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An empirical investigation on the impacts of ground-level ozone concentrations on national ambient air quality standards: The case of Lake Charles, Louisiana

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AN EMPIRICAL INVESTIGATION ON THE IMPACTS OF GROUND-LEVEL OZONE CONCENTRATIONS ON NATIONAL AMBIENT AIR QUALITY STANDARDS...THE CASE OF LAKE CHARLES, LOUISIANA

by

Benedict Nweke Nwokolo, B.S., M.B.A., M.S.

A Dissertation Presented in Partial Fulfillment
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We hereby recommend that the thesis prepared under our supervision by Benedict Nweke Nwokolo entitled An Empirical Investigation on the Impacts of Ground-Level Ozone Concentration on National Ambient Air Quality Standards: The Case Study of Lake Charles, Louisiana be accepted in partial fulfillment of the requirements for the Degree of Doctor of Engineering

Supervisor of Thesis Research

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ABSTRACT

This study presents information upon which the state of Louisiana can base its ozone State Implementation Plans (SIPs) designed to achieve planned emissions reduction that are required by the Clean Air Act (CAAA) of 1990. The research investigation included an assessment survey on a number of Transportation Control Measures (TCMs) and their degree of acceptability by the residents of Lake Charles area of Louisiana, the research target area. The TCMS were first ranked on the basis of people's perception of each TCM and four TCMs were later analyzed for cost-effectiveness using computer mathematical models. The Traffic Flow Improvements TCM was shown as the most acceptable TCM, with a value of 4.06 on a Likert-type scale of 1 to 5, where 1 and 5 represent highly unacceptable and highly acceptable respectively. Results also show that the most acceptable TCM based on the people's perception was not cost-effective in reducing mobile source emissions. The study listed several suggestions for future research, one of which was that a comprehensive analysis of the other TCMs should be done in order to offer the region a range of TCM options to choose from. Finally, this investigation noted that Home Base Survey (HBS) offered good merits for estimating trips and vehicle miles of travel (VMT). However, the study also noted associating the VMT from HBS with the different roadway classifications for emissions inventory may pose some problems. This study

concluded by suggesting a combination of Home Survey and the HPMS methods of VMT estimation where feasible. This approach is viewed to provide better cost-effectiveness figures. Also, a sensitivity analysis on the relative emission notes versus speeds was done to demonstrate that emission rates were sensitive to speeds at various speed ranges for hydrocarbon or volatile organic compounds, carbon monoxide and oxides of hydrogen for the study area. MOBILE5a EPA-approved emission modeling computer software was used for the determination of the investigated mobile source emission rates for HC or VOC, CO, and NO_x. Results of the air quality analysis showed that the region has now moved from its nonattainment status to attainment status in NAAQS.

DEDICATED TO MY MOTHER

Victoria Chinwude Ekpe

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CHAPTER 1

INTRODUCTION AND BACKGROUND

Prior to the 1960's, the U. S. road builders and transportation planners concentrated on mobility and the adequacy of both public and private transportation services to the U.S. differing socioeconomic groups. To enhance mobility and interstate commerce, Interstate Highway Systems were developed and constructed nationwide followed by state and local road networks. During this period, federal-aid highway acts were the primary legislative driving force. Beginning in the 1960's, however, non-highway legislation has played an increasingly important role in the development of the entire U.S. transportation program.

The National Environmental Policy Act of 1969, the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, and many others created a new awareness of the role of the road within the context of social, economic and environmental concerns. Now, with the enactment of the Clean Air Act Amendments of 1990 (CAAA), transportation planners have been challenged again, this time to maintain the nation's mobility while enhancing our air quality.

Experts have come to predict that for the next 20 to 30 years the CAAA may have a greater effect on the nation's transportation than any of the non-highway laws enacted since the 1960's. More than a decade in the making, the CAAA recast the planning function to ensure that, in areas experiencing air quality problems, transportation planning is geared to improved air quality as well as mobility. State and local officials have been challenged by the CAAA to find ways to reduce emissions from the vehicle fleet, to develop projects and programs that will alter driving patterns designed to discourage single-occupant vehicles (SOVs), and to make alternatives such as mass transit and bicycles an increasingly important part of the transportation network. For all nonattainment areas, the CAAA, with the tough political decisions they force government to make, provided a strong incentive to expand efforts to reach attainment as expeditiously as possible.

The requirements of the CAAA are complex in nature. They involve rigorous planning, complex computer modeling, difficult choices, and changes in the way every traveler thinks about his or her mobility -- as well as a complex new terminology. The advent of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), with its restructured surface transportation programs, gave state and local transportation officials the tools to adapt their transportation plans to the requirements of the CAAA. Together, the CAAA and the ISTEA provide us with the means to help achieve both mobility and clean air.

1.1 Statement of the Problem

During the 1980's, the problem of urban/suburban mobility and their concomitant effects received considerable attention from transportation planners. Today with vast segments of the population living in the suburbs, we are confronted with a flurry of articles, reports, and media accounts that have characterized urban/suburban congestion as one of the most pressing problems in the transportation field, and most probably, one that will hold the center stage in the transportation policy arena of the future [Cervero, 1984, 1986; Orski, 1987]. In some major cities and suburbs of the United States, peak hour velocities are down to 25 mph and even as low as 8 mph on Route 20 in Boston area of Massachusetts. Here in the state of Louisiana, the problem of urban/suburban mobility is acute in some of the major cities. According to the latest study conducted by the Shreve Area Council of Governments (SACOG) for the Shreveport-Bossier City metro area of Louisiana, the amount of travel in the area is directly related to the population, employment, and other socio-economic characteristics of the area.

If the mobility problem is bad for the Shreveport-Bossier area, it is even worse for some other cities of Louisiana such as the Baton Rouge area. The fact that a large portion of the trip origins and destinations are widely dispersed with travel patterns resembling Brownian motion -- they appear random in nature and are taking place in every direction all at once -- has negated the best efforts of conventional mass transit to provide an economically viable mode of transportation. The above travel characteristics are now creating enormous transportation problems that stem from increased environmental pollution due to exhaust emissions, increased user costs in terms of travel delays and increased energy costs not only for some of the cities in Louisiana, but for a great number of cities across the United States. Cervero [1988] agreed that urban/suburban traffic conditions have markedly worsened in recent years. He went on to conclude that the low density, single-use, and non-integrated character of many urban/suburban office-commercial centers and corridors, combined with the tendency to provide plentiful free parking have compelled many workers to become dependent on their automobiles for accessing work and circulating within projects, thereby worsening the air quality.

While traffic congestion has long been a concern in urban areas, megatrends in the suburbanization of employment are now resulting in some of the country's worst traffic problems occurring in the suburbs. Every year according to government statistics:

- the U.S. economy loses about $100 billion because of traffic congestion;
- traffic accidents kill 40,000 people and injure three million others;
- idling trucks, buses, and automobiles emit tons of pollutants into the atmosphere and waste billions of gallons of fuel.

In the past, the general solution to these problems has been to build more or bigger highways. That approach is no longer adequate. Furthermore, growth projections as we enter the 21st century strongly suggest an ever-widening gap between the demand for travel and the physical capacity to accommodate such demand. In other words, today's traffic problems will get much worse.

The problem of congestion/transportation air quality impacts cannot be over-emphasized at this juncture. Mobile pollution sources, especially automobiles, account for a sizeable share of the emission of pollutants, controlled by the Federal Clean Air Act. The Environmental Protection Agency (EPA) established standards for several pollutants and released the nonattainment area designations and boundaries for the following pollutants:

- Nitrogen Oxides (NO_x);
- Ozone (O_3);
- Carbon Monoxide (CO);
- Small Particulate Matter (PM_{10}) and
- Hydrocarbons (HC).

A nonattainment area is a geographic region of the United States that the EPA has designated as not meeting the national ambient air quality standards (NAAQS). Depending on the severity of the air quality problem, officials in each nonattainment area must take specified actions within a set time frame to reduce emissions and attain the NAAQS. The actions become more numerous and more stringent as the air quality problem gets worse. Title I of the CAAA provides the following:

- a requirement that transportation plans, programs, and projects conform with the State Implementation Plan (SIP) for attaining the NAAQS;
- a requirement for greater integration of transportation and air quality planning procedures in order to address air quality concerns;
- the conditions under which EPA can impose sanctions, including the loss of federal-aid highway funds.

Under Title II, the CAAA identify actions which are imposed on manufacturers for reducing emissions from mobile sources such as motor vehicles.

The NAAQS ensure that certain pollutants do not exceed specified levels more than once a year. The threshold for each pollutant ensures protection for even the most sensitive groups of the population. Areas with levels that violate the standard are designated as nonattainment areas for whatever pollutants are involved. Nonattainment areas must reduce the emissions from the source causing the pollution. There are three types of sources:

- Mobile sources -- They include motor vehicles, aircraft, seagoing vessels, and other transportation modes. The mobile source related pollutants of greatest concern are CO, transportation hydrocarbons, nitrogen oxides and PM_{10}.

- Stationary sources -- These are relatively large, fixed sources of emissions (i.e., chemical process industries, petroleum refining and petrochemical operations, wood processing).
- Area sources -- These are small stationary and non-transportation pollution sources that are too small and or numerous to be included as stationary sources but may collectively contribute significantly to air pollution (i.e., dry cleaners).

Included in Title I are transportation provisions with attainment dates for defining and reducing the emissions problem. The provisions and attainment dates vary according to the type of pollutant and level of severity. The section to follow attempts to describe some of the transportation - related requirements and health effects for ozone, nitrogen oxides, hydrocarbon, carbon monoxide, and small particulate matter. Furthermore, discussion will be limited to only on-road mobile source provisions of the CAAA.

1.2 Effects of Pollutant on Humans

As concentrations of O_3, CO, and PM_{10}, rise, they can cause or exacerbate health problems[1]. The NAAQS for these pollutants are set at levels the EPA believes will protect the public's health and welfare.

1.3 Transportation Provisions for Ozone Nonattainment Areas

Ozone is a colorless gas with a pungent odor. Ground-level ozone, the main component of smog or haze, is formed by the reaction of hydrocarbons, nitrogen oxides (NO_x), and volatile organic compounds (VOC) with heat and sunlight. Although the ozone in the upper atmosphere protects us from harmful ultraviolet rays, high ground-level concentrations of ozone produce an unhealthy environment. Ozone irritates the mucus membranes of the respiratory system. Exposure can result in coughing, choking, nausea, chest pain, headaches, and eye irritations. Ozone can also reduce resistance to colds and pneumonia and aggravate existing respiratory conditions such as asthma, bronchitis, and emphysema[2]. Because ozone is a precursor emission of HC, NO_x, and VOC in the presence of sunlight and as such, not a direct emission from transportation sources, understanding and controlling ozone formulation requires understanding of all HC and NO_x emissions within a region.

1.4 Hydrocarbon and Nitrogen Dioxide Environmental Effects

Transportation hydrocarbons constitute approximately 45% of manufactured sources[1]. Those emitted from motor vehicles form a colorless, gaseous compound originating from evaporation and incomplete combustion of fuels. Nitric oxide (NO) and nitrogen dioxide (NO_2) are collectively referred to as oxides of nitrogen (NO_x). The literature review suggests that nitrogen dioxide has health effects independent of its contribution to ozone and is regulated by a separate NAAQS. Los Angeles is currently the only nitrogen dioxide nonattainment area according to EPA. The above pollutants also do affect ecosystems and environments through corrosion. They can decrease visibility, create unpleasant odors, and damage crops, livestock, commercial forests, and lawns.

[1] EPA, National Air Quality and Emissions Trends Report, 1992

[2] Ibid.

Nitric oxide forms during high-temperature combustion processes. NO_2 forms when NO further reacts in the atmosphere.

Ozone nonattainment areas are classified according to the second highest hourly level of ozone in the air on a yearly basis. Ozone levels are measured in parts per million (ppm). Figure 1-1 shows the CAAA ozone control requirements. Table 1-1 below shows the NAAQS classifications for ozone as defined by the EPA and the timetable for achieving attainment status. Note that areas with worse problems are given more time to attain the NAAQS. The requirements for defining andreducing the ozone precursor emissions problem increase with each worsening classification. These requirements must be included in the State Implementation Plan (SIP), a plan mandated by the CAAA that contains procedures to monitor, control, maintain, and enforce compliance with the NAAQS.

Table 1-1: NAAQS Classifications for Ozone

CLASSIFICATION	1-HOUR CONCENTRATION (PPM)	ATTAINMENT DATE
Marginal	0.121 up to 0.138	11/15/93
Moderate	0.138 up to 0.160	11/15/96
Serious	0.160 up to 0.180	11/15/99
Severe 1	0.180 up to 0.190	11/15/2005
Severe 2	0.190 up to 0.280	11/15/2007
Extreme	0.280 and above	11/15/2010

Source: 1990 CAAA

[1] EPA Journal, "The New Clean Air Act: What it Means to You", P. 14.

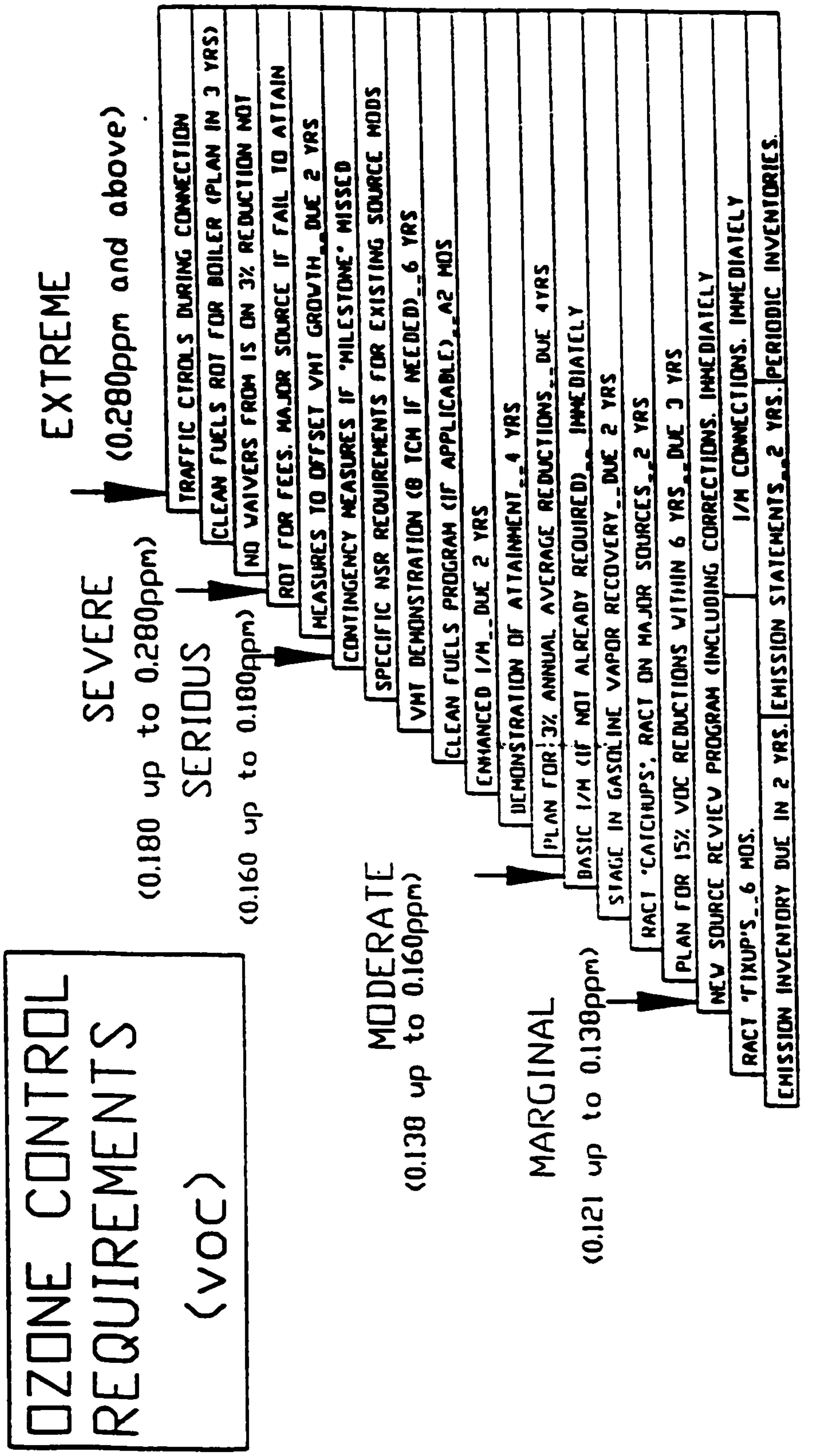


Figure 1-1: Ozone Control Requirements

1.5 Transportation Provisions for CO Nonattainment Areas

Carbon monoxide interferes with the delivery of oxygen to the body's organs and tissues. The NAAQS for CO require an area's near-peak average 8-hour concentration to be less than 9.0 parts per million. Note that pollution concentrations of CO are measured in PPM. The health effects of CO vary depending upon the length and intensity of the exposure and the health of the individual. Healthy individuals may experience impairment of visual perception, thought, and reflexes, as well as drowsiness, with longer exposures at high levels. Persons with cardiovascular disease may experience impaired cardiovascular function.

Carbon monoxide is a colorless, odorless, tasteless gas formed in large part by incomplete combustion of fuel. Fuel combustion activities are the major sources of CO. High concentrations of CO can develop near these combustion sources. Areas designated as non-attainment for CO are classified according to the severity of their CO problem. As in the case of ozone, areas with worse problems are given more time to attain the NAAQS. Table 1-2 shows the NAAQS classifications for carbon monoxide. Figure 1-2 shows the CAAA CO control requirements. Also the requirements for defining and reducing the CO emission problem increase with each worsening classification. The CAAA require that these requirements be included in the SIP.

Table 1-2: NAAQS Classification for CO

CLASSIFICATION	8-HOUR CONCENTRATION (PPM)	ATTAINMENT DATE
Moderate	9.1 through 16.4	12/31/95
Serious	16.5 and above	12/31/2000

Source: 1990 CAAA

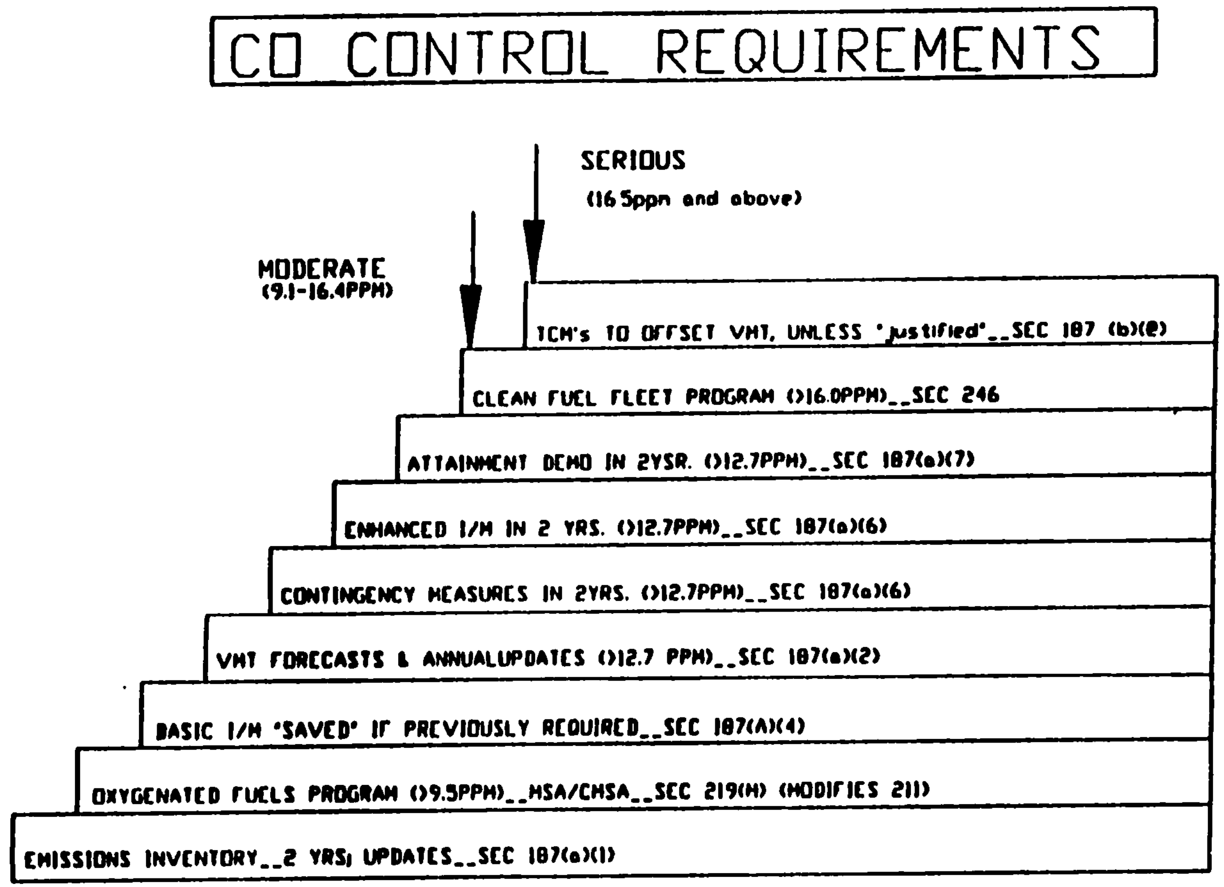


Figure 1-2: CO Control Requirements

1.6 Transportation Provisions for Small Particulate Matter Nonattainment Areas

Particulate matter (PM) is any material that exists as a solid or liquid in the atmosphere. It may be in the form of fly ash, soot, dust, fumes, etc. While the sources of PM are yet to be defined, particulate matter can be caused by

tailpipe emissions, and dust from paved and unpaved roads. Small particulate matter which is less than 10 microns in size is referred to as PM_{10}. A micron is one millionth of a meter. Particulate matter this size is too small to be filtered by the nose and lungs, thus, allowable concentration levels of PM_{10} are specified for the NAAQS.

Particulate matter irritates the membranes of the respiratory system, possibly resulting in aggravation of existing respiratory and cardiovascular disease, alterations of the body's defense systems, carcinogenesis, and premature mortality. In addition, PM_{10} is strongly associated with infant mortality in urban areas.

Areas designated as nonattainment for PM_{10} are classified according to its weight in the air. Pollutant concentrations are measured in micrograms per cubic meter (□g/m^3). The NAAQS for PM_{10} require an average annual concentration of less than 50 micrograms per cubic meter. An annual average over 50 □g/m^3 is classified as moderate nonattainment areas. The EPA may classify any of the moderate areas to a serious status if they cannot reach attainment. Again, the requirements for defining and reducing the PM_{10} problem increase with each worsening classification.

1.7 Conformity

Conformity is the determination made by metropolitan planning organizations (MPOs) and the United States Department of Transportation (U.S. DOT) that transportation plans and programs in nonattainment areas meet the "purpose" of the SIP, which is reducing pollutant emissions to meet the NAAQS.

The transportation program, otherwise known as the transportation improvement program (TIP), is composed of transportation projects drawn from a conforming transportation plan. Specifically, the transportation plan and program must contribute to reducing motor vehicle emissions. Only transportation projects that are federally funded or approved must meet the conformity requirements, but all regionally significant projects, including non-federally funded ones, must be included in the plan and TIP conformity analysis.

According to the CAAA, transportation plans and programs cannot:

- Create new NAAQS violations;
- Increase the frequency or severity of existing NAAQS violations;
- Delay attainment of the NAAQS.

1.8 State Implementation Plans (SIPs)

Under the Federal Clean Air Act, the EPA sets nationwide standards as shown in Tables 1-1 and 1-2 for maximum permissible levels of air pollution, while states retain the primary responsibility for monitoring air quality and choosing measures to comply with these standards.

When an area is found to violate federal air quality standards, the state in which it is located is required to develop and implement a state implementation plan (SIP) for eliminating the violation and then maintaining the standard.

Among the required elements of a SIP are a comprehensive inventory of current emissions from all sources in that area, and projections showing how actions to be taken by the state will produce the emission reductions necessary for it to attain the NAAQS. The task of complying with the state implementation plan rests with the MPOs, at the regional level. Emissions inventory is a complex task and as such many of the MPOs have to increase their professional staffing in order to dramatically deal with their air quality issues. A national survey conducted by the National Association of Regional Councils (NARC), U.S. DOT, and U.S. EPA found that half the responding MPOs had hired new staff to "address their air quality issues" [Deysher and Spadafora-Rodriguez, 1993].

Despite such staffing increases, Deysher and Spadafora-Rodriguez concluded that many MPOs have continued to feel understaffed nationwide in dealing with air quality issues. Another study found that "clearly, nonattainment is the transportation issue in those cities that have severe problems", with 45-50 percent of the staff resources at MPOs in "severe" ozone nonattainment areas being devoted to CAAA activities [Hartgen et. al., 1993]. According to Hargen and others, many MPOs have resorted to retaining consultants in air quality areas requiring specialized aspects of their planning tasks. The NARC/DOT/EPA survey found that 70 percent of all MPOs (ranging from 55 percent of marginal MPOs to 78 percent of moderate MPOs) report having inadequate numbers of staff to address CAAA requirements.

1.9 Growth in Vehicle Miles of Travel (VMT)

While significant trends in automobile use have been apparent during the last 20 to 30 years, the situation is even worse as we move into the 21st century. These trends are growth in vehicle miles of travel (VMT) and vehicle hours of travel (VHT). VMT has increased dramatically since the early 1970s. In 1986, VMT had increased 19.7 percent from 1972 levels, to 1,849 trillion miles [U.S. DOT, FHWA, 1986]. This mileage equated 10,500 miles per vehicle annually in 1986 according to U.S. DOT/FHWA report. A large portion of this annual VMT is produced on metropolitan freeway systems. Lindley [1989] reported that freeways accounted for 2.6 percent of the 1987 roadway mileage in urban areas and were responsible for more than 31 percent of the total VMT. The U.S. Department of Transportation has underestimated the growth rate since 1983. The forecast was 2.4 percent average annual VMT growth rate; however, the actual VMT growth rate has been 3.6 percent, 50 percent higher than projected [Hawthorn, 1991]. The VMT increase is due to changes in the demographic characteristics of many U.S. cities as well as increases in auto ownership of households. Specifically, the number of women in the labor force and the number of licensed drivers have been on the increase lately. In 1950, 57 percent of the driving age population was licensed to drive. In 1986 this number had increased by 86 percent according to U.S. DOT/FHWA 1986 joint report. Even more surprising is the increase in the number of registered vehicles.

