximum temperatures or twenty-four hourly temperatures.

2.3.12 Altitude

This command lets the user specify whether emissions are to be calculated for a low altitude region (approximately 500 feet above sea level) or for a high altitude region (approximately 5,500 feet above sea level). The MOBILE6 default is low altitude.

Input data required by user:

- For which altitude region (high or low) the emissions are being calculated.

2.3.13 Weekend/weekday

Weekend activity patterns of vehicle owners are significantly different from weekday patterns. Using this command, the user is allowed to specify whether MOBILE6 should use weekday or weekend data in its computations. By default, MOBILE6 uses weekday data in its computations.

Input data required by user:

- From which days of the week the data is obtained.

2.3.14 Fuel characteristics

MOBILE6 allows the user to model the impact of various gasoline fuel parameters. The user can specify one of two Tier 2 sulfur phase-in schedules to model the impact of a reformulated gasoline program or to specify the sulfur content for gasoline after 1999. For a more comprehensive discussion on the options available to the user, refer to Bhat et al. [2].

3. TRAFFIC RELATED INPUT NEEDS FOR MOBILE6 MODEL

This section discusses the needs of the MOBILE6 model in terms of traffic-related inputs. The latest revision to the MOBILE series of models poses some important challenges in improving traffic-related inputs. MOBILE6 allows a very high temporal resolution during the day for all traffic indicators. Specifically, hourly input can be provided for each hour of the day instead of 24-hour averages. Secondly, MOBILE6 fleet characterization projections of future vehicle fleet size and fraction of travel are based on several dimensions such as vehicle age, mileage accumulation rate, and 28 vehicle classes (expanded from eight classes in MOBILE5).

Three of the most important traffic-related inputs are the vehicle registration distribution, annual mileage accumulation rate, and the distribution of vehicle miles traveled (VMT) by vehicle class and roadway type. This section discusses in detail two of these traffic-related inputs for which relevant data could be obtained-namely, vehicle registration distribution by age and VMT mix by time of day. The mileage accumulation data are more difficult to model at the local level primarily because odometer readings are typically not recorded on an annual basis unless an inspection maintenance program is operational in the area under consideration. In our research effort, such data could not be obtained, and hence mileage accumulation rates were not modeled. Hence, the focus of this research has been the modeling of vehicle registration distribution and VMT distribution of the MOBILE6 vehicle classes.

a) Registration distribution by age and vehicle type

Registration distribution refers to the distribution of the regional in-use fleet among age and various vehicle classes. MOBILE6 allows the user to input twenty-five age fractions for each of the 16 composite vehicle types (see Appendix I, Table 1.2). These represent the fraction of vehicles of each vehicle class for each age group. Granell et al. [10] have examined the variation in regional composition of vehicles. They found that there are several local factors, such as socio-economic characteristics, land use patterns, and local roadway management practices, affecting vehicle purchase decisions.

b) Vehicle miles traveled (VMT) by vehicle class

The MOBILE5 model allowed users to enter the fractions of VMT for eight vehicle classes. However, the user was allowed to specify only a single value for each day representing the average over a 24-hour period. The new model allows the user to specify 24 hourly values for a greatly expanded set of twenty-eight vehicle classes (see Table 1.1 of Appendix I), representing the fractions for each hour of the day. The variation of traffic volumes over the day and the implications for mobile-source emissions can now be modeled. For each roadway link in a study region, the fraction of VMT accumulated by each of the twenty-eight vehicle classes for every hour of the day can be specified. These fractions must add up to one across all vehicle classes for each hour, and also across all times of the day for each vehicle class.

3.1 Registration Age Distribution

3.1.1 Introduction

The registration distribution by vehicle age is an important descriptor of the vehicle fleet. Registration distributions by age, for each of the vehicle types in the model, are a set of twenty-five fractional values ($0.0 \leq$ each individual fraction ≤ 1.0, and they sum to 1.0) that represent the fractions of vehicles (of the particular vehicle class) belonging to each age category. One of the important revisions to the MOBILE model has been the expansion of the vehicle classification from eight classes in MOBILE5 to 28 vehicle classes in the MOBILE6 version [2, 9]. For the purpose of registration distribution, these twenty-eight classes are aggregated into sixteen groups (see Appendix I, Table 1.1 and Table 1.2 for both classifications). This expanded classification of vehicles is designed to translate into more accurate emissions factors. However, these changes to MOBILE6 pose challenges in terms of data collection and analysis. Typically, agencies that collect vehicle information, such as the state Departments of Transportation (DOTs), do not follow the MOBILE classification. Hence, it is necessary to translate the vehicle information obtained from such sources into MOBILE classes in order to develop the age distributions. The use of local registration data requires considerable effort in linking the vehicle records, using GIS, to the locations at which they are registered. However, this approach has substantial benefits in terms of more accurate predictions of future distributions. Previous research efforts in this area have demonstrated the advantages of this procedure. Granell et al. [10] examined the variation in regional composition of vehicles. They found that there are several local factors affecting vehicle purchase decisions such as socio-economic characteristics, land use patterns, and local roadway management practices. Qiao et al. [15] have also developed models to predict future age distributions. They show that the absolute number of vehicles for a particular vehicle type with a particular age in a certain area can be regarded as a function of predictable socioeconomic indices such as population, average income, household population density, and so forth. However, both these efforts focused on developing distributions at the relatively less disaggregate county level.

In this analysis we investigate the impact of zonal demographic variables such as employment, population density, and median zonal income as well as zonal land use patterns on the registration distribution for the various vehicle classes in the MOBILE6 classification. The level of analysis is highly disaggregate-namely, the traffic analysis zones (TAZs) level. The area of study is the Dallas Fort Worth metropolitan area. A fractional split model is proposed for predicting the age distributions for future years. Sections 3.1.2 and 3.1.3 describe the acquisition of registration data, data analysis, and development of the baseline registration distribution by age (for the year 1998). Section 3.1.4 describes the model structure used. The model was calibrated using registration data for the year 1998, acquired from the TxDOT's Vehicles and Titles Registration (VTR) division. The calibration results and the interpretation of results are presented in Section 3.1.5.

3.1.2 Data acquisition

3.1.2.1 Registration data

Vehicle registration data for the year 1998 for the Dallas Fort Worth region were obtained from the Texas Department of Transportation's (TxDOT) Vehicles and Titles Registration (VTR) division. The information collected by the VTR includes the following.

- Addresses of the current and former owners of the vehicle.
- The make and model of the vehicle.
- The gross weight of the vehicle.

- The registration class code[1].
- Year of registration.
- A variable that indicates if the fuel type (diesel/gas) of the vehicle.

This information is available specific to each county. Registration data for Collin, Dallas, Denton, Ellis, Johnson, Kaufmann, Parker, Rockwall, and Tarrant counties were acquired.

3.1.2.2 Maps and zonal data

The GIS road network maps for each of the counties mentioned in Section 3.1.1 were obtained from the Census Bureau website [19]. These county level maps were combined to obtain the road network map for the DFW region. A GIS map of the 858 transportation analysis zones (TAZs) in the DFW area was available from an earlier research effort (TxDOT Project 0-1838).

Demographic and land use data for the TAZs were also available from the aforementioned research project. The demographic variables available were zonal population, median income for each zone, and employment in each of three sectors: basic (such as agriculture-related industries), retail (includes manufacturing, retail, and wholesale units) and service (such as administrative offices, banks, etc.). Zonal land use variables included the total acreage of each zone and the acreages of each of the following land uses: airports, offices, retail, hotel/motel, manufacturing plants/warehouses, parking structures/lots, and transportation and communication facilities.

3.1.3 Data analysis and development of baseline registration age distribution

3.1.3.1 Vehicle classification

Vehicle records with missing weight or year of registration were dropped from the data set. In addition, those records missing registration class or the make of the vehicle were discarded. The vehicles in the data set were categorized into the sixteen-vehicle MOBILE6 classification (see Table 1.2 of Appendix I) using the registration class codes. Certain registration codes provided no information on the vehicle type. For instance, the

[1] This is a code that classifies the vehicles into various categories for registration purposes. For example, registration class code 25 represents passenger vehicles under 6,000 lbs.

category “exempt” comprises vehicles of various types that are exempt from registration such as fire engines, police cars, official vehicles, and ambulances. For such categories, where the vehicle could not be classified on the basis of registration class, the vehicle make and the gross vehicle weights were used to classify the vehicles. For light-duty trucks, there was no information on the loaded vehicle weights (LVW), hence the classification was done solely on the basis of gross vehicle weight rating (GVWR). Light-duty trucks were classified into the combined classes Light-Duty Trucks 1 (LDT1) + Light-Duty Trucks 2 (LDT2), and Light-Duty Trucks 3 (LDT3) + Light-Duty Trucks 4 (LDT4). Buses could not be classified into School Buses (HDBS) and Transit and Urban Buses (HDBT) because this information was not available in the data set. Hence, buses were categorized into the combined bus class (HDBS+HDBT). In total, there were 13 vehicle classes.

The age of each vehicle was determined using the year of registration field. Twenty-five vehicle categories were created with ages ranging from 1 to 25 and above. All vehicles over 25 years of age were categorized in the last category. The records corresponding to each age/vehicle class combination were stored in separate files. The twenty-five age groups for the thirteen vehicle classes yielded 325 files.

3.1.3.2 Geo-coding

Geo-coding is the process of matching each record in the table of addresses to a physical location on the GIS map. The matched records are represented by symbols on the map and are stored in a GIS layer. Figures 3.1 and 3.2 illustrate the geo-coding process.

Each of the 325 files obtained using the procedure above was geo-coded onto the DFW road network map using the GIS platform TransCAD. During the geo-coding process, a number of records could not be matched to map locations. A possible reason for this could be errors in the input addresses such as incorrect address formats or incomplete addresses. The addresses collected by the VTR were recorded at the time of purchase of the vehicle. The data set contained some vehicles that had been purchased in other cities and states, and these contributed to the unmatched records. The statistics for unmatched records in each category are available in Table 4.1 of Appendix IV. Note that the average percentage of unmatched records is much lower for vehicles such as cars and motorcycles, which are mostly individually owned, as compared with those for the heavy-duty truck and bus categories, which are typically owned by firms. This could be because there is more "fluidity" in the fleet ownership of firms. For instance, a trucking company may move a fleet of trucks registered in California to operations centered in the DFW area. Such a fleet would not be matched in our procedure and would contribute to the unmatched segment. The proportion of unmatched light-duty trucks is in between the values for cars and heavy-duty trucks. This might be because even though light-duty trucks are popular individually owned vehicles, they are also used extensively by a lot of small firms.

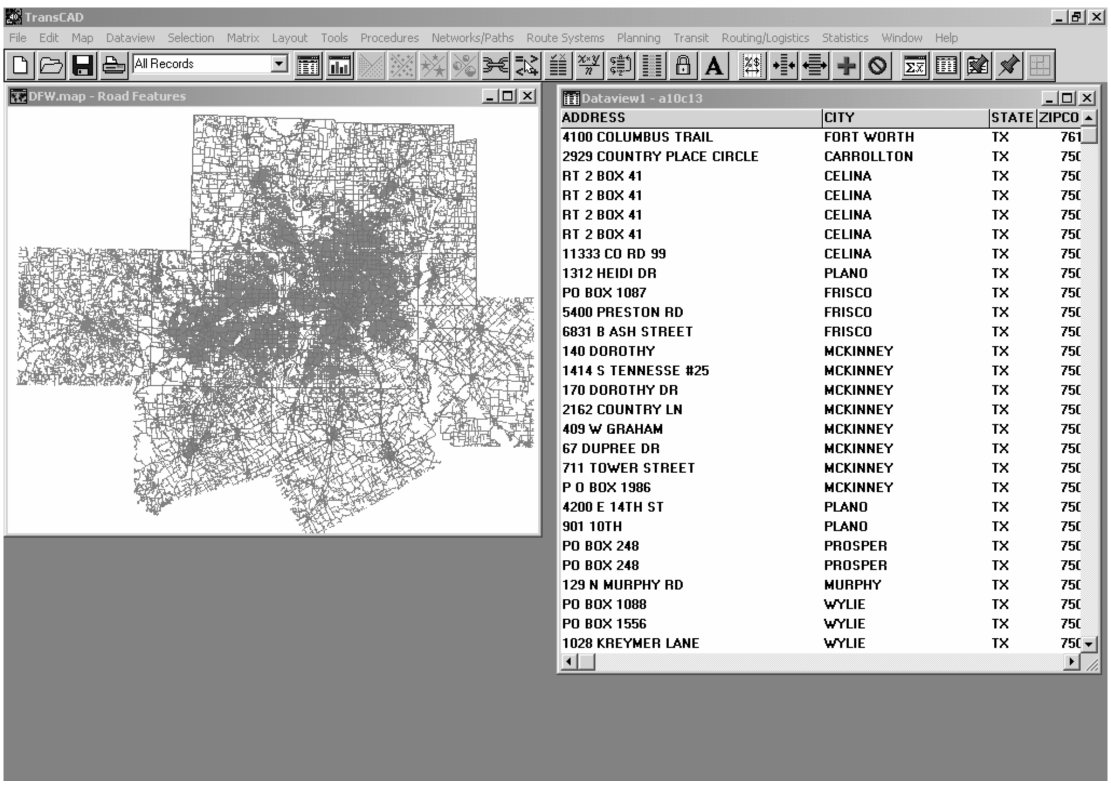

Figure 3.1 Map of TransCAD DFW region and address table before geo-coding of addresses

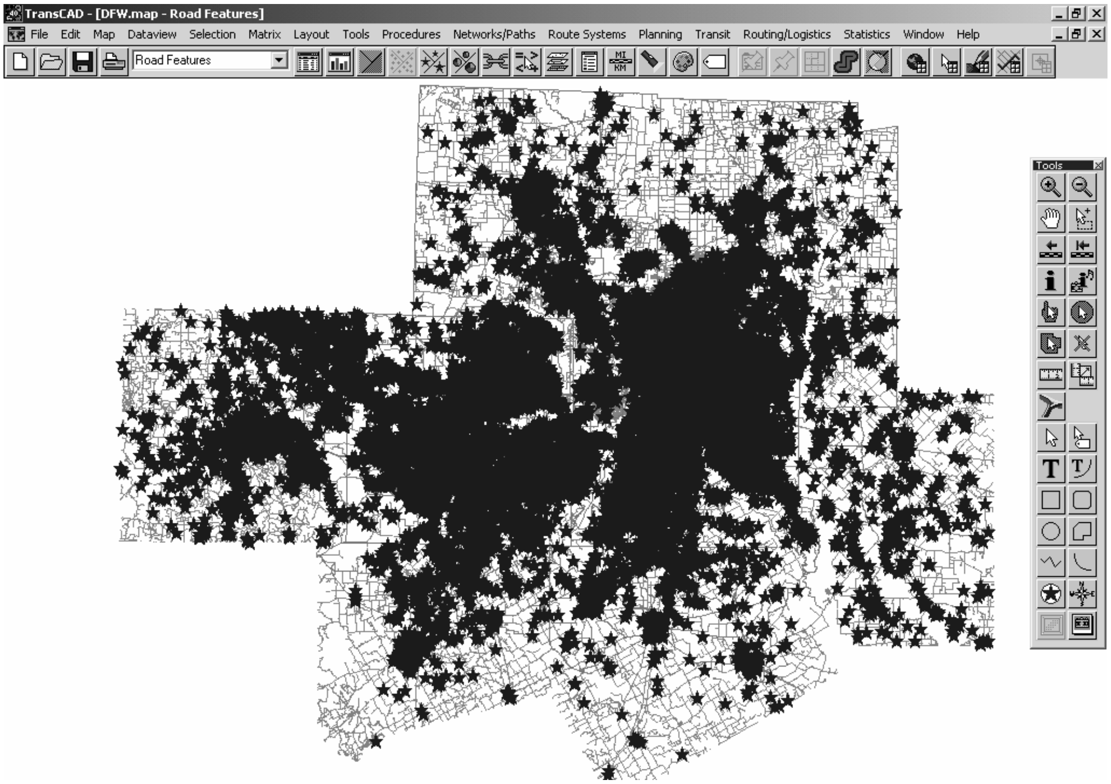

Figure 3.2 TransCAD map of DFW region after geo-coding of address table

The spatial variation across zones of the age/vehicle class distributions cannot be captured for the unmatched records. However, a comparison of the vehicle class-specific age distributions for the entire DFW area and for the unmatched segment indicates that for most vehicle classes the distribution for the latter group is fairly similar to that for the former. Plots of these comparisons are shown in Figures 4.1 to 4.13 in Appendix IV. Hence, it is reasonable to assume that the distribution of vehicle age and class across the geo-coded segment is the same as the distribution across the entire vehicle population.

3.1.3.3 Aggregation within TAZs and development of fractions

The Dallas Fort Worth planning region consists of 858 Transportation Analysis Zones (TAZs). All the 325 output GIS maps obtained from the above geo-coding process were overlaid with the TAZ map layer, and the number of geo-coded points within each zone were aggregated. These aggregate values represent the number of vehicles of each age/vehicle class category belonging to each of the TAZs. A data table of the aggregate values across twenty-five age groups for each vehicle class was assembled. From these values, the fractions of vehicles in each age group are easily calculated by dividing each value by the sum of values across the twenty-five age groups. As mentioned earlier, the light-duty truck classes were combined into two classes because loaded vehicle weight data was unavailable. The combined classes LDT1+LDT2 and LDT3+LDT4 are broken up into LDT1, LDT2, LDT3, and LDT4 using the procedure in the MOBILE6 User's Guide [9] for conversion of MOBILE5 registration input into MOBILE6 format. The combined class LDT1+LDT2 represents the LDT Group 1 class of MOBILE5. The combined class LDT3+LDT4 corresponds to the LDT Group 2 class. The adjustment factors A, B, C, and D were assumed to be for the year 1998 and were obtained from Appendix D of the MOBILE6 User's Guide. The number of transit and school buses were assumed to be equal, and the bus fractions were assigned in equal proportions to the two MOBILE6 classes HDBS and HDBT.

The final product of the above procedure is the set of twenty-five age fractions for sixteen classes of vehicles for each of the 858 transportation analysis zones (TAZs) in the DFW area for the year 1998. The distributions for future years can be predicted using a fractional-split multinomial model, which is discussed in section 3.1.4.

3.1.4 Fractional response model structure

The model structure used in this study is the fractional-split model proposed by Bhat and Nair [1] to predict the vehicle miles traveled (VMT) mix as a function of roadway and zonal characteristics. The fractional split model is a useful formulation for modeling the distribution of vehicle age fractions among various age categories because it accommodates the boundary values of the age fractions in each age category and is easy to estimate using available econometric software. The model can be very easily applied to forecast the future fractions for each age category.

3.1.4.1 Background

Fractional response variables arise in several transportation analysis contexts. Examples of such variables include the proportion of intercity trips made by each of several travel modes, time spent by an individual in one of several activity types (work, recreation, shopping), the fraction of vehicle miles traveled by various modes on a roadway link, and (as in the present analysis) the fraction of registered vehicles in each age category in each zone of an area. A characteristic of all these analyses is that the variable of interest is in the form of fractions. The sum of the fractions across all categories of the variable is equal to one, and each fraction is bounded between zero and one. Further, one or more of the fractions may take the boundary values of zero or one. In the subsequent discussion we present the fractional-split model structure in the context of registration distribution by age.

3.1.4.2 Quasi-likelihood estimation

The model employed in this research is an extension of the binary fractional-split model proposed by Papke and Woolridge [14]. It is identical to the structure used by Bhat and Nair [1] to predict the distribution of VMT on roadway links.

Let y_{qi} be the fraction of vehicles of age i (i=1,2,…,I) in zone q. Let this fraction be a function of a vector x_q of relevant explanatory variables associated with the attributes of the zone q. The approach used here does not need any *ad hoc* adjustment for boundary values of the dependent variable fractions and specifies a model for $E(y_{qi} \mid x_q)$. The approach makes no assumptions about the distribution of y_{qi} conditional on x_q and is easy to implement using available econometric software.

The econometric specification is as follows:

$$E(y_{qi} \mid x_q) = G_i(\infty, x_q),\ \ 0 \,''\, G_i(.) \,''\, 1,\ \ \sum_{j=1}^{I} G_j(.) = 1,\ \text{ where } \ \infty = (\infty_2', \infty_3', ..., \infty_I')'. \qquad (1)$$

$G_i(.), (i = 1,2,..., I)$ in the above equation is a pre-determined function, and the properties specified above ensure that the predicted fraction of vehicles in each age category for any zone will lie in the interval (0,1) and will sum to 1 across age categories. The econometric model specified in equation (1) is well defined even if y_{qi} takes on the value of 0 or 1 with non-zero positive probability. No assumption is made about the true underlying conditional distribution of y_{qi} given x_q. This is considered unknown and can have any underlying structure.

The $\propto$ parameter in the conditional mean model of Equation 1 is estimated by maximizing a likelihood function associated with a family of probability distributions, which does not necessarily contain the true unknown distribution. The label "quasi-likelihood estimation" is used for such estimations. Specifically, we use the multinomial log-likelihood function in the quasi-estimation:

$$L_q(\infty) = \sum_{i=1}^{I} y_{qi} \log G_i(\infty, x_q). \tag{2}$$

The multinomial quasi-likelihood estimator used above belongs more generally to the linear exponential family (LEF). We assume the functional form of G_i in the conditional mean specification of equation 2 to be multinomial logit because this structure is easy to program and implement. In this specification we write the following:

$$G_i(\infty, x_q) = \frac{e^{\infty_i' x_q}}{\sum_{j=1}^{I} e^{\infty_j' x_q}},$$

where $\infty = (\infty_2', \infty_3', ..., \infty_I')'$. (3)

3.1.5 Empirical results

In the subsequent discussion, the term age-fraction is used to denote the proportion of vehicles of a particular vehicle type that belong to a particular age group. For instance, the age-fraction of 10-year old cars in a zone denotes the fraction of all cars in the zone that are 10 years old. For each vehicle class twenty-five age-fractions are required by MOBILE6. The first twenty-four represent the fractions for ages 1 to 24, and the last fraction represents the fraction in the age category 25 years and older.

The descriptive statistics of the dependent variable (*i.e.*, the age fractions for each age category) for each of the vehicle classes are provided in Table 4.2 of Appendix IV. The portion of cars and light-duty trucks over the age of 10 is significantly lower than the mean proportion of other vehicles over the age of 10. This is a fairly intuitive observation because the frequency of fleet turnover of individual/personal vehicles is likely to be higher than that for commercial vehicles. The model results corroborate this intuition.

Fractional-split models were estimated using LIMDEP to obtain the registration distributions by age for each of the thirteen vehicle classes for which the baseline distributions were developed. The estimates of the β parameter vector for each of the classes are shown in Table 4.3 of the Appendix IV. The interpretation of the coefficients for each of the vehicle classes is discussed below.

Light-Duty Vehicle (LDV) Class - Passenger Cars

The explanatory variables that proved significant were the zonal median income, the population density of the zone, and the zonal employment level.

*a) Zonal Median Income***:** The base age category for this variable is the age group consisting of cars less than 10 years of age. The negative coefficient of the variable *MINC1025* indicates that zones with high median incomes are likely to have low proportions of cars over the age of 10. High zonal median incomes imply that most individuals in the zone have good living standards and are likely to own relatively new cars and there will be fewer used (second-hand) cars.

b) Population Density of the Zone: This variable was obtained by dividing the zonal population by the area of the zone (in thousands of acres). The results from the model estimation indicate that the zones with high population densities are likely to have higher proportions of cars in the age ranges 4 –14 years and 16 - 18 years. The coefficient of the variable *POPD418* indicates that the proportion of cars in the age group 4 - 14 and 16 - 18 is likely to be higher than all the other age categories combined (which form the base category). Densely populated zones are usually located in CBD areas where transit service is likely to be frequent. This combined with a shortage of inexpensive parking may discourage frequent purchase of new vehicles. However, people would still not be willing to hold on to their vehicles beyond a certain age, approximately 15 - 20 years. Hence most of the vehicles are likely to be in the “young” to “middle age” categories.

c) Zonal Employment Level: The coefficient of the variable *EMP325* indicates that zones with higher levels of employment are likely to have a higher proportion of cars under the age of 3 years as compared with the proportion of cars that are three years of age or older. Higher employment levels may indicate greater prosperity and economic activity of the zone. Hence, these zones are likely to have a greater proportion of new cars.

Light-Duty Truck Classes 1 and 2 LDT1+LDT2 (Gross Weight ″ 6,000 lbs)

This category comprises smaller sized pick up trucks, smaller sports utility vehicles (SUVs), and mini-vans. The zonal median income, the population density of the zone, and the zonal employment level were found to have significant impacts on the age distribution of vehicles in each zone.

a) Zonal Median Income: The effect of high zonal median income for light-duty trucks less than 6,000 lbs. is similar to that for passenger cars. In addition, the results indicate that in zones with higher median incomes the proportion of older vehicles decreases with increasing age. This is indicated by the relative magnitude of the coefficients of *MINC38* and *MINC925.* The coefficient of *MINC925* is lower than the coefficient of *MINC38,* implying that, for zones with higher median incomes, the proportion of light-duty trucks in the age category of 9 years and above is likely to be lower than the proportion of light-duty trucks in the age category of 3 - 8 years. The base age category for this variable is the age group consisting of light-duty trucks less than 3 years of age. High zonal median incomes imply good living standards and hence more new pickups, minivans, and SUVs.

b) Population Density of the Zone: The population density for each zone was calculated by dividing the zonal population by the area of the zone (in thousands of acres). The results from the model indicate that the zones with higher population densities are likely to have a higher proportion of light-duty trucks in the age ranges 6 –13 years and 16 - 18 years as compared with the other age categories. This result is similar to that of population density for passenger cars, and the interpretation is identical. Residents may be driven to retain vehicles that are "middle-aged" in densely populated CBD areas where parking comes at a premium and transit availability and frequency reduce auto dependence.

c) Zonal Employment Level: The results from the model indicate that zones with higher level of employment are likely to have a higher proportion of light-duty trucks under the age of 3 years as compared with the proportion of light-duty trucks that are of age 3 years or older. This result is again very similar to that of zonal employment on passenger cars, and the interpretations are identical. The results are consistent with the expected effects of employment on personal vehicle fleet turnover.

d) Area of Retail Trades and Services: The model results indicate that zones with high retail acreage are likely to have a higher fraction of light-duty trucks over the age of 3 years. High retail acreage can be taken to be indicative of the presence of numerous retailers or large retailers in the zone. Retail merchants use fleets of light-duty trucks that are likely to have low frequency turnovers, i.e. vehicles are likely to be retained longer. Light-duty commercial vehicles are typically retained for longer periods than personal vehicles. Hence, the proportion of new vehicles is likely to be lower.

e) Area of Parking Structures and Lots in the Zone: The results indicate that greater availability of parking (measured in acres of parking lots) implies a higher proportion of vehicles under the age of 11 years. The availability of parking in the zone is likely to influence the vehicle purchase decisions of individuals in the zone. Shortage of parking space, high parking costs, and so forth. may deter individuals from buying new light-duty trucks. Hence, the proportion of new light-duty trucks may be low in zones with a shortage of parking structures.

Light-Duty Truck Classes 3 and 4 LDT3+LDT4 (6,000 lbs.＜Gross Weight″ 8,500 lbs.)

This category comprises large-sized pick up trucks, large SUVs, and vans. The zonal median income, the population density of the zone, and the retail acreage in the zone were found to have significant impacts on the age distribution of vehicles in each zone.

a) Zonal Median Income: The coefficients for the zonal median income variables indicate that zones with higher median incomes are likely to have a lower proportion of light-duty trucks of age 5 years and older as compared with the proportion of such vehicles under the age of 5 years. This effect is similar to that of income on passenger cars and light-duty trucks < 6,000 lbs. The interpretation of the result is identical. Prosperous zones are likely to have more new vehicle purchases in any year than other zones. Hence the fraction of newer SUVs, pick up trucks, and vans is likely to be higher.

b) Population Density of the Zone: The population density for each zone was calculated by dividing the zonal population by the area of the zone (in thousands of acres). The results indicate that the zones with higher population densities are likely to have a higher proportion of light-duty trucks aged 7 years and above as compared with the proportion of such vehicles under the age of 7 years. This effect is identical to that for the passenger cars and light-duty trucks < 6,000 lbs. category. In a given year, the number of purchases of large SUVs, pick up trucks is likely to be lower in densely populated CBD zones where the high premium on parking and restrictions on space would discourage people from buying a large vehicle.

c) Area of Retail Trades and Services: The model results indicate that zones with high retail acreage are likely to have a higher fraction of large pick-ups over the age of seven. This result is identical to that for light-duty trucks < 6000 lbs. The turnover rates of commercial light-duty trucks are likely to be low, and hence the proportion of new vehicles being infused into the fleet in any given year is likely to be low.

Heavy-Duty Trucks (HDV 2B) (Gross Weight 8,501–10,000 lbs.)

This category comprises small-sized heavy-duty trucks. The level of basic employment in the zone and the acreage of industrial units in the zone were found to have significant impacts on the age distribution of vehicles in each zone.

a) Zonal Basic Employment: The level of employment in basic industries such as agriculture-based industries, forestry, and so forth is indicative of the size of such industries in that zone. The base category in this analysis is the proportion of heavy-duty trucks aged 1 year. The model results indicate that zones with a high presence of basic industries are likely to have a greater proportion of vehicles in the age category of 2 - 15 years as compared with the base category. However for such zones the proportion of vehicles in the age category 16 years and above is likely to be lower than the proportion in the base category. This indicates that basic industries are more likely to have "young" to "middle-aged" heavy-duty trucks, rather than older or brand-new ones.

b) Zonal Acreage of Infrastructure (Airports, Transportation/Communication): The model results indicate that vehicles under 5 years of age are likely to be greater in number as compared with older vehicles in zones that have a significant presence of infrastructure such as airports and transportation/communication facilities. The presence of sizeable infrastructure such as airports, transportation, communication facilities and so forth is likely to influence the age distribution of heavy-duty trucks in the zone. Vehicles owned by agencies that operate such infrastructure are likely to be used frequently. For example, the use of small-sized heavy-duty trucks for transportation around airports is considerable. Such agencies can also afford to replace vehicles that have been subject to wear more frequently. Hence, the fraction of younger vehicles is likely to be higher.

Heavy-Duty Trucks (HDV 3) (Gross Weight 10,001–14,000 lbs.)

This category comprises medium-sized heavy-duty trucks. The zonal median income, the acreage of industrial units in the zone, and the acreage of parking space in the zone were found to have significant impacts on the age distribution of vehicles in each zone.

a) Industrial Acreage: The model results indicate that the proportion of older heavy-duty trucks is likely to be lower for zones that have a greater presence of industrial units. This is expected because heavy-duty trucks used by industrial units are likely to last for a limited period of time, given the heavy payloads and frequent usage.

b) Parking Acreage: The model results indicate that the proportion of older heavy-duty trucks is likely to be lower for zones with higher acreage of parking. Scarcity of parking acreage is likely to discourage purchase of many new vehicles, and firms are likely to manage older fleets better.

Heavy-Duty Trucks (HDV 4) (Gross Weight 14,001–16,000 lbs.) & Heavy-Duty Trucks (HDV 5) (Gross Weight 16,001–19,500 lbs.)

This category comprises medium-sized heavy-duty trucks. None of the demographic or land use variables appear to have any significant effect on the age distribution of vehicles in each zone.

Heavy-Duty Trucks (HDV 6) (Gross Weight 19,501–26,000 lbs.)