With this back drop of information, it is fair to state that the combination of the above named trends has produced both increases in VMT, VHT and congestion in many U.S. urban and suburban areas. The increase in VMT, VHT and congestion has brought mobile emissions to the forefront of environmental concerns. Research is needed for innovative ways designed to assist many of the MPOs with limited technical backgrounds for handling complex environmental air quality analyses. The CAAA of 1990 were enacted to reduce the extent of mobile source emissions in urban areas. The amendments specifically call for the use of TCMs to reduce air pollution. One major problem with the use of TCMs in the evaluation of air quality benefits is the public acceptability of a given TCM, especially one that has proven to be technically feasible and effective at decreasing mobile source activity [Transportation Research Board/National Research Council, 1992]. According to Transportation Research Board (TRB) and National Research Council (NRC), research is needed to determine the public's acceptability of a given TCM program.

TCMs are best defined by the California Clean Air Act Amendments of 1988 which describe them as strategies that "reduce vehicle trips, vehicle use, vehicle miles traveled, vehicle idling, or traffic congestion for the purposes of reducing motor vehicle emissions" [San Francisco Metropolitan Transportation Commission, 1991].

Specific TCMs in the CAAA described in the United States Code section 108(f) are:

- Programs for improved public transit;
- Restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high occupancy vehicles;
- Employer-based transportation management plans, including incentives;
- Trip-reduction ordinances;
- Traffic flow improvement programs that achieve emission reductions;

- Fringe and transportation corridor parking facilities serving multiple occupancy vehicle programs or transit services;
- Programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration, particularly during periods of peak use;
- Programs for the provision of all forms of high-occupancy, shared ride services;
- Programs to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicle or pedestrian use, both as to time and place;
- Program for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;
- Programs to control the extended idling of vehicles;
- Programs to reduce motor vehicle emissions caused by extreme cold start conditions;
- Employer-sponsored programs to permit flexible work schedules;
- Programs and ordinances to facilitate non-automobile travel, provisions and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel, as part of transportation planning and development efforts of a locality, including programs and ordinances applicable to new shopping centers, special events, and other centers of vehicle activity;
- Programs for new construction and major reconstruction of paths, tracks or areas solely for pedestrian use or other non-motorized means of transportation when economically feasible and in the public interests; and
- Programs to encourage the voluntary removal from use and the marketplace of pre-1980 model year light duty vehicles and pre-1980 model light duty trucks.

In the state of Louisiana, the Baton Rouge area and Calcasieu Parish have been classified in accordance with the 1990 CAAA as ozone nonattainment areas. As a result, the MPOs of both Lake Charles and Baton Rouge have requested guidance from the Louisiana Department of Transportation and Development (LaDOTD) and the State Department of Environmental Quality (LaDEQ) in selecting appropriate TCMs to bring their air quality levels into attainment status. However, both LaDOTD and the MPOs are in urgent need of guidance on which TCMs will be cost effective for implementation in Louisiana. Furthermore, since above-ground levels of ozone concentrations vary from one regional location to the other according to experts, research is needed in order to assist the MPOs of both Baton Rouge and Lake Charles determine a reliable emissions budget as required by the SIP.

1.10 Research Objectives

The major objective of this study is to conduct an empirical investigation on the extent of ozone nonattainment status of Calcasieu Parish in Louisiana and to conduct an assessment survey on sixteen 1990 CAAA TCMs in order to determine the degree of public acceptability of these TCMs some of which have proven effective at reducing on-road mobile source emissions. Figure 1-3 shows the study area. The end result is designed to assist the MPO of Lake Charles' area in the implementation of the SIP which is necessary in order to move the region from its current nonattainment status to attainment status. Specifically the study seeks to address the following secondary objectives:

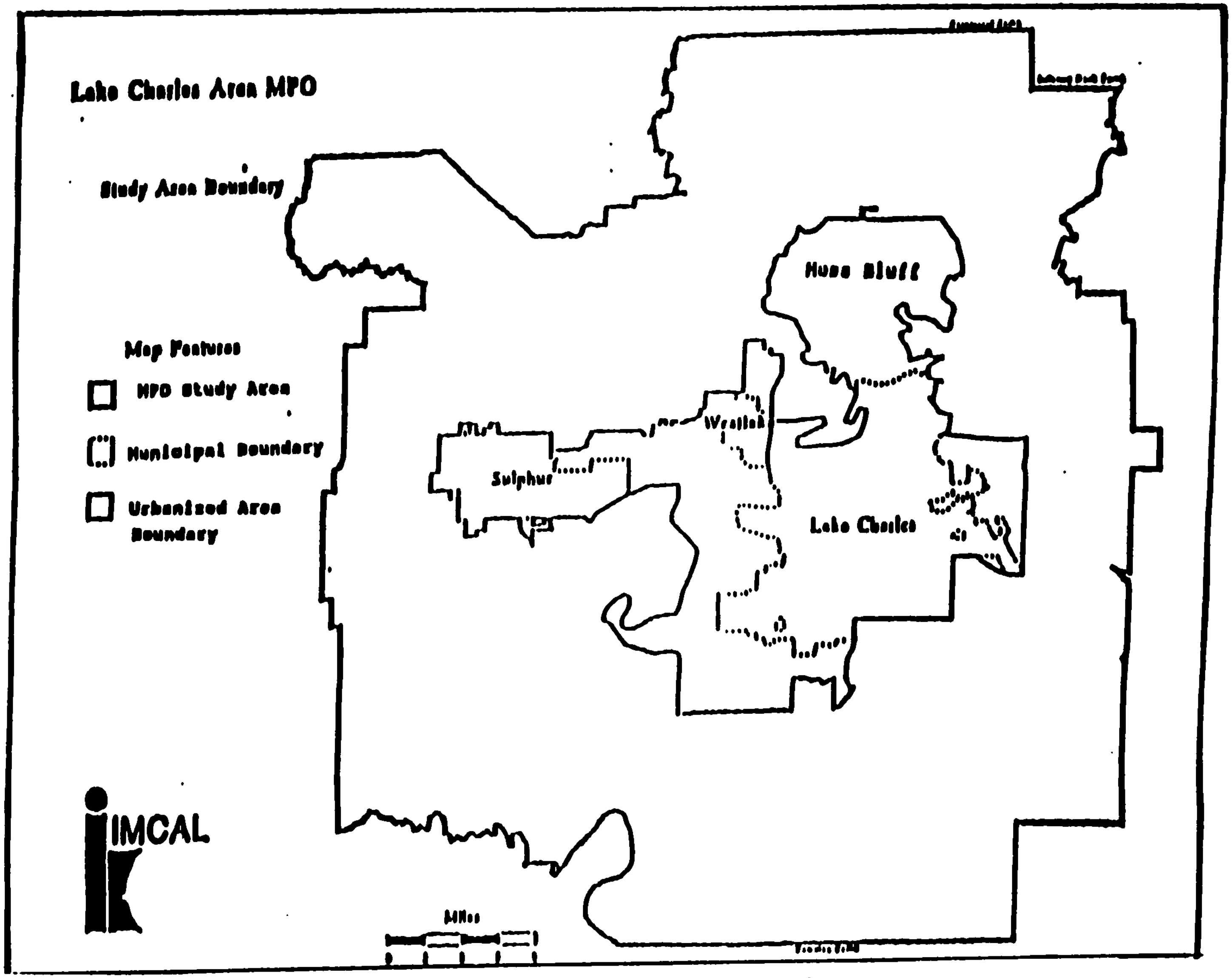


Figure 1-3: Lake Charles Area MPO Study Area Boundary

- Determine the cost effectiveness of two or three most favored TCMs and their probable impacts on air quality for the region;
- Develop a mathematical model using either primary or secondary data in order to determine both the 1990 base line VMT and the future projected VMT for the research area;
- Develop or use an approved EPA computer modeling technique(s) to determine the 1990 base line emissions budget or inventory for on-road mobile source emissions for the region;
- Determine whether reductions in motor vehicles' volatile organic compounds (VOC) and NO_x emissions rates likely to result from any TCM measures could be offset by continuing vehicle miles traveled growth during the foreseeable future.
- Investigate the effects of vehicle miles traveled growth, vehicle classes and meteorological considerations on ozone trends; determine any probable relationship between these variables in addition to the areas' population, growth in employment, economic growth as measured by the gross domestic product (GDP) with ozone precursor variables of CO, NO_x, and HC.

1.11 Study Approach and Scope

As hinted earlier, the 1990 CAAA required cities not in compliance with the mobile source emissions to develop plans by 1993 designed to bring these mobile source emissions into compliance by the use of the prescribed TCMs. The first activity will be a detailed literature review on both transportation and TCMs air quality impacts in Louisiana and the U.S. at large. It is anticipated that much of the available historical rewards on TCM implementation will be secured from California where there are some data bases that contain more than three years of monitoring the effects of various TCM implementation. These data bases will be located, copied, and made operational by use of computers. Additionally, a survey instrument for primary data will be developed and tested for adequacy and then used for gathering information pertinent to both air quality analysis and to the travel characteristics of the citizens of the research target area. Also historical data from the LaDOTD, LaDEQ, and the MPO of Lake Charles on all variables that have impacts on air quality in the region will be collected and used in the analysis. For this research, only selected areas of Lake Charles, Moss Bluff, West Lake, and Sulphur all of Calcasieu Parish will be studied (see figure 1-3). Figure 1-4 shows all the nonattainment areas of Louisiana. However, the methodology used will be documented to provide guidance to other MPOs around the state and the nation at large that may have similar air quality characteristics like Lake Charles, Louisiana. Furthermore, the scope will be limited to the 16 CAAA TCMs.

Specifically, historical data from the LaDOTD gathered using the highway performance monitoring systems (HPMS) will be collected on both the major and minor corridors of the study area. Information on the research area relating to vehicle registrations and classes of vehicles will also be requested from LaDOTD. Information on traffic volumes, make-up of traffic stream, availability and schedule of mass transit plus ridership, intersection characteristics, traffic signal characteristics, parking conditions, number and width of lanes will be collected from the MPO of Lake Charles. Since the LaDEQ have in place emissions monitoring devices in various parts of the study

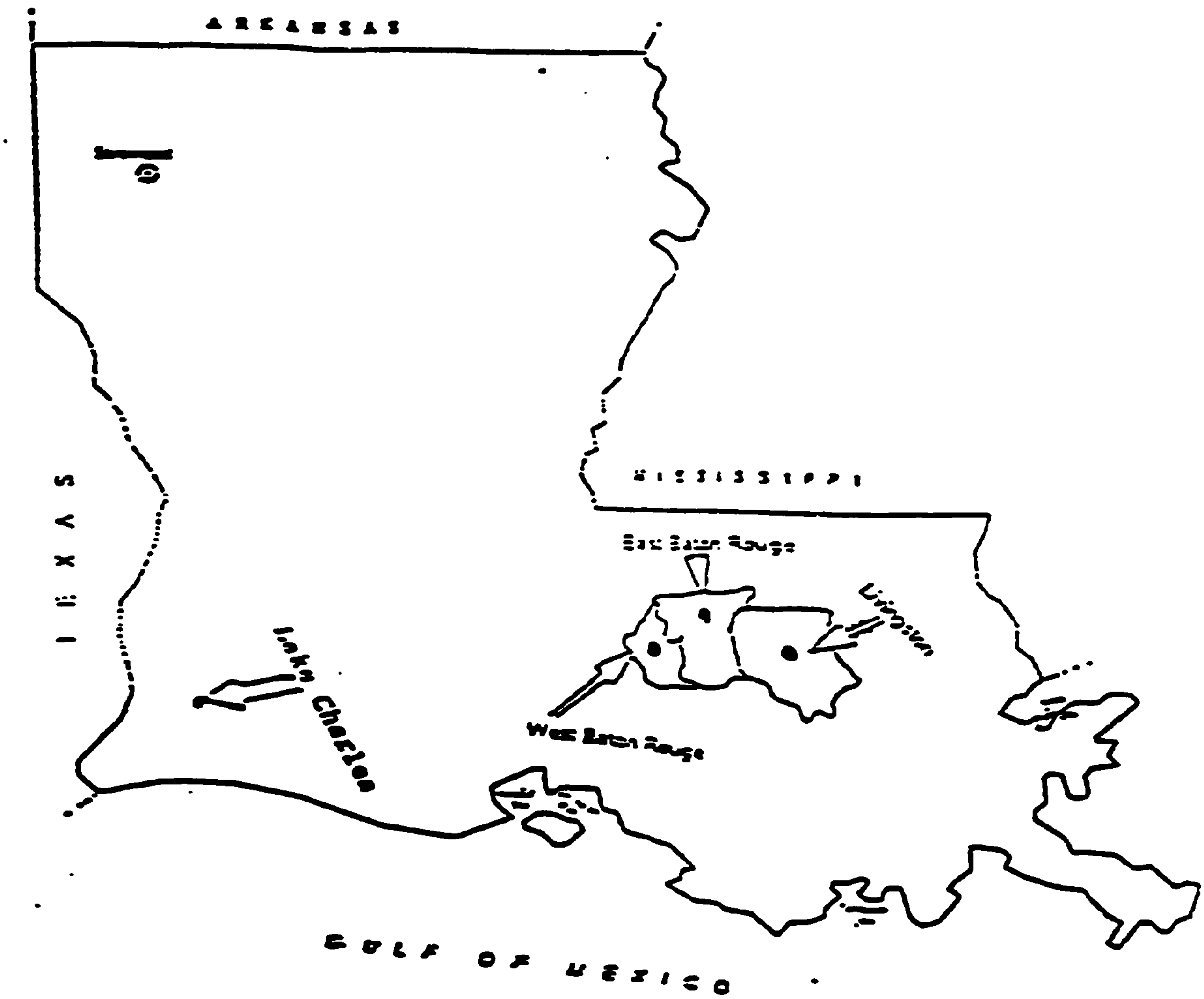


Figure 1-4: Map of Louisiana Showing Key Air Quality Nonattainment Areas for NAAQS (Ozone) Based on 1990 Clean Air Act

area, historical data on ground-level ozone concentrations and meteorological data will be gathered and used in the analysis.

Once these data are secured, a series of analyses will be conducted designed to address the objectives of this research. The degree of public acceptance of a given TCM will be determined from the primary data using rank order statistical procedure. Furthermore, an analysis will be conducted to determine the cost-effectiveness of two or three most favored TCMs on reducing on-road mobile source emissions in the region. The merits of transferability of the results of individual TCM evaluation and the likelihood of its application to Louisiana conditions will be determined. From the analyses, a table can be prepared that will rank the various TCMs into categories of high, medium, and low cost-effectiveness. Additionally, a rating will be prepared for each TCM as to its applicability to Louisiana conditions. A rating scheme will be developed which includes the key factors in determining whether there is enough similarity between corridors in Louisiana and those from where the data were secured in order to be able to apply the results to Louisiana. The TCMs with both the highest cost-effectiveness and highest ratings on applicability to Louisiana will be selected and applied to the corridors of interest on Lake Charles and their effects on pollution levels estimated.

Although much effort has been made to enhance and refine emission estimation approaches over the past two decades, the basic form of the calculation has remained unchanged. The total vehicle miles traveled (VMT) by on-road vehicles is used to describe the level of vehicle use. Emissions will be estimated by multiplying VMT by a "composite" emission factor (expressed as grams of emissions per mile of travel). In short, estimates of on-road mobile source emissions for the research target area will be made using computer based air quality models that quantify a given pollutant in terms of tons per day or grams per day. An acceptable air quality model will be developed if the existing models are not reasonable at estimating the on-road mobile source emissions.

Using a mathematical regression model a realistic future VMT projections for the region will be developed for the period 1990 through 2021. A careful evaluation will be made using the VMT projections for the period 1990 through 2021, a calculated average emissions per mile of the pollutants CO, NO_x, and HC, and all applicable TCMs in the region will be determined for the purpose of determining the foreseeable future for the region to attain and maintain the NAAQS.

1.12 Study Outline

In this study both statistical and interpretative approaches are used in quantifying the most acceptable TCM. The TCMs are first ranked on the basis of people's perceptions of each TCM. The end result of this is to enable the MPOs and city planners to learn which TCMs are more likely to win peoples' approval. The most favored TCM is then analyzed for cost-effectiveness using one of the existing analytical methods. Much of the empirical work is based on the survey data gathered from the sampled area of Calcasieu Parish of Louisiana. The empirical phase of the study is also complemented by historical data of the research target area and data based on literature reviews. Both the primary and the secondary data for the region are used in developing mathematical regression model for VMT projections. Powerful computer modeling techniques are also used to quantify ozone precursor pollutants for the region.

The research document is divided into a number of chapters. Chapter 1 provides a general overview of the problem and the events that have prompted this study as well as the overall significance of the study.

Chapter 2 presents an extensive review of relevant literature pertaining to the study. The review provides additional focus for the problem statement and the rationale for the study.

Chapter 3 describes the research methodology, the study design, the procedure for data collection. The Chapter also presents a detailed information relative to the research model(s) developed or used to quantify the ozone pollutant concentration for the target area. The VMT estimates methodology as well as an example problem are presented. A 30-year emissions projection are presented for the period 1990-2020.

Chapter 4 presents all the results in four basic sections. The first section presents the result of TCM acceptability. The second section presents the forecasted VMTs. The third and four sections presents the cost effectiveness of the most favored TCMs in terms of improving the air quality of the study region and the evaluation of the air quality situation for the study region, respectively.

Chapter 5 presents the conclusions, remarks, including general implications and areas for further research.

The appendices include the survey instruments, assumptions and calculations used in estimating emissions, VMT, trips, and sensitivity analysis, and cost-effectiveness estimates. Mobile 5a computer input and output information, federal register notice, and other relevant computation materials are included in the appendices.

CHAPTER 2

REVIEW OF LITERATURE

A review of some recent statistics indicates that traffic congestion is rapidly becoming one of the most serious transportation problems affecting the U.S. roadway network. Urban travel, in general, is increasing at a rate of 4 percent per year, but construction of new facilities is expected to accommodate less than one-fourth of this demand [Hawthorn, 1990]. The 37 largest U.S. metropolitan areas are annually experiencing a total of 1.2 billion vehicles-hours of delay on freeways alone. Current predictions are for nearly a 50 percent increase in travel demand on urban freeways between the years 1984 and 2005. This would result in recurring congestion and over a 400 percent increase in delay. Therefore, increased congestion and continued loss of mobility are expected in the years ahead. The problem is further highlighted by the following recent reports: (1) In September 1988, it was reported that the average speed for commuters across the Woodrow Wilson Bridge near Washington, D.C., was 23 miles per hour (mph), down from 47 mph in 1981. (2) A report published by the Texas Transportation Institute placed the cost of congestion in 19 U.S. cities in 1986 at over $24 billion, based on delays, wasted fuel, and high insurance premiums. (3) In September 1989, the Southern California Association of Governments forecast that average peak-hour speeds on Los Angeles freeways will soon be reduced to as low as 17 mph.

Based on the above backdrop of serious existing and growing congestion problem nationwide, ISTEA [1991] established the Congestion Mitigation and Air Quality Improvement (CMAQ) Program. To emphasize the importance of the link between transportation and air quality, CMAQ program provided $6 billion between 1992-1997 for transportation projects and programs to improve air quality. In the early 1970's, the Houston area of Harris County, Texas, was experiencing growth in traffic trends that were creating some of the most congested freeways in the nation. Recognizing the economic and physical impossibility of providing enough highway capacity to serve the demand created by reliance on low-occupancy vehicles, local officials developed a scheme that was designed to implement a system of transportation demand management measures (TDM) designed to maximize the movement of "people", not vehicles, within the transportation system.

Today, the problems of congestion and air pollution from mobile source emissions have worsened not only for the Harris County area residents, but also for the residents of Baton Rouge and Lake Charles areas of Louisiana [U.S. General Accounting Office, 1992]. According to the U.S. General Accounting Office report [1992], Baton Rouge, Louisiana is the only metropolitan statistical area with a population between 500,000 and 1 million residents reported to experience "severe" congestion. Woodward [1996] projected a 46 percent increase in daily VMT for the Baton Rouge area based on 1996 figures. Crawford and Krammes [1993] indicated that the prevailing rise of VMT with its associated congestion has brought mobile source emissions to the forefront of environmental concerns. Crawford and Krammes went on to add that the VMT increases were due to increases in drivers, automobile ownership, and economic well being of citizens. Beckham et al., [1990] concluded that mobile sources produce half of the ground-level ozone concentrations in the United States and that they are also responsible for 70 to 90 percent of the CO problem in the U.S. Lindley [1989] stated that metropolitan freeway systems were responsible for more than 31 percent of the total VMT using 1987 figure. According to Shrouds [1991], congestion with its associated pollution is increasing in urban areas of all sizes and vehicle delays are significant contributions to mobile source emissions. He added that transportation planners need to place much more emphasis on transportation demand management (TDM) strategies, operational improvements, mass transit options, and other strategies that discourage SOV.

Based on recent emission inventories released by LaDEQ, mobile source emissions constitute about 17.8 percent and 19.2 percent of volatile organic compounds (VOCs) and NO_x respectively that are emitted annually into the atmosphere in the Baton Rouge area alone. Furthermore, and according to the 1990 CAAA, Baton Rouge and Lake Charles areas of Louisiana are classified as serious and marginal nonattainment areas respectively in terms of NAAQS for ozone. Horowitz [1982] noted that the distribution of these mobile source pollutants (CO, HC and NO_x) emitted within metropolitan areas vary geographically across the nation. Research is therefore critical in order to study the ozone nonattainment situation in Lake Charles area of Louisiana. Furthermore, research is necessary in order to determine what TCM or group of TCMs are effective at reducing mobile source emissions for the study area.

Apparently nowhere in the world has the air quality problem received as much attention from planners as in Southern California, and no environmental agency has proposed a more radical set of VMT-reduction strategies than the South Coast Air Quality Management District (SCAQMD) [Bae and Chang - Hee, 1990]. In March 1989 the governing board of SCAQMD and the Executive Committee of the Southern California Association of Governments (SCAG) voted to adopt an ambitious and far-reaching Air Quality Management Plan (AQMP) aimed at making the Los Angeles region comply with federal clean air standards by the year 2010 [SCAQMD, 1989]. A substantial proportion of the control measures proposed in the plan were directed at reducing transportation emissions. Transportation Research Board/National Research Council [1992] emphasized the need for continued evaluation of those TCMs that have been proven to be technically feasible and effective at decreasing mobile source activity. The seven "Reasonably Available" TCMs are: 1) employer based trip reduction rules, 2) trip reduction rules for other sources that attract vehicle trips, 3) management of parking supply and pricing, 4) high occupancy vehicle system plans and implementation programs, 5) comprehensive transit improvement programs for bus and rail, 6) development policies for motor vehicle trip reduction, and 7) development policies to strengthen on-site transit access for new and existing land development.

According to recent findings [Transportation Research Board (TRB)/National Research Council (NRC), 1992], the effectiveness of these and other TCMs is usually evaluated based on changes in VMT and emissions, but this has not been correlated with air pollutant concentrations. Experts agree that in order to complete the picture, estimates of reductions in criteria pollutant concentrations achievable by specific TCMs or combinations of TCMs are critical. Experts also argue that pollutant concentrations may not necessarily be proportional to reductions in emissions and that multiple TCM strategies may result in synergism. It must be emphasized at this point that only few studies have been conducted to determine how, when, and where TCMs augment or interfere with one another. Furthermore, transportation control measures face numerous barriers to acceptance [TRB/NRC, 1992]. According to TRB/NRC different concerns are raised by different groups within the public and as such, public acceptability of a given TCM is critical for implementation of an effective TCM. Much work has been done to implement a number of TCM programs but nothing has been done to determine the degree of public acceptability of a given TCM. This research is designed to address this by using Lake Charles as a case study for the investigation.

At this juncture, it must be stated that while the state of California has led the nation in terms of implementing a number of TCM programs, other states with severe congestion and other gridlock on their road networks have in place one or more of the sixteen CAAA TCMs. In Washington, D.C., the Shirley Highway HOV lanes were the first major TCM application of HOV lanes in the U.S. in 1969 [TRB, NRC, 1991].

McCormick [1990], indicated that HOV facilities were designed to discourage drive alone automobile usage with one ultimate result of relieving congestion and gridlock in most metropolitan and suburban areas as well as protecting the environmental impacts of automobile emissions. Again, the 1990 HOV Facilities Conference showed that there are more than 40 HOV projects in operation in 20 metropolitan areas in North America. Furthermore, there are many more applications of HOV projects on arterial streets, bus-only lanes in downtown areas, and HOV bypasses at freeway ramp meters. According to

Turnbull [1991], the Texas Transportation Institute [TTI] has recently completed a survey of HOV projects on either freeways or in separate rights-of-way for the purpose of mitigating congestion.

Kuzmyak and Schreffler [1989], also showed that TDM had become a popular terminology to describe a system of actions in which the purpose was to alleviate traffic and pollution problems through improved management of vehicle trip demand. The actions are primarily directed at commuter travel and structured such as they either reduce the dependence on and use of SOV, or to alter the timing of travel to other less congested time periods. According to Kuzmyak and Schreffler, TDM offers travelers legitimate alternatives to driving alone. Alternatives include various types of transit service, carpooling, vanpooling, and where appropriate, provisions for walking and bicycling. Note that work hours management is a form of TDM. Work hours management strategies try to affect vehicle trip demand on highway facilities by shifting that demand to less congested time periods. Kuzmyak and Schreffler concluded that TDM is effective in reducing traffic and its concomitant pollution and that such reduction can be measured and validated.

Bae [1990] did not share the above view by stating that the VMT-reduction measures such as the alternate work schedules (AWS), and "mode shift" strategies, offer negligible reduction in mobile source emissions. He went on to conclude by indicating that more transit use, ridesharing, and telecommuting were not needed to achieve clean air objectives. Horowitz and Pernelia [1976] disagreed with the above view. They affirmed that reduction of automobile emissions of carbon monoxide, hydrocarbons, and nitrogen oxide is a major objective of programs to improve air quality in urban areas.

They indicated that one of the many possible approaches to achieving this objective is to reduce automobile travel through the use of high-occupancy vehicles such as transits, vanpooling and carpooling, and imposing fees for or restrictions on automobile use. Turnball [1990] pointed out that HOV facilities represent just one approach to dealing with urban congestion problems and air quality and stated that HOV facilities should not be viewed as the most appropriate solution in all cases. This study also investigates the cost-effectiveness of at least two TCMs in order to determine any possible TCM benefits to NAAQS for the study area.

Efforts have already been made to better quantify the air quality benefits and energy conservation. Sierra Research, Inc., [1991] developed a methodology for quantifying the TCM effectiveness on emissions reduction. Loudon and Dagnang [1992] developed a procedure for predicting the impacts of TCMs on travel behavior and pollutant emissions. Apogee Research, Inc., [1993] conducted a comprehensive literature review on the use of TCMs to quantify air quality and categorized TCMs as either "Bait" or "Bites." Table 2-1 shows the grouping of TCMs and the objectives they are designed to accomplish based on Apogee Research, Inc. analysis. Woodward-Clyde [1996] cited a number of TCMs which included employer-based transportation management programs and area-wide rideshare programs as superior for implementation for the Baton Rouge area of Louisiana. Apparently no research work has been done to determine which TCM or combination of TCMs can be implemented for the Lake Charles area in order to move the region from its current nonattainment status to attainment status. Furthermore, the MPO for the Lake Charles area of Louisiana has requested some guidance from the LaDOTD in selecting appropriate TCMs to bring their nonattainment air quality.