This category comprises of medium sized heavy-duty trucks. The level of retail employment has a significant effect on the age distribution of vehicles in each zone.

a) Level of Employment in Retail Industry: The level of employment in retail industry is an indicator of the presence of large retail outlets, wholesale outlets, or shopping malls in the zone. Such firms are likely to own fleets of heavy-duty trucks that are in continuous use. The resultant wear is likely to lower the effective life of the trucks, and hence the fleet will have to be replaced fairly regularly. Hence higher levels of retail employment may imply fewer old heavy-duty trucks.

Heavy-Duty Trucks (HDV 7) (Gross Weight 26,000–33,000 lbs.)

This category comprises of medium-sized heavy-duty trucks. The level of basic employment and the acreage of infrastructure have significant effects on the zonal age distribution of heavy-duty trucks of this category.

a) Level of Employment in Basic Industry: The model results indicate that zones having a greater level of basic employment have a lower proportion of old vehicles (over the age of 14 years). High levels of basic employment indicate the presence of a sizeable number of primary sector industries such as agriculture-based industries. Such firms may not need to replace vehicles frequently or may not be able to afford vehicle replacements as frequently as retail and manufacturing industries can.

b) Acreage of Infrastructure (Airports, Transportation/Communication): The model results indicate that the zones with higher acreage of infrastructure such as airports, transportation, and communication facilities are likely to have a higher fraction of newer vehicles aged less than 3 years as compared with trucks that are 3 or more years old. This effect is similar to that for the vehicle category HDV2B, and the explanation may be identical. Trucks in such environments are subject to high wear, and the firms that own and operate large infrastructure facilities can afford relatively frequent fleet replacements.

Heavy-Duty Trucks (HDV8A) (Gross Vehicle Weight 33,001–60,000 lbs.):

This category consists of large heavy-duty trucks. The model results indicate that the levels of zonal retail and basic employment influence the age distribution of this category.

a) Zonal Retail Employment: The model results indicate that zones having a greater level of retail employment have a lower proportion of older vehicles. Large heavy-duty trucks are primarily used by big retailers and manufacturers. High levels of zonal retail employment may indicate the presence of such establishments. The vehicle fleets of these establishments are typically in constant use and are subject to considerable wear. Also, such firms are likely to have a nation-wide presence and exchange of fleets among different locations may result in a constant flux in the fleet.

b) Zonal Basic Employment: The model results indicate that zones having a greater level of basic employment have a lower proportion of old vehicles (over the age of 16 years). High levels of basic employment indicate the presence of a sizeable number of primary sector industries such as agriculture-based industries. Although such firms may own and operate sizeable truck fleets, they may not need to replace vehicles frequently or be able to afford vehicle replacements as frequently as retail and manufacturing industries can. Hence, the threshold age is considerably higher in this case as compared with that of retail employment.

Heavy-Duty Trucks (HDV 8B) (Gross Weight >60,000 lbs.)

This category comprises medium-sized heavy-duty trucks. None of the available demographic or land use variables appears to have a significant effect on the age distribution of vehicles in each zone.

Heavy-Duty Transit and School Buses (HDBS+HDBT)

The explanatory variables available do not satisfactorily explain the age distribution of school and transit buses. Hence a constants only model was estimated. The base age category was buses aged less than 1 year old. The coefficients of *UNO222*, *UNO23,* and *UNO24* indicate that the bias against age categories 2 - 22 years, age 23, years and age 24 years are higher than that for the base category. However the bias against buses over 25 years of age is the same as that for the base age category.

Motorcycles (MC)

The median income of the zone has an impact on the age distribution of motorcycles in the zone. Zones with a higher median income are likely to have a higher proportion of new motorcycles (under the age of 7 years).

a) Zonal Median Income: The coefficients for the zonal median income variables indicate that zones with higher median incomes are likely to have a higher proportion of motorcycles aged 7 years or less. This is to be expected because motorcycles are usually owned by relatively higher income individuals who will be able to afford newer vehicles.

3.2 Vehicle Miles Traveled

3.2.1 Introduction

The MOBILE6 model can produce emission factors at a highly disaggregate temporal resolution. Emissions are calculated for each hour, as opposed to a composite daily output produced by MOBILE5. In view of the non-attainment problems faced by several metropolitan areas including Houston, Dallas Fort Worth, and El Paso in Texas, such accurate modeling may be necessary for future conformity determinations. To improve such forecasts, the model allows various parameters to be inputted at the hourly level. One such input is the link-specific vehicle miles traveled (VMT) mix across different vehicle classes. The MOBILE5 model allowed users to enter the fractions of VMT for eight vehicle classes. However, the user was allowed to specify only a single value for each day representing the average over a 24-hour period. MOBILE6 allows the user to specify twenty-four values for a greatly expanded twenty-eight vehicle classes (see Table 1.1 of Appendix I), representing the fractions for each hour of the day. The variation of traffic volumes over the day and the implications for mobile-source emissions can now be modeled. For each roadway link in a study region, the fraction of VMT accumulated by vehicles in each of the twenty-eight vehicle classes during each hour of the day can be specified. These fractions must add up to one across all vehicle classes for each hour and also across all times of the day for each vehicle class.

In this research effort, the VMT mix by hour of day was developed for the Dallas Fort Worth region. The model developed by Bhat and Nair [1] was used to predict the daily average VMT mix for the links. However, because hourly vehicle counts were unavailable for the DFW area, counts from the Austin metropolitan area were used instead, in order to develop the hour-by-hour split up of the VMT mix. It was assumed that the hourly variation in VMT for any link type in the DFW area is similar to the hourly variation in VMT for the corresponding link type in Austin. The following section describes the procedure used in arriving at the hourly VMT mix distribution.

3.2.2 Methodology

MOBILE6 requires hourly VMT mix inputs, as opposed to the 24-hour averages that MOBILE5 required. Hourly VMT mix data was not available for the Dallas Fort Worth study area, and the MOBILE6 user guide recommends using the same value for each hour (meaning to use the 24-hour average for each hour) in the event that this happens. Proceeding as the MOBILE6 user guide suggests underutilizes the capabilities of MOBILE6; therefore, our goal was to find a way to capture the hourly variation in Dallas without having the actual data available.

The Bhat and Nair [1] fractional-split model was applied to the Dallas Fort Worth study area to obtain 24-hour average VMT mixes. Their model predicts fractional split on links as a function of the following.

- Roadway classification of the link
  - Freeways, major arterials, minor arterials, collectors, and local/residential roads
- Physical attributes of the link
  - Whether the road is divided

  - Number of lanes
- Operating conditions of the link
  - Free speed
- Attributes of the traffic analysis zone in which the link lies
  - Degree of urbanization of the zone
  - Airport presence
  - Presence of churches, schools, and hospitals
  - Zone acreage in retail and office space
  - Acreage in manufacturing plants and warehousing

The model could forecast the VMT mix for six vehicle classifications (autos, sports utility vehicles, pickups and vans, motorcycles, buses, and trucks) for each link in the Dallas Fort Worth study area.

After applying this model, it was necessary to find a method to vary this average data across all hours of the day. As mentioned previously, hourly VMT mix data was not available for the Dallas Fort Worth study area, but this data was obtained for the city of Austin. The VMT mix for Austin was for five vehicle classifications (autos, a combined category comprising sports utility vehicles, pickups and vans all together, motorcycles, buses, and trucks).[2] The data was also collected on four different road types: major arterial, minor arterial, collector, and highway.

The assumption was made that the hourly VMT variation is similar in metropolitan areas, and that specifically, Dallas VMT mix varies by hour in a way similar to that of Austin's. We assumed that the relationship between each hour's VMT mix and the 24-hour average is the same between Austin and Dallas. We applied the Austin hourly VMT mix variation to the 24-hour mix for the Dallas region on the basis of the road type of the links. Weights were obtained as follows and applied to the Dallas data:

[2] Note that the only difference in vehicle classifications between Austin and Dallas is that Austin has sports utility vehicles (suvs) and pickups and vans (puvs) all in one category, whereas Dallas has separate categories for suvs and puvs.

$$Fract_{i,t,Dallas} = \frac{Fract_{i,t,r,Austin}}{\overline{Fract_{i,r,Austin}}} * \overline{Fract_{i,Dallas}}$$

i = vehicle type

t = hour

r = road type.

For the sake of clarity, let us consider a simple example.

Let us consider a link picked at random from Dallas, and refer to it as link #1. Link #1 is classified as a minor arterial and its 24-hour average auto mix is 20 percent. We need the auto mix between 1 a.m. and 2 a.m. We refer to the Austin data and calculate a weight that is then applied to link #1. In order to calculate a weight from the Austin data, we divide the Austin minor arterial auto mix from 1 a.m. – 2 a.m. (50 percent) by the Austin 24-hour average auto mix for minor arterials (25%). A weight of two is obtained and then multiplied by the Dallas 24-hour average auto mix. The resulting auto mix for link #1 in Dallas from 1 a.m. to 2 a.m. is now 40 percent.

A problem that arose when applying these weights to the Dallas data was that the VMT mix fractions for each vehicle type did not necessarily sum to one. To remedy this problem, the motorcycle, truck, and bus categories were constrained to their 24-hour averages across all hours, and the auto and SUV/PUV categories were varied by hour (weights from Austin were applied to these vehicle classifications). This was deemed acceptable because, according to the Austin data, the three categories constrained to their 24-hour values did not vary much from hour to hour, and their relative VMT mix was so small compared with the auto and SUV/PUV categories. After the motorcycle, truck, and bus categories were constrained to their 24-hour average values, the auto and SUV/PUVs were weighted and scaled to equal the remainder of the mix (meaning one minus [bus + truck + motorcycle]) to ensure that all VMT mixes equal one. After hourly mixes were obtained for the Dallas data for the five vehicle categories, the mixes were first converted to MOBILE5. The hourly VMT fractions for the MOBILE6 vehicle classes are then obtained by applying the factors suggested in the MOBILE6 user's guide to convert the VMT of MOBILE5 classes to MOBILE6 classes.

4. INTEGRATION OF INPUT MODELS INTO A GIS FRAMEWORK

The traffic-related input models-namely, the vehicle registration distribution model and the VMT mix model for the MOBILE6 classes were embedded into TransCAD, a GIS platform, to enable easy representation and to facilitate TCM analysis. This required the integration of the estimated models with GIS-based data on zonal configuration, zonal land use and demographics, and the road network for the Dallas Fort-Worth metropolitan region. The integration of the input models into the GIS framework is extremely useful for performing TCM analysis because the application can make predictions about the fleet characteristics under different TCM scenarios. The GIS framework also enables easy association of the estimated fleet characteristics (such as vehicle age distribution, and VMT distribution) with spatial regions on a zonal map or a road network. In other words, each spatial entity on the map would contain information on the fleet characteristics associated with it. The fleet information for any spatial entity can be accessed by selecting the spatial entity of interest and viewing all the information associated with it. In TransCAD, this can be achieved by using the Info button on the toolbar. Unfortunately, this tool displays all the information associated with the selected spatial entity and does not allow selective viewing of information. It can be quite cumbersome for the user to sort through all the data and find the information he or she needs. In order to facilitate easy access to specific information, a graphical user interface was developed using the TransCAD macro language, GISDK. This user-friendly interface allows the user to select the data that he or she needs for display. Two user interfaces were developed, one for the vehicle registration distribution and the other for the VMT Mix distribution. The underlying structures of the two user interfaces are discussed below, but they are not discussed in detail in this report. A separate user's guidebook has been written, which discusses the user interfaces in greater detail and also provides step-by-step instructions to use this GIS application.

4.1 Vehicle Registration Distribution

The vehicle registration distribution fractional-split models calibrated at the zonal level for the twenty-five age groups for each of the thirteen vehicles classes were coded in GISDK macro language and embedded into TransCAD. Hence, given the zonal land use and demographic characteristics, TransCAD will be able to predict the fractions of the twenty-five age groups within each vehicle class for each zone in the metropolitan area. This information is then mapped onto the zonal map file. The vehicle registration information for any zone can then be viewed using the interactive graphical interface that has been developed in TransCAD using the GISDK macro language. The interface allows the user to select a zone from the zonal map, and it also allows the user to select the vehicle class for which the information is desired. For the chosen zone, the age distribution of the vehicles of the chosen vehicle class is then displayed in a tabular form. In this way, the user can view only the information that he or she desires. The user can select only one zone and one vehicle class at a time. However, a tool button is available to the user and, by using this tool repeatedly, the user can view the information for any number of zones and vehicle classes.

4.2 VMT Distribution

The VMT mix distribution models estimated were embedded into TransCAD using GISDK. Hence, given information on the link characteristics and zonal land use demographic characteristics, TransCAD can predict the 24-hour average VMT mix for the five vehicle classifications (auto, SUV/PUV, truck, bus, motorcycle). It then applies the embedded factors to convert the 24-hour averages into hourly VMT fractions and converts the VMT of the five vehicle classes into 16 MOBILE6 vehicle classes. The user can access all the VMT information for any link in the road network by clicking on the desired link. However, it would be difficult to sift through all the information and extract the desired information. In order to facilitate easy access to specific information and for better representation of information, a graphical user interface was developed using the TransCAD macro language, GISDK. The interface allows the user to select a link from the road network map of the metropolitan area and gives the user the option to view VMT information for the MOBILE 6 classes or the five basic vehicle classes. If the user wishes to view the VMT information for the five vehicle classes, then he or she can choose to either view the 24 hour VMT mix averages or the VMT mix information for a particular hourly duration of day. On the other hand, if the user desires to see the VMT information for the sixteen MOBILE6 vehicle classes, then he or she can choose to view the VMT information for a particular time of day for the selected link or he or she can choose to view the variation of VMT fraction on the selected link for any of the sixteen MOBILE6 vehicles classes. The structure of the user interface is shown in Figure 4.1 below.

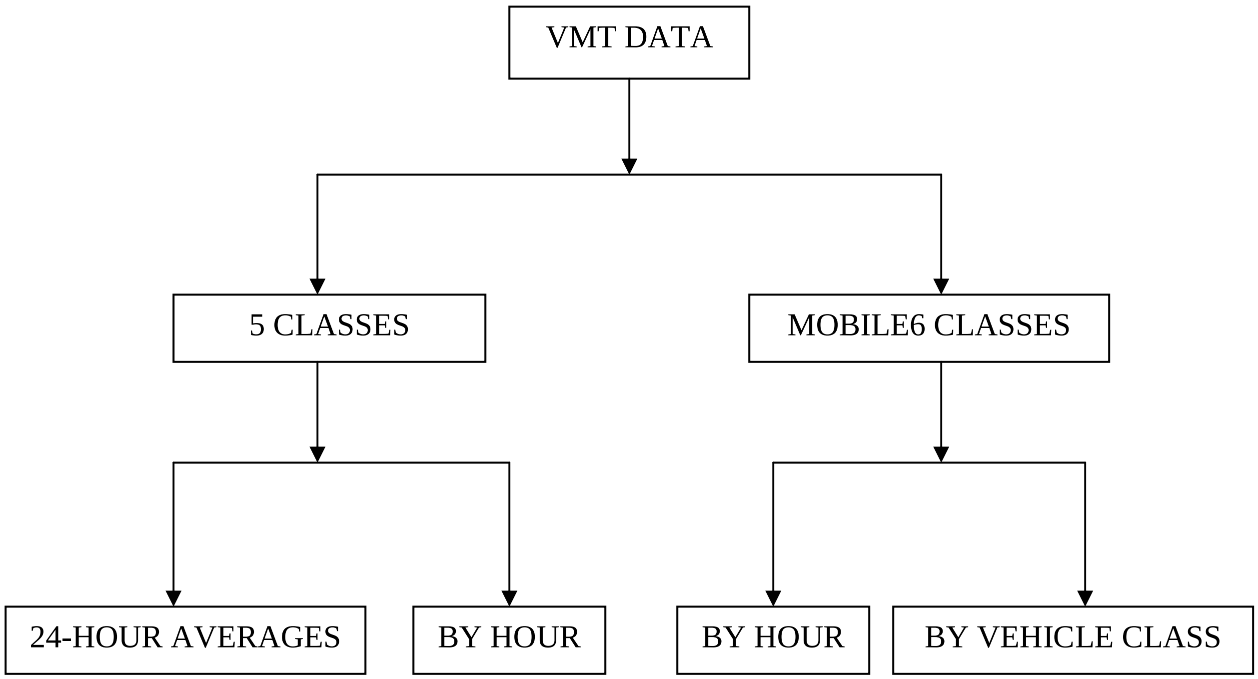

Figure 4.1. User Interface for VMT Mix Representation

5. TCM ANALYSIS

The Metropolitan Planning Organizations (MPOs) of non-attainment areas are required to implement transportation control measures (TCMs) in order to modify driving behavior and limit emissions resulting from mobile sources. Typically, a wide range of TCMs is available for any MPO, and ideally the MPOs would like to implement the TCM with the maximum "bang per buck". Also, it is essential for the MPOs to know how much reduction in emissions can be achieved by the implementation of different TCMs to be able to use a combination of TCMs to attain conformity. Usually, transportation modeling methodologies yield the most accurate and detailed estimates for future predictions. The models developed in this research effort for traffic-related inputs to MOBILE6 are primarily aimed to facilitate TCM analysis. In addition, the software application developed allows quick and easy assessment of the effectiveness of different TCMs. In order to demonstrate the use of the software application in performing TCM analysis, two simple, hypothetical TCMs were implemented as part of this study.