Table 2-1: TCM Categorization Matrix

OBJECTIVE:					
B A I T		Mode Switch	Flow Improvement	Workweek/ workplace Changes	Changes in Vehicles
		No change in number or schedule of personal trips. Reduction in vehicle trips; increase in AVO.	No change in number of trips; some change in schedule. No change in AVO.	Change in number of trips and VMI.	No change in travel Change in emissions only.
	Exhortation and Informa-tion: Employer-based Regula-tions	Employer trip reduction ordinances. Reg. XV. Area-wide ride sharing programs, information, etc.	Flextime	Telecommu-nicating Compresses week	
	Facility or Service Improve-ments	Transit improvements HOV lanes Park-and-ride lots for car/ vanpool, transit Bicycle/ pedestrian facilities	Signal timing Misc. Traffic operations imporvements Incident management	Land use planning activity centers	Improved hardware for CO emissions in extreme cold starts
R I T E	Regulations and Restrict-ions	Parking restrict- ions Mandatory no drive days Auto-restricted zones	Certain parking restrictions Auto-restricted zones	Land use regulations	Truck idling restrict-ions
	Market Mechanisms	Parking taxes Congestion or road/bridge pricing	Congestion or road/bridge pricing	Parking taxes or cash-out	Smog/VMT tax Buy-backs of older vehicles

Note: AVO means Average Vehicle Occupancy, HVO means High Occupancy Vehicle. Source: Apogee Research, Inc.

It is critical therefore, that research be conducted to determine the effectiveness of a given TCM included or to be included in the State Implementation Plan for the region. Texas Transportation Institute (TTI) [1993] emphasized that before TCMs can be used to reduce emissions in metropolitan areas, the type and the extent of their implementation ought to be decided. According to TTI sketch-planning tools have been used over the years to evaluate potential TCMs for a region. The two most current methodologies are: (1) the Systems Applications International (SAI) prepared for the EPA and (2) the San Diego Association of Governments (SANDAG) methodology developed by Sierra Research, Inc., with support from JHK and Associates. Although several emission reduction estimation methods have been developed during the past 20 years, there is currently no universally acceptable methodology for evaluating TCMs [Sacramento Metropolitan Air Management District, 1991]. Table 2-2 provides an overview of the dates of development for a number of sketch-planning methods used in evaluating TCM's effectiveness. National Cooperative Highway Research Program (NCHRP) 263 methodology uses a flowchart-type process beginning with problematic transportation conditions and ending with suggested solutions. In short NCHRP 263 uses selection aides to evaluate the effectiveness of TMCs. The Air Quality Analysis Tools (AQAT) was developed by the California Department of Transportation and the California Air Resources Board (CARB) to evaluate emissions associated with the transportation system. The current release of this tool is the third version, AQAT-3. Austin et al. [1992] indicated that AQAT-3's strength lies in its ease of integration with other air quality modeling computer software programs such as the URBEMIS #3, EMFAC7PC, and CALINE4. URBEMIS#3 software model allows the computation of mobile source emissions as a function of the number of vehicle trips associated with a given land use and VMT. EMFAC7PC is a California emission factor model software. CALINE4 is the third air quality computer software model which determines the concentration levels of pollutants on or near roadways using a Gaussian diffusion algorithm.

Table 2-2: TCM Sketch-Planning Methods

METHOD	YEAR
National Cooperative Highway Research Program (NCHRP)	1983
AQAT-3	1990
Turnball	1990
San Luis Obispo Air Pollution Control District	1991
Sacramento Air Quality Management District	1991
SanDiego Association of Governments (SANDAG)	1991
Systems Applications International (SAI)	1992
North Central Texas Council of Governments	1992
Houston-Gavelston Area Council	1992
Texas Department of Transportation	1993

The Turnball method calculates the effects of TCMs in terms of potential trips affected and the number of vehicles removed from the roadway and this method lacks the use of VMT and speeds variables in estimating emissions. The San Luis Obispo Air Pollution Control District (SLO) calculates the changes in emissions and the cost-effectiveness of the TCM and this method uses a spreadsheet. The Sacramento Metropolitan Air Quality Management District (SMAQMD) uses five computer software modules to evaluate the impacts of TCMs on air quality. Austin et al., noted that this methodology was the "first step in determining which combinations of TCM, would be most effective in achieving desired mobile source emission reductions" and according to Austin and others, the method is highly qualitative. Presently the SMAQMD has abandoned this method and adopted the SANDAG method due to ease of use. The SANDAG methodology has three computer software modules (travel impacts, emissions impacts, cost-effectiveness) and it is designed to predict the effect of a single TCM on mobile source emissions [Loudon and Dagnang, 1992]. The SAI methodology is the most recent attempt by the EPA to estimate the potential emission reductions from the implementation of TCMs. It has two computer software modules- travel effects and emission effects. The North Central Texas Council of Governments (NCTCOG) method was developed to aid in selecting TCMs to be included in the TIP. It is a qualitative process that evaluates individual TCMs based on several variables. The Houston-Galveston Area Council (H-Gac) method was used to calculate emission reductions from a number of TCMs. Travel changes from TCMs were modeled with runs of the travel demand forecasting models and the method calculates VOC emission exclusively. Lastly, the Texas Department of Transportation (TxDOT) methodology was developed to assist the Texas MPOs in estimating emission reductions resulting from transportation projects being considered in the TIP. The method determines the effects on travel and emissions from TCMs and then calculates their cost-effectiveness.

While it is important to present a brief account of some of the methods used in evaluating the air quality benefits and the cost-effectiveness of a given TCM, an understanding of the methodology for quantifying mobile source emissions is equally important. Guensler et. al. [1991] indicated that motor vehicle emissions are estimated by quantifying emission-producing vehicle activities and coupling those activities with activity-specific emission rates. Table 2-3 depicts the details of the emission-producing vehicle activities and the emissions that are produced as put together by Guensler and others. Table 2-3 also depicts the items that are often included in the emission inventory modeling process. The elevated emissions of CO, NO_x, PM_{10}, and SO_x noted in Table 2-3 generally result from engine conditions that exacerbate incomplete combustion and from catalytic converter temperatures too low to facilitate efficient control of exhaust gas emissions [Jacobs, et al., 1990; Heywood, 1988; Joy, 1992; Stone, et al., 1990; Pozniak, 1980]. In addition to the activities in Table 2.3, high power and bad conditions, such as rapid acceleration or high speed activities produce significant emissions [CARB, 1991; Benson, June 1989; Gorblick; 1990; Calspan Corporation, 1973a, 1973b; Kunselman, et al., 1974] and these may be considered discrete emission-producing activities. Also recent laboratory testing indicates that high acceleration rates greater than 3.3 mph/second contribute significantly to instantaneous rates, and that tends to suggest that the current emission estimates based on the federal test procedure (FTP) may be inaccurate. The FTP uses vehicle speed of 57 mph and acceleration of 3.3 mph/second for emission modeling. Finally, air quality modeling is a complex process and as such, the current modeling tools which incorporate the emission- producing activities depicted in Table 2-3, may not in essence, adequately address all spatial and temporal aspects of transportation networks and environmental conditions affecting air quality. Roth [1990] states that air quality modeling should recognize the effects of upwind generation of air pollutants and their transport. Uncertainties and the potential for error in emission. estimates have long been recognized. Nevertheless, several recent findings regarding mobile source emissions have disturbing implications: running losses (evaporative losses during vehicle operation, which had previously not been quantified) were found to be significant [EPA, 1989].

Table 2-3:Emission-Producing Vehicle Activities and Emissions that are Produced

Emission-Producing Veh. Activ.	Type of Emissions Produced
Vehicle Miles Traveled	o Running Exhaust (CO, VOC, NO_x, PM_{10}, SO_x) o Running Evaporative Emissions(VOC)
Cold Engine Starts	o Elevated Running Exhaust Emissions (CO, VOC, NO_x, PM_{10}, SO_x)
Warm or Hot Engine Starts	o Elevated Running Exhaust Emissions (CO, VOC, NO_x, PM_{10}, SO_x
Engine "Hot Soaks" (shut downs)	o Evaporative Emissions (VOC)
Engine Idling	o Running Exhause Emissions (CO, VOC, NO_x, PM_{10}, SO_x) o Elevated Evaporative Emissions (VOC)
Exposure to Diurnal and Multi-Day Diurnal Temperature Fluctuation	o Evaporative Emissions (VOC)
Vehicle Refueling	o Evaporative Emissions (VOC)
Modal Behavior (e.g. High Power Demand, Heavy Engine Loads, or Engine Motoring)	o Elevated Running Exhaust Emissions (CO, VOC, NO_x, PM_{10}, SO_x)

Source: Guensler, 1991

Note: CO= Carbon Monoxide; VOC = Volatile Organic Compounds;NO_x = Oxides of Nitrogen; PM_{10} = Fine Particulate Matter Less than 10 Microns in diameter); SO_x = Oxides of Sulfur.

Furthermore, Ingalls [1989] found in-use vehicle emissions to be substantially higher than model estimates. Other studies also provided further confirmation of major uncertainties in mobile source emissions [Lawson et al., 1990]. In an attempt to refine on-road mobile source emission estimates, a number of computer modeling techniques have been developed by both public and private organizations. The following briefly describes a number of some of these models.

Mobile 4, Mobile 4.1, Mobile 5, and the latest version, Mobile5a, were developed by the United States Environmental Protection Agency (EPA). This model is used to calculate emission factors for HC, CO, and NO_x from motor vehicles. The program takes into account various factors such as the ambient temperature, speed, and fleet vehicle mix. TRFCON Emissions Forecast Model (Arizona Department of Health) treats traffic on a link-by-link basis. It can address terminal traffic volume and capacity, thus allowing for measurement of the effects of congestion on emissions. The model's outputs are CO, NO_x, and HC emissions by district, and by hour of the day.

CAL3QHC [EPA, 1990] is a "line source" dispersion model for CO designed to predict CO concentrations on a microscale level (i.e., at an intersection rather than an entire region) and it is used to determine if intersections modeled meet the NAAQS for CO level. According to Lindemann [1994], this model is conservative and has large uncertainties. The model was developed for a queuing model (Connecticut DOT Queuing Model) and a dispersion model (FHWA CALINE3).

The other models suitable for microscale CO modeling for intersections are:

- FHWAINT-Federal Highway Administration (FHWA) Intersection Model:
- GIM - Georgia Intersection Model;
- EPAINT - EPA Intersection Model;
- CALINE4 - California Line Source Model;
- VOL9MOB4 - Mobile4 modified Volume 9 Technique;
- TEXIN2 - Texas Intersection Model;
- IMM - Intersection Midblock Model.

The Urban Airshed Model (UAM) which was earlier cited is recommended by the EPA for regional ozone analysis. The model is based on species continuity equations (atmospheric diffusion), and it can be used to simulate 12 to 72 hour pollutant episodes.

The EMFAC7E is an emission factor model developed by California Air Resources Board in 1990. The model integrates with another computer software module, BURDEN to generate a county-level total emissions. The model does not provide spatial or temporal breakdowns but it accepts VMT distributions by vehicle speed range rather than using a default speed. The two most broadly known procedures for producing emission estimates are the UAM Emission Processing System (EPS) [SAI, 1990] and the California EMFAC7E/BURDEN system [CARB, 1990b].

Based on the above cited techniques for modeling mobile source emissions, there is still no "standard" emission calculation system in the sense that Mobile5a and EMFAC7E are the "standard" emission factor models [Ireson, et al,. 1991]. The basic estimating approach nevertheless has remained the same as depicted in Figure 2-1. The process is probably best described in a backward fashion, that is, from right to left in the Figure 2-1. The desired objective is to accurately predict ambient air pollutant concentrations.

In summary therefore, this section has presented a review of the related literature pertinent to this research study. An extensive literature review clearly showed that while a number of the existing TCMs offer merits for mitigating environmental pollution, not much has been done in terms of research efforts to evaluate the cost-effectiveness of a given TCM program for the research target area. Furthermore, not much has been done in terms of determining the probable foreseeable future for the region to move to attainment status for NAAQS. This study is designed to address all of these. The literature review in this section provides the basis for analyzing the objectives of this study.

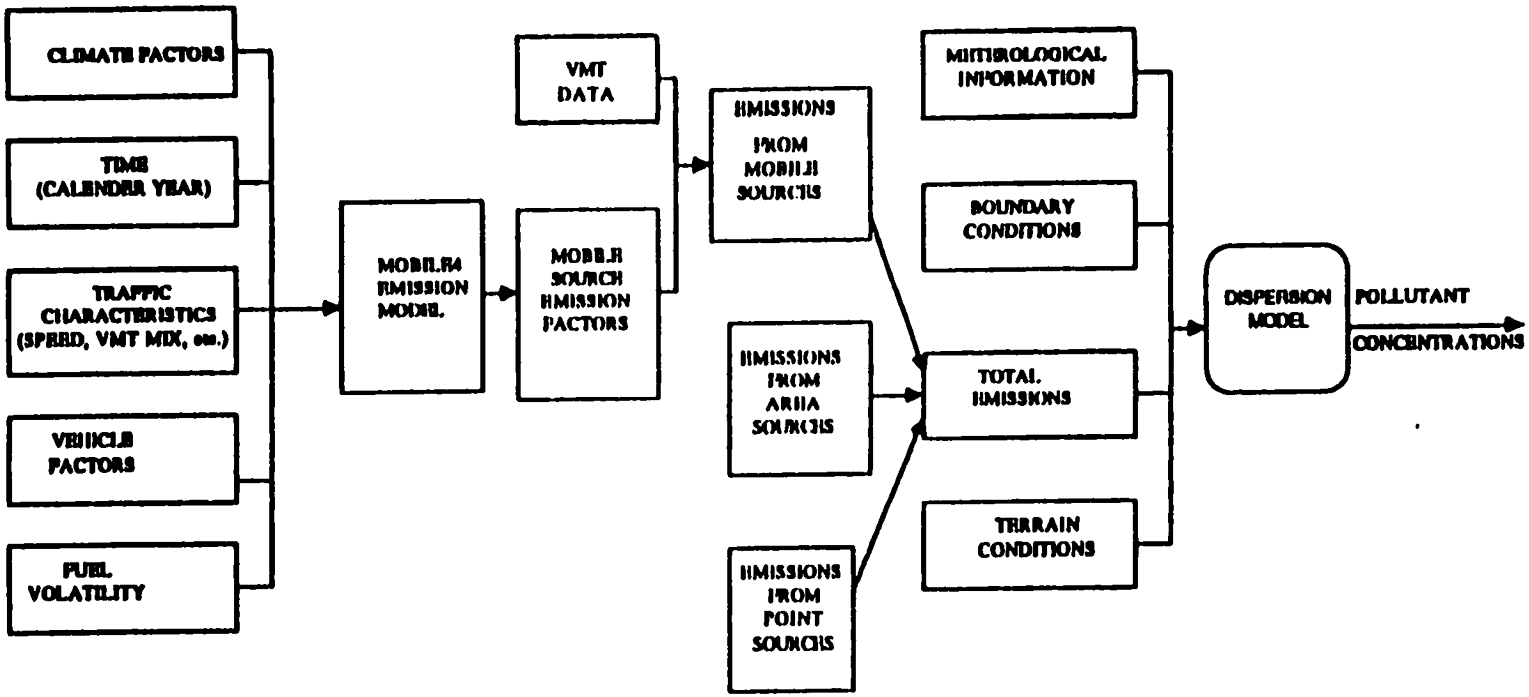


Figure 2-1: The Air Pollution Modeling Process

CHAPTER 3

METHODOLOGICAL PROCEDURE

This section discusses the procedures followed in conducting the study. They include (a) data collection (b) data processing, analysis and interpretation,(c)VMT estimating, forecasting and tracking, (d) vehicle emission factors estimation techniques, (e) methodology for the determination of total mobile source emissions for the region, (f) cost-effectiveness of one or two TCM(s) and (g) statistical analysis.

3.1 Procedure for Data Collection

For this study, two major sources of data are as follows:

- Primary source;
- Secondary source.

For the primary data, two survey instruments were developed for the research target area. Three major governmental agencies consisting of LaDEQ, LaDOTD, and the MPO of Calcasieu were the major sources for the secondary data. A great deal of the secondary data was used in the air quality modeling phase.

3.2 Sampling Size Determination

The 1990 Census of information indicates the research target area population to be 142,619 residents. This figure was used to determine the minimum sample size using the procedure developed by Kalton [1983]. To determine the appropriate sample size, a precision of 2% was specified. In other words, the initial specification calls for an estimation (percentage of residents who will demonstrate a high degree acceptability to any of the TCM(s) that is within 2% of the population percentage with 95% probability. Thus,

$$1.9\ SE(P) = 2\% \qquad (3\text{-}1)$$

where P = Sample percentage

SE(P) = Standard error of the sample percentage. Assuming the use of simple random sampling (SRS) initially and ignoring the finite population correction (fpc), then

$$SE(P) = \sqrt{\frac{PQ}{n^1}} \qquad (3\text{-}2)$$

where P = population percentage

Q = 100 - P

n^1 = initial sample size.

Thus

$$1.96\sqrt{\frac{PQ}{n^1}} = 2 \qquad (3\text{-}3)$$

$$n^1 = \frac{(1.96)^2 (PQ)}{2^2} \tag{3-4}$$

In order to incorporate the finite population correction (fpc), a revised sample size is achieved using the following formula:

$$n = \frac{Nn^1}{(N + n^1)} \tag{3-5}$$

where n = revised sample size

N = population size and n' as earlier defined.

The equations (3-1) - (3-5) were used to determine a sample size of 2152 for the TCM survey and also used to determine the sample size of 927 for the employee survey.

3.3 Development of Survey Instruments

Once the sample size was determined, the next phase was the development of a set of survey instruments. The survey instruments were pre-tested for validity and adequacy before they were administered to the research target area residents and area employees. The questionnaires consisted of: (1) Questionnaire on TCMs, and (2) An area resident (employees) survey. Appendix A shows the questionnaire on the TCMs, Appendix B shows the survey instrument on the employees of major employment centers for the region, and Appendix C shows the details of sample size calculations. A major employment center is defined as a business with 200 or more employees.

The questionnaire in Appendix A elicited the following basic information:

I. A computer coded answer sheet containing a comprehensive listing of the sixteen 1990 CAAA TCMs;

II. An explanation sheet containing the transportation consequences/impacts and benefits relating to each of the sixteen listed TCMs;

III. A TCM acceptability scale of 1-5 in which 1 means highly unacceptable while 5 mean highly acceptable. This is also contained on the computer coded answer sheet for the respondents.

The questionnaire in Appendix B was used to collect information that would provide another method for estimating the VMT and the number of trips generated in the research target area. The data obtained from this was used to compare with the data obtained using the HPMS methodology. The questionnaire in Appendix B elicited the following information.

I. Demographic information of respondents;

II. Car ownership and maintenance characteristics;

III. Income characteristics;

IV. Travel characteristics of respondents;

V. Home based work (HBW) travel characteristics;

VI. Employment characteristics;

VII. Parking availability;

VIII. Modal choice;

IX. Driving characteristics.

3.4 Data Collection

The data collection phase started in the month of March 1997 through September 1997. The questionnaires were administered by paid interviewers who were provided with adequate training regarding the purpose of the study and the administration of the questionnaires. The written instruction sheet was read and explained to each interviewer.

The research target area was divided into blocks in accordance with the 1990 census tracts for the region. The blocks were selected on a random basis to minimize any bias in statistical analysis. Questionnaires were administered to the residents of each block on proportionate basis. The sample size for the employee survey (ES) was 927.

The ES was also based on a random process and the questionnaires were distributed on a door to door basis by paid interviewers. There was over 100% return rate on TCM questionnaires while there was a 49% return rate on ES.

There were 2,171 completed and returned questionnaires for the TCM survey. Of the 927 randomly selected employees from 26 major employment centers, 452 questionnaires were returned completed (49%). Some employers prevented their employees from participating which contributed in lowering the return rate. Anyway, the return rate of 49% was considered good based on literature review. Table 3-1 shows the distribution of population, percent of population, computed sample size and the actual sample size completed by Block Groups for the target area. Table 3-2 shows the details of the major employment centers for the target area including the required sample size and the actual sample collected for the ES.

3.5 Data Processing, Analysis, and Interpretation

A combination of simple statistical tabulations, descriptive data analysis and rank order measures were used to address the primary objective of determining the degree of public acceptance of a given TCM. The Statistical Package for Social Sciences (SPSS-X)

Table 3-1: Distribution of Population, % of Populations, Required Sample Size, and Actual Sample Size by Block Groups

Block Group Number	Total Population	% of Population	Sample Size	Sample Collected
1.1	406	0.003	6	6
1.2	382	0.003	6	6
2.1	868	0.006	13	13
2.2	416	0.003	6	6
2.9	52	0.001	1	1
3.1	885	0.006	13	16
3.2	903	0.006	14	14
3.3	697	0.005	10	10
3.4	655	0.005	10	9
3.5	665	0.005	10	10
4.1	985	0.007	15	25
4.2	611	0.004	9	9
4.3	780	0.005	12	13
4.4	752	0.005	11	11
4.5	455	0.003	7	8
5.1	833	0.006	13	13
5.2	614	0.004	9	10
5.3	825	0.006	12	12
5.4	760	0.005	11	11
5.5	541	0.004	8	8
5.6	551	0.004	8	8
6.1	905	0.006	14	14
6.2	716	0.005	11	11
6.3	931	0.007	14	14
6.4	952	0.007	14	14
6.5	729	0.005	11	11
6.6	1468	0.010	23	23
6.7	661	0.005	10	10
6.8	854	0.006	13	10
7.1	1203	0.008	18	10
7.2	681	0.005	10	24
7.3	415	0.003	6	26
7.4	1148	0.008	17	17
7.5	1291	0.009	20	10

Table 3-1: contd.

Block Number	Total Population	% of Population	Sample Size	Sample Collected
8.1	805	0.006	12	12
8.2	821	0.006	12	12
8.3	760	0.005	11	11
8.4	1019	0.007	15	15
9.1	911	0.006	14	14
9.2	708	0.005	11	11
9.3	830	0.006	12	12
9.4	516	0.004	8	8
9.5	402	0.003	6	6
9.6	537	0.004	8	8
10.1	485	0.003	7	7
10.2	1255	0.009	19	19
10.3	495	0.003	7	7
10.4	750	0.005	11	11
10.5	816	0.006	12	13
11.1	530	0.004	8	8
11.2	557	0.004	8	8
11.3	1825	0.013	27	9
11.4	696	0.005	10	10
11.5	688	0.005	10	10
12.11	1575	0.011	25	25
12.12	1525	0.011	24	26
12.13	1815	0.013	27	28
12.21	2477	0.017	37	37
13.1	1156	0.008	17	17
13.2	959	0.006	14	14
13.3	1012	0.007	15	15
13.4	578	0.004	9	5
13.5	1122	0.008	17	10
13.6	2350	0.016	35	15
13.7	988	0.007	15	15
14.1	1116	0.008	17	18
14.2	931	0.007	14	14
14.3	1002	0.007	15	15
14.4	792	0.006	12	12

Table 3-1: contd.

Block Group Number	Total Population	% of Population	Sample Size	Sample Collected
14.5	1013	0.007	15	30
14.6	900	0.006	14	14
14.8	795	0.006	12	10
15.1	634	0.004	10	10
15.2	1304	0.009	20	15
15.3	310	0.002	5	5
16.1	2288	0.016	34	34
16.2	1009	0.007	15	15
16.3	897	0.006	13	13
16.4	335	0.002	5	5
16.7	200	0.001	3	3
16.9	17	0.000	0	0
17.1	2070	0.015	31	62
17.2	2007	0.014	30	30
18.1	745	0.005	11	22
18.2	2343	0.016	35	33
19.11	1451	0.010	22	23
19.12	1829	0.013	28	28
19.19	30	0.001	1	1
19.21	1204	0.008	18	18
19.22	1684	0.012	25	25
19.23	1486	0.010	22	22
19.24	1700	0.012	26	26
19.29	2389	0.017	36	29
20.2	1658	0.012	25	15
22.11	1331	0.009	20	20
22.12	1704	0.012	26	26
22.13	1269	0.009	19	19
22.21	1485	0.010	22	25
22.22	2572	0.018	39	39
22.23	1417	0.010	21	21
22.24	768	0.005	12	12
22.25	1797	0.013	27	29
25.1	1816	0.013	27	27
25.9	987	0.007	15	15

Table 3-1: contd.

Block Group Number	Total Population	% of Population	Sample Size	Sample Collected
26.1	1651	0.012	25	26
26.2	619	0.004	9	9
26.3	150	0.001	2	2
26.4	598	0.004	9	9
26.5	1090	0.008	16	16
26.6	1283	0.009	19	19
27.1	593	0.004	9	9
27.2	763	0..005	11	11
27.3	235	0.002	4	4
27.8	1168	0.008	18	18
27.9	2571	0.018	39	39
28.1	786	0.006	12	12
28.2	1164	0.008	18	10
28.3	273	0.002	4	4
28.4	611	0.004	9	9
28.5	2088	0.015	31	32
29.1	245	0.002	4	4
29.2	263	0.002	4	4
29.3	1143	0.008	17	16
29.4	561	0.004	8	8
30.1	427	0.003	6	6
30.2	1382	0.010	22	22
30.3	369	0.003	6	6
30.4	1673	0.012	25	22
30.5	1457	0.010	22	22
31.11	43	0.001	1	1
31.12	1714	0.012	26	25
31.13	2326	0.016	35	35
31.14	1129	0.008	17	17
31.21	1238	0.009	19	19
31.22	812	0.006	12	13
32.1	58	0.001	1	1
32.9	1056	0.007	16	16
33.1	777	0.005	12	13
33.2	1707	0.012	26	26
33.9	952	0.007	16	14
34.1	1806	0.013	27	27
TOTAL	142,619		2145	2171

Table 3-2: Major Employment Center - Calcasieu Parish

Name of Business	Address of Business	City of Location	Sample Size Required	Total # of Empl.	Actual Sample Gathered
Olin Corp.	U.S.I-10W	Westlake	69	780	56
Gulf State Utilities	314 Broad Street	Lake Charles	34	538	34
PPG Ind.	Columbia South. Rd.	Westlake	129	1612	122
Sears Co.	600 Ryan Street	Lake Charles	13	214	13
St. Patrick Hosp.	524 South Ryan	Lake Charles	67	1064	0
DOTD District Office	U.S. 90 East of Lake Charles	Lake Charles	26	361	25
McNeese St. Univ.	4105 Ryan St.	Lake Charles	69	1096	36
L. Charles Mem. Hosp.	1701 Oak Park	Lake Charles	62	994	47
Conoco Inc.	2200 Old Spanish Trail	Westlake	49	781	0
Era Aviation	P. O. Box 6550 L.C. Memorial Airport	Lake Charles	18	291	6
Sipco Services	3200 Elliswood Drive	Sulphur	16	235	0
The Kroger Co.	1014 Vine Street	Lake Charles	31	499	0
West Cal Cameron Hosp.	619 Cypress St.	Sulphur	32	506	26
IMTC Inc.	2028 Houston River Rd.	Westlake	16	258	0

Table 3-2: contd.

Name of Business	Address of Business	City of Location	Sample Size Required	Total # of Empl.	Actual Sample Gathered
Olin Corp.	U.S. I-10W	Westlake	69	780	56
West Cal Const.	Highway 90 East	Sulphur	15	241	14
Himont USA, Inc.	4101 La.	Westlake	34	541	31
Thermal Insulation, Inc.	3747 S.Arizona	Sulphur	14	227	0
Citgo Petroleum	4401 State Hwy 108	Lake Charles	109	1739	0
Walmart Stores, Inc.	3230 State Hwy 14	Lake Charles	13	206	0
Amer. Citadel	2116 Hodges Street	Lake Charles	19	295	0
Walmart Stores, Inc.	4501 Nelson Road	Lake Charles	13	212	0
W. R. Grace & Co.	1800 Davison Road	Sulphur	8	234	7
South Central Bell	415 Division Street	Lake Charles	17	271	0

Table 3-2: contd.

Firestone Tire & Rubber Co.	Highway 108	Sulphur	18	290	12
Walmart Stores, Inc.	291 S. Cities	Sulphur	13	201	0
Calcasieu Parish Sheriff's Office	5400 E. Broad Street	Lake Charles	23	362	23

main frame computer software was used in the analysis of data. The SPSS-X contained powerful sub-programs and procedures used to determine the level of acceptability for each TCM using a Likert-type scale of 1-5 as earlier explained. An average score per TCM item was calculated. This represented an average acceptability level per Likert scale response. The mean responses were then ranked. This procedure was used in reaching any conclusion regarding the degree of public acceptability of a given TCM presented in the result section of this study.

3.6 VMT Estimating

One of the major inputs for determining mobile source emissions is the amount of vehicular travel measured as vehicle-miles of travel (VMT). The VMT estimates needed for this study had to meet the following requirements:

- should be classified according to commonly used
- highway functional classification scheme;
- should be estimated for each 3 1/8 by 3 1/8 mile
- or 5km by 5km grid;
- should represent an average weekday in July;
- should be able to be converted into vehicle hours of
- travel (VHT).

In order to meet the above stated requirements, a number of data gathering procedures were used that included the use of HPMS, the use of TRANPLAN Computer Transportation Network - based modeling technique, and an employee survey. A mathematical regression modeling technique was used to project future VMT based on HPMS historical data which were supplemented by data computed using the TRANPLAN software. The year 1990 was used as the base year for the HPMS historical data from LaDOTD. The roadway functional classification for the region and their descriptions are as summarized in Table 3-2a.

Table 3-2a: Roadway Functional Classifications

Functional Class (FC)	Description
01	Rural Principal Arterial, Interstate
02	Rural Principal Arterial, Other (State)
06	Rural Minor Arterial, (State & Local)
07	Rural Major Collector, (State & Local)
08	Rural Minor Collector, (State & Local)
09	Rural Local
11	Urban Principal Arterial, Interstate
14	Urban Principal Arterial, Other (State & Local)
16	Urban Minor Arterial, (State & Local)
17	Urban Collector (State & Local)
19	Urban Local

Source: LaDOTD

Areas such as the research target area, that are designated as nonattainment are required to develop procedures that they must follow in order to reach attainment within a specified target date that ranges from 3 to 20 years from the date of CAAA enactment. These procedures are normally contained in the revisions to the State Implementation Plans (SIPs), and they focus on procedures for reducing emissions through the use of TCMs and other actions such as land use design and use of TDMs for reducing forecasted travel, trips, and congestion. The SIP revisions are therefore designed to demonstrate how an area will attain the emission reduction targets by the specified date. In this study, the future projected VMT is used to determine the projected emissions which are used to compare with the actual emissions.

VMT therefore, along with other parameters such as speed and vehicle hours of travel, play a big part in the attainment demonstration. Forecasts of VMT for the attainment date are the basis from which the future emissions are estimated. For the target area, this study recommends the use of TCM(s) to offset any growth in emissions resulting from a growth in VMT or growth in vehicle trips. The basis for measuring actual travel is the traffic count program used by both the LaDOTD or the MPO of Lake Charles area as input to the on-going Highway Performance Monitoring System (HPMS).

3.6.1. Highway Performance Monitoring System (HPMS)

The HPMS is a state-specific coordinated data base that is updated annually by the state and MPOs. It includes three major components:

- Area-wide data that includes mileage and travel summaries for rural, small urban and individual urbanized areas;
- Universe data that identifies highway systems, their location, number of lanes, average annual daily traffic (AADT) for Interstate sections, and mileage; and
- Sample section data that includes physical characteristics, AADT, and condition.

The original purpose of the HPMS was to provide a continuing source of information on the condition and performance of the nation's highways. This continues to be the primary use, but the traffic monitoring program, which is the basis for the HPMS data, has a number of attributes that make it beneficial for VMT estimates for air quality purposes. Some of the attributes are as follows:

- Traffic counts for HPMS are based on sample design conforming to established statistical principles and well documented standard procedures as outlined in the Traffic Monitoring Guide [FHWA, 1985].
- Data have been reported for HPMS for almost a decade, resulting in procedures that are familiar to most of the staffs and agencies involved.
- The HPMS is continually monitored and assessed for needed modifications and upgrades. Improvement to the data collection methods has begun and additional modifications are made over time.
- There is an existing field monitoring process in place in which FHWA staff conduct a review of the traffic data to insure that procedures are followed. Flaws in the process may be detected and corrections made to the collection procedures for future years.

HPMS sample sections are the primary source of the VMT data and are identified through a systematic stratified, random sampling process, resulting in known precision levels of the resultant estimates. The HPMS Field Manual (FHWA, 1987), specifies that estimates of highway travel are to be derived using count-based traffic data. Data collection and AADT derivation procedures are to follow federal highway administration's Traffic Monitoring Guide. The HPMS panels of sections have been statistically designed for a high level of measurable VMT accuracy --- AADT was the critical design data element.

According to FHWA guidelines, traffic must be counted on one-third of the sample sections and one-sixth of the non-sample Interstate universe sections each year, [Hanks, J.W. and Timothy J. Lomax, 1990]. Correction factors for axles, day of the week and season of the year are applied to short duration counts to obtain AADTs. Growth factors are applied to those sample and Interstate sections that are not counted in the current year to update these AADTs to the current year.

3.6.2. TRANPLAN Travel-Demand Modeling Software

Another procedure used in estimating the VMT and VHT was the use of the microcomputer version of the TRANPLAN transportation forecasting model [TRANPLAN User's Guide, 1989]. The TRANPLAN model permits the user to forecast traffic conditions for a specified roadway and land use network based on user-specified relationships between traffic demand and capacity constraints of a roadway system. Once a roadway network is developed it can incorporate several thousand individual roadway links, including expressways, major arterial and local streets.

TRANPLAN can be used to estimate average weekday traffic volumes that are critical for determining area-wide air quality emission of various different TCMs, peak hour volumes, and average hourly traffic volumes for the 8-hour period for estimating C0 levels. In general, estimates of link level traffic volumes are more accurate than the link level traffic speeds produced by urban transportation models which uses the shortest path method for traffic volume distribution.

In this study, the TRANPLAN travel-demand network-based transportation model was used to derive the VMT and the VHT for all roadways classified as urban collector and above. The VMT for all roadways classified as rural was obtained from the LaDOTD HPMS. Furthermore, and since local roads are not modeled in TRANPLAN, HPMS was also used for local urban roads VMT. The VMT derived using TRANPLAN was adjusted to closely resemble HPMS data by the use of computed adjustment factors. To obtain the required adjustment factors, the HPMS VMT was divided by the calibrated TRANPLAN VMT by functional classification. Figure 3-1 shows the road network for the research target area.

The employee survey (ES) was used to gather specific data requirements necessary to compute the cost-effectiveness of a given TCM for the target area. Additionally the data was used to compare the accuracy of both the HPMS and the TRANPLAN data. Tables 3-3 through 3-13 show the Daily Vehicle Miles of travel (DVMT) for the research area by functional classifications, while tables 3-14 and 3-15 show the summary of DVMT for the years 1990 through 1997. Table 3-16 & 3-17 show the data from the ES. Appendix D contains all computations leading to results and conclusions using the data listed in tables 3-3 through 3-18.

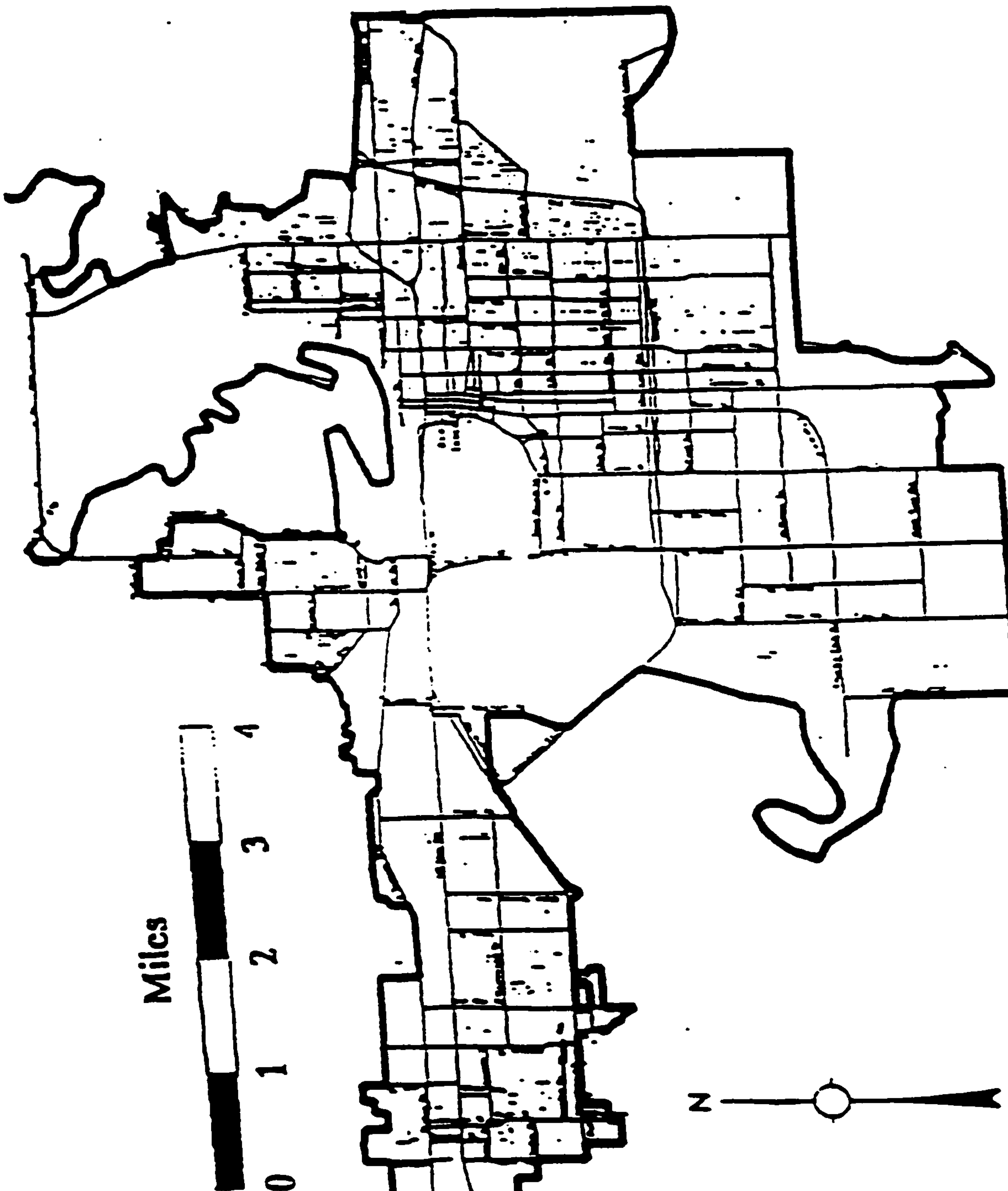


Figure 3-1: Research Target Area Road Network

Table 3-3: DVMT for Principal Arterial (FC-01)

Year	DVMT from HPMS
1990	787,448
1991	804,337
1992	821,225
1993	838,114
1994	855,002
1995	871,891
1996	888,779
1997	905,668
1998	922,557

Table 3-4: DVMT for Rural Principal Arterial (FC-02)

Year	DVMT
1990	46,812
1991	
1992	
1993	50,053
1994	
1995	50,073
1996	53,294
1997	54,375
1998	55,455

Table 3-5: DVMT for Rural Minor Arterial (FC-06)

Year	DVMT
1990	121,080
1991	122,252
1992	123,425
1993	124,597
1994	125,769
1995	126,942
1996	128,114
1997	129,287
1998	130,459

Table 3-6: DVMT for Rural Major Collector (FC-07)

Year	DVMT
1990	379,513
1991	391,433
1992	403,353
1993	415,273
1994	427,193
1995	439,112
1996	451,032
1997	462,952
1998	474,872

3.7 Baseline Travel Characteristics

As indicated earlier in this report, the employee survey provided a great deal of information used to estimate a number of the baseline travel characteristics variables shown in Table 3-17. Table 3-18 contains the TCMs user supplied input data and the assumptions used along with the Baseline travel data in the transportation module. The procedures used in the data analysis as well as some of the assumptions used in a number of calculations for the figures in Table 3-2 are shown in Appendix D. The baseline travel characteristics will later be used to determine probable TCM transportation impacts.

Table 3-7: DVMT For Rural Minor Collector (FC-08)

Year	DVMT
1990	95,388
1991	97,459
1992	99,530
1993	101,601
1994	103,672
1995	105,743
1996	107,814
1997	109,885
1998	111,956

Table 3-8: DVMT for Rural Local (FC-09)

Year	DVMT
1990	161,300
1991	
1992	
1993	
1994	
1995	181,624
1996	179,749
1997	183,684
1998	187,706

Table 3-9: DVMT for Urban Principal Arterial (FC-11)

Year	DVMT
1990	921,815
1991	938,907
1992	955,999
1993	973,091
1994	990,182
1995	1,007,274
1996	1,024,366
1997	1,041,458
1998	1,058,550

Table 3-10: DVMT for Urban Principal Arterial (FC-14) State and Local

Year	DVMT
1990	407,990
1991	397,145
1992	399,437
1993	401,729
1994	404,021
1995	459,397
1996	423,707
1997	426,426
1998	429,157

Table 3-11: DVMT For Urban Minor Arterial (FC-16)

Year	DVMT
1990	522,486
1991	323,156
1992	331,452
1993	339,748
1994	348,004
1995	588,318
1996	590,703
1997	602,879
1998	615,122

Table 3-12: DVMT for Urban Collector (FC-17)

Year	DVMT
1990	348,452
1991	
1992	
1993	2,370
1994	
1995	392,357
1996	379,546
1997	388,997
1998	396,202

Table 3-13: DVMT for Urban Local (FC-19)

Year	DVMT
1990	17,011
1991	
1992	
1993	
1994	
1995	19,154
1996	17,145
1997	17,172
1998	17,199

Table 3-14: DVMT Transplan Data Adjusted for HPMS for Calcasieu (June, July and August Values)

Year	11 Urban Inter state Vehicle Miles	14 Urban Other Princ. Art. Vehicles Miles	16 Urban Minor Art. Vehicle Miles	17 Urban Collector St. Vehicle Miles	19 Urban Local (HPMS) Vehicle Miles
1990	921,815	407,990	522,486	348,452	17,011
1991	938,907	397,145	323,156		
1992	955,999	399,437	331,452		
1993	973,091	401,729	339,748	2,370	
1994	990,182	404,021	348,004		
1995	1,007,274	459,397	588,318	392,357	19,154
1996	1,024,366	423,707	590,703	379,546	17,145
1997	1,041,458	426,426	602,879	388,997	17,172
1998	1,058,550	429,157	615,122	396,202	17,199

Table 3-15: Rural Area HPMS DVMT for Calcasieu Parish (June, July and August Value)

Year	01 Rural Inter state Vehicle Miles	02 Rural Princ. Art. Vehicle Miles	06 Rural Minor Art. Vehicle Miles	07 Rural Major Collect. Vehicle Miles	08 Rural Minor Collector Vehicle Miles	09 Rural Local Rds Vehicle Miles
1990	787,448	46,812	121,080	379,513	95,388	161,300
1991	804,337		122,252	391,433	97,459	
1992	821,225		123,425	403,353	99,530	
1993	838,114	50,053	124,597	415,273	101,601	
1994	855,002		125,769	427,193	103,672	
1995	871,891	50,073	126,942	439,112	105,743	181,624
1996	888,779	53,294	128,114	451,032	107,814	179,749
1997	905,668	54,375	129,287	462,952	109,885	183,684
1998	922,557	55,455	130,459	474,872	111,956	187,706

Table 3-16: Commute Trips or Home-Based-Work Trips from ES

Vehicle Number	VMT per day
1.	5120.3
2.	3214.1
3.	886.4
Daily VMT for 425 households = 9221 VMT	

Table 3-17: Baseline Travel Characteristics from Employees

Total person trips	1,434,230
Total commute person trips	239,376
Total commute vehicle trips	221,568
Total non-commute vehicle trips	1,108,792
Total peak period VMT	1,116,186
Total off-peak period VMT	1,901,334
Drive-alone share of commute person-trips	94.7%
Percent of all trips in peak period	49.6%
Percent of all trips that are commute trips	16.7%
Percent of all trips that are non-commute trips	83.3%
Percent of commute trips in peak period	97.8%
Percent of non-commute trips in peak period	33.3%
Percent of peak trips that are commute trips	32.9%

Table 3-17: contd.

Percent of off-peak trips that are commute trips	0.7%
Average commute trip length	9.4
Average con-commute trip length	8.0
Average daily commute out-of-pocket cost per vehicle	$5.00
Average number of telecommuters per day	-
Percent of all trips that are transit	0.1%
Percent of commute trips that are transit	0.3%
Commute trip share of transit	0.3%
Total transit vehicle miles	1121
Percent of commute trips less than 6 miles	29.4%
Percent of non-commute trips less than 5 miles	60.0%
Average cost per gallon	$1.21
Average cost per mile to drive	$0.240
Average commute out-of-pocket cost per vehicle per trip	$3.00
Average non-commute out-of-pocket cost per vehicle per trip	$1.00
Percent of trips that use the freeway	13.7%

Table 3-17: contd.

Average trip length for freeway users	28.3
Percent of trip on freeway for freeway users	13.7%
Percent of VMT on freeway	52.9%
Average trip length for trucks	9.4

Table 3-18: User Supplied TCM Specific Input Parameters and Assumptions for the Transportation Module

Traffic Flow Improvements	
Traffic Signal Improvements	(2.490)
Reduction in peak trips	(299)
Reduction in off peak trips	5.0%
Percent increase in peak trips	0.4%
Percent increase in off-speak speeds	
Capacity increases	
Reduction in peak trips	(2.490)
Reduction in off-peak speeds	(299)
Percent increase in peak speeds	5.0%
Percent increase in off-peak speeds	0.4%
Improved Public Transit	
Increase in vehicle miles	281
Average percent fare decrease	

Table 3-18: contd.

Percent of transit rider ship increase that equals the trip reduction	30.0%
Employer-Based Transportation Management	
Employee Transit Pass Subsidy	8.0
Percent of cost of a monthly transit pass subsidized	8.5%
Percent of employees affected	52.1%
Percent of transit rider ship increase that equals the trip reduction	30.0%
Employer-Based Ride Sharing	80.0%
Percent increase in non-drive-alone modes	10.0%
Percent of maximum VMT realized due to circuit of ridesharing or access to transit	80.0%
Percent of new car pool riders that still make a trip (such as to a park-and-ride lot), not including car pool driver	5.2%
Average car pool size	2.9%
Percent of employees affected	16.7%
High Occupancy Vehicle Lanes	
Miles of freeway affected	40.0
Avg. # of HOV lanes added per freeway	1.0

Table 3-18: contd.

Number of hours in peak periods	6.0
Number of existing lanes on freeway	2.0
Induced number of vehicle trips on mixed-flow lanes due to additional capacity	200.0
Percent of freeways affected	2.0
Assumptions	
Elasticity of speed with respect to volume Peak Off-Peak	 -0.750 -0.375
Elasticity of transit use with respect to cost to commuters	-0.220
Elasticity of transit use with respect to cost	-0.510
Elasticity of transit use with respect to service	-0.220
Average mode shift from drive alone per mile of HOV lane per hour	-0.510
Elasticity of parking demand with respect to cost for commute trips	-0.200
Elasticity of auto use with respect to cost of gasoline	-0.050
Elasticity of auto use with respect to auto operating costs	-0.200
Elasticity of parking demand with respect to cost for non-commute trips	-0.400

3.8 VMT Forecasting

Forecasts of VMT for the CO non attainment areas are required for each year up to attainment, beginning in 1993 through year 2000 depending on the degree of an area's non attainment status. Based on literature review, the most efficient way to estimate future VMT is to use the area's modeling capability for those areas that have an on-going analytical process (i.e., calibrated network-based travel model such as TRANPLAN). Model-based VMT from a base year and a forecast year are used to calculate an annual growth factor which is then applied to the 1990 HPMS-based VMT. This approach was used in order to avoid the incompatibility between the HPMS area and the transportation study area data.

In this study, the urban local roads VMT was added to the TRANPLAN VMT without any adjustment in determining the total urban VMT. Using 1990 as the base year, and the VMT data for subsequent years including VMT for 1997, a mathematical regression model was used to forecast future VMT up to the year 2021.

3.9 Tracking VMT

What is forecast may not actually happen, so non- attainment areas must verify that they are "on track" toward attainment by checking in annually with current "on the ground" estimates of VMT. If the forecast VMT is below the "actual" VMT, this is an early warning that the area will not reach an attainment. According to the EPA Guideline, if the actual VMT is more than two percent higher than the forecast VMT, contingency measures in the SIP revisions must automatically be implemented. In this study, the forecast figure are compared with the actual VMT in order to determine the foreseeable future for the region to move from nonattainment to that of attainment status.

3.10 Statistical Analysis

After the historical data from the HPMS have been acquired and used to project future VMT that are used to determine the projected on-road emissions for the target area, the data need to be checked by comparison with the "actual" VMT for the region. The validity of the mathematical model is established only if the calculated forecast VMT are within some prescribed interval bands around the mean historical data line. The details of statistical analysis is lengthy and not presented here, but the specific steps in calibrating the forecast model are outlined here. Specifically, the following procedures are performed on the historical data:

I. A regression analysis is performed by formulating a mathematical model for both VMT and time. The form of the relationship between VMT, V and time,Y can be deduced from the scatter diagram obtained from plotting the historical data using linear regression techniques.

II. A $\pm 2\sigma$ line is constructed around the regression line to be used for comparison with the analytical prediction.

III. If the forecasted VMT stay within the specified parallel $\pm 2\sigma$ lines, the model is considered valid, otherwise the model does not give sufficiently accurate predictions and the discrepancies have to be explained or the model must be modified.

IV. A test of goodness of fit of the regression of dependent variable on independent variable can also be performed by the use of t-statistic for a null and alternate hypotheses regarding the regression slope.

V. An evaluation of the logic relationship of the dependent and the independent variables are performed to determine whether or not the model is a good predictor, otherwise the presence of poor scatter, clumping, and gaps implies that the model is not a good predictor.

3.11 Regression Model

Regression is a highly useful statistical technique for developing a quantitative relationship between a dependent variable and one or more independent variables [Bethea, Robert M. Et al, 1985]. It utilizes experimental data on the pertinent variable(s) to develop a numerical relationship showing the influence of the independent variables on a dependent variable of the system. The major purpose of regression in this study is to predict or estimate the future VMT from the historical or known VMT for the target area. Thus an assumption of a relationship between VMT, versus time in years is required. Experimental observations when plotted (scatter diagram of V versus Y) may indicate a linear relationship can be assumed between V and Y. Recognizing that nothing can be predicted exactly, the relationship between V and Y are described by means of the following probabilistic, or statistical model:

$$V = \beta_0 + \beta_1 Y + \varepsilon \qquad (3\text{-}6)$$

where ϵ represents the error in the predictions and accounts for variables that affect V but are not included as predictors. It accounts for chance, or random variability as well as imprecision in the underlying relationship which is assumed to be approximately linear.

Since the exact values of β_0, β_1 and ϵ can never be known, the primary goal is to use a device to estimate these parameters. The experimental data are used to obtain numerical estimates, a and b_1, of β_0 and β_1 in order to obtain the regression, or prediction equation:

$$\hat{V} = a + b_1 Y \tag{3-7}$$

Then, since the estimated VMT, $\hat{V}$, can be expected to differ somewhat from the actual VMT in any individual instance, the secondary concern is to estimate the uncertainty in the prediction. If this uncertainty is too large, this might be an indication that the relationship is incorrect and that a different relationship may exist between the variables. On the other hand, if the magnitude of the uncertainty is sufficiently small, the assumed relationship is assumed to be valid.

3.12 Method of Least Squares

The purpose here is to find the line

$$\hat{V} = a + b_1 Y \tag{3-7}$$

in which the values of a and b_1 make the average deviation from the data points to the mean data line a minimum. The following equations can be solved simultaneously in order to estimate the values of a and b_1 [Walpole, R.E. and H. R. Myers, 1978]:

$$\sum_{i=1}^{n} V_i = na + b_1 \sum_{i=1}^{n} Y_i \tag{3-8}$$

$$\sum_{i=1}^{n} V_i Y_i = a \sum_{i=1}^{n} Y_i + b_1 \sum_{i=1}^{n} Y_i^2 \tag{3-9}$$

Where n is the number of data points and the other terms are self explanatory. The equation of the line found in the above manner is limited to the range of the experimental data and one must be extremely cautious in using the sample to predict the VMT outside to this range.

3.13 Error Measurement

Now that it is known how to predict the average VMT corresponding to a given value of time in years, Y, (within the range of V-Values in the experimental data), the question of how much variability about this mean is considered. What is needed is the measure of the scatter, or error. Specifically it is required to determine how much the actual V data values differ from the mean V computed values because of random variations and the inaccuracy of the form of the model. This can be done by obtaining the standard error of estimate. Since there is only a sample of experimental data, the mathematical definition of the sample variance is employed.

3.14 Standard Error of Estimates

If V is used to denote the estimated value of V for a given value of initial time period of Y, as obtained from the regression curve of V versus Y then a measure of the scatter about the regression curve is

$$S_{v \cdot y} = \sqrt{\frac{\sum \left(V_i - \hat{V}_i \right)^2}{n-2}} \tag{3-10}$$

This is called the standard error of estimate of V on Y, where V_i is the observed value, $\hat{V}_i$ is the estimated value from the regression equation and the quantity n-2 is the number of degrees of freedom.