The following TCMs were implemented in this study:

1. Reduction in the zonal basic employment by 15 percent; and
2. Reduction in zonal office and retail space acreage by 20 percent.

Whereas the first TCM is aimed at affecting the vehicle registration distribution, the second TCM is directed towards modifying the VMT mix distribution. The model estimation results for the vehicle registration distribution clearly indicate that the zonal basic employment level is an important determinant of the vehicle registration distribution in a zone. Similarly, the model estimation results for the VMT mix distribution indicate that the VMT mix on any link is dependent on the zonal acreage of office and retail space. This was the reason for selecting the TCMs discussed above. The implementation of the two TCMs is discussed below in greater detail.

5.1 Reduction in the Zonal Basic Employment

For forecasting the vehicle age fractions of different vehicle classes for each zone, an input table containing information on the zonal land use and demographic characteristics must be prepared. In order to implement the TCM, the zonal basic employment was decreased by 15 percent in the preparation of the input table. In other words, the variable BASIC_EM was computed as 85 percent of the original basic employment variable. The Vehicle Registration Distribution module of the software application was then used to forecast the new age fractions for the MOBILE6 vehicle classes using the modified input table. After obtaining the predictions for the age fractions after the implementation of the TCM, they can then be used in the MOBILE6 model to estimate the emissions for the "after TCM" scenario. In this way, the effectiveness of any TCM in reducing emissions can be tested in a quick and easy way. In this study, the sensitivity analysis was not undertaken because the intent of TCM analysis was just to demonstrate the application of the software developed for performing TCM analyses.

The vehicle age fractions of the HDV2B vehicle class for a randomly selected zone for the "before TCM" and "after TCM" scenarios are presented in Table 5.1.

Table 5.1 Age Fractions of HDV2B in Zone 5 Before and After TCM Implementation

	Before TCM Scenario	After TCM Scenario
Age Fraction 1	0.16003	0.16045
Age Fraction 2	0.09540	0.09525
Age Fraction 3	0.05288	0.05280
Age Fraction 4	0.05798	0.05789
Age Fraction 5	0.03867	0.03861
Age Fraction 6	0.03079	0.03074
Age Fraction 7	0.03716	0.03710
Age Fraction 8	0.03723	0.03717
Age Fraction 9	0.03492	0.03487
Age Fraction 10	0.03821	0.03815
Age Fraction 11	0.03150	0.03145
Age Fraction 12	0.03396	0.03390
Age Fraction 13	0.03989	0.03983
Age Fraction 14	0.04588	0.04581
Age Fraction 15	0.04386	0.04380
Age Fraction 16	0.03107	0.03115
Age Fraction 17	0.02637	0.02644
Age Fraction 18	0.01779	0.01783
Age Fraction 19	0.01434	0.01438
Age Fraction 20	0.02778	0.02785
Age Fraction 21	0.02476	0.02483
Age Fraction 22	0.02106	0.02111
Age Fraction 23	0.01535	0.01539
Age Fraction 24	0.00730	0.00732
Age Fraction 25	0.03578	0.03587

As can be seen from Table 5.1, the age fractions of the vehicle class HDV2B are different for the "before TCM" and "after TCM" scenarios. The changes in vehicle age fractions will translate into changes in emissions when the new vehicle age fractions are used in MOBILE6 as inputs.

5.2 Reduction in Office and Retail Acreage

Just as in the case of vehicle registration distribution, an input table has to be prepared for forecasting the VMT mix on any link in the road network. This input table must contain information on the link characteristics, the zonal land use and demographic characteristics of the zone in which the link falls. To implement a TCM, we first need to modify the input table and then use the modified input table in forecasting the VMT fractions of different vehicle classes. For implementing the TCM considered in this case, the zonal office and retail acreage in the input file needs to be reduced by 20 percent. This was accomplished by computing the variable OFFICE95 as 80 percent of the original OFFICE95 variable. Once the input table is ready, we then need to apply the VMT mix models developed in this study to obtain forecasts of VMT mix proportions for all the links after the implementation of this TCM. The GIS-based software application comes in extremely handy for this purpose because the VMT models have been integrated within the software. Hence, the VMT mix proportions after the implementation of the TCM can be obtained very easily by using the modified input table to run the VMT module of the software application. Once the predictions for the VMT mix proportions are obtained, they can be inputted to the MOBILE6 model to estimate the emissions and to test the effectiveness of the TCM in reducing emissions. In this study, the sensitivity analysis was not undertaken because the intent of TCM analysis was to just demonstrate the usefulness of the software developed in performing TCM analyses.

The vehicle age fractions of the five vehicle classes for a randomly selected link for the "before TCM" and "after TCM" scenarios are presented in Table 5.2. The results in Table 5.2 indicate that the VMT fractions are not hugely different for the "before TCM" and "after TCM" scenarios but an understanding of how these small changes are translated into emissions reduction can be found only by applying these values in the MOBILE6 model.

Table 5.2 24-Hour VMT Fractions of Five Vehicle Classes on Link 11007 Before and After TCM Implementation

	Before TCM Scenario	After TCM Scenario
SUV/PUV	0.33322	0.33324
Truck	0.03478	0.03483
Bus	0.00265	0.00265
Motorcycle	0.00367	0.00367
Autos	0.62568	0.62561

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Appendix I

Vehicle Classes

Table 1.1. List of Vehicle Classes in MOBILE6

Number	*Abbreviation*	*Description*
1	LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-Duty Gasoline Trucks 1 (0-6,000 lbs. GVWR, 0-3,750 lbs. LVW)
3	LDGT2	Light-Duty Gasoline Trucks 2 (0-6,000 lbs. GVWR, 3,751-5750 lbs. LVW)
4	LDGT3	Light-Duty Gasoline Trucks 3 (6,001-8500 lbs. GVWR, 0-3750 lbs. LVW)
5	LDGT4	Light-Duty Gasoline Trucks 4 (6,001-8500 lbs. GVWR, 3,751-5750 lbs. LVW)
6	HDGV2b	Class 2b Heavy-Duty Gasoline Vehicles (8501-10,000 lbs. GVWR)
7	HDGV3	Class 3 Heavy-Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
8	HDGV4	Class 4 Heavy-Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
9	HDGV5	Class 5 Heavy-Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
10	HDGV6	Class 6 Heavy-Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
11	HDGV7	Class 7 Heavy-Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
12	HDGV8a	Class 8a Heavy-Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
13	HDGV8b	Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14	LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
15	LDDT12	Light-Duty Diesel Trucks 1and 2 (0-6,000 lbs. GVWR)
16	HDDV2b	Class 2b Heavy-Duty Diesel Vehicles (8501-10,000 lbs. GVWR)
17	HDDV3	Class 3 Heavy-Duty Diesel Vehicles (10,001-14,000 lbs. GVWR)
18	HDDV4	Class 4 Heavy-Duty Diesel Vehicles (14,001-16,000 lbs. GVWR)
19	HDDV5	Class 5 Heavy-Duty Diesel Vehicles (16,001-19,500 lbs. GVWR)
20	HDDV6	Class 6 Heavy-Duty Diesel Vehicles (19,501-26,000 lbs. GVWR)
21	HDDV7	Class 7 Heavy-Duty Diesel Vehicles (26,001-33,000 lbs. GVWR)
22	HDDV8a	Class 8a Heavy-Duty Diesel Vehicles (33,001-60,000 lbs. GVWR)
23	HDDV8b	Class 8b Heavy-Duty Diesel Vehicles (>60,000 lbs. 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 Diesel Trucks 3 and 4 (6,001-8,500 lbs. GVWR)

Source: U.S. EPA. Draft User's Guide to MOBILE6.0 Mobile Source Emission Factor Model, August 2001. http://www.epa.gov/otaq/models/mobile6/d01003.pdf.

Table 1.2. Composite Vehicle Classes

Number	Abbreviation	Description
1	LDV	Light-Duty Vehicles (Passenger Cars)
2	LDT1	Light-Duty Trucks 1 (0-6,000 lbs. GVWR, 0-3,750 lbs. LVW)
3	LDT2	Light-Duty Trucks 2 (0-6,000 lbs. GVWR, 3,751-5,750 lbs. LVW)
4	LDT3	Light-Duty Trucks 3 (6,001-8,500 lbs. GVWR, 0-5,750 lbs. ALVW*)
5	LDT4	Light-Duty Trucks 4 (6,001-8,500 lbs. GVWR, 5,751 lbs. and greater ALVW)
6	HDV2B	Class 2b Heavy-Duty Vehicles (8,501-10,000 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 Buses
15	HDBT	Transit and Urban Buses
16	MC	Motorcycles (All)

* ALVW = Alternative Loaded Vehicle Weight: The adjusted loaded vehicle weight is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR)

Source: U.S. EPA. Draft User's Guide to MOBILE6.0 Mobile Source Emission Factor Model, August 2001. http://www.epa.gov/otaq/models/mobile6/d01003.pdf.

Table 1.3. Composite Vehicle Types for Diesel Sales Fractions

Number	Abbreviation	Description
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 (0-6,000 lbs. GVWR, 3751-5750 lbs. LVW)
4	LDT3	Light-Duty Trucks 3 (6,001-8,500 lbs. GVWR, 0-5750 lbs. ALVW)
5	LDT4	Light-Duty Trucks 4 (6,001-8,500 lbs. GVWR, 5751 lbs. and greater ALVW)
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 Buses

Source: U.S. EPA. Draft User's Guide to MOBILE6.0 Mobile Source Emission Factor Model, August 2001. http://www.epa.gov/otaq/models/mobile6/d01003.pdf.

Table 1.4. Vehicle Classes Affected By the Starts Per Day Command

Number	Abbreviation	Description
1	LDGV	Light-Duty Gasoline Vehicles (Passenger Cars)
2	LDGT1	Light-Duty Gasoline Trucks 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
3	LDGT2	Light-Duty Gasoline Trucks 2 (0-6,000 lbs. GVWR, 3751-5750 lbs. LVW)
4	LDGT3	Light-Duty Gasoline Trucks 3 (6,001-8,500 lbs. GVWR, 0-5750 lbs. ALVW)
5	LDGT4	Light-Duty Gasoline Trucks 4 (6,001-8,500 lbs. GVWR, 5751 lbs. and greater ALVW)
6	HDGV2B	Class 2b Heavy-Duty Gasoline Vehicles (8501-10,000 lbs. GVWR)
7	HDGV3	Class 3 Heavy-Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
8	HDGV4	Class 4 Heavy-Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
9	HDGV5	Class 5 Heavy-Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
10	HDGV6	Class 6 Heavy-Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
11	HDGV7	Class 7 Heavy-Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
12	HDGV8A	Class 8a Heavy-Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
13	HDGV8B	Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
14	LDDV	Light-Duty Diesel Vehicles (Passenger Cars)
15	LDDT12	Light-Duty Diesel Trucks 1 and 2 (0-6,000 lbs. GVWR)
24	MC	Motorcycles (Gasoline)
25	HDGB	Gasoline Buses (School, Transit and Urban)
28	LDDT34	Light-Duty Diesel Trucks 3 and 4 (6,001-8,500 lbs. GVWR)

Source: U.S. EPA. Draft User's Guide to MOBILE6.0 Mobile Source Emission Factor Model, August 2001. http://www.epa.gov/otaq/models/mobile6/d01003.pdf.

Table 1.5 MOBILE6 Vehicle Classes Mapped to Typical Vehicle Classes

MOBILE6 class	Vehicle type
LDGV	Passenger cars
LDGT1	PUVs, SUVs
LDGT2	
LDGT3	
LDGT4	
HDGV2b	Trucks
HDGV3	
HDGV4	
HDGV5	
HDGV6	
HDGV7	
HDGV8a	
HDGV8b	
LDDV	Passenger cars
LDDT12	PUVs, SUVs
HDDV2b	Trucks
HDDV3	
HDDV4	
HDDV5	
HDDV6	
HDDV7	
HDDV8a	
HDDV8b	
MC	Motorcycles
HDGB	Buses
HDDBT	
HDDBS	
LDDT34	PUVs, SUVs

PUV: Pick-ups and vans, SUV: Sports utility vehicle.

Source: VMT Mix modeling for MOBILE source emissions forecasting: Formulation and Empirical Application, Chandra R. Bhat and Harikesh S. Nair, The University of Texas at Austin.

Appendix II

One Time Data

Table 2.1 Default Values for Engine Starts per Day and Distribution by Hour

Vehicle Class	Weekday (trips/day)	Weekend (trips/day)
Light-duty passenger vehicles	7.28	5.41
Light trucks	8.06	5.68
Motorcycles	1.35	1.35
Heavy-duty gasoline vehicles and buses	6.88	6.88
Heavy-duty diesel vehicles and buses	6.65	6.65

Source: U.S. EPA. Draft User's Guide to MOBILE6.0 Mobile Source Emission Factor Model, August 2001. http://www.epa.gov/otaq/models/mobile6/d01003.pdf.

Table 2.2 Hourly Start Distributions

Nominal Name	Hourly Intervals	
	Hourly Range	Time
6	6-7	6 a.m. – 7 a.m.
7	7-8	7 a.m. – 8 a.m.
8	8-9	8 a.m. – 9 a.m.
9	9-10	9 a.m. – 10 a.m.
10	10-11	10 a.m. – 11 a.m.
11	11-12	11 a.m. – 12 p.m.
12	12-13	12 p.m. – 1 p.m.
13	13-14	1 p.m. – 2 p.m.
14	14-15	2 p.m. – 3 p.m.
15	15-16	3 p.m. – 4 p.m.
16	16-17	4 p.m. – 5 p.m.
17	17-18	5 p.m. – 6 p.m.
18	18-19	6 p.m. – 7 p.m.
24	19-24 and 24-5	7 p.m. – 6 a.m.

Source: U.S. EPA Assessment and Modeling Division report on "Soak Length Activity Factors for Start Emissions", February 1998.
http://www.epa.gov/OMS/models/mobile6/m6flt003.pdf.

Appendix III

Scenario Selection

Table 3.1 Trip Duration Categories

Category Number	Trip Duration Range (in Minutes)
1	0 – 10 minutes
2	11 – 20 minutes
3	21 – 30 minutes
4	31 – 40 minutes
5	41 – 50 minutes
6	51+ minutes

Source: U.S. EPA Assessment and Modeling Division report on "Soak length Activity Factors for Start Emissions", February 1998. http://www.epa.gov/OMS/models/mobile6/m6flt003.pdf.