The reason that standard error is used is because σ^2 is generally unknown and must be estimated. A natural way to estimate σ is to use the deviation in V about the fitted line. Also the deviation squared and error sum of squares are presented in equation (3-11) and (3-12) respectively.

$$\sum \left(V - \hat{V} \right)^2 = \sum d^2 \tag{3-11}$$

and

$$SS_E = \sum_{i=1}^{n} \left(V_i - \overline{V} \right)^2 - b_1^2 \sum_{i=1}^{n} \left(Y_i - \overline{Y} \right)^2 \tag{3-12}$$

where b_1 is the estimator of the regression slope, β_1. It is seen that out of all possible regression curves, the least squares curve has the smallest standard error of estimate. In the case of regression line $V=a+b_1Y$, with a and b_1 obtained from solving equations (3-8) and (3-9) we have

$$S_{v\cdot y}^2 = \frac{\sum V^2 - a\sum V - b_1\sum YV}{n-2} \tag{3-13}$$

or

$$S_{v\cdot y}^2 = \frac{\sum \left(V-\bar{V}\right)^2 - b_1\sum \left(Y-\bar{Y}\right)\left(V-\bar{V}\right)}{n-2} \tag{3-14}$$

The standard error of estimate has properties analogous to those of standard deviation and provides a second measure for a given functional approximation in that it permits us to evaluate the relative certainty that can be attached to derived functions. For example, if a pair of lines parallel to the regression line of V versus Y is constructed at respective vertical distances $S_{v,y}$, $2S_{v,y}$, and $3S_{v,y}$ from it, we should find that there would be included between these pairs of lines about 68.3%, 95%, and 99.9% of the sample points respectively. In other words the following statements can be made:

V $\pm$ 1σ = 68.3% certainty;

V$\pm$ 2σ = 95.0% certainty;

V$\pm$ 3σ = 99.9% certainty.

It is evident that the smaller the σ is, the more certain we can be of the derived approximation. It is also noted that the above statements are correct if the number of data points are large. If the number of data points are less than 30, lower certainty are predicted (the scatter bands are narrower).

3.15 Test of Hypothesis for Goodness of Fit

To ensure that a calibrated model performs what is intended to predict, a test of the goodness of fit is conducted for the null and alternate hypotheses stated as follows:

(1). $H_0 : \beta_1 = 0$

(2). $H_a : \beta_1 \neq 0$

where β_1 is the slope of the regression line. To make inferences regarding the parameter β_1, it is necessary to know the distributions of its estimate b_1. The estimator b_1 can be written as a linear combination of $V_1, V_2, \ldots, V_n$. That is

$$b_1 = \sum_{i=1}^{n} \left(\frac{Y_1 - \bar{Y}}{\sum_j \left(Y_j - \bar{Y}\right)^2} \right) V_i \qquad (3\text{-}15)$$

From this it can be shown that β_1 has a normal distribution with mean β_1 and variance $\sigma_{b1}^2 = \sigma^2 \Big/ \sum_{i=1}^{n} \left(Y_i - Y\right)^2$, keeping in mind that the y's are not random variables.

From this it follows that the random variable.

$$T=\left(\hat{\beta}_1-\beta_1\right)/\hat{\sigma}_{\beta_1}=\left(b_1-\beta_1\right)\Big/ s_{b_1}=\left(b_1-\beta_1\right)\Bigg/\left[\left(\frac{SS_E}{n-2}\right)\Big/\sum_{i=1}^{n}\left(Y_i-\overline{Y}\right)^2\right]^{\frac{1}{2}} \quad (3\text{-}16)$$

has a t-distribution with n-2 degrees of freedom, which can be used to make inferences relative to β_1, where $\beta_1 = b_1$ slope of the "fitted" regression line.

Note that in Equation (3-16), the estimator for σ^2 is $\hat{\sigma}^2$. Thus

$$\hat{\sigma}^2 = s^2 = MS_E = \frac{SS_E}{n-2} \quad (3\text{-}17)$$

$$S_{b_1}^2 = \frac{S^2}{\sum_{i=1}^{n}\left(Y_i-\overline{Y}\right)^2} \quad (3\text{-}18)$$

$$S_{b_1} = \frac{S}{\left[\sum_{i=1}^{n}\left(Y_i-\overline{Y}\right)^2\right]^{\frac{1}{2}}} \quad (3\text{-}19)$$

I. A regression line is constructed using equations (3-8) and (3-9).

II. The standard error of estimation is calculated to estimate σ using either equation (3-10) or equation (3-17).

III. $V \pm 2\sigma$ is computed for given points and plotted.

IV. A t-value is calculated and compared with t-value from a t-table in order to perform a test of hypothesis relating to the goodness of fit of the calibrated model.

3.16 An Example

The following example is used to apply the standard error of estimate to construct two lines parallel to the regression line having a vertical distance $\pm 2\sigma$. Table 3-19 presents the experimental data by Bethea et al [1985]. These data are the results of a pilot plant studies on a reaction process A→B carried out at an atmospheric pressure during which the temperature varied from 1°C to 10°C. In order to optimize this process, the relation between conversion of A and temperature must be obtained.

Table 3-19: Experimental Data Used in Example 1

Temperature, X (°C)	1	2	3	4	5	6	7	8	9	10
Yield, Y	3	5	7	10	11	14	15	17	20	21

The details of the procedure are as follows: First the scatter diagram of the experimental data is constructed as in Figure 3-2. By plotting experimental data from Table 3-19, it is seen that a linear relationship can be assumed between the yield and the temperature. Second, the coefficient of this regression line is obtained by solving the normal equations (3-8) and (3-9) using:

$$\sum V_i = 123.0; \quad \frac{\sum Y_i}{n} = \overline{Y} = 5.5$$
$$\sum Y_i = 55.0$$
$$\sum YY_i = 844.0$$
$$\sum Y_i^2 = 385.0$$
$$\sum \left(Y_i - \overline{Y}\right) = 82.5$$

Then,

$$123.0 = 10a = b_1(55.0)$$
$$844 = a(55.0) + b_1(385.0)$$

which gives a = 1.1333 and b_1=2.0303. Thus the equation of the regression line is:

$$\hat{V}_i = 1.1333 + 2.0303 Y_i \qquad (3\text{-}20)$$

This equation gives an estimated value of V corresponding to specified values of temperature. Then an estimate of σ is obtained from the standard error of estimate by using equation (3-10). Figure 3-2 presents the scatter diagram and regression line from data from table 3-19.

$$S_{v \cdot y} = 0.5031$$

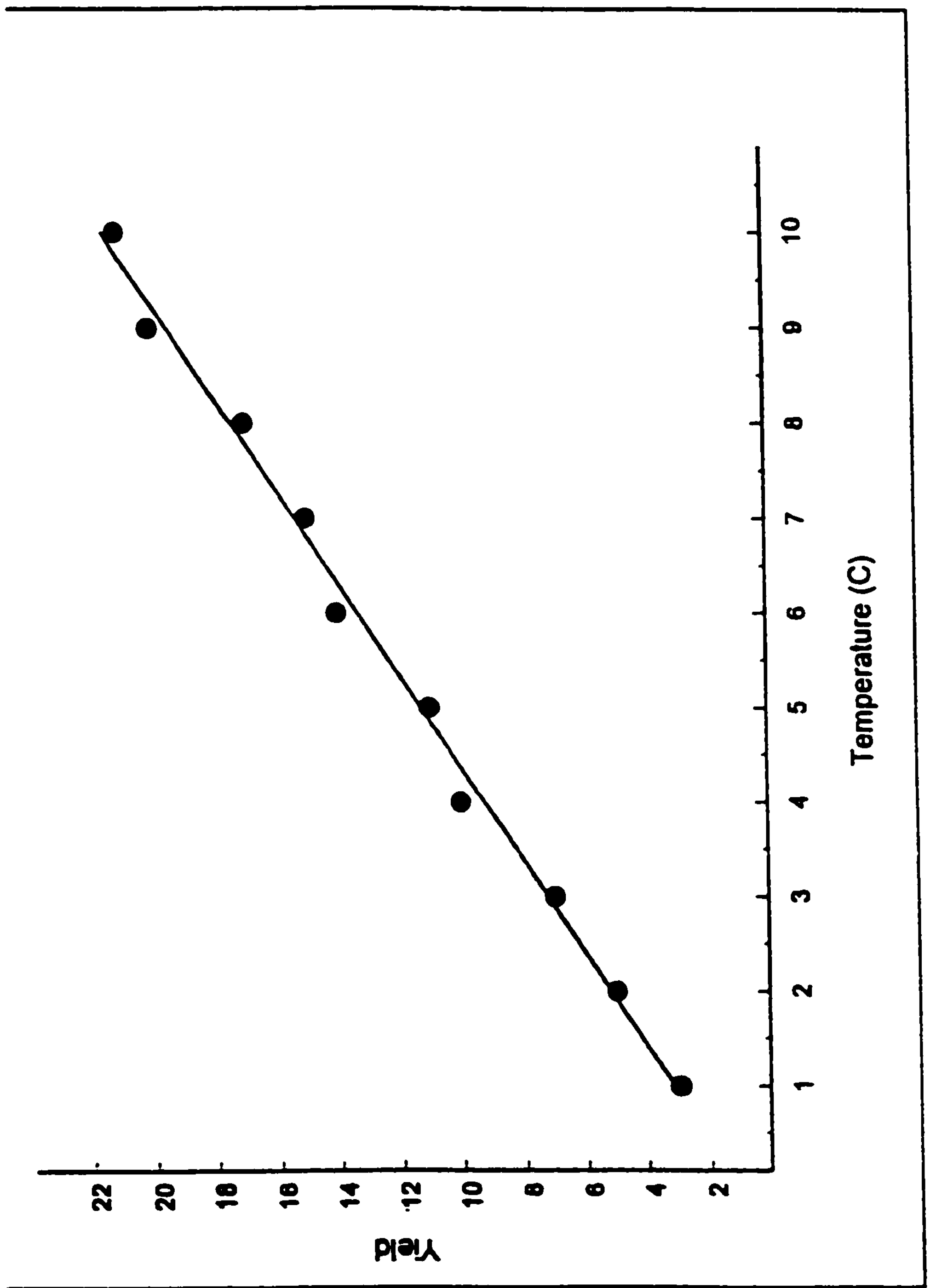


Figure 3-2: Scatter Diagram and Regression Line Data from Table 3-19.

Finally V ± 2σ are calculated for given data points. The results are tabulated in Table 3-20 and plotted in Figure 3-3. Since the number of data points are less than 30, the ±2σ lines constructed in this manner do not correspond to 95% confidence interval. However to find the confidence level corresponding to ± 2σ lines the following equation is used:

$$(t_{n-2})\,S_{v\cdot y}\left(\sqrt{\frac{\sum_{i=1}^{n} Y_i^2}{n\sum_{i=1}^{n}\left(Y_i-\overline{Y}\right)^2}}\right)=2S_{v\cdot y} \qquad (3\text{-}21)$$

Where t_{n-2} is t-distribution parameter with n-2 degrees of freedom. Substituting all the relevant parameters in equation 3-21 results in

$$(t_{n-2})(S_{v\cdot y})\left(\sqrt{\frac{385.0}{(10)(82.5)}}\right)=t_{n-2}\,(0.68313)\,S_{v\cdot y}=2\,S_{v\cdot y}$$

or

$$t_{n-2}\,(0.68313)\,S_{v\cdot y}=2\,S_{v\cdot y}\ or\ t_{n-2}=2.9277$$

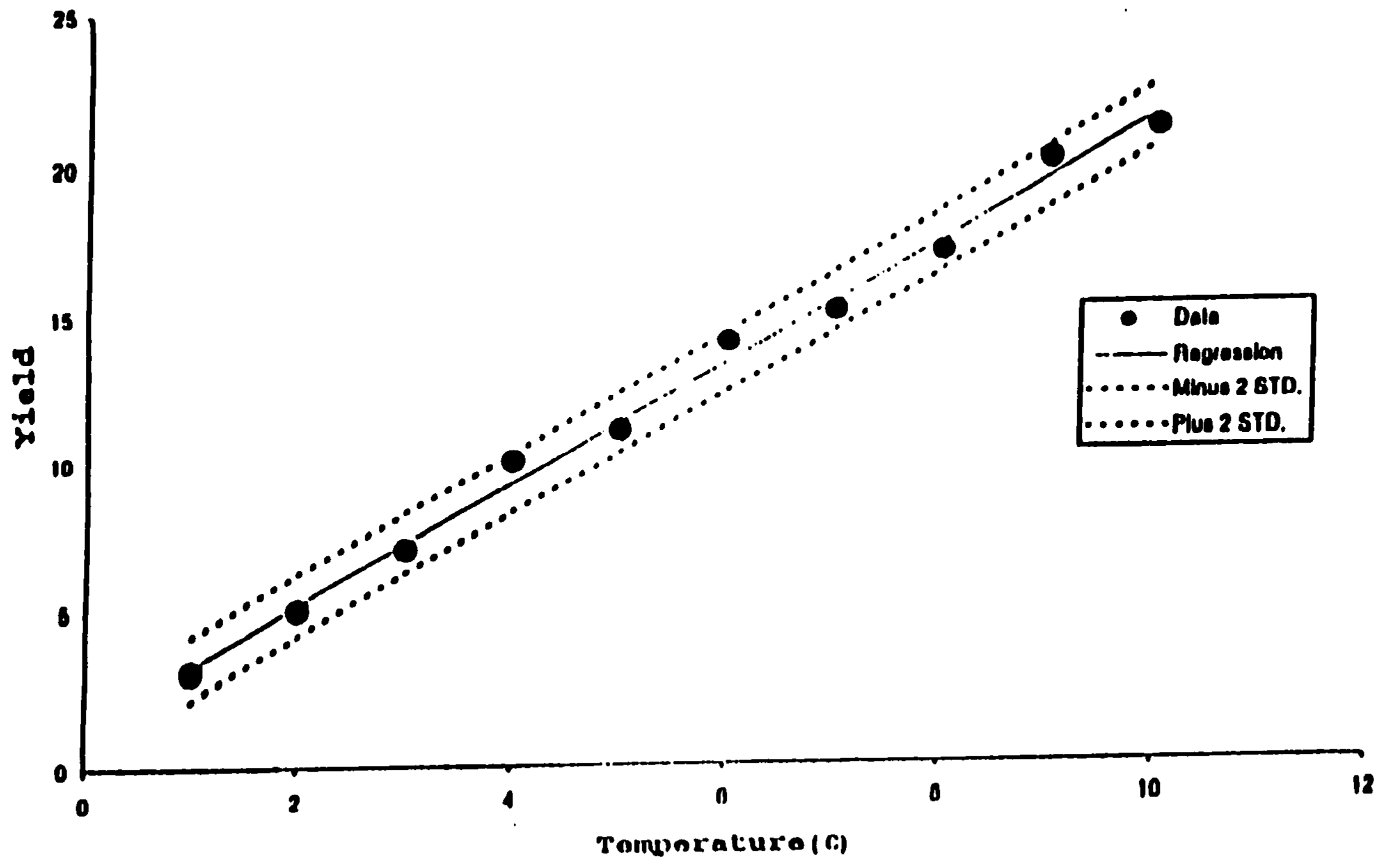


Figure 3-3: 2 – Sigma Error Bands and Regression Line, from Table 3-20 Data

Table 3-20: Estimated V Corresponding to Given Temp.

Temperature (°C)	Yield	Estimated Yield	V-2σ	V+2σ
1	3	3.16	2.15	4.17
2	5	5.19	4.18	6.20
3	7	7.22	6.21	8.23
4	10	9.25	8.24	10.26
5	11	11.28	10.27	12.29
6	14	13.32	12.31	14.33
7	15	15.35	14.34	16.36
8	17	17.38	16.37	18.39
9	20	19.41	18.40	20.42
10	21	21.44	20.43	22.45

From the table of t-distribution for n-2 equal to 8 it is found that:

$$t_8(0.025) = 2.9277$$

Thus the confidence limit is 1-.025=.975 or 97.5%. Now, after constructing the ±2σ lines, the calculated yields are plotted and compared with the experimental data. If the calculated yields are within the confidence bands, then the results of the model are considered to be satisfactory. The standard deviation of the slope of the regression line from equation (3-19) is

$$S_{b_1} = 0.05539$$

To test the regression of V on Y, that is, H_0: β_1=0, the t-statistic in equation (3-16) with β_1=0 is used. The computed t-value is

$$t = \frac{b_1}{S_{b_1}} = 36.655$$

From t-distribution table for n-2 equal to 8 degrees of freedom at0.025 significance level, t=2.9277. Since the calculated t-value falls above the tabular value $t_{8,0.975}$ = 2.9277, the hypothesis that B_1=0 is rejected and the alternate hypothesis is accepted.

The foregoing procedures have been performed on all of the experimental data. A microcomputer program, axum, with its powerful sub-programs was used to perform the required calculations for the regression analysis performed in this study. Details of the program description are found in the user's manual, [Mathsoft, Inc., 1996]. Sample output of this example 1 output are included in Appendix D.

3.17 Air Quality Modeling

Based on literature review, it is apparent that in air quality modeling, the current understanding of the physical phenomena is far from complete. The relationships between traffic volumes and driving behaviors, vehicle emissions, and corresponding meteorology are complex and somewhat unpredictable. Each variable in air quality modeling has its own set of uncertainties, many of which are unquantifiable, and so in air quality modeling, an attempt is made to combine these variables in a way that produces reasonable results that decision makers can trust. In general, all models have limitations. Describing real world phenomena in mathematical terms invariably requires some simplification of the process or certain assumptions are made. To properly build and use a model, it is necessary to first understand the physical phenomena being modeled, and secondly to apply reasonable mathematical equations, and finally to acknowledge the limitations of the model and use it only when appropriate. Furthermore, any model, particularly air quality model for nonattainment areas, should be validated before an official endorsement is given. The above issues were considered in this study.

With the above backdrop of information, it was decided that to embark on a development of a new air quality model for the research target area would be time consuming and uneconomical. Therefore to quantify the various on-road mobile pollutants in the research target area, it was necessary to examine the various air quality modeling techniques cited in the literature review section with a view to selecting the most appropriate technique(s) for the region. This section presents some of the considerations used in selecting a modeling technique for the research target area. Note that since most of the modeling techniques have been presented in the literature review section, it is not necessary to list them here. The rationale used in choosing a modeling technique(s) was based on the following factors:

- The Model has been validated and approved for use by the EPA;
- The Model's limitations have been evaluated;
- The model's ease of use and ability to be applied in the target area.

For the research target area, it was necessary to evaluate the air quality modeling techniques both on micro scale and macroscale levels and to evaluate their limitations before adoption. Examples of few of the air quality models considered for adoption are hereby presented.

3.18 CAL3QHC Modeling Technique

In evaluating CAL3QHC computer model used to model the dispersion of carbon monoxide (CO) concentrations on a micro scale level (i.e. at an intersection rather than an entire region), it was noted that the model has serious limitations and so could not be adopted for use in this study. The model assumes a Gaussian distribution for CO dispersion and the validity of this assumption is at best questionable. The Gaussian equation was originally used for stationary point source emissions in a uniform wind field traveling along the x-axis. It describes the dispersion of a emission plume as a Gaussian or normal distribution in both the horizontal and vertical direction and the model is as given below:

$$C_c = \frac{ES_s}{2\pi\, v_s\, \sigma_y \sigma_z} \exp - 1/2\left[\left(\frac{y}{\sigma_y}\right)^2 + \left(\frac{z}{\sigma_z}\right)^2\right] \qquad (3\text{-}22)$$

where

C_c	=	CO concentration at coordinates (x,y);
Es_s	=	emissions source strength;
V_s	=	wind speed;
y	=	horizontal dispersion;
z	=	vertical dispersion;
σ_Y	=	horizontal dispersion standard deviation;
σ_Z	=	vertical dispersion standard deviation;

Figure 3-4 shows the horizontal and vertical Gaussian distributions for a point source.

One limitation of the above model is the fact that the model does not process cases where the wind speed is zero, and it is assumed to behave poorly for wind speeds less than 1 m/s (as V_s is in the denominator). These calm hours are precisely the times when high concentrations of CO are thought to occur and since CAL3QHC is not able to model those hours with the Gaussian equation, it is reasonable to question its use. Furthermore, the fact that CAL3QHC uses peak traffic volumes and worst case meteorological values, its estimates of CO concentrations are considered very conservative. However, based on observed CO concentrations, actual worst case conditions should include calm winds (less than 1 m/s) if not because of Gaussian equation limitation. In addition to wind speed limitations, the parameters σ_y and σ_z, it is necessary to first determine the stability class which is defined by the amount of cloud cover and solar radiation during a one hour time period and is assigned a letter A through F, with F being the most stable [Wark and Warner, 1981]. As a result, σ_y and σ_z are then a function of stability class and distance from the emission source. The fact that these parameters are not directly measurable, they can add an unknown amount of uncertainty to the model. Although CAL3QHC is an EPA approved air quality modeling tool at microscale level, it was not used in this investigation due to its over conservative estimations of CO concentrations.

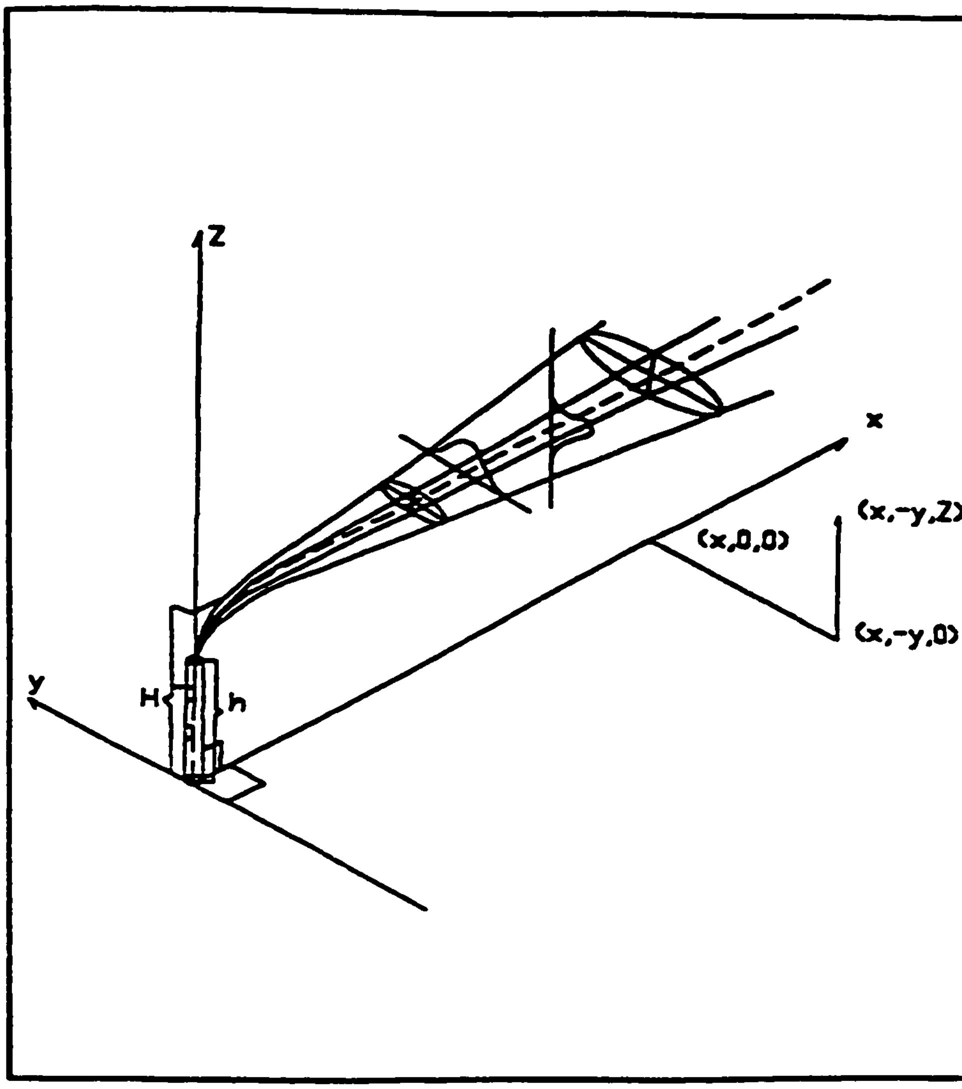


Figure 3-4: Horizontal and Vertical Gaussian (Turner, 1970) Distribution for a Point Source

3.19 Pivot Point Modeling Technique

Similar analyses were performed in evaluating and eliminating other currently used air quality modeling tools. For instance PIVOT POINT Model which is the only computer modeling method used to evaluate travel impacts of transportation system was also not used due to its several limitations. PIVOT POINT Model estimates the shift of trips between drive alone and shared ride models. It estimates trip shift or mode use by using a multinomial logit model:

$$P(\mathrm{mod}\, e_i) = f\frac{\left(U_{\mathrm{mod}\, e_i}\right)}{\sum_{i=1}^{\infty} U_{\mathrm{mod}\, e_i}} \tag{3-23}$$

P($mode_i$) =probability of using $mode_i$,

$Mode_i$ =mode of transportation used;

single-occupancy vehicle (S0V),

Transit, carpool, buspool, vanpool, etc.);

$Umode_i$ =utility of using $mode_i$.

PIVOT POINT uses an incremental form of multinomial logit such that results are revised probabilities for choosing a given mode based upon an existing base modal share and changes in utility for each mode [CARB, 1990]. This model is only limited to work trips in its evaluation; non-work trip changes are deduced. Non-work trips are equally important to mobile source pollution evaluation. Furthermore, PIVOT POINT model uses data collected in Washington, D.C., during the late 1960s. The data may not accurately represent modern modal trends of this research target area. Also, Austin et al., noted that the model does not precisely calculate how changes in modal shares would translate to trips, VMT, and speed changes which are variables used in calculating emission changes.

3.20 AQAT/AQAT-3 Modeling Techniques

PIVOT POINT emission estimation model just described is only one of the computer air quality evaluation modules employed by the California Department of Transportation and the California Air Resources Board for evaluating emissions associated with transportation system. The California Department of Transportation and the California Air Resources Board developed the Air Quality Analysis Tools (AQAT) and its current version, AQAT-3 in three other computer modules: URBEMIS#3, EMFAC7PC, and CALINE4. The URBEMIS#3 module allows the computation of mobile source emissions as a function of the number of vehicle trips associated with a given land use and the VMT for each type [Randall, P.C. and A. Diamond, 1990]. The emissions calculated in this module are HC, No_x, PM_{10}, and other inert gaseous pollutants. CALINE4 estimates the concentration levels of these pollutants on and near roadway using a Gaussian diffusion algorithm which has earlier been explained.

The limitations of Gaussian model has already been demonstrated earlier and based on the aforesaid, the AQAT techniques were not adopted for this study. As hinted earlier, the above procedures were used to eliminate a number of other modeling techniques.