Table 3.2 Daily Distribution of Hot Soaks across the 14 Time Periods of the Day

Hour	Weekday	Weekend
6	2.33	0.99
7	6.05	2.26
8	6.30	3.38
9	4.62	6.41
10	5.08	6.98
11	6.32	8.80
12	7.80	9.23
13	7.32	7.40
14	7.87	8.10
15	8.63	6.62
16	8.71	8.03
17	7.99	6.91
18	5.88	6.27
24	15.10	18.62

Source: U.S. EPA Assessment and Modeling Division report on "Hot Soak Emissions as a function of time", June 1998. http://www.epa.gov/OMS/models/mobile6/m6evp007.pdf

Appendix IV

Analysis Results

Table 4.1 Geocoding Results

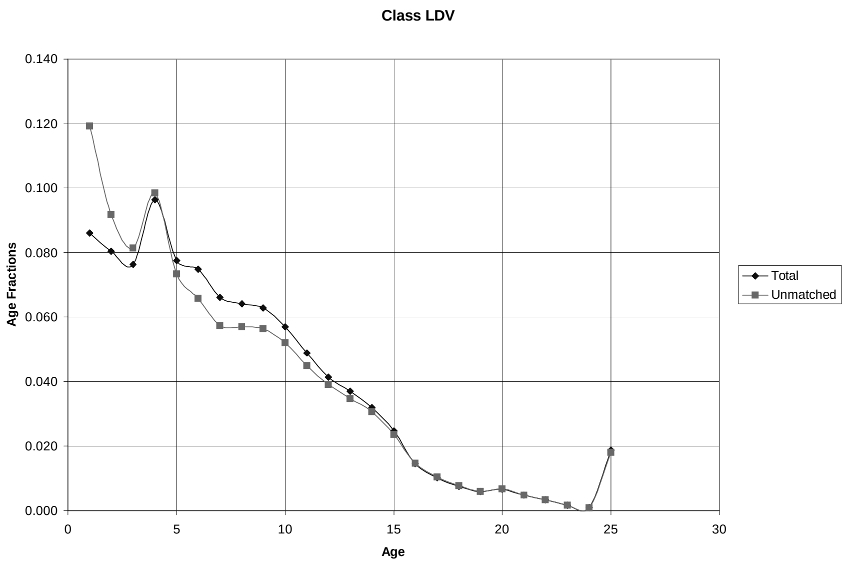
Age	LDV			LDT12			LDT34			HDV2B			HDV3			HDV4		
	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM
1	156,202	31,320	20.05	119,303	20,624	17.29	19,877	5,829	29.33	2,315	920	39.74	1,164	397	34.11	818	347	42.42
2	145,798	24,083	16.52	95,480	16,044	16.80	14,040	3,781	26.93	1,537	604	39.30	850	300	35.29	854	281	32.90
3	138,603	21,390	15.43	79,614	14,240	17.89	10,328	2,939	28.46	782	296	37.85	570	165	28.95	491	187	38.09
4	174,939	25,878	14.79	80,461	14,503	18.02	9,908	3,029	30.57	978	500	51.12	901	282	31.30	627	251	40.03
5	140,701	19,270	13.70	77,904	13,754	17.66	6,434	2,145	33.34	786	404	51.40	1,384	796	57.51	345	147	42.61
6	135,918	17,288	12.72	60,904	10,180	16.71	5,530	1,784	32.26	420	162	38.57	743	242	32.57	263	94	35.74
7	120,042	15,053	12.54	51,532	8,365	16.23	4,006	1,246	31.10	441	150	34.01	590	130	22.03	219	79	36.07
8	116,508	14,963	12.84	49,051	8,446	17.22	3,041	1,080	35.51	459	164	35.73	455	123	27.03	266	82	30.83
9	114,099	14,827	12.99	41,236	7,330	17.78	2,796	855	30.58	494	159	32.19	1,825	994	54.47	243	48	19.75
10	103,452	13,649	13.19	41,756	7,894	18.91	3,015	959	31.81	478	154	32.22	753	167	22.18	249	92	36.95
11	88,607	11,818	13.34	37,641	6,747	17.92	2,672	855	32.00	416	148	35.58	557	171	30.70	177	90	50.85
12	75,046	10,277	13.69	28,536	4,966	17.40	1,855	578	31.16	531	293	55.18	628	256	40.76	136	66	48.53
13	67,211	9,134	13.59	33,359	5,911	17.72	2,871	969	33.75	526	163	30.99	539	171	31.73	234	105	44.87
14	57,937	8,037	13.87	28,792	5,224	18.14	2,795	878	31.41	503	119	23.66	605	191	31.57	205	99	48.29
15	44,954	6,214	13.82	25,123	4,567	18.18	2,708	792	29.25	464	114	24.57	484	135	27.89	67	22	32.84
16	26,524	3,851	14.52	15,830	2,974	18.79	1,580	461	29.18	299	86	28.76	249	79	31.73	34	9	26.47
17	18,489	2,742	14.83	13,569	2,596	19.13	1,476	410	27.78	277	70	25.27	174	49	28.16	37	14	37.84
18	13,700	2,030	14.82	10,670	2,049	19.20	869	235	27.04	205	72	35.12	131	36	27.48	43	15	34.88
19	10,721	1,542	14.38	7,055	1,371	19.43	778	225	28.92	142	43	30.28	104	35	33.65	46	13	28.26
20	12,005	1,800	14.99	11,924	2,320	19.46	1,480	383	25.88	701	368	52.50	207	78	37.68	89	22	24.72
21	8,808	1,267	14.38	11,277	2,241	19.87	1,199	335	27.94	815	365	44.79	172	59	34.30	58	27	46.55
22	6,033	880	14.59	9,450	1,786	18.90	1,096	291	26.55	650	460	70.77	153	48	31.37	178	17	9.55
23	3,141	442	14.07	6,874	1,257	18.29	980	257	26.22	283	149	52.65	127	49	38.58	142	33	23.24
24	1,761	231	13.12	3,545	606	17.09	562	131	23.31	79	20	25.32	79	31	39.24	110	20	18.18
25	34,118	4,740	13.89	32,555	6,172	18.96	1,679	422	25.13	358	105	29.33	582	231	39.69	335	74	22.09
	1,815,317	262,726	14.47	973,441	172,167	17.69	103,575	30,869	29.80	14,939	6,088	40.75	14,026	5,215	37.18	6,266	2,234	35.65

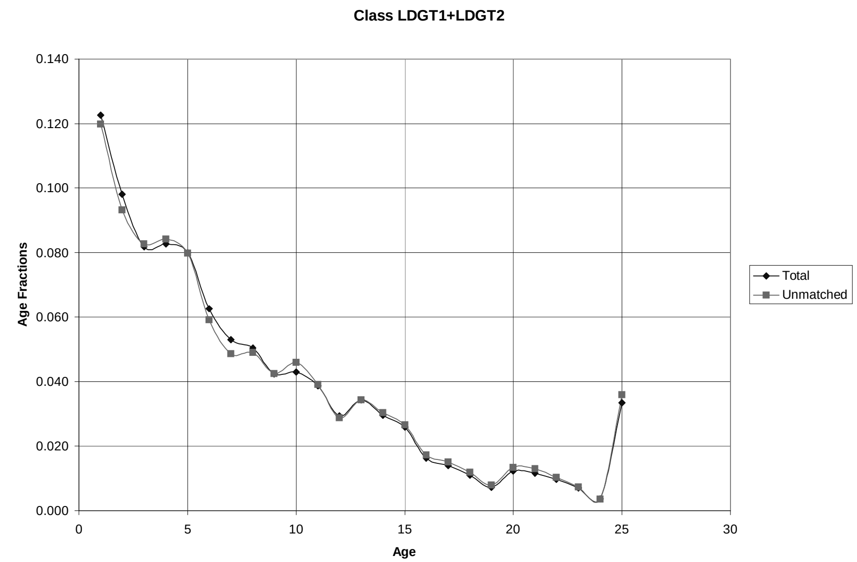
Table 4.1 Geocoding Results (continued)

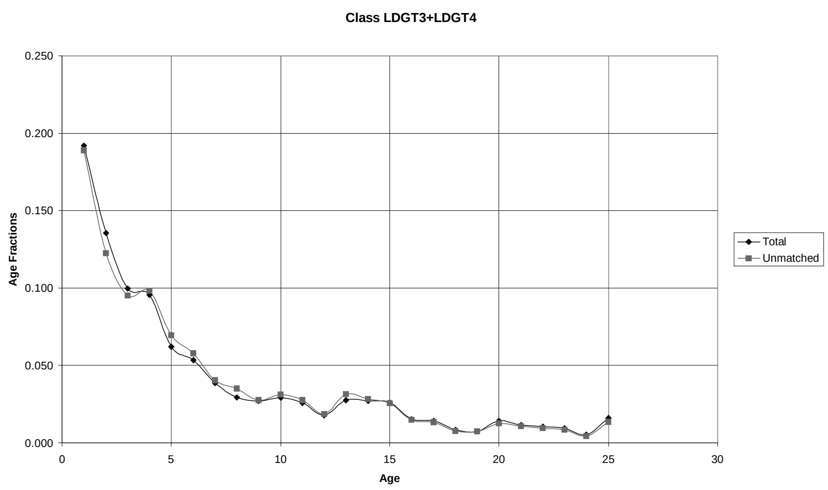
Age	HDV5			HDV6			HDV7			HDV8A			HDV8B			HDBTS			MC		
	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM	Total	UM	% UM
1	421	170	40.38	1,624	663	40.83	943	387	41.04	3,076	1,316	42.78	3,627	1,733	47.78	217	58	26.73	3,717	645	17.35
2	235	70	29.79	1,154	311	26.95	553	265	47.92	1,073	406	37.84	2,002	850	42.46	135	35	25.93	2,839	429	15.11
3	288	57	19.79	803	306	38.11	479	184	38.41	1,065	500	46.95	2,199	1,085	49.34	157	66	42.04	2,731	403	14.76
4	439	144	32.80	769	344	44.73	495	205	41.41	1,290	548	42.48	2,427	1,392	57.35	131	51	38.93	2,185	323	14.78
5	220	94	42.73	442	200	45.25	383	183	47.78	1,114	473	42.46	2,026	1,072	52.91	194	65	33.51	1,895	268	14.14
6	199	66	33.17	447	175	39.15	301	133	44.19	931	383	41.14	1,428	675	47.27	107	30	28.04	1,474	209	14.18
7	150	42	28.00	397	134	33.75	229	112	48.91	585	288	49.23	909	375	41.25	77	25	32.47	1,067	159	14.9
8	224	91	40.63	427	184	43.09	318	135	42.45	907	406	44.76	853	394	46.19	91	24	26.37	776	123	15.85
9	216	52	24.07	332	113	34.04	366	147	40.16	820	361	44.02	900	411	45.67	85	18	21.18	736	112	15.22
10	1,149	999	86.95	325	136	41.85	222	98	44.14	803	331	41.22	958	439	45.82	84	30	35.71	821	120	14.62
11	996	797	80.02	266	111	41.73	191	81	42.41	671	303	45.16	618	277	44.82	87	18	20.69	726	106	14.6
12	166	81	48.80	338	159	47.04	180	80	44.44	610	251	41.15	502	246	49.00	73	15	20.55	800	112	14
13	185	81	43.78	300	115	38.33	186	55	29.57	607	256	42.17	411	188	45.74	92	25	27.17	1,268	195	15.38
14	172	74	43.02	344	125	36.34	206	99	48.06	687	294	42.79	519	265	51.06	117	38	32.48	1,323	172	13
15	143	62	43.36	192	16	8.33	170	65	38.24	632	291	46.04	366	179	48.91	84	20	23.81	1,088	165	15.17
16	61	23	37.70	164	77	46.95	70	26	37.14	239	112	46.86	134	69	51.49	87	18	20.69	1,171	190	16.23
17	152	69	45.39	158	65	41.14	95	35	36.84	286	137	47.90	160	62	38.75	64	14	21.88	1,684	269	15.97
18	90	26	28.89	169	70	41.42	95	43	45.26	303	111	36.63	174	73	41.95	88	21	23.86	1,083	162	14.96
19	53	14	26.42	155	71	45.81	68	26	38.24	329	103	31.31	123	59	47.97	73	17	23.29	1,065	169	15.87
20	67	26	38.81	190	87	45.79	97	46	47.42	328	109	33.23	132	74	56.06	55	15	27.27	714	115	16.11
21	65	32	49.23	148	65	43.92	42	25	59.52	278	91	32.73	60	27	45.00	58	28	48.28	581	86	14.8
22	53	14	26.42	82	38	46.34	36	17	47.22	225	101	44.89	62	31	50.00	36	11	30.56	391	79	20.2
23	22	9	40.91	74	34	45.95	22	12	54.55	94	45	47.87	26	14	53.85	17	6	35.29	335	57	17.01
24	46	13	28.26	79	37	46.84	25	12	48.00	79	38	48.10	31	24	77.42	35	10	28.57	286	45	15.73
25	179	63	35.20	397	183	46.10	127	67	52.76	389	179	46.02	99	54	54.55	122	26	21.31	1,526	232	15.2
	5,991	3,169	52.90	9,776	3,819	39.07	5,899	2,538	43.02	17,421	7,433	42.67	20,746	10,068	48.53	2,366	684	28.91	32,282	4,945	15.32