3.21 Mobile Modeling Techniques

In the final analysis, the EPA developed MOBILE model evaluation technique was chosen on the basis of the following factors:

- The model is not a region-specific emission factor model;
- The model is an EPA approved regulatory air quality model for use in both SIP_s and TIP_s;
- The model has gone through a number of updates that better represent emissions from in-use vehicles. The EPA has released several versions of MOBILE over the past few years:
  - MOBILE4-released February 1989,
  - MOBILE4.1-released November 1991,
  - MOBILE5.0-released December 1992, and
  - MOBILE5a -released March 1993.

In this study, much of the analysis was based on MOBILE 5a modeling technique. The primary components of this MOBILE5a emission factor techniques include the base emission factors, the effect of local conditions such as temperature and vehicle speed, characterizations of the vehicle fleet, the impact of fuel characteristics, and the effect of inspection and maintenance programs. Apparently none of these factors are static: technology is continually evolving, leading to changing in-use emission performance, while changes in economic conditions can lead to changes in vehicle sales and travel patterns. As indicated earlier, EPA expends considerable effort to quantify and stay current with the influence of all these factors on motor vehicle emission levels. The key factors in the MOBILE5a model are discussed below.

3.21.1 Emission Factors

These are also known as the "base emissions rates" and the factors developed from test measurements of in-use vehicles at various odometer readings. The emission factors are represented by two components: a zero-mile level or intercept and a deterioration rate or slope. The zero-mile level represents the new vehicle emission rate, while the deterioration rate represents emission control system deterioration that takes place as the vehicle ages.

3.21.2 Test Conditions

As a framework for determining compliance with the standard, the environmental protection agency developed The Federal Test Procedure (FTP), which contained a specific driving cycle-pattern of start, accelerations, cruising, decelerations, and idles over a specified terrain. Vehicles could then be tested to determine whether they were within the threshold limit of emissions over this FTP driving cycle, the average speed for which was 19.6 miles per hour [Horowitz, 1982]. Although the test procedures were developed from data intended to represent average urban driving conditions, they do not necessarily match those that vehicles experience in each community. Therefore EPA developed correction factors to account for differences between the test procedures and actual operating conditions.

3.21.3 Fleet Characteristics

The base emission rates represent the average emission level of each model year in the vehicle fleet for each vehicle class from light-duty gasoline vehicle through heavy-duty diesel truck. A fleet average emission rate incorporating the contribution of all model years and vehicle classes is the output from the MOBILE5a model. The age distribution, the rate of mileage accumulation, and the mix of travel experienced by the vehicle classes considered in MOBILE5a can all influence the contribution of each vehicle class to the fleet average emission rate. Although MOBILE5a model utilizes national average data as default values for these parameters, local data as was done in this study, were used as input data in order to tailor the computer model runs for this research target area for a more accurate estimate of emissions.

3.21.4 Fuel Characteristics

Emission test measurements are normally conducted on a standardized test fuel known as Indolene. The characteristics of this fuel are well defined and they ensure that these results are repeatable. However, in-use fuels are generally much different than Indolene, and differences in fuel volatility and other fuel parameters such as oxygenate contain influence both evaporative and exhaust emission rates. In this analysis, MOBILE5a requires the fuel volatility as an input data.

3.21.5 Emission Control Programs

The model-year-specific emission factor equations are based on test data that do not include the effects of local emission control programs such as inspections and maintenance (I/M) and anti-tampering programs. These programs are intended to reduce emissions from in-use vehicles, and differences in program design such as annual versus biannual testing can have a significant impact on their effectiveness. Mobile5a contains provisions for identifying the specific parameters applicable to the program being modeled.

3.22 MOBILE5a User Inputs

In order to execute MOBILE5a computer model, a number of local conditions that describe the travel parameters, ambient conditions, and fuel parameters are required as input to the data file. These input data shown in Table 3-21 are briefly explained as follows:

- Volatility class - Used for modeling the effects of reformulated gasoline
- Temperature -Due to the fact that emissions are impacted by ambient temperature, minimum, maximum and average daily temperatures are required.
- Reid Vapor Pressure (RVP) - The fuel volatility which is measured as RVP in pounds per square inch, also is an important parameter in emissions calculations. The RVP has a significant influence on evaporative emissions (higher fuel volatility translates into higher evaporative emissions), and it also impacts exhaust emission estimates.
- Region - The user must input the region as low or high altitude. Altitude has effect on vehicles particularly older vehicles with mechanically based fuel delivery systems which generally run risk at high altitudes. This is to say that more fuel is introduced into the combustion chamber than can be completely burned by the available oxygen, and as such, hydrocarbon and carbon monoxide emissions are magnified.

- Calendar year - The calendar year of evaluation must be specified by the user. Because of increasingly stringent motor vehicle emission standards, the fleet-average emission rate generally decreases as future years are specified.
- Average speed - Speed also plays an important role in estimating vehicle emissions. Because emissions are reported in grams/mile, lower speeds (i.e., below 20 mph) result in higher emissions (i.e., it takes a longer time to cover the same distance). At high speeds above 55 mph in MOBILE5a, emissions are also predicted to increase.
- Operating mode - The condition (i.e., cold start, hot start, or stabilized) under which the vehicle is operating has a significant impact on vehicle exhaust emissions. For example, exhaust hydrocarbon emissions can be several times higher while the vehicle is warming up compared to those under stabilized operation.

Table 3-21: MOBILE5a Input Data

Required Inputs	
Parameter	Comments
Volatility Class	Used in conjunction with reformulated gasoline effects (M5).
Min and Max Daily Temperatures	Used to estimate TCF temp. Evap temps, diurnal emissions.
Period 1" RVP	RVP before volatility control.
Period 2" RVP	RVP with volatility control.
Period 2" Start Year	Implementation date for volatility control (1989 earliest.
Region	Low/high altitude
Calendar Year	Range: 1960 to 2020
Average Speed	Single speed for all vehicle types or separate speed for each.
Ambient Temperature	Utilized for TCFs, etc., if user specifies.
Operating Mode Percentages	Percent VMT in cold start, hot start, and stabilized modes.

Optional Inputs - In addition to the above required inputs, the MOBILE5a model allows for a number of optional inputs that better describe the locality being modeled; these are shown in Table 3-21a. Among the more important optional inputs are the following:

- Registration distribution - Because the age of the vehicle fleet is an important parameter in determining the fleet-average emission rate, many local-level analyses make use of this option. These data are readily available from LaDOTD.
- Inspection and maintenance (I/M) programs - If an area has an operating I/M program, the effects of this can, and should, be modeled. The impact can be quite significant, particularly for transient, loaded mode programs which can be modeled by MOBILE5a.
- Anti-tampering programs - I/M programs often include a visual check of emission control system components to assure the vehicle owner has not disabled or otherwise tampered with the system. The MOBILE5a model allows for the impact of these programs to be modeled.
- Refueling emissions - Although many air pollution control districts consider refueling emissions (i.e., emissions that occur when a fuel tank is filled) to be stationary source emissions, the MOBILE5a model is capable of modeling this process.
- Oxygenated and reformulated fuels -Fuels containing oxygenates (e.g., ethanol) result in significant reductions in exhaust hydrocarbon and carbon monoxide levels. Additionally, the reformulated gasoline requirements contained in the

Table 3-21a: Optional Inputs/Features

Optional Inputs/Features	
Parameter	Comments
Month of Evaluation	Jan or Jul - choice based on winter or summer evaluation.
Tampering Rates	User may input locally derived tampering rates.
Trip Length Dist (Trip Duration)	Used in estimating running loss emissions.
VMT Mix by Vehicle Type	User may input locally derived VMT mix.
Mileage Accumulation	User may input locally derived mileage accumulation.
Registration Distribution	User may input locally derived registration distribution.
Basic Emission Rates	User may input alternate basic emission rate equations.
Reporting HC Results	HC can be reported as THC, NMHC, VOC, TOG, NMOG
New Evaporative Test Procedures	Differing phase-in for evap procedures can be modeled.
Disable CAAA Requirements	Cold CO, Tier 1 exhaust, and evap benefits can be disabled.
I/M Program	Transient (IM240) test included in MOBILE5 and MOBILE4.1
A/C-Towing-Humidity Corrections	These corrections can be included, but accuracy uncertain.
Anti-Tampering Program	Effects of an anti-tampering program can be included.
Functional Pressure/Purge	Effects of a functional evap system check can be included.
Refueling Emissions	Uncontrolled, with Stage II, with on-board, or zeroed.
Oxygenated Fuels	Ether/alcohol market share and oxygen content required.
Alternate Diesel Sales Fraction	User may input locally derived LDV Diesel registration info.
Reformulated Gasoline	Effects of reformulated gasoline can be included.

1990 CAAA result in decreased hydrocarbon emissions. MOBILE5a has the capability of modeling the effects of oxygenated fuels.

3.23 MOBILE5a Model Output

The MOBILE5a output consists of exhaust hydrocarbon (HC), carbon monoxide (CO), and oxides of nitrogen (No_x) emission rates (in grams/mile [g/mi]) for eight separate vehicle categories:

- LDGV- light-duty gasoline vehicles (i.e., passenger cars),
- LDGT1- light-duty gasoline trucks (under 6000 lbs. Gross vehicle weight),
- LDGT2- light-duty gasoline trucks (6000 to 8500 lbs, gross vehicle weight),
- HDGV - heavy-duty gasoline vehicles (over 8500 lbs, gross vehicle weight),
- LDDV - light-duty Diesel vehicles (i.e, passenger cars),
- LDDT - light-duty Diesel trucks (under 8500 lbs, gross vehicle weight),
- HDDV - heavy-duty Diesel vehicles (over 8500 lbs. gross vehicle weight), and
- MC - motorcycles.

In addition, evaporative HC emissions are reported as g/mi or grams/event (e.g., grams per hot soak).

3.24 Motor Vehicle Emission Modes

In order to understand the air quality modeling process of Mobile5a, it is necessary to specify the various vehicle emission modes. Motor vehicle emissions consist of a large number of chemical species that primarily result from combustion within the engine and from fuel evaporation at various locations throughout the fuel delivery and storage system. Three particular emission components are modeled by the MOBILE5a Model: hydrocarbons (HC), Carbon monoxide (CO), and oxides of nitrogen NO_x. These are the emission components that result in the two major non-attainment pollutants related to mobile sources: ozone and carbon monoxide.

The quantification of on-road mobile source emissions involves the determination of emission rates for two fundamentally different types of emission-producing processes: emittance from the vehicle's exhaust system, and evaporation from the fuel storage and delivery system. Emissions from each of these basic types of emission-producing processes, exhaust and evaporative, can further be broken down as presented below.

3.24.1 Exhaust Emissions

Under the exhaust emission-producing process, there are four vehicle emission modes classified as cold start, hot start, hot stabilized and idle emissions.

- Cold Start - Under cold start conditions, the vehicle engine has been turned off for some time and the catalytic converter (if the vehicle is so equipped) is cold. HC and CO emissions are higher when a cold engine is first started than after the vehicle is warmed up. This is because catalytic emission control systems do not provide full control until they reach operating temperature (i.e., light-off), and a richer fuel-air mixture must be provided to the cylinders under cold operating conditions to achieve satisfactory engine performance (e.g., startability and driveability). (EPA considers a cold start for a catalyst-equipped vehicle to occur after the engine has been turned off for one hour. For non-catalyst vehicles, a four-hour engine-off period distinguishes a cold start.)

- Rich mixtures are necessary to achieve smooth combustion during warm-up because gasoline does not fully vaporize and mix with the air in a cold engine. Extra fuel is added to ensure that an adequate amount of fuel is vaporized to achieve a combustible mixture. Complete vaporization eventually occurs in the engine cylinder as a result of the high temperatures created by combustion. However, the excess fuel that was needed to ensure adequate vaporization to start the combustion process cannot be completely burned due to a lack of sufficient oxygen in the cylinder. The result is that partially burned fuel and unburned fuel are emitted in relatively high concentrations from a cold engine. Elevated emissions of these pollutants in this cold transient phase occur from the time a cold engine starts until it is fully warm. While engine-out NO_x emissions tend to be low during rich operation of a cold engine, the lack of catalyst activity to control this pollutant results in elevated cold start NO_x emissions as well.
- Hot start - Under hot start conditions, the vehicle engine has been turned off for such a short time that the catalyst has not had time to cool to ambient temperature. Thus, the warm-up period is shorter (if present at all) than that required under cold start conditions. For that reason, HC and CO hot start emissions are significantly lower than under cold start operation. Under the standard test procedure used by EPA, a "hot start" is a test that begins exactly 10 minutes, no mixture enrichment is required to achieve a reliable re-start and the catalyst is usually still above its "light-off" temperature.

- Hot Stabilized - After warm-up has occurred, and the engine and emission control systems have reached full operating temperatures, the vehicle is considered to be in the hot stabilized mode. Generally, emissions are relatively low (compared to cold start emission rates) under hot stabilized conditions. However, emissions are also highly dependent on vehicle speed and engine load.
- Idle Emissions - Although not generally considered for inventory purposes, idle emissions may need to be considered for certain transportation-related analyses. The MOBILE models report idle emissions in terms of grams/hour, and emissions are a function of operating mode (i.e., stabilized or cold start) and temperature. Because many of the changes incorporated into the MOBILE5a model (e.g., incorporation of Tier I emission standards, reformulated gasoline, low-emission vehicles) resulted in unreliable estimates of idle emissions, the idle subroutines have been temporarily disabled in MOBILE5a. However, EPA has recently developed a methodology to convert MOBILE5a gram/mile running exhaust emission rates to gram/hour idle rates.

3.24.2 Evaporative Emissions

Evaporative emissions consist entirely of hydrocarbon emissions. These emissions can be categorized into the six groups discussed below.

- Hot Soak - When a hot engine is turned off, fuel exposed to the engine (e.g., in carburetor float bowls or in fuel injectors) may evaporate and escape to the atmosphere. These so-called "hot soak" emissions are modeled by MOBILE5a as grams/event, which are then converted within the model to a g/mi basis.

- Diurnal - Diurnal temperature fluctuations occurring over a 24-hour period cause "breathing" to occur at the gasoline tank vent. To prevent the escape of fuel vapor, the vent is routed to a charcoal canister where the vapor can be absorbed and later purged into the running engine. These emissions are calculated by the MOBILE5a model in terms of grams/event, and, as with hot soak emissions, are then converted to a g/mi basis.
- Running Losses - Running loss emissions are those resulting from vapor generated in gasoline fuel tanks during engine operation. Running losses are especially a problem on vehicles that have exhaust systems in close proximity to the gasoline tank. Running loss emissions occur when the vapors emitted from the tank vent exceed the rate at which they are being purged from the canister by the engine. This HC emission category had long been assumed to be insignificant, but research over the past several years has shown this assumption to be incorrect, and running losses have been included in EPA's emission factors models since the MOBILE4 version (published in 1989). These emissions are calculated by the MOBILE5a model in terms of g/mi.
- Resting Losses - Resting losses have only recently been included in the MOBILE models, with the MOBILE4.1 version (published in 1991) included resting losses for the first time. EPA considers resting losses to be "those emissions resulting from vapors permeating parts of the evaporative emission control system (e.g., rubber vapor routing hoses), migrating out of the carbon canister, or evaporating liquid fuel leaks." EPA also states that a portion of what are now considered resting losses was previously included in the hot soak and diurnal categories.

Resting losses are dependent upon temperatures and the type of carbon canister that is used in the evaporative emission control system (i.e., open-bottom versus closed-bottom). These emissions are calculated as grams/hour and are then converted to g/mi.

- Refueling Losses - There are two components of refueling emissions: vapor space displacement and spillage. As a fuel tank is being refueled, the incoming liquid fuel displaces gasoline vapor that has established a pseudo-equilibrium with the fuel in the tank, effectively "pushing" the vapor out of the tank. Spillage simply refers to a small amount of fuel that is assumed to drip on the ground and subsequently evaporate into the ambient air. Refueling emissions are calculated in terms of grams/gallon of dispensed fuel and are converted to a g/mi basis.
- Crankcase Emissions - Although not a true "evaporative" source, crankcase emissions are generally considered in the evaporative emissions category. They are the result of defective positive crankcase ventilation (PCV) systems that allow blow-by from the combustion process (which is normally routed to the vehicle's intake manifold) to escape to the atmosphere. These emissions are modeled as grams/mile.

3.25 MOBILE5a Modeling Approach for Emission Factor

Emissions from each of the processes outlined in section 3.24 are estimated by MOBILE5a model separately for the eight vehicle classes specified in section 3.23 and table 3-22. The emissions estimate is performed by just determining the emission rate of each model year making up the vehicle class, weighting the model-year-specific emission rate by the fractional usage experienced by that model year (i.e., travel fraction or VMT fraction), and summing over all model years that comprise the vehicle class. Furthermore, a number of corrections are applied to the base emission rates to account for conditions that are not included in the standard test cycles used to develop the base emission rates such as correction for exhaust emission rates due to the use of non-standard speeds and correction for evaporative emissions due to use of non-standard temperatures.

In equational form, the emission factor calculation by MOBILE5a can be described as follows:

$$EF_{i,j,k} = \sum_{n=1}^{N} VF_n * \left(BER_{j,k,n} * Cf_{j,k,n}\right) \tag{3-24}$$

where

$EF_{i,j,k}$ = fleet-average emission factor for calender year i, pollutant j, and process k (i.e., exhaust or evaporative);

VF_n = fractional VMT or travel fraction attributed to model year n (the sum of VF_n over all model year, N, is unity);

$BER_{j,k,n}$ = base emission rate for pollutant j, process k, and model year n;

$Cf_{j,k,n}$ = correction factor(s) (e.g., temperature, speed) for pollutant j, process k, and model year n.

The sum is carried out over the N model years making up the vehicle class (e.g. 25 years for LDGV in MOBILE5a).

3.26 Registration Distribution and Travel Fraction

The registration distribution and its resulting travel fraction have some important impacts on the calender-year-specific, fleet-average emission factors: These are particularly apparent for cases in which the model-year emission factors undergo significant changes from one year to the next such as where new emission standards are implemented. A higher proportion of the travel fraction being allocated to newer vehicles (with presumably lower emission rates) will result in a lower fleet-average emission rate, and thus, lower emission inventory calculations. In this study, the local vehicle registration data were provided by the Louisiana Department of Public Safety through the LaDEQ. The registration data are summarized in vehicle model years and eight vehicle types as shown in Table 3-22. The Calcasieu motor vehicle registration and age distribution shown in Table 3-22 summarizes the contribution that each vehicle model-year has upon the total number of registered vehicles for the period 1967 through 1991.

The methodology used to calculate travel fractions is based on applying an estimated annual mileage accumulation rate by vehicle age (determined from National Purchase

Table 3-22: Calcasieu Motor Vehicle Registration and Age Distribution

Model Year	Light Duty Gas Vehicle. LDGV	Light Duty Gas Truck-1 LDGT1	Light Duty Gas Truck-2 LDGT2	Heavey Duty Gas Truck HDGV	Light Duty Diesel Vehicle LDDV	Light Duty Diesel Truck LDDT	Heavy Duty Diesel Truck HDDV	Motor-cycles	Total
1991	6632	3600	99	95	7	6	137	45	10629
1990	6555	3665	100	97	7	6	140	50	10629
1989	7229	4116	112	109	7	6	157	73	11818
1988	7426	4292	117	114	7	7	163	76	12212
1987	6630	3345	92	88	7	5	127	114	10416
1986	7249	4119	113	109	7	6	157	251	12021
1985	7604	4185	115	111	8	4	160	269	12466
1984	7841	4216	116	112	8	4	161	198	12666
1983	5756	2836	78	76	6	3	109	243	9113
1982	6399	3036	83	81	6	3	116	412	10143
1981	6784	3098	85	82	7	3	118	384	10568
1980	6715	2590	71	69	7	3	99	1446*	11006
1979	7758	3753	104	100	8	4	144	--	11871
1978	7295	3134	87	85	7	3	121	--	10732
1977	6277	2695	76	73	6	3	105	--	9235
1976	4836	2100	60	57	5	2	82	--	7142
1975	3076	1408	40	39	3	1	55	--	4622
1974	2770	1535	43	42	3	2	60	--	4455
1973	2473	1299	37	36	2	1	52	--	3900
1972	1886	1078	31	30	2	1	43	--	3071
1971	1233	735	21	21	1	7	29	--	2047
1970	1001	669	19	18	1	7	26	--	1741
1969	818	672	19	18	1	6	26	--	1560
1968	697	529	15	15	1	5	21	--	1283
1967+	2831	2055	57	55	3	2	80	--	5083
Total	125771	64760	1790	1732	127	100	2488	3561	200429

*1980 and Earlier, *1967 and Earlier, Source: LaDOTD

Diary Data) to an estimated registration distribution for the number of model years assumed to comprise the fleet (i.e., 25 years for MOBILE5a). The travel fraction for each model year VF_n is calculated from the following equation:

$$VF_n = \frac{RF_n * AM_n}{\sum_{n=1}^{N} \left(RF_n * AM_n \right)} \qquad (3\text{-}25)$$

where

RF_n = the registration fraction for model year, n;

AM_n = the annual mileage accumulation for model year,

N = total number of model years in the fleet.

Table 3-23 shows the area-specific VMT mix fractions for each vehicle type by scenario. There are nine scenarios based on the grouping of the existing road functional classes. The details of the scenarios, vehicle speeds used, scenario definition, and scenario mileages for this study are shown in Table 3-24.

Table 3-23: MOBILE5a VMT Mix Fractions for Calcaseiu Parish

Vehicle Type	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
LDGV	0.561	0.534	0.557	0.591	0.596	0.635	0.614	0.626	0.660
LDGT1	0.208	0.264	0.287	0.323	0.323	0.192	0.252	0.274	0.265
LDGT2	0.054	0.069	0.066	0.045	0.023	0.048	0.057	0.047	0.042
HDGV	0.014	0.019	0.015	0.009	0.010	0.012	0.015	0.018	0.008
LDDV	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LDDT	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
HDDV	0.157	0.107	0.068	0.027	0.033	0.108	0.054	0.027	0.016
MC	0.002	0.003	0.003	0.001	0.001	0.001	0.004	0.004	0.005

Source: LaDOTD

Table 3-24: Vehicle Speeds for Different Roadway Classes/Scenarios

Functional Class (FC)	Mileage per day	Vehicle speed (m.p.h.)	Scenario Definition	Scenario Mileage
01		58.5	1	
02 06		49.5	2 (02+06)	
07		45.0	3	
08 09		36.0	4 (08+09)	
11		54.3	5	
14		39.7	6	
16		36.9	7	
17		39.9	8	
19		27.0	9	

3.27 Estimation of Base Emission Rate Using MOBILE5a

The basic exhaust emissions data contained in the MOBILE5a model are based on a standardized driving cycle called the Urban Dynamometer Driving Schedule (UDDS), or "LA4 cycle." This chassis dynamometer test cycle involves duplicating a speed-time profile from an actual road route identified in the Los Angeles area in the late 1960s and chosen to represent the typical urban area driving pattern. The driving cycle was then incorporated into EPA's Federal Test Procedure (FTP), the testing process used by all motor vehicle manufacturers to certify that their vehicles are capable of meeting federal emission standards.

The FTP consists of three distinct segments at a standard test cell temperature of 68° to 86°F. Because the mass emissions from each of the three segments are collected in separate tedlar bags, the three operating modes are often referred to in terms of "bags." A complete FTP is comprised of:

- a cold start (or cold transient) portion ("Bag 1"), which is the first 3.59 miles of the UDDS (505 seconds in length);
- a stabilized portion ("Bag 2"), which is the final 3.91 miles of the UDDS (867 seconds in length); and
- a hot start (or hot transient) portion ("Bag 3"), which is the first 3.59 miles of the UDDS and follows an engine-off period of 10 minutes.

The LA4, shown in Figure 3-5, has been the standard driving cycle for the certification of light-duty vehicles since the 1972 model year. It is approximately 7.5 miles in length with an average speed of 19.6 mph. The cycle includes segments of non-zero speed activity (at varying engine loads) separated by idle periods. Since the 1975 model year, the initial 505 seconds of the cycle have been repeated following a 10-minute hot soak. It is believed that after cold/hot start weighting factors (i.e., 43 percent of the starts are assumed to be cold starts, 57 percent are assumed to be hot starts) are applied to the Bag 1 and Bag 3 results, the test provides a more accurate reflection of typical customer service than running just one 7.5 mile cycle from a cold start [Huts, 1973]. This change was incorporated because a significant fraction of vehicle starts do not occur with the vehicle in a completely cold condition, and running the first 505 seconds of the LA4 with the vehicle in a warmed-up condition gives an indication of stabilized emissions over a

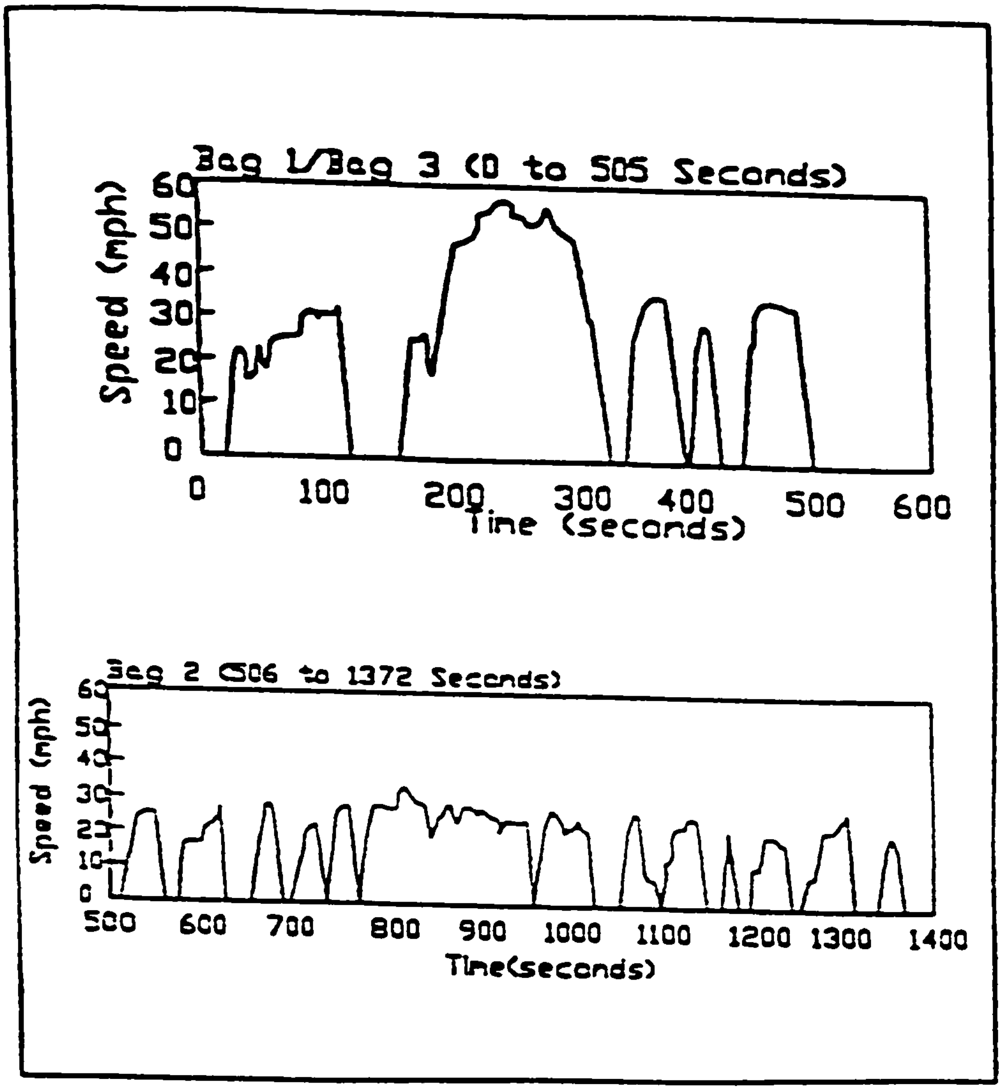


Figure 3-5: Urban Dynamometer Driving Cycle

higher speed cycle than represented by Bag 2. The FTP composite emission rate is calculated from the bag-specific emissions results according to the following formula:

$$BER = \frac{3.59 * (0.43 * BAG1 + 0.57 * BAG3)}{7.5} + \frac{3.91 * BAG2}{7.5} \qquad (3\text{-}26)$$

which reduces to

$$BER = 0.206 * BAG1 + 0.521 * BAG2 + 0.273 * BAG3 \qquad (3\text{-}27)$$

where

BER	=	composite FTP base emission rate (g/mi),
BAG1	=	bag 1 emission rate (g/mi),
BAG2	=	bag 2 emission rate (g/mi), and
BAG3	=	bag 3 emission rate (g/mi).