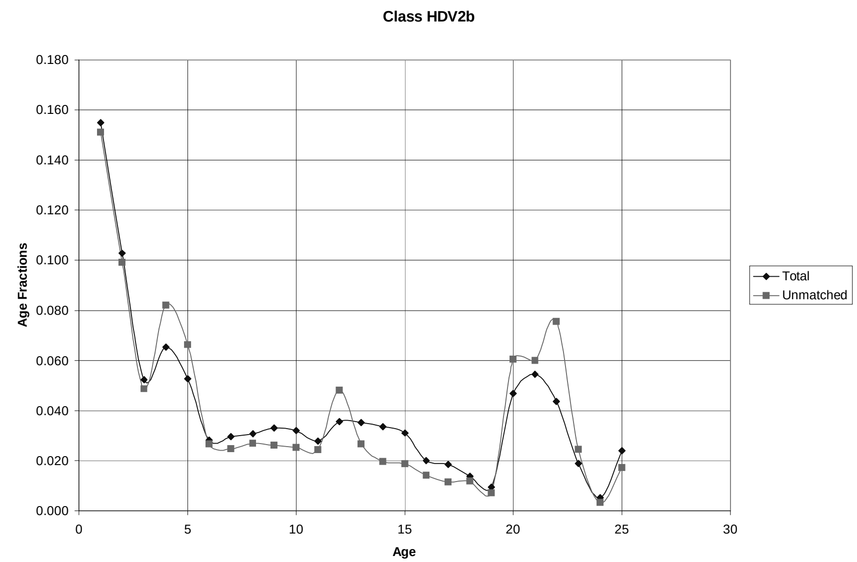
UM = number of unmatched records

% UM =percentage of total records that are not matched

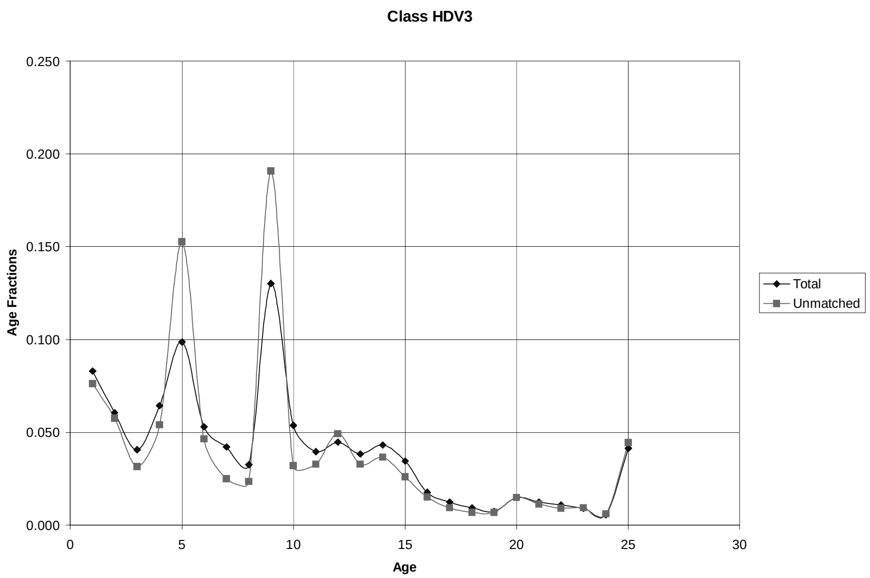


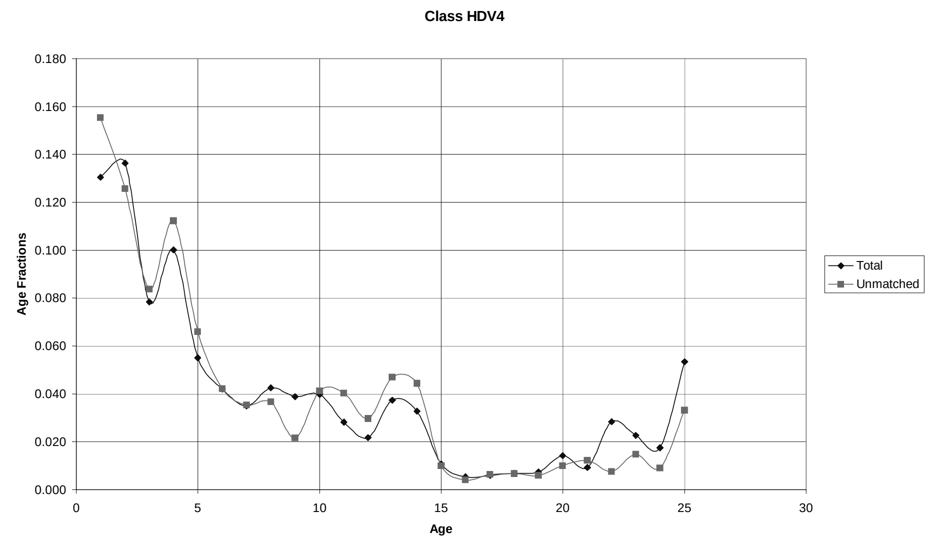


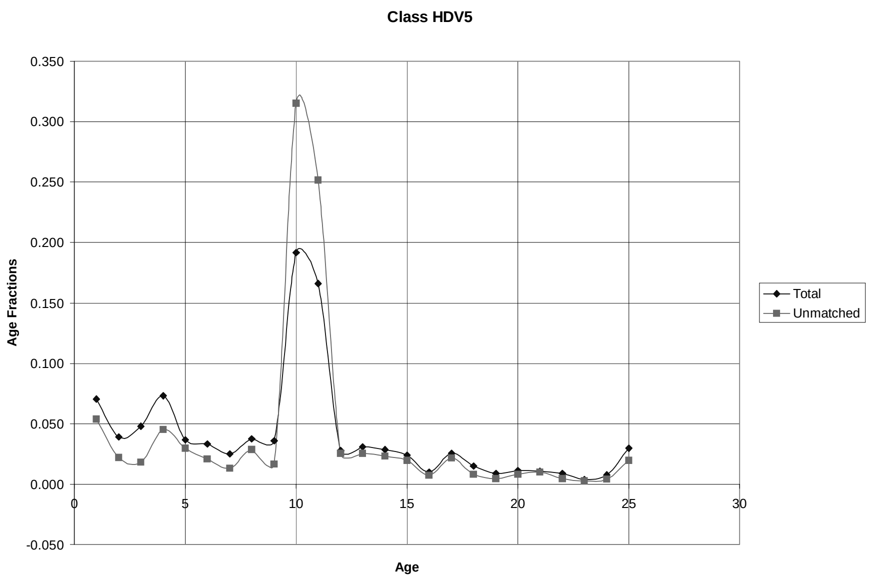


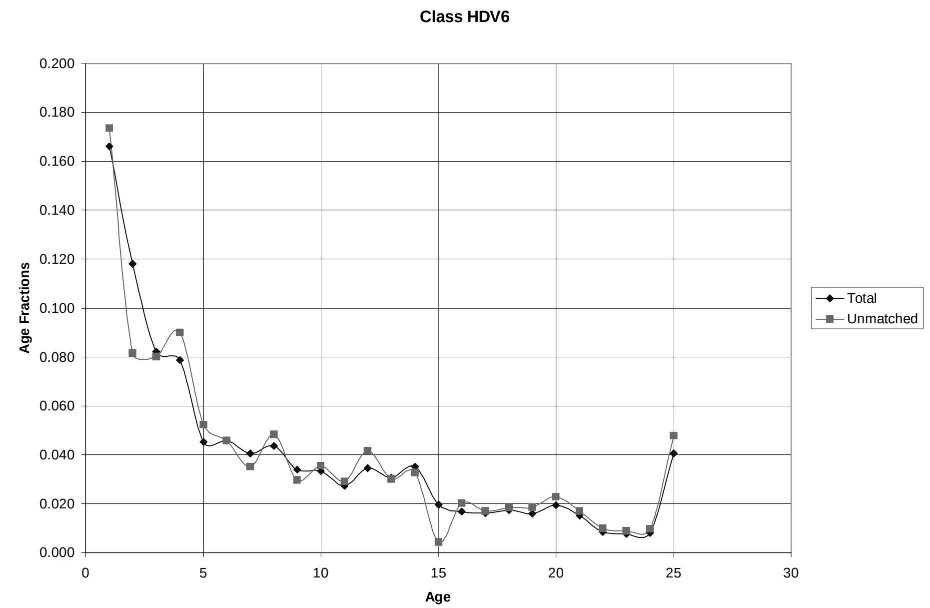


Figures 4.1-4.4 Comparison of Aggregate Age Distributions of Total Fleet and Unmatched Segment

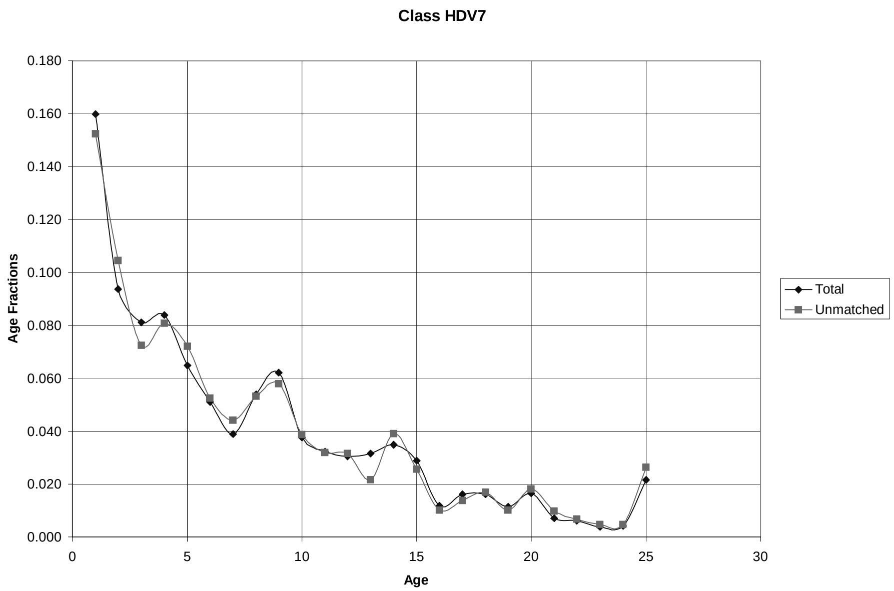


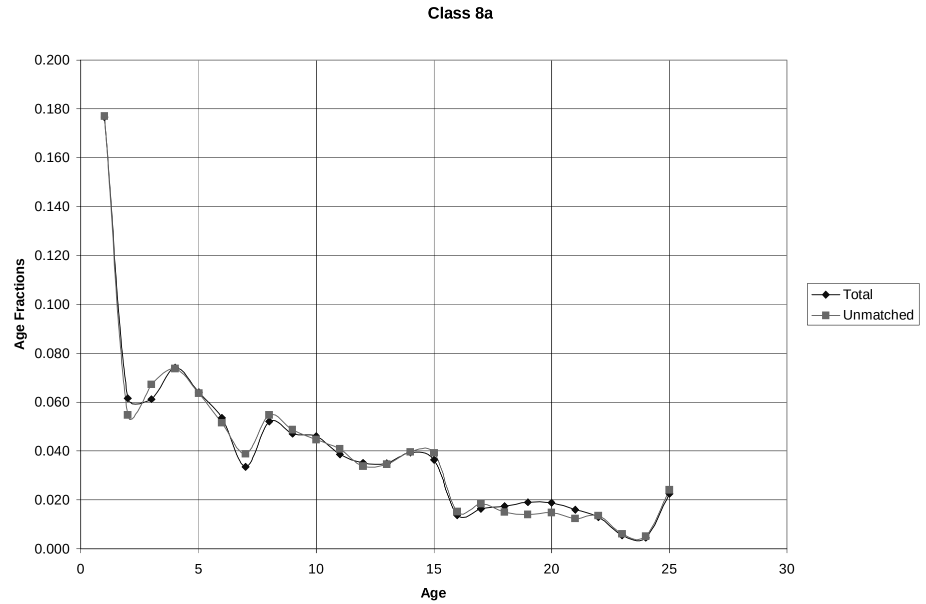


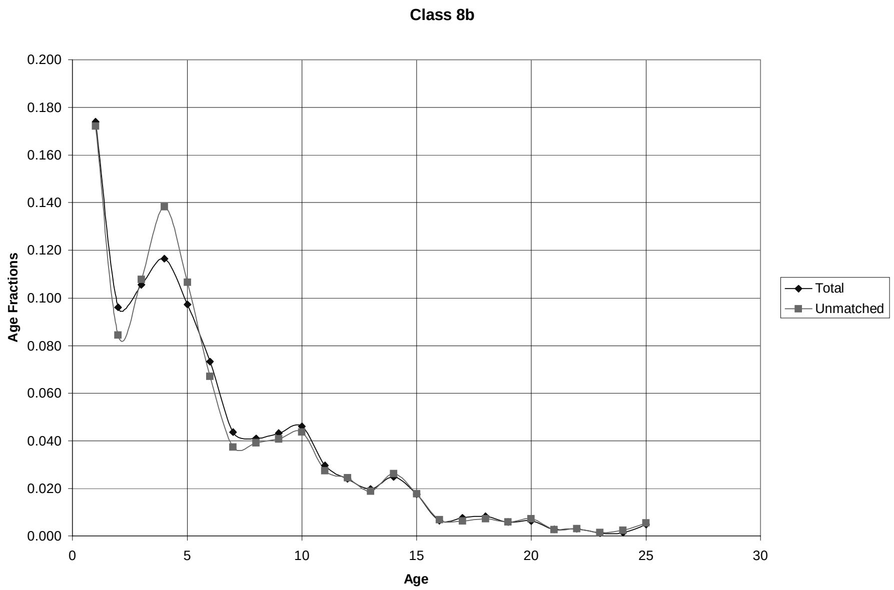


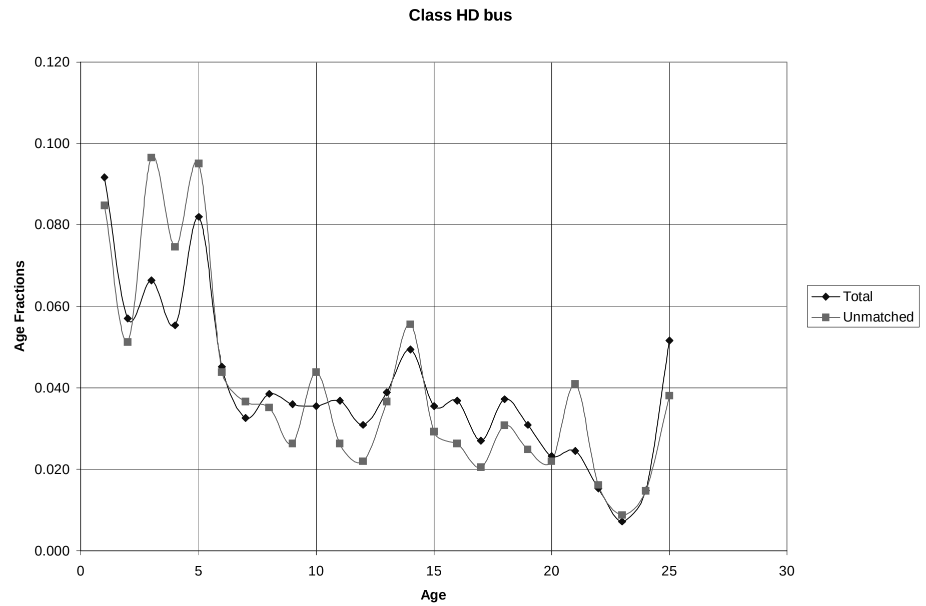


Figures 4.5-4.8 Comparison of Aggregate Age Distributions of Total Fleet and Unmatched Segment (continued)









Figures 4.9-4.12 Comparison of Aggregate Age Distributions of Total Fleet and Unmatched Segment (continued)

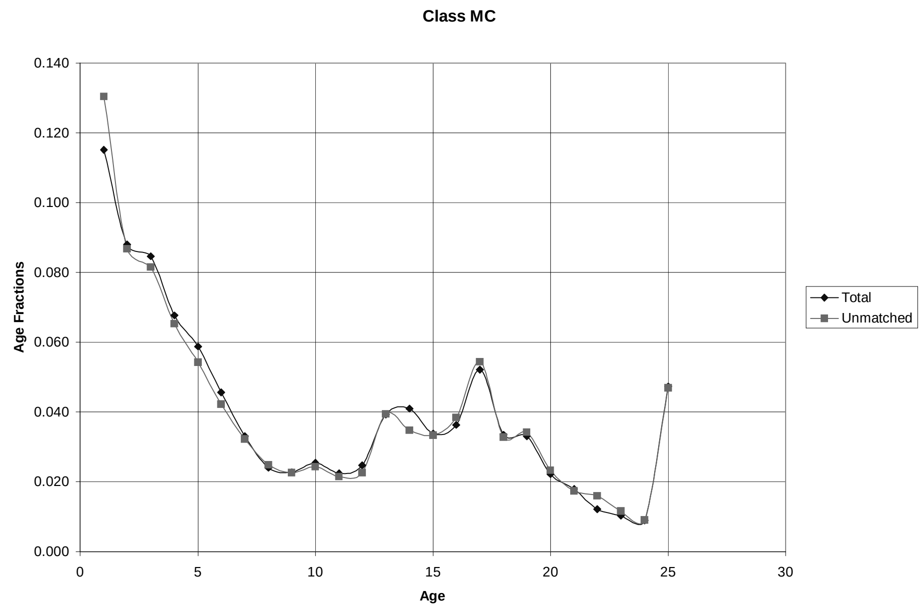


Figure 4.13 Comparison of Aggregate Age Distributions of Total Fleet and Unmatched Segment (continued)