Corrections for Nonstandard Conditions - Because the emissions test is performed over the same standard operating conditions for all vehicles, the MOBILE5a emission factor model makes use of a variety of correction factors to tailor the FTP results to the specific local conditions being modeled. For example, operating mode correction factors (also referred to as a bag correction factors) are applied to the FTP composite emission rate to determine the emission rate of a vehicle in the cold start mode, stabilized mode, or hot start mode. Because emission rates from motor vehicles are much higher at very low temperatures, temperature correction factors are used to account for this effect. Finally, a vehicle's emission rate is also a strong function of its average speed. Thus, speed correction factors modify the FTP results to account for speeds different from the FTP average of 19.6 mph.

The overall emission rate from a vehicle is the product of the basic emission rate (determined from the FTP results) and a number of correction factors that are specific to the conditions being modeled. Although the actual modeling procedure is very complex, this can be simply represented by:

$$EF = BER * BCF * TCF * SCF \tag{3-28}$$

where EF = emission factor (g/mi) corrected for operating mode, temperature, and speed;

BER = composite FTP base emission rate (g/mi);

BCF = bag (or operating mode) correction factor;

TCF = temperature correction factor; and

SCF = speed correction factor.

3.28 Basic Emission Rate Correction Factors for LDGVs

MOBILE5a predicts that the bag or operating mode correction factors (BCF_S) for catalyst-equipped vehicles are a function of vehicle mileage, with a decrease in weight for Bags 1 and 3 as the vehicle ages. Figures 3-6 through 3-8 depict the 1990 model year LDGVs bag correction factor coefficients for HC, CO, and NO_x respectively.

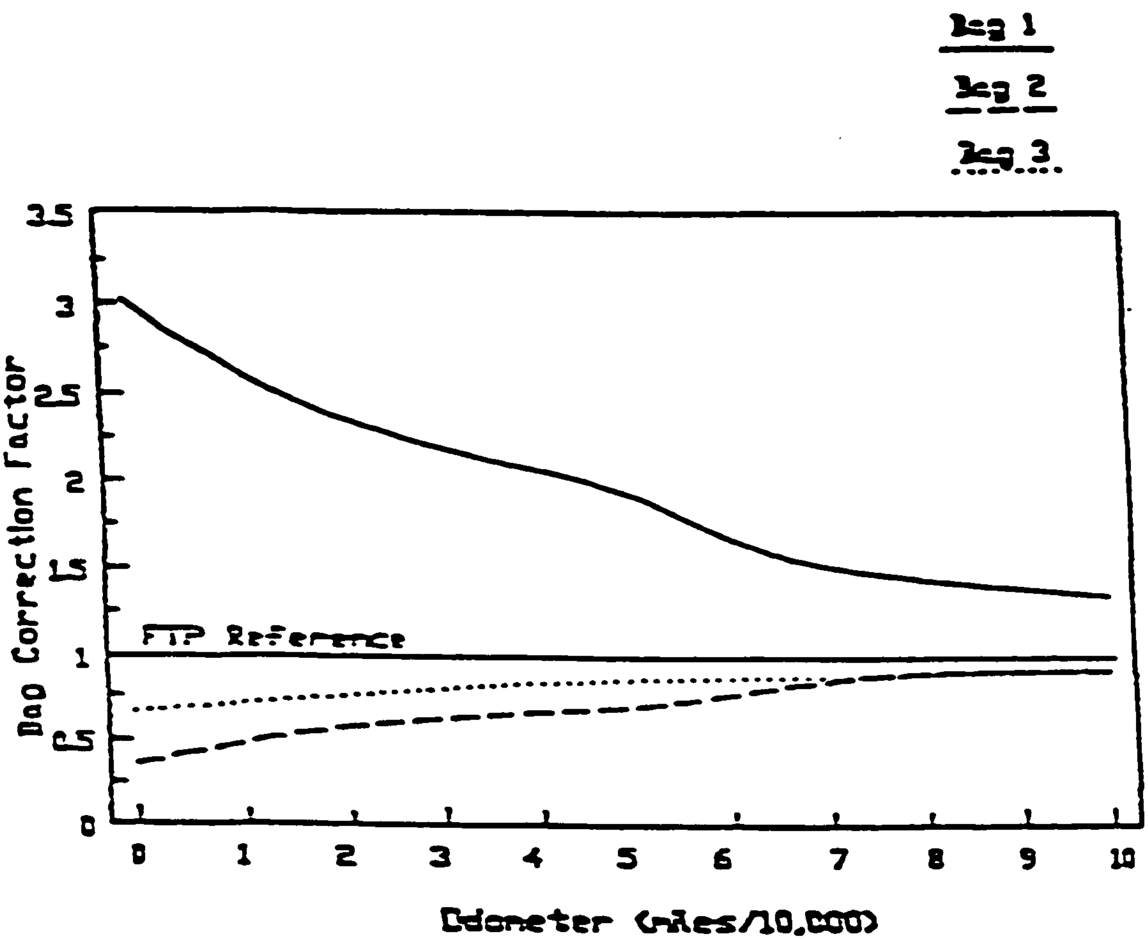


Figure 3-6: MOBILE5A Hc Bag Fractions 1990 LDGVs

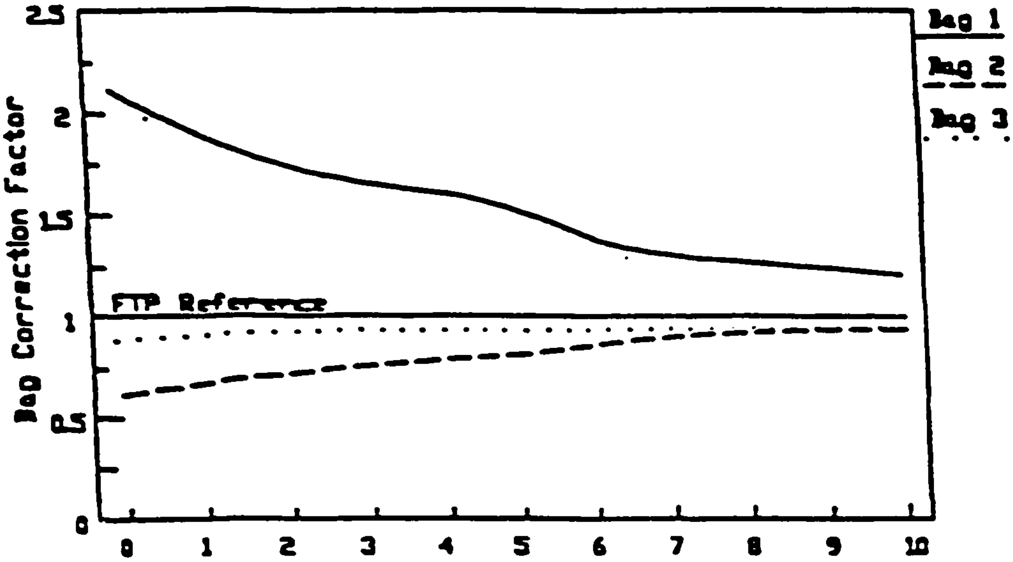


Figure 3-7: MOBILE5a CO Bag Fractions 1990 LDGVs

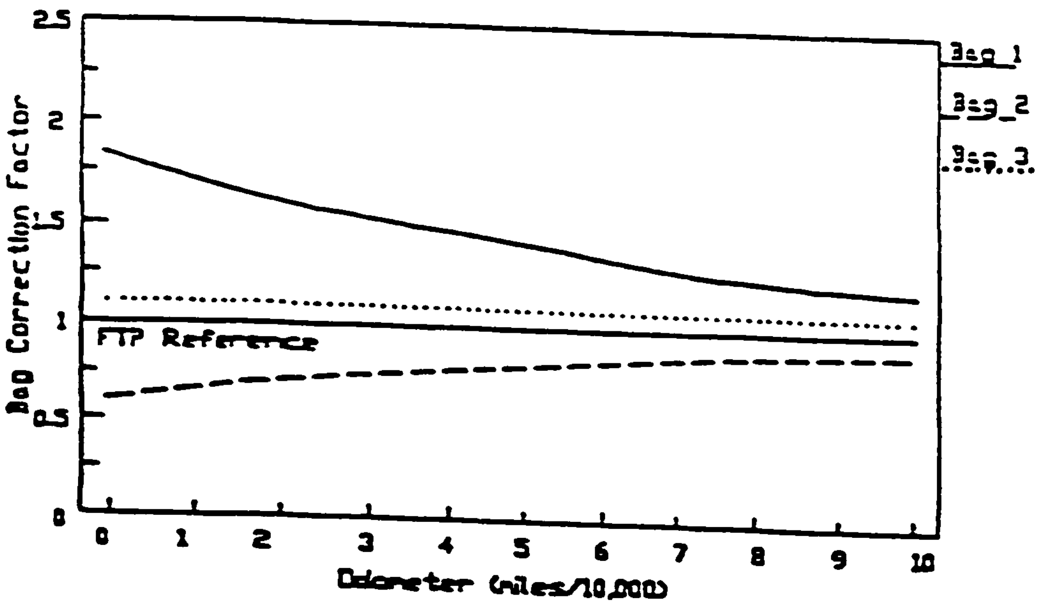


Figure 3-8: MOBILE5a NO_x Bag Fractions 1990 LDGVs

Note that at any mileage point, the equation

$$0.206*BCF1 + 0.521*BCF2 + 0.273*BCF3 = 1 \qquad (3\text{-}29)$$

is valid. This is to say that the sum of the FTP weighted *BCFs is unity.*

3.28.1 Temperature and RVP Corrections

Federal Test Procedure performs emissions tests within a temperature range of 68°F to 86°F. Temperature corrections are therefore required on emissions outside the FTP temperature range. MOBILE5a consequently contains factors to adjust the base emission rates to reflect the temperature for which the model is being run.

Fuel volatility, measured as Reid Vapor Pressure (RVP) also impacts vehicle emissions and the impact is closely related to temperature. At temperatures below 75°F, the RVP adjustment is a simple multiplication factor. At temperatures above 75°F, the temperature and RVP adjustment is combined into a single correction factor. RVP impacts exhaust emissions primarily through its influence on vapor storage in the evaporative emission control system.

Note that because temperature affects emissions differently for each operating mode, temperature correction factors (TCFs) are derived separately by MOBILE5a for Bags 1,2, and 3. Furthermore, emissions at lower temperatures are dependent on the type of fuel delivery system with which the vehicle is equipped such as carburetion (CARB), throttle-body fuel-injection (TBJ), or multiport fuel-injection (PFI) delivery systems. Figure 3-9 shows the Bag1 HC low-temperature correction factors for the three fuel

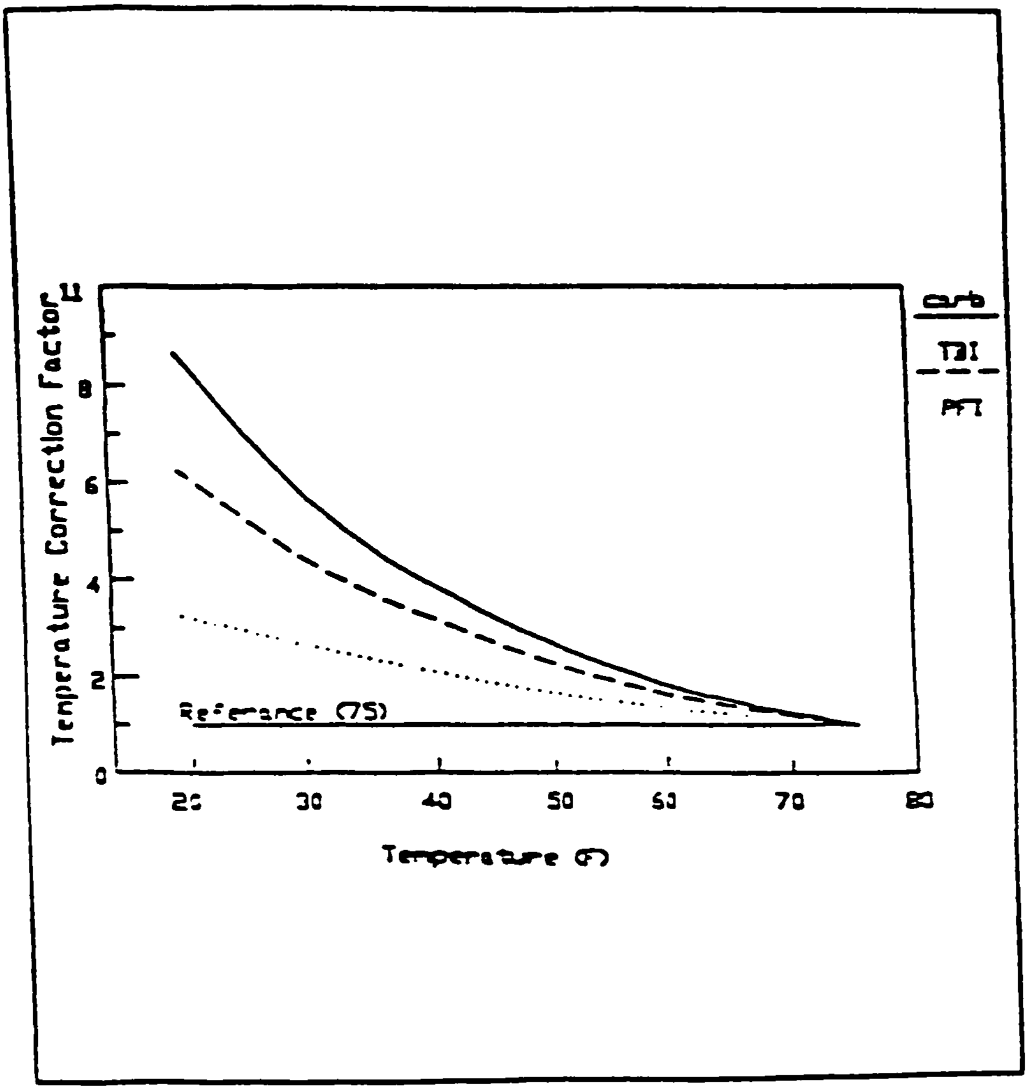


Figure 3-9: Bag 1 HC Temperature Correction Factors
by Fuel Delivery System (1983 + LDGVs)

delivery systems for 1983 and above LDGVs. Figure 3-9 shows that as the fuel delivery system is improved, cold-temperature emissions are improved.

Figures 3-10 through 3-12 show the temperature correction factors by operating mode for 1992 and above model year light duty gasoline vehicles (LDGVs) from MOBILE5a for HC, CO, and N0x respectively. Note that CO emission factor for Bag 1 is not reflected in figure 3-11 as MOBILE5a handles that differently. Instead of being a multiplicative correction factor, the Bag1 CO temperature correction is an offset which is added to the base emission rate before corrections for speed and fuel are applied. The offset is a linear function of temperature and it varies according to fuel delivery system.

As hinted earlier, the RVP correction factors for low temperature operation are calculated independently from temperature correction factors by MOBILE5a. Also the RVP correction is not bag specific and it is not applied to vehicles older than the 1971 model year. Figures 3-13 and 3-14 show the low temperature RVP correction factors for HC and CO for 1983 and above model year vehicles for LDGVs from MOBILE5a for a series of fuel RVPs.

Again as stated earlier, for high temperatures the TCF and the RVP correction factor are combined. Figures 3-15 and 3-16 show the high temperature for MOBILE5a RVP/temperature correction factors for HC and CO for LDGVs for model year 1983+ by RVPs.

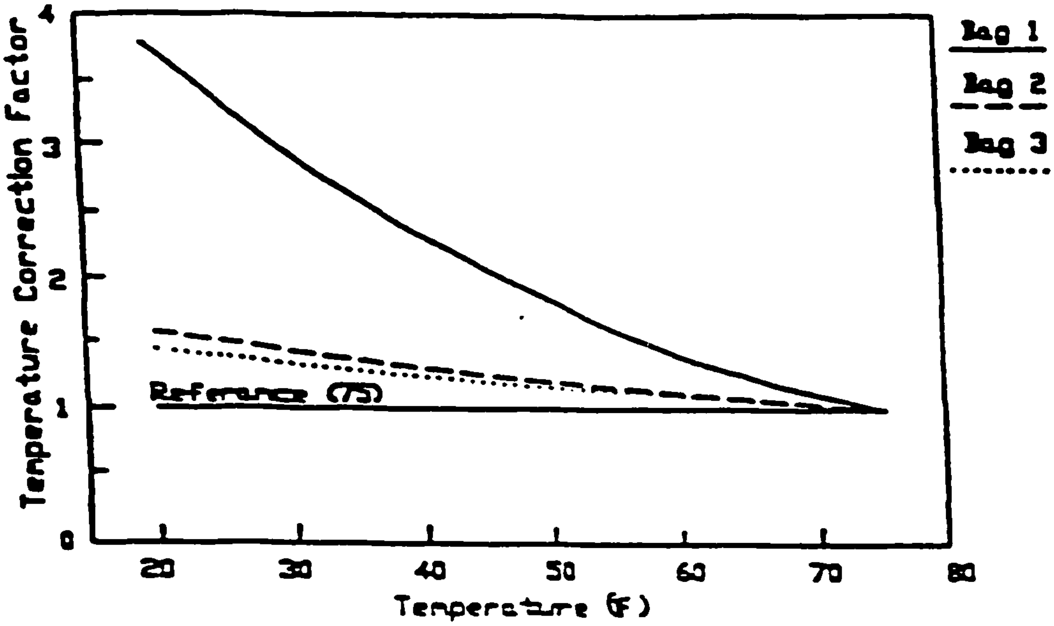


Figure 3-10: HC Temperature Corrections Factors by Operating Model (1992 + LDGVs)

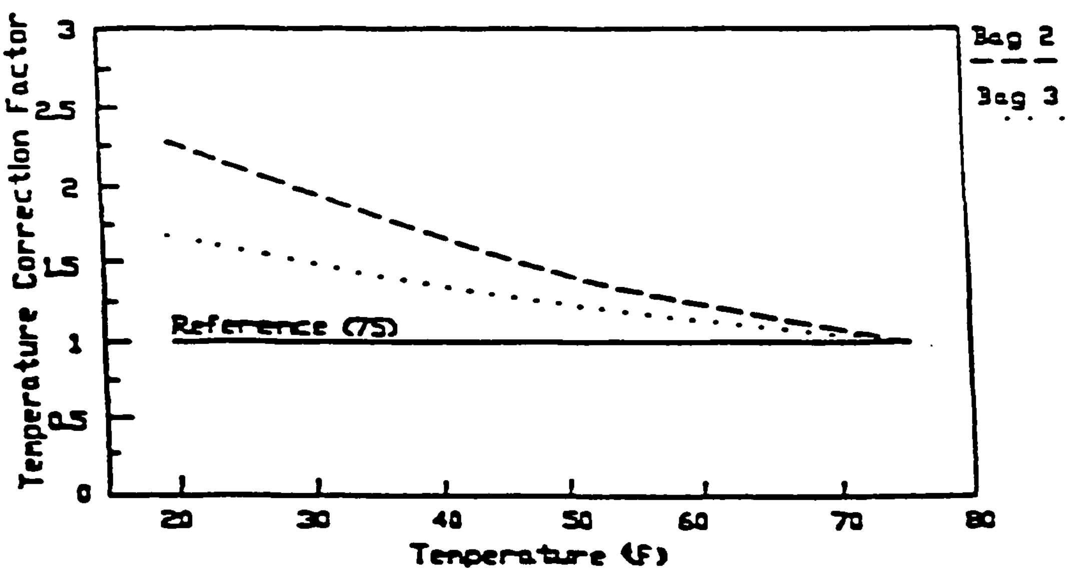


Figure 3-11: CO Temperature Correction Factors by Operating Model (1992 + LDGVs)

Note: Bag 1 CO is corrected for temperature with an offset, thus bag 1 is not included here.

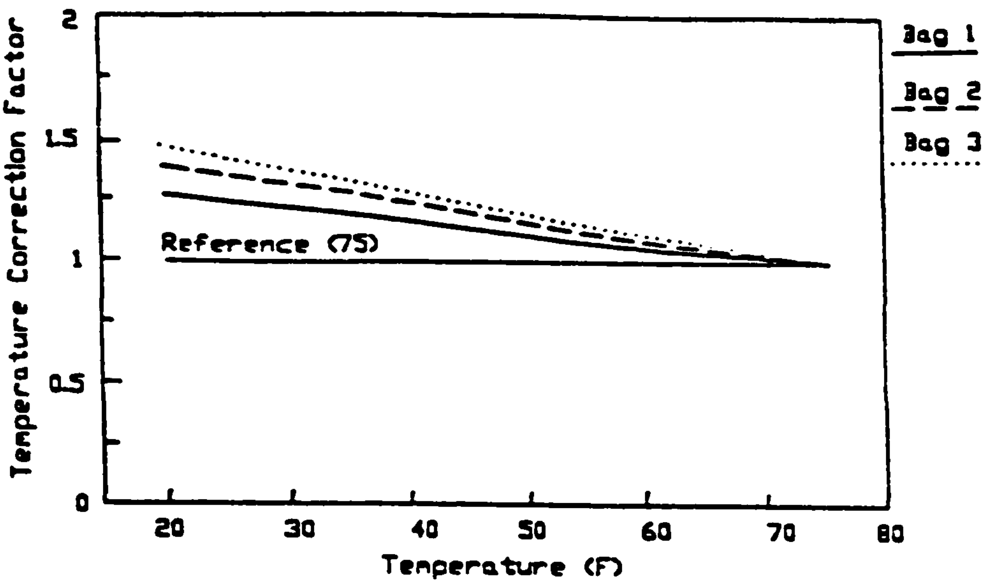


Figure 3-12: NO_x Temperature Correction Factors by Operating Mode (1992 + LDGVs)

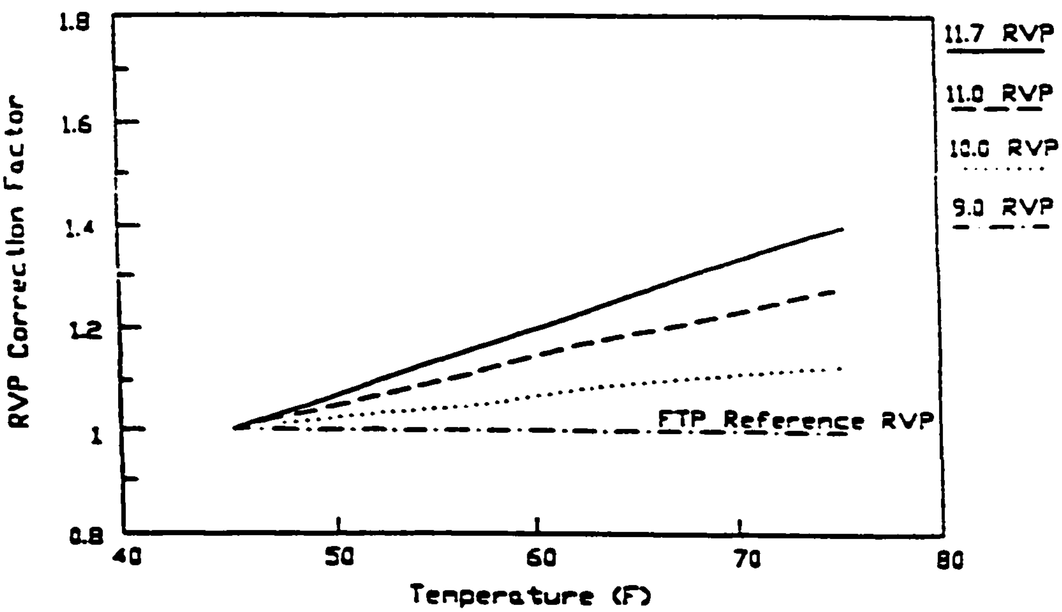


Figure 3-13: MOBILE5a Low Temperature HC RVP Correction Factors (1983 + LDGVs, FTP Composite)

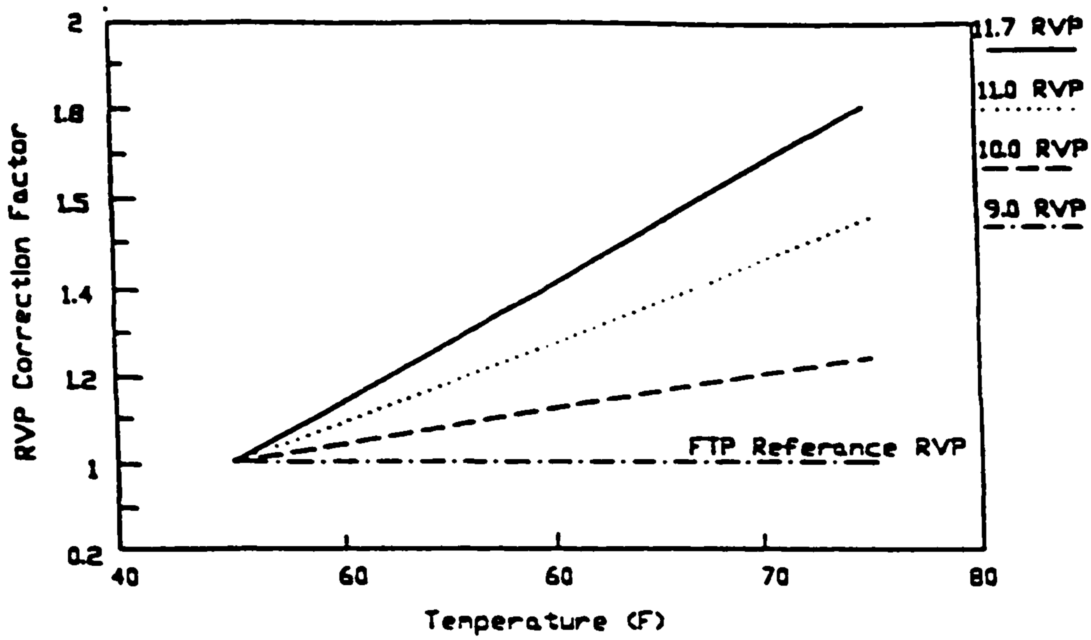
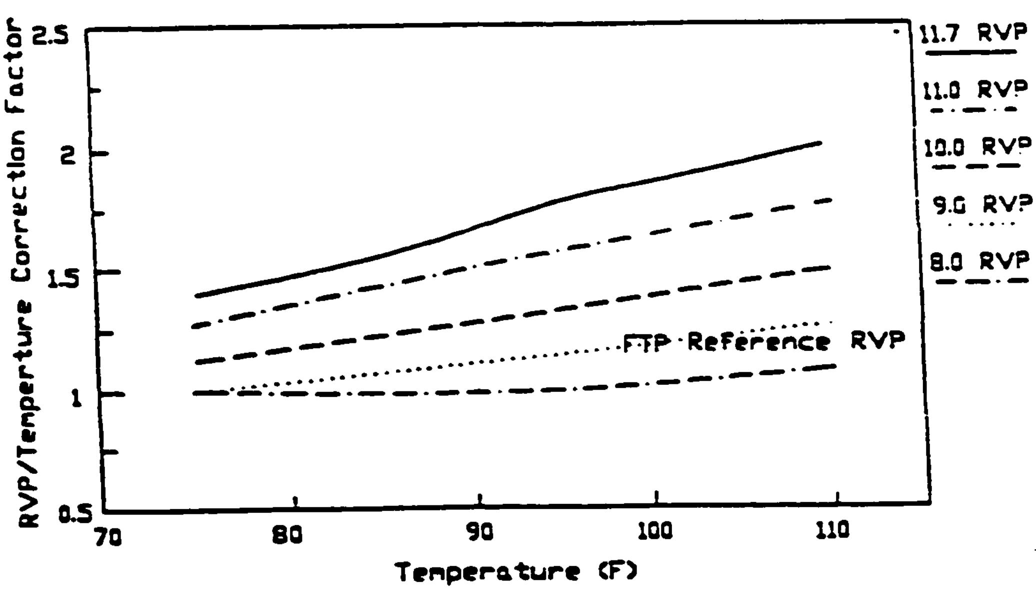


Figure 3-14: MOBILE5a Low Temperature CO RVP Correction Factors (1983 + LDGVs, FTP Composite)



Note: This Correction does not fall below 1.