Table 4.2 Descriptive Statistics for Baseline Year (1998) Age Distribution

	LDV				LDT12				LDT34				HDV2B				HDV3				HDV4				HDV5			
Age	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
1	0.000	0.986	0.082	0.074	0.000	0.683	0.108	0.065	0.000	1.000	0.190	0.127	0.000	1.000	0.161	0.218	0.000	1.000	0.069	0.152	0.000	1.000	0.098	0.221	0.000	1.000	0.102	0.245
2	0.000	1.000	0.080	0.055	0.000	0.368	0.089	0.048	0.000	1.000	0.143	0.100	0.000	1.000	0.096	0.175	0.000	1.000	0.063	0.130	0.000	1.000	0.120	0.229	0.000	1.000	0.078	0.202
3	0.000	0.500	0.078	0.039	0.000	0.315	0.073	0.039	0.000	0.500	0.098	0.068	0.000	1.000	0.055	0.130	0.000	1.000	0.057	0.141	0.000	1.000	0.089	0.203	0.000	1.000	0.050	0.156
4	0.000	0.417	0.093	0.034	0.000	0.159	0.074	0.037	0.000	1.000	0.093	0.075	0.000	1.000	0.059	0.133	0.000	1.000	0.077	0.152	0.000	1.000	0.113	0.224	0.000	1.000	0.075	0.192
5	0.000	0.400	0.076	0.029	0.000	0.199	0.073	0.037	0.000	1.000	0.059	0.060	0.000	1.000	0.040	0.094	0.000	1.000	0.079	0.151	0.000	1.000	0.063	0.162	0.000	1.000	0.078	0.217
6	0.000	0.296	0.074	0.026	0.000	0.164	0.057	0.030	0.000	1.000	0.055	0.065	0.000	1.000	0.032	0.102	0.000	1.000	0.057	0.133	0.000	1.000	0.066	0.170	0.000	1.000	0.055	0.167
7	0.000	0.500	0.065	0.029	0.000	0.174	0.049	0.027	0.000	0.300	0.037	0.035	0.000	1.000	0.037	0.103	0.000	1.000	0.055	0.128	0.000	1.000	0.051	0.156	0.000	1.000	0.054	0.173
8	0.000	0.250	0.062	0.021	0.000	0.182	0.047	0.027	0.000	0.500	0.028	0.035	0.000	1.000	0.037	0.112	0.000	1.000	0.045	0.119	0.000	1.000	0.042	0.150	0.000	1.000	0.043	0.158
9	0.000	1.000	0.062	0.039	0.000	0.165	0.040	0.025	0.000	0.500	0.028	0.036	0.000	1.000	0.035	0.089	0.000	1.000	0.054	0.127	0.000	1.000	0.041	0.139	0.000	1.000	0.046	0.165
10	0.000	0.250	0.056	0.022	0.000	0.145	0.040	0.026	0.000	0.333	0.027	0.030	0.000	1.000	0.039	0.106	0.000	1.000	0.050	0.119	0.000	1.000	0.038	0.122	0.000	1.000	0.036	0.131
11	0.000	0.286	0.049	0.023	0.000	0.233	0.049	0.043	0.000	1.000	0.026	0.048	0.000	1.000	0.033	0.094	0.000	1.000	0.046	0.113	0.000	1.000	0.037	0.140	0.000	1.000	0.031	0.111
12	0.000	0.250	0.041	0.022	0.000	0.233	0.049	0.043	0.000	0.289	0.017	0.023	0.000	1.000	0.035	0.122	0.000	1.000	0.030	0.086	0.000	1.000	0.018	0.096	0.000	1.000	0.045	0.163
13	0.000	0.163	0.037	0.020	0.000	0.198	0.042	0.038	0.000	0.500	0.027	0.037	0.000	1.000	0.042	0.106	0.000	1.000	0.038	0.103	0.000	1.000	0.018	0.088	0.000	1.000	0.029	0.128
14	0.000	0.333	0.034	0.025	0.000	0.222	0.036	0.033	0.000	0.333	0.026	0.030	0.000	1.000	0.046	0.112	0.000	1.000	0.037	0.101	0.000	1.000	0.024	0.106	0.000	1.000	0.027	0.117
15	0.000	0.167	0.026	0.018	0.000	0.129	0.030	0.026	0.000	1.000	0.027	0.050	0.000	1.000	0.045	0.107	0.000	1.000	0.048	0.128	0.000	1.000	0.022	0.111	0.000	1.000	0.028	0.131
16	0.000	0.177	0.016	0.013	0.000	0.161	0.018	0.018	0.000	0.130	0.014	0.020	0.000	1.000	0.029	0.087	0.000	1.000	0.024	0.074	0.000	1.000	0.010	0.073	0.000	1.000	0.025	0.125
17	0.000	1.000	0.013	0.037	0.000	0.095	0.016	0.015	0.000	1.000	0.015	0.039	0.000	1.000	0.025	0.078	0.000	0.400	0.017	0.056	0.000	1.000	0.009	0.067	0.000	1.000	0.017	0.097
18	0.000	0.167	0.008	0.009	0.000	0.065	0.012	0.013	0.000	0.250	0.009	0.019	0.000	1.000	0.017	0.069	0.000	1.000	0.016	0.074	0.000	1.000	0.008	0.054	0.000	1.000	0.017	0.098
19	0.000	0.500	0.007	0.019	0.000	0.111	0.008	0.010	0.000	0.169	0.007	0.016	0.000	1.000	0.013	0.061	0.000	1.000	0.013	0.070	0.000	1.000	0.015	0.086	0.000	1.000	0.018	0.090
20	0.000	0.200	0.007	0.010	0.000	0.085	0.014	0.014	0.000	0.167	0.014	0.022	0.000	1.000	0.026	0.086	0.000	1.000	0.018	0.076	0.000	1.000	0.023	0.106	0.000	1.000	0.021	0.099
21	0.000	0.167	0.005	0.008	0.000	0.091	0.013	0.013	0.000	0.250	0.012	0.022	0.000	0.667	0.023	0.069	0.000	1.000	0.015	0.064	0.000	1.000	0.014	0.085	0.000	1.000	0.019	0.097
22	0.000	0.025	0.003	0.003	0.000	0.060	0.011	0.011	0.000	0.250	0.012	0.023	0.000	1.000	0.021	0.074	0.000	0.500	0.014	0.052	0.000	1.000	0.012	0.081	0.000	1.000	0.013	0.078
23	0.000	0.100	0.002	0.004	0.000	0.060	0.011	0.011	0.000	0.333	0.009	0.019	0.000	1.000	0.016	0.064	0.000	1.000	0.011	0.055	0.000	1.000	0.009	0.060	0.000	1.000	0.009	0.075
24	0.000	0.031	0.001	0.002	0.000	0.032	0.004	0.005	0.000	0.200	0.006	0.015	0.000	1.000	0.007	0.047	0.000	0.500	0.006	0.032	0.000	1.000	0.009	0.069	0.000	1.000	0.011	0.076
25+	0.000	0.429	0.022	0.023	0.000	0.333	0.039	0.038	0.000	1.000	0.020	0.049	0.000	1.000	0.033	0.098	0.000	1.000	0.062	0.150	0.000	1.000	0.052	0.166	0.000	1.000	0.074	0.211

Table 4.2 Descriptive Statistics for Baseline Year (1998) Age Distribution (continued)

	HDV6				HDV7				HDV8A				HDV8B				HDBTS				MC			
Age	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev
1	0.000	1.000	0.114	0.214	0.000	1.000	0.110	0.232	0.000	1.000	0.084	0.201	0.000	1.000	0.092	0.181	0.000	1.000	0.075	0.212	0.000	1.000	0.108	0.119
2	0.000	1.000	0.085	0.185	0.000	1.000	0.069	0.197	0.000	1.000	0.044	0.140	0.000	1.000	0.048	0.133	0.000	1.000	0.059	0.195	0.000	1.000	0.087	0.107
3	0.000	1.000	0.068	0.166	0.000	1.000	0.057	0.162	0.000	1.000	0.035	0.113	0.000	1.000	0.057	0.137	0.000	1.000	0.045	0.164	0.000	1.000	0.079	0.086
4	0.000	1.000	0.064	0.158	0.000	1.000	0.063	0.175	0.000	1.000	0.041	0.119	0.000	1.000	0.064	0.140	0.000	1.000	0.048	0.170	0.000	1.000	0.069	0.109
5	0.000	1.000	0.044	0.137	0.000	1.000	0.048	0.156	0.000	1.000	0.042	0.129	0.000	1.000	0.086	0.181	0.000	1.000	0.055	0.181	0.000	1.000	0.061	0.105
6	0.000	1.000	0.048	0.130	0.000	1.000	0.035	0.131	0.000	1.000	0.043	0.128	0.000	1.000	0.110	0.201	0.000	1.000	0.045	0.158	0.000	1.000	0.044	0.073
7	0.000	1.000	0.056	0.153	0.000	1.000	0.049	0.172	0.000	1.000	0.028	0.099	0.000	1.000	0.072	0.155	0.000	1.000	0.035	0.143	0.000	1.000	0.033	0.074
8	0.000	1.000	0.040	0.128	0.000	1.000	0.046	0.148	0.000	1.000	0.048	0.153	0.000	1.000	0.043	0.099	0.000	1.000	0.038	0.140	0.000	1.000	0.028	0.082
9	0.000	1.000	0.036	0.113	0.000	1.000	0.080	0.202	0.000	1.000	0.050	0.129	0.000	1.000	0.061	0.150	0.000	1.000	0.052	0.187	0.000	0.500	0.021	0.044
10	0.000	1.000	0.039	0.138	0.000	1.000	0.044	0.148	0.000	1.000	0.052	0.136	0.000	1.000	0.077	0.169	0.000	1.000	0.036	0.146	0.000	1.000	0.027	0.059
11	0.000	1.000	0.032	0.118	0.000	1.000	0.038	0.135	0.000	1.000	0.060	0.164	0.000	1.000	0.051	0.127	0.000	1.000	0.050	0.174	0.000	1.000	0.023	0.061
12	0.000	1.000	0.030	0.105	0.000	1.000	0.040	0.149	0.000	1.000	0.052	0.143	0.000	1.000	0.040	0.122	0.000	1.000	0.041	0.157	0.000	1.000	0.025	0.056
13	0.000	1.000	0.036	0.118	0.000	1.000	0.040	0.137	0.000	1.000	0.037	0.107	0.000	1.000	0.031	0.104	0.000	1.000	0.042	0.156	0.000	0.667	0.034	0.056
14	0.000	1.000	0.047	0.133	0.000	1.000	0.045	0.149	0.000	1.000	0.056	0.133	0.000	1.000	0.038	0.122	0.000	1.000	0.046	0.159	0.000	0.500	0.041	0.060
15	0.000	1.000	0.043	0.137	0.000	1.000	0.046	0.153	0.000	1.000	0.059	0.155	0.000	1.000	0.031	0.107	0.000	1.000	0.047	0.165	0.000	0.400	0.032	0.049
16	0.000	1.000	0.019	0.086	0.000	1.000	0.025	0.123	0.000	1.000	0.015	0.072	0.000	1.000	0.013	0.074	0.000	1.000	0.037	0.132	0.000	1.000	0.042	0.089
17	0.000	1.000	0.019	0.088	0.000	1.000	0.023	0.112	0.000	1.000	0.027	0.099	0.000	1.000	0.019	0.097	0.000	1.000	0.028	0.112	0.000	1.000	0.051	0.081
18	0.000	1.000	0.020	0.091	0.000	1.000	0.021	0.105	0.000	1.000	0.038	0.132	0.000	1.000	0.025	0.117	0.000	1.000	0.041	0.151	0.000	1.000	0.034	0.071
19	0.000	1.000	0.025	0.109	0.000	1.000	0.018	0.090	0.000	1.000	0.041	0.136	0.000	0.500	0.009	0.042	0.000	1.000	0.034	0.128	0.000	1.000	0.036	0.070
20	0.000	1.000	0.026	0.103	0.000	1.000	0.032	0.145	0.000	1.000	0.048	0.155	0.000	1.000	0.011	0.075	0.000	1.000	0.021	0.106	0.000	0.500	0.021	0.042
21	0.000	1.000	0.021	0.092	0.000	0.500	0.005	0.035	0.000	1.000	0.031	0.102	0.000	1.000	0.006	0.049	0.000	1.000	0.018	0.101	0.000	0.500	0.017	0.039
22	0.000	1.000	0.012	0.073	0.000	1.000	0.013	0.091	0.000	0.667	0.014	0.067	0.000	1.000	0.006	0.048	0.000	1.000	0.018	0.101	0.000	1.000	0.013	0.049
23	0.000	1.000	0.009	0.066	0.000	0.333	0.003	0.027	0.000	1.000	0.009	0.067	0.000	0.200	0.001	0.013	0.000	1.000	0.007	0.056	0.000	0.500	0.011	0.035
24	0.000	0.500	0.010	0.054	0.000	1.000	0.007	0.060	0.000	1.000	0.009	0.059	0.000	0.111	0.001	0.007	0.000	1.000	0.020	0.113	0.000	1.000	0.013	0.060
25+	0.000	1.000	0.058	0.162	0.000	1.000	0.044	0.164	0.000	1.000	0.038	0.124	0.000	1.000	0.011	0.076	0.000	1.000	0.063	0.182	0.000	1.000	0.049	0.076

Table 4.3 Registration Age Distribution: Model Estimation Results

Variable	**LDV**				**LDT1+LDT2**				**LDT3+LDT4**				**HDV2B**			
		Coeff.	***Std.Err.***	***t-ratio***		***Coeff.***	***Std.Err.***	***t-ratio***		***Coeff.***	***Std.Err.***	***t-ratio***		***Coeff.***	***Std.Err.***	***t-ratio***
	age 2	-0.024	0.170	-0.144	***age 2***	0.302	0.294	1.029	***age 2***	-0.275	0.121	-2.266	***age 2***	-0.545	0.164	-3.333
	age 3	0.101	0.186	0.543	***age 3***	-0.0216	0.305	-0.071	***age 3***	-0.655	0.136	-4.806	***age 3***	-1.135	0.195	-5.818
	age 4	0.101	0.195	0.516	***age 4***	-0.00597	0.305	-0.020	***age 4***	-0.191	0.202	-0.946	***age 4***	-1.043	0.189	-5.511
	age 5	-0.104	0.203	-0.515	***age 5***	-0.077	0.306	-0.251	***age 5***	-0.651	0.220	-2.960	***age 5***	-1.448	0.218	-6.650
	age 6	-0.134	0.204	-0.656	***age 6***	-0.327	0.313	-1.043	***age 6***	-0.726	0.224	-3.247	***age 6***	-1.676	0.237	-7.063
	age 7	-0.257	0.209	-1.231	***age 7***	-0.500	0.319	-1.567	***age 7***	-1.376	0.265	-5.193	***age 7***	-1.488	0.221	-6.734
	age 8	-0.309	0.211	-1.462	***age 8***	-0.559	0.321	-1.740	***age 8***	-1.638	0.283	-5.793	***age 8***	-1.486	0.221	-6.730
	age 9	0.143	0.257	0.558	***age 9***	-0.703	0.327	-2.150	***age 9***	-1.641	0.283	-5.798	***age 9***	-1.550	0.226	-6.854
	age 10	0.040	0.261	0.154	***age 10***	-0.72	0.328	-2.198	***age 10***	-1.692	0.287	-5.896	***age 10***	-1.460	0.219	-6.677
	age 11	-0.103	0.267	-0.386	***age 11***	-0.822	0.332	-2.474	***age 11***	-1.747	0.291	-5.997	***age 11***	-1.653	0.235	-7.028
	age 12	-0.265	0.275	-0.966	***age 12***	-0.822	0.332	-2.474	***age 12***	-2.151	0.329	-6.532	***age 12***	-1.578	0.229	-6.905
Alternative specific constants	***age 13***	-0.375	0.281	-1.335	***age 13***	-0.964	0.340	-2.839	***age 13***	-1.667	0.285	-5.849	***age 13***	-1.417	0.215	-6.582
	age 14	-0.450	0.285	-1.579	***age 14***	-1.106	0.348	-3.182	***age 14***	-1.718	0.289	-5.944	***age 14***	-1.277	0.205	-6.235
	age 15	-0.712	0.303	-2.354	***age 15***	-1.260	0.358	-3.524	***age 15***	-1.670	0.285	-5.855	***age 15***	-1.322	0.208	-6.354
	age 16	-1.240	0.350	-3.541	***age 16***	-1.714	0.395	-4.339	***age 16***	-2.308	0.347	-6.650	***age 16***	-1.639	0.240	-6.837
	age 17	-1.435	0.373	-3.851	***age 17***	-1.788	0.403	-4.442	***age 17***	-2.275	0.343	-6.629	***age 17***	-1.803	0.256	-7.037
	age 18	-1.894	0.439	-4.318	***age 18***	-2.137	0.444	-4.817	***age 18***	-2.810	0.418	-6.726	***age 18***	-2.197	0.303	-7.250
	age 19	-2.013	0.459	-4.384	***age 19***	-2.495	0.498	-5.014	***age 19***	-2.978	0.447	-6.665	***age 19***	-2.412	0.333	-7.236
	age 20	-1.986	0.454	-4.371	***age 20***	-1.989	0.425	-4.680	***age 20***	-2.311	0.347	-6.651	***age 20***	-1.751	0.251	-6.981
	age 21	-2.299	0.515	-4.465	***age 21***	-2.076	0.436	-4.765	***age 21***	-2.487	0.370	-6.725	***age 21***	-1.866	0.263	-7.095
	age 22	-2.798	0.638	-4.389	***age 22***	-2.204	0.453	-4.868	***age 22***	-2.526	0.375	-6.735	***age 22***	-2.028	0.282	-7.200
	age 23	-3.321	0.808	-4.109	***age 23***	-2.204	0.453	-4.868	***age 23***	-2.730	0.405	-6.741	***age 23***	-2.344	0.323	-7.249
	age 24	-3.934	1.080	-3.643	***age 24***	-3.173	0.641	-4.947	***age 24***	-3.150	0.480	-6.567	***age 24***	-3.088	0.455	-6.781
	age 25	-0.889	0.316	-2.808	***age 25***	-0.962	0.339	-2.834	***age 25***	-1.984	0.312	-6.353	***age 25***	-1.498	0.227	-6.607
Median Income	***age => 9***	-0.014	0.00466	-3.067	***age => 2***	-0.0145	0.00619	-2.344	***age => 4***	-0.016	0.005	-3.501				
Population Density	***age=>4***	5.01E-05	2.36E-05	2.125	***age => 2***	3.35E-05	3.09E-05	1.083	***age => 7***	0.043	0.020	2.174				
Zonal Employment	***age=>3***	-5.32E-05	2.28E-05	-2.337	***age => 2***	-4.73E-05	2.69E-05	-1.761								
Zonal Retail Acreage					***age => 3***	0.00206	0.00144	1.434	***age => 7***	0.002	0.001	1.412				
Basic Employment													***age =>2 & age<=15***	0.000116	5.29E-05	2.201
Zonal Infrastructure Acreage													***age =>2***	-0.000751	0.000523	-1.437
Number of Observations	849				847				834				736			
Log Likelihood Function	-2446.85	**R Sqr**	0.105		-2461.82	**R Sqr**	0.097		-2294.85	**R Sqr**	0.145		-2207.29	**R Sqr**	0.0683	
Log Likelihood (No Coeffs)	-2732.82	**R Sqr (a)**	0.103		-2726.39	**R Sqr (a)**	0.096		-2684.54	**R Sqr (a)**	0.144		-2369.09	**R Sqr (a)**	0.0669	

Table 4.3 Registration Age Distribution: Model Estimation Results (continued)

Variable	HDV3				HDV4				HDV5				HDV6			
		Coeff.	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*
	age 2	-0.080	0.200	-0.397	***age 2***	0.212	0.177	1.201	***age 2***	-0.265	0.231	-1.151	***age 2***	-0.273	0.197	-1.385
	age 3	-0.189	0.206	-0.916	***age 3***	-0.107	0.191	-0.559	***age 3***	-0.705	0.260	-2.718	***age 3***	-0.522	0.209	-2.492
	age 4	0.120	0.191	0.631	***age 4***	0.152	0.179	0.85	***age 4***	-0.331	0.234	-1.413	***age 4***	-0.583	0.213	-2.741
	age 5	0.144	0.190	0.761	***age 5***	-0.416	0.208	-1.995	***age 5***	-0.376	0.237	-1.585	***age 5***	-0.952	0.237	-4.018
	age 6	-0.182	0.206	-0.885	***age 6***	-0.391	0.207	-1.888	***age 6***	-0.691	0.258	-2.672	***age 6***	-0.861	0.230	-3.737
	age 7	-0.227	0.208	-1.089	***age 7***	-0.641	0.224	-2.865	***age 7***	-0.788	0.266	-2.961	***age 7***	-0.751	0.223	-3.369
	age 8	-0.427	0.221	-1.935	***age 8***	-0.876	0.242	-3.616	***age 8***	-1.038	0.288	-3.601	***age 8***	-1.012	0.241	-4.191
	age 9	-0.233	0.209	-1.118	***age 9***	-0.842	0.239	-3.517	***age 9***	-0.759	0.264	-2.879	***age 9***	-1.147	0.252	-4.547
	age 10	-0.291	0.214	-1.364	***age 10***	-0.924	0.246	-3.747	***age 10***	-1.005	0.290	-3.461	***age 10***	-1.113	0.249	-4.462
	age 11	-0.383	0.219	-1.745	***age 11***	-0.964	0.250	-3.856	***age 11***	-1.180	0.303	-3.900	***age 11***	-1.236	0.260	-4.752
	age 12	-0.816	0.253	-3.231	***age 12***	-1.656	0.328	-5.046	***age 12***	-0.863	0.272	-3.168	***age 12***	-1.331	0.269	-4.953
Alternative specific constants	***age 13***	-0.560	0.232	-2.416	***age 13***	-1.665	0.329	-5.055	***age 13***	-1.306	0.317	-4.128	***age 13***	-1.114	0.250	-4.465
	age 14	-0.604	0.235	-2.567	***age 14***	-1.402	0.296	-4.742	***age 14***	-1.316	0.318	-4.144	***age 14***	-0.875	0.231	-3.783
	age 15	-0.334	0.216	-1.542	***age 15***	-1.469	0.304	-4.836	***age 15***	-1.336	0.320	-4.176	***age 15***	-0.834	0.233	-3.579
	age 16	-1.046	0.274	-3.812	***age 16***	-2.416	0.459	-5.264	***age 16***	-1.425	0.331	-4.310	***age 16***	-1.633	0.310	-5.270
	age 17	-1.403	0.312	-4.491	***age 17***	-2.397	0.455	-5.268	***age 17***	-2.073	0.429	-4.835	***age 17***	-1.814	0.333	-5.443
	age 18	-1.441	0.320	-4.504	***age 18***	-2.478	0.472	-5.247	***age 18***	-1.929	0.404	-4.779	***age 18***	-1.703	0.294	-5.798
	age 19	-1.682	0.354	-4.758	***age 19***	-1.889	0.363	-5.21	***age 19***	-1.628	0.357	-4.555	***age 19***	-1.400	0.283	-4.941
	age 20	-1.319	0.305	-4.329	***age 20***	-1.423	0.298	-4.772	***age 20***	-1.835	0.388	-4.726	***age 20***	-1.467	0.266	-5.509
	age 21	-1.532	0.332	-4.614	***age 21***	-2.384	0.452	-5.271	***age 21***	-1.622	0.357	-4.550	***age 21***	-1.556	0.301	-5.176
	age 22	-1.561	0.336	-4.644	***age 22***	-2.096	0.397	-5.278	***age 22***	-2.011	0.418	-4.815	***age 22***	-2.125	0.380	-5.596
	age 23	-1.874	0.380	-4.926	***age 23***	-2.422	0.460	-5.262	***age 23***	-2.419	0.526	-4.602	***age 23***	-2.392	0.427	-5.604
	age 24	-2.474	0.502	-4.923	***age 24***	-2.322	0.440	-5.281	***age 24***	-2.343	0.482	-4.861	***age 24***	-2.32	0.413	-5.612
	age 25	-0.087	0.202	-0.433	***age 25***	-0.624	0.222	-2.806	***age 25***	-0.436	0.241	-1.812	***age 25***	-0.559	0.215	-2.605
Zonal Parking Acreage	**age =>10**	-0.0739	0.0441	-1.677												
Basic Employment									***age=>2***	0.000167	0.000104	1.602	***age=>2 & age <=14***	0.000107	5.25E-05	2.033
Retail Employment													***age=>2***	-0.0002	0.000144	-1.375
Number of Observations	756				593				467				657			
Log Likelihood Function	-2305.75	**R Sqr**	0.0525		-1717.3	**R Sqr**	0.100		-1416.95	**R Sqr**	0.0574		-2002.96	**R Sqr**	0.0529	
Log Likelihood (No Coeffs)	-2433.46	**R Sqr (a)**	0.0512		-1908.8	**R Sqr (a)**	0.0988		-1503.22	**R Sqr (a)**	0.0553		-2114.8	**R Sqr (a)**	0.0513	

Table 4.3 Registration Age Distribution: Model Estimation Results (continued)

Variable	HDV7				HDV8A				HDV8B				HDBTS				MC			
		Coeff.	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*		*Coeff.*	*Std.Err.*	*t-ratio*
Alternative specific constants	***age 2***	-0.424	0.221	-1.919	***age 2***	-0.654	0.236	-2.769	***age 2***	-0.663	0.226	-2.936	***age 2***	-0.283	0.266	-1.065	***age 2***	-0.222	0.162	-1.369
	age 3	-0.512	0.246	-2.084	***age 3***	-0.864	0.254	-3.406	***age 3***	-0.480	0.213	-2.255	***age 3***	-0.623	0.295	-2.111	***age 3***	-0.313	0.167	-1.877
	age 4	-0.361	0.235	-1.536	***age 4***	-0.724	0.242	-2.997	***age 4***	-0.370	0.206	-1.797	***age 4***	-0.536	0.287	-1.868	***age 4***	-0.454	0.174	-2.614
	age 5	-0.642	0.256	-2.512	***age 5***	-0.701	0.24	-2.923	***age 5***	-0.071	0.190	-0.374	***age 5***	-0.388	0.274	-1.413	***age 5***	-0.581	0.181	-3.216
	age 6	-0.947	0.283	-3.347	***age 6***	-0.669	0.237	-2.821	***age 6***	0.172	0.179	0.963	***age 6***	-0.517	0.285	-1.812	***age 6***	-0.894	0.201	-4.448
	age 7	-0.709	0.261	-2.715	***age 7***	-1.085	0.275	-3.948	***age 7***	-0.252	0.199	-1.266	***age 7***	-0.757	0.309	-2.454	***age 7***	-0.815	0.27	-3.019
	age 8	-0.673	0.258	-2.609	***age 8***	-0.57	0.23	-2.481	***age 8***	-0.771	0.234	-3.292	***age 8***	-0.676	0.300	-2.250	***age 8***	-0.975	0.282	-3.458
	age 9	-0.153	0.222	-0.689	***age 9***	-0.53	0.227	-2.336	***age 9***	-0.420	0.209	-2.010	***age 9***	-0.368	0.273	-1.350	***age 9***	-1.263	0.307	-4.11
	age 10	-0.862	0.275	-3.137	***age 10***	-0.382	0.228	-1.68	***age 10***	-0.183	0.195	-0.935	***age 10***	-0.736	0.306	-2.402	***age 10***	-1.031	0.287	-3.597
	age 11	-0.877	0.276	-3.177	***age 11***	-0.237	0.218	-1.084	***age 11***	-0.596	0.221	-2.697	***age 11***	-0.397	0.275	-1.444	***age 11***	-1.208	0.302	-3.998
	age 12	-0.861	0.275	-3.136	***age 12***	-0.388	0.228	-1.701	***age 12***	-0.843	0.240	-3.512	***age 12***	-0.645	0.297	-2.170	***age 12***	-1.1	0.292	-3.761
	age 13	-0.834	0.272	-3.066	***age 13***	-0.729	0.254	-2.87	***age 13***	-1.092	0.263	-4.157	***age 13***	-0.581	0.291	-1.996	***age 13***	-0.792	0.268	-2.95
	age 14	-0.518	0.269	-1.926	***age 14***	-0.306	0.223	-1.377	***age 14***	-0.875	0.243	-3.604	***age 14***	-0.486	0.283	-1.719	***age 14***	-0.597	0.256	-2.334
	age 15	-0.488	0.267	-1.828	***age 15***	-0.263	0.22	-1.197	***age 15***	-1.097	0.263	-4.169	***age 15***	-0.513	0.285	-1.801	***age 15***	-0.865	0.274	-3.162
	age 16	-1.109	0.329	-3.373	***age 16***	-1.609	0.355	-4.531	***age 16***	-1.926	0.369	-5.217	***age 16***	-0.775	0.310	-2.495	***age 16***	-0.579	0.255	-2.271
	age 17	-1.249	0.347	-3.602	***age 17***	-1.042	0.284	-3.67	***age 17***	-1.577	0.318	-4.956	***age 17***	-0.967	0.332	-2.910	***age 17***	-0.387	0.244	-1.583
	age 18	-1.700	0.378	-4.499	***age 18***	-0.701	0.252	-2.786	***age 18***	-1.312	0.286	-4.590	***age 18***	-0.731	0.306	-2.388	***age 18***	-0.798	0.269	-2.967
	age 19	-1.678	0.388	-4.326	***age 19***	-0.609	0.244	-2.495	***age 19***	-2.329	0.442	-5.270	***age 19***	-0.797	0.313	-2.546	***age 19***	-0.736	0.265	-2.781
	age 20	-0.972	0.313	-3.107	***age 20***	-0.474	0.234	-2.024	***age 20***	-2.165	0.410	-5.276	***age 20***	-1.383	0.389	-3.551	***age 20***	-1.623	0.267	-6.085
	age 21	-2.786	0.638	-4.364	***age 21***	-0.916	0.271	-3.377	***age 21***	-2.809	0.552	-5.087	***age 21***	-1.397	0.392	-3.567	***age 21***	-1.478	0.33	-4.481
	age 22	-1.733	0.421	-4.114	***age 22***	-1.662	0.363	-4.577	***age 22***	-2.818	0.555	-5.081	***age 22***	-1.415	0.395	-3.587	***age 22***	-1.752	0.363	-4.822
	age 23	-3.158	0.806	-3.921	***age 23***	-2.157	0.45	-4.789	***age 23***	-4.128	1.046	-3.948	***age 23***	-2.413	0.608	-3.967	***age 23***	-1.903	0.385	-4.949
	age 24	-2.418	0.57	-4.246	***age 24***	-2.107	0.441	-4.784	***age 24***	-4.970	1.586	-3.134	***age 24***	-1.294	0.376	-3.442	***age 24***	-1.784	0.368	-4.852
	age 25	-0.533	0.271	-1.972	***age 25***	-0.706	0.252	-2.801	***age 25***	-2.155	0.408	-5.275	***age 25***	-0.174	0.258	-0.673	***age 25***	-0.433	0.247	-1.757
Basic Employment	***age =>14***	-0.00022	8.51E-05	-2.579	***age =>10***	-0.000108	4.73E-05	-2.279												
Zonal Acreage of Infrastructure	***age => 3***	-0.000919	0.000522	-1.762																
Zonal Median Income																	***age => 7***	-0.0111	0.005	-2.39
Number of Observations	488				623				625				427				788			
Log Likelihood Function	-1472.85	**R Sqr**	0.0624		-1941.89	**R Sqr**	0.0317		-1815.07	**R Sqr**	0.0978		-1340.21	**R Sqr**	0.0249		-1340.21	**R Sqr**	0.0249	
Log Likelihood (No Coeffs)	-1570.81	**R Sqr (a)**	0.0603		-2005.35	**R Sqr (a)**	0.0300		-2011.8	**R Sqr (a)**	0.0963		-1374.46	**R Sqr (a)**	0.0226		-1374.46	**R Sqr (a)**	0.0226	