Figure 3-15: MOBILE5a High Temperature HC RVP/Temperature Correction Factors (1983 + LDGVs, FTP Composite)

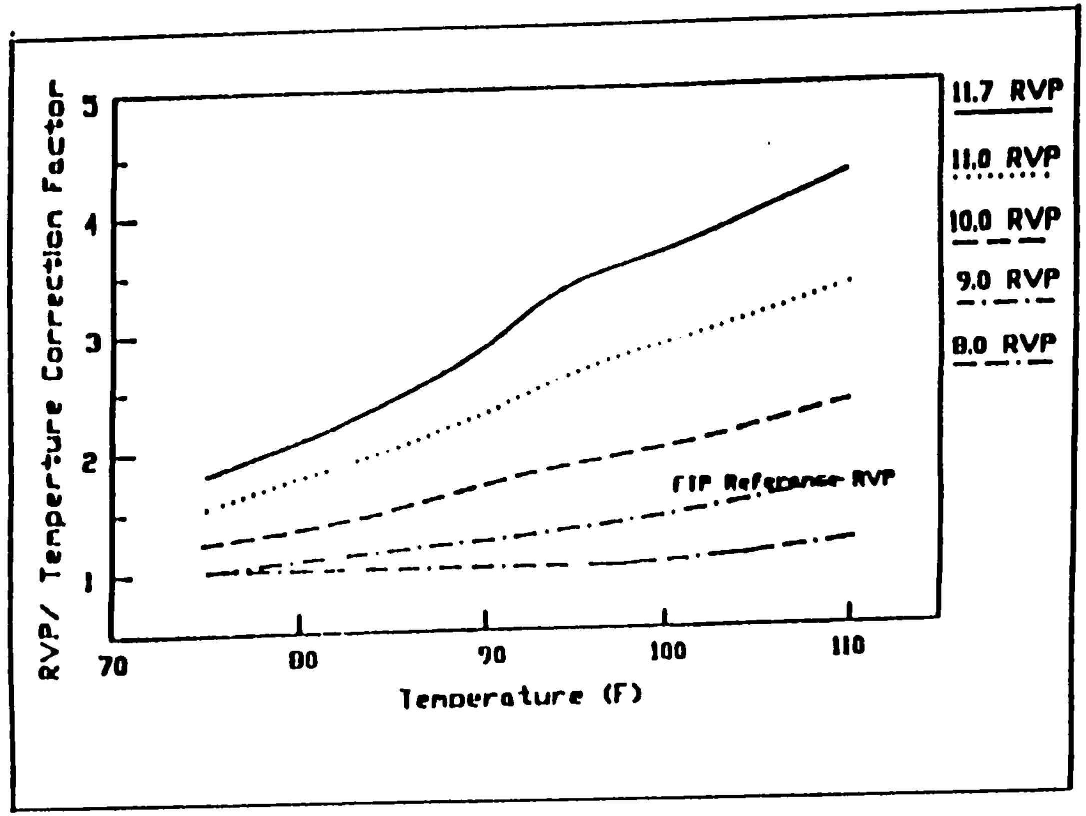


Figure 3-16: MOBILE5a High Temperature CO RVP/
Temperature Correction Factors
(1983 + LDGVs, FTP Composite)

Note: This correction does not fall below 1.

Note that the impact falls as the temperature declines and no correction is applied at temperatures below 45°F. The RVP correction for N0x is very small and as such is not shown.

3.28.2 Speed Corrections

Based on literature review, emission factors are very sensitive to the average speed that is assumed. In general, emissions tend to increase as average speeds decrease from the 19.6 mph value employed in the FTP. The MOBILE5a model does not assume an average speed: it is a requirement that an estimate of the speed experienced by vehicles operating in the are of analysis be specified. MOBILE5a adjusts the emission factors for speeds other than 19.6 mph through the use of speed correction factors. These multiplicative adjustments to the base emission factors follow a non-linear relationship that increases the emission levels as speeds decline.

Two forms of speed correction factors used in MOBILE5a model are presented as follows:

$$SCF = \left(A/S + B\right)/\left(A/FTPS + B\right) \tag{3-30}$$

$$SCF = \frac{\exp(A + B*S + C*S*2)}{\exp(A + B*FTPS + C*FTPS*2)} \tag{3-31}$$

where

SCF = speed correction factor as earlier defined;

FTPS = operating mode adjusted FTP speed;

S = vehicle speed in mph;

A,B = constants specific to each pollutant, model year group, and vehicle category.

Equations 3-30 and 3-31 are generally used for 1979 and later model vehicles. Equation 3-30 is used for HC and CO emissions, while equation 3-31 is used for N0x emission. The data used to develop the speed correction factors are based on a number of different test cycles in which the speed-time profile is changed to reflect different average speeds. A total of eight different test cycles used by EPA in modeling the effect of speed on emissions are presented as follows:

- EPA Low speed #3 2.5 mph;
- EPA Low speed #2 3.6 mph;
- EPA Low speed #1 4.0 mph;
- New York City cycle 7.1 mph;
- EPA speed cycle 12 12.1 mph;
- FTP speed 19.6 mph;
- EPA speed cycle 36 35.9 mph;
- Highway fuel Economy test 47.9 mph;

In addition to the above test cycles, EPA has used data from CARB's high-speed testing to develop the high-speed (i.e., speeds over 48 mph) correction factor. Details of the speed-time profiles traces of cycles used in speed correction factor development are presented in Appendix E. Figure 3-17 through 3-19 show the speed correction factors for HC, CO, and N0x respectively as computed by MOBILE5a for 1990 model year LDGVs using 19.6 mph as the reference speed. There are three speed regimes modeled by

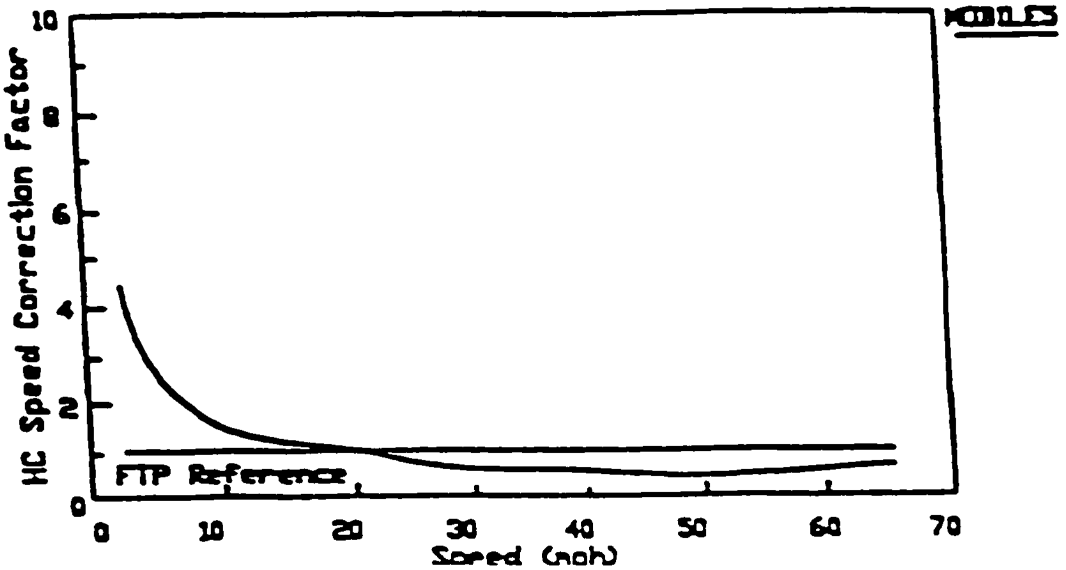


Figure 3-17: Hydrocarbon Speed Correction Factors MOBILE5a (1990 LDGVs)

Note: MOBILE5a speed correction factors are equivalent below 19.5 mph.

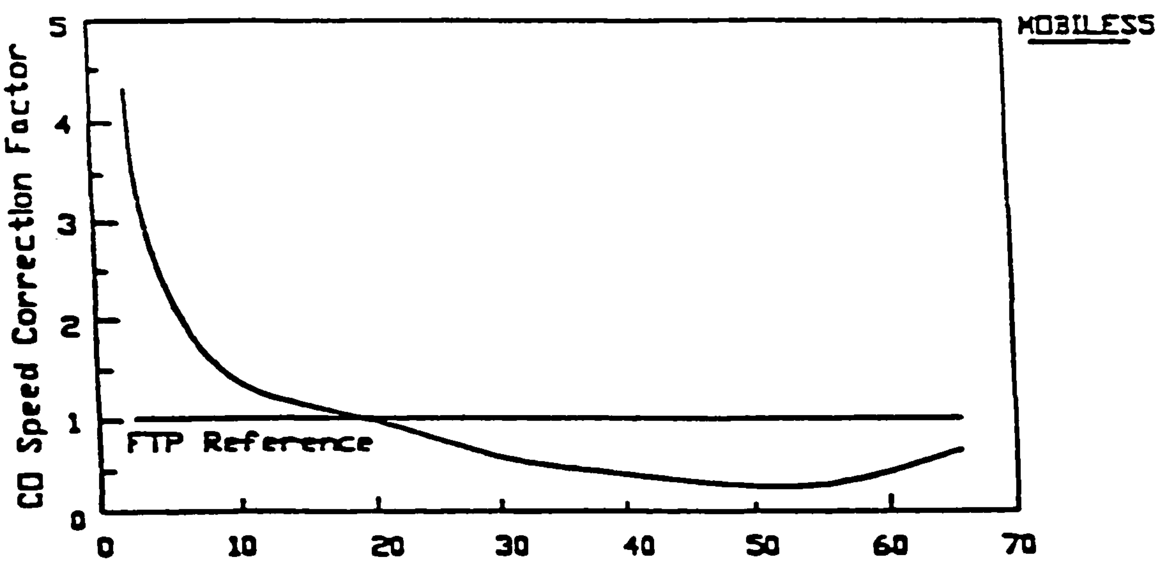


Figure 3-18: Carbon Monoxide Speed Correction Factors MOBILE5a (1990 LDGVs)

Note: MOBILE5a speed correction factors are equivalent below 19.5 mph.

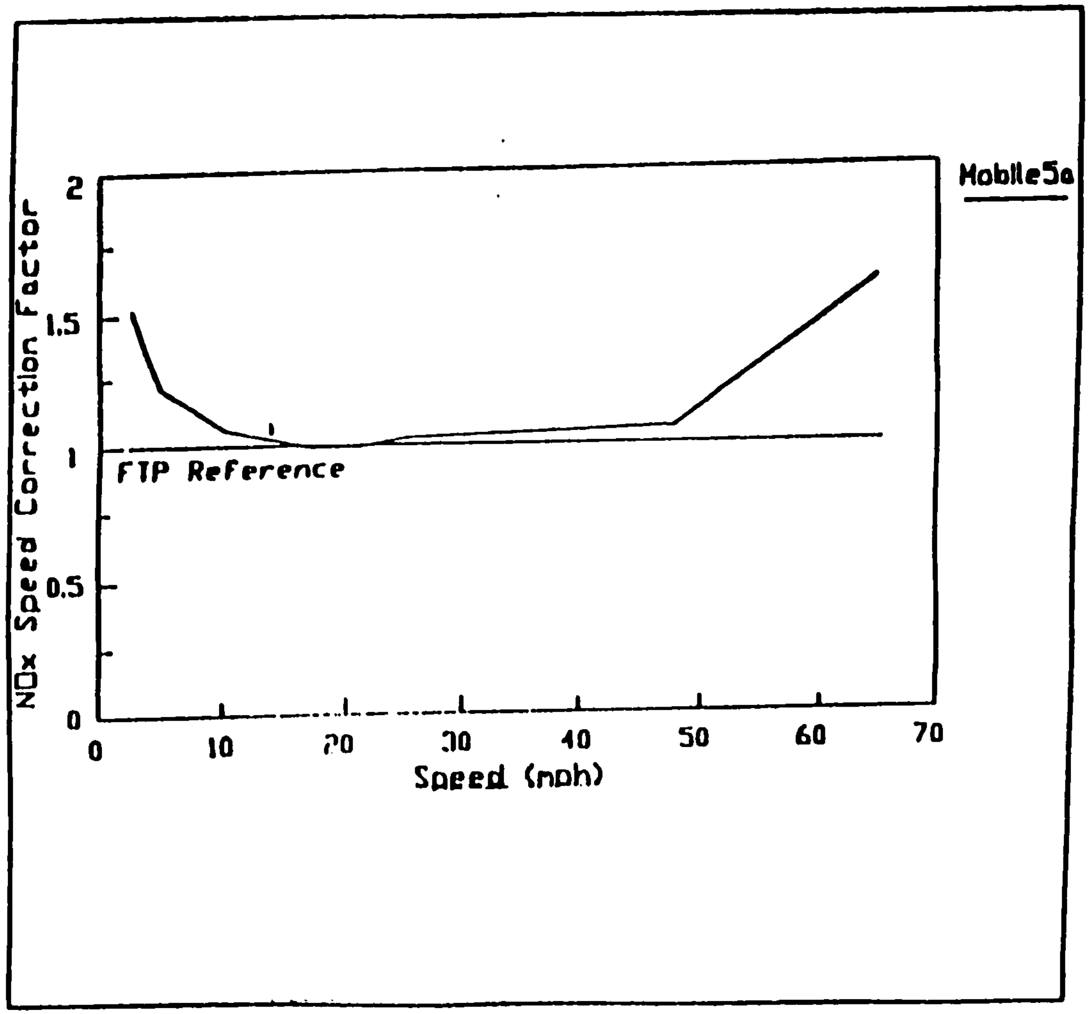


Figure 3-19: Dioxides of Nitrogen Speed Correction Factors (1990 LDGVs)

Note: MOBILE5a speed correction factors are equivalent below 19.5 mph.

MOBILE5a: low speed (under 19.6 mph), mid-speed (19.6 to 48 mph), and high speed (48 to 65 mph).

The low-speed regime results in the highest SCFs (and thus emissions) for HC and CO, with MOBILE5a predicting an SCF of over 4 at 2.5 mph. On the other hand, low-speed NO_x emissions are predicted to increase by only about 50 percent from the reference speed. Higher emissions at these very low speeds occur because the vehicle is operating over a longer time period to cover the same distance, and the test cycles used to develop the low-speed corrections have a higher fraction of time spent under acceleration modes.

The mid-range HC and CO SCFs are steadily decreasing from 19.6 to 48 mph. The result for NO_x, however, is quite different with MOBILE5a as figure 3-19 shows a steady increase throughout the mid-speed regime. Finally, MOBILE5a has a significant SCF for high speed and the data used to develop the SCF for high speed were obtained from CARB.

3.29 Basic Emission Rate for Using Heavy Duty Vehicles (HDVs)

In section 3.27, the methodology for the determination of BER for LDGVs was presented. This section presents briefly the methodology for the determination of BER for both heavy duty gasoline and diesel vehicles. Details of the BER, constants used, and the derivation of the associated conversion factors for heavy-duty vehicles are contained in the EPA technical report [Smith, 1984; Machiele, 1988].

Heavy-duty vehicles consist of vehicles that exceed 8500 pounds gross vehicle weight (GVW). This general class is further segregated into specific classes according to to GVW The additional segregation is necessary because of the differing characteristics of engines making up these classes.

3.29.1 Standard Test Procedure

Because of the large number of applications for which heavy-duty engines are utilized, emissions testing is normally engine-specific and is performed on an engine dynamometer. Additionally, the heavier GVW rating of heavy-duty vehicles precludes testing on most chassis dynamometers. Therefore, transient engine dynamometer test cycles have been developed that stimulate average urban driving for gasoline and diesel heavy-duty engines. These test cycles specify revolution per minute (RPM) and torque by second and are roughly 20 minutes long. The test procedure, outlined in 40CFR86, calls for a "cold start" portion which is initiated after the engine temperature is stabilized at 68° to 86°F. (This can be accomplished through an extended "cold soak" period or with a "forced cool-down" procedure.) A "hot start" portion, is also commencing 20 minutes after the end of the cold start test, is also required and follows the same dynamometer test cycle. The test results are reported in units of grams per brake-horsepower-hour (g/Bhp-hr), and the composite emission rate is determined by weighting the cold portion of the test by 1/7 and the hot portion of the test by 6/7. The test procedure is diagramed in Figure 3-20.

The transient test cycles developed for heavy-duty gasoline and diesel engines are the result of a significant effort by EPA and industry to simulate heavy-duty vehicle operation in urban areas. The data used to develop the cycles were collected from

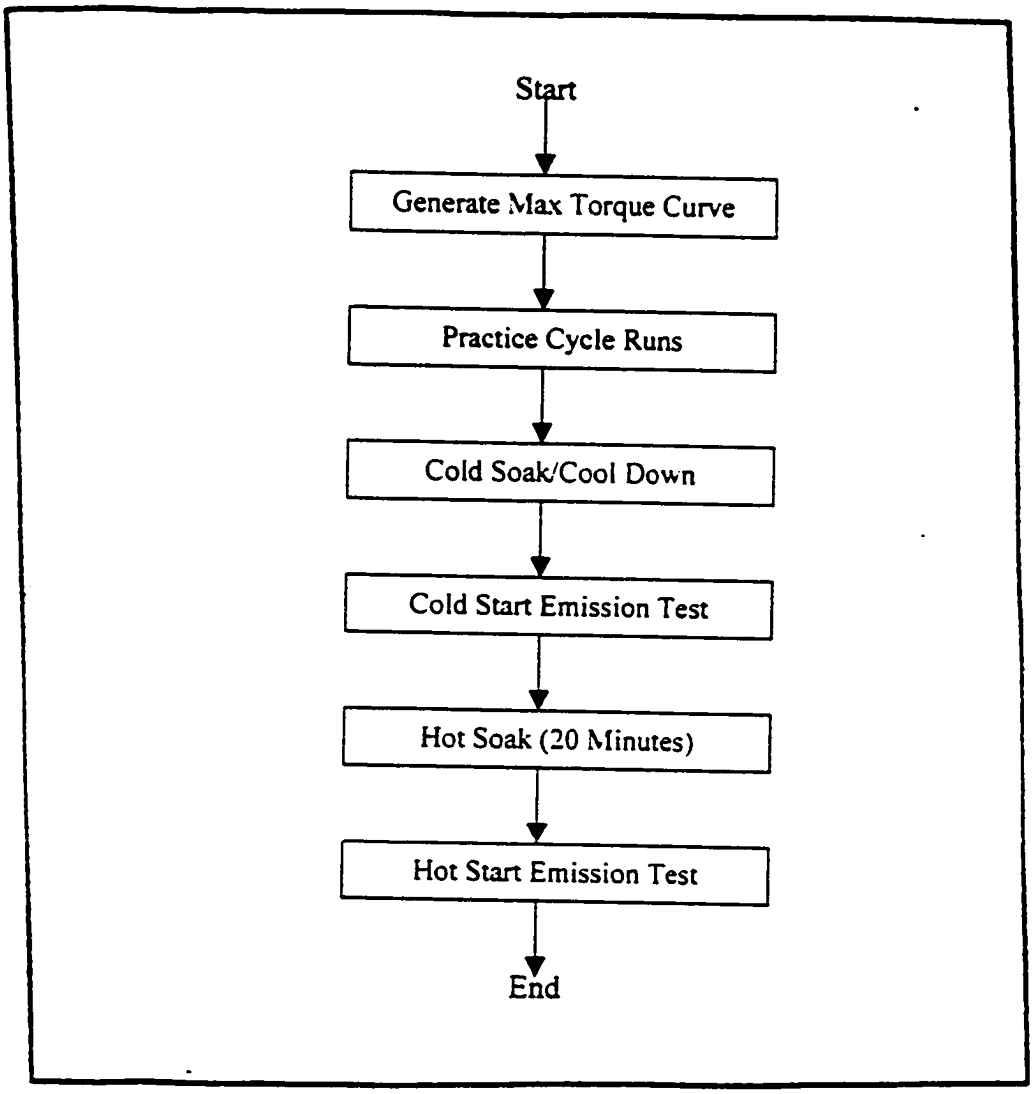


Figure 3-20: Heavy-Duty Engine Test Procedure

instrumented heavy-duty trucks that operated in New York City and the Los Angeles Basin in the mid-1970s [Systems Control, Inc., 1978]. The complete 20-minute cycles were formulated from four separate 5-minute cycles that represented freeway driving in Los Angeles, and non-freeway driving in Los Angeles. An optional chassis dynamometer test cycle was also developed in this program which covers 5.73 miles at an average speed of 19.45 mph [Wysor, T. and C. France, 1978].

3.29.2 Basic Emission Rates

The basic emission rates developed for the MOBILE models are based on engine dynamometer test results. For MOBILE4, data from a cooperative test program with engine manufacturers formed the basis of the g/Bhp-hr emission estimates (for 1979 and later model years). For heavy-duty diesel vehicles, a total of 30 engines were tested that were representative of the 1979 to 1984 model years. For heavy-duty gasoline emission rates, 18 engines were tested by EPA. These were from the 1970 to 1982 model years. Unfortunately, heavy-duty engine testing is very expensive, so data are generally sparse. No new data since the MOBILE4 effort have been developed with which to update heavy-duty emission factors.

3.29.3 Conversion Factors

Due to the fact that the exhaust emission test procedure results in emissions reported in units of g/Bhp-hr, it is necessary to convert the results into g/mi units to be consistent with available travel information. Therefore, conversion factors (in Bhp-hr/mi) are developed to represent the emission results obtained from engine dynamometer testing in units appropriate for inventory purposes.

Because it is difficult to measure Bhp-hr/mi directly, a methodology was developed to calculate this parameter with available data. In equational form, the conversion factor is represented by:

$$C_F = \frac{F_D}{BSFC * F_E} \tag{3-32}$$

where

C_F = conversion factor (Bhp-hr/mi),

F_D = fuel density (lb/gal),

BSFC = brake-specific fuel consumption (lb/Bhp-hr), and

F_E = fuel economy (mi/gal).

Thus, by obtaining estimates of fuel density, brake-specific fuel consumption, and fuel economy, it is possible to estimate C_F. Once the values of C_F are obtained for each GVW class, a fleet composite C_F is established by weighting the class-specific values by an estimated VMT mix. These calculations are carried out separately for gasoline and diesel vehicles.

The data sources used in developing the conversion factors for 1982 and previous model years are summarized as follows:

- Fuel Density - Gasoline fuel density was based on data published by the National Institute for Petroleum and Energy Research (NIPER), and diesel fuel density was based on surveys by the Motor Vehicle Manufacturers Association (MVMA). (The same value for fuel density was used for all model years.)

- Fuel Economy - Estimates for heavy-duty trucks were obtained from the Department of Commerce's "1982 Truck Inventory and Use Survey" (TIUS), while bus data came from documents published by the Federal Highway Administration (FHWA).
- Brake-Specific Fuel Consumption (BSFC) - The pre-1978 heavy-duty truck data came from a 1983 report prepared by Energy and Environmental Analysis (EEA) for the MVMA. For model years 1978 to 1982, the BSFC values were interpolated from the above 1977 estimates and more recent data submitted to EPA by manufacturers for 1987 model year engines. Bus data were based on EPA testing of high sales-volume bus engines.

The 1983 and subsequent conversion factors were developed by incorporating fuel economy improvements into the 1982 class-specific conversion factors. (Because engine-related fuel economy improvements also result in decreased BSFC (which cancels the overall impact on the C_F), only non-engine-related fuel economy improvements were considered. Specific improvements accounted for in the analysis included weight reduction, radial tires, aerodynamic add-on devices, drivetrain lubricants, improved fan drives, overdrive, electronic transmission controls, and speed controls.

The sales and VMT estimates used to composite the class-specific conversion factors for each model year were based on information contained in various publications authored by MVMA, the Department of Energy, the American Public Transit Association, and FHWA, as well as data in the TIUS.

3.30 Basic Emission Rate Correction Factors for HDVs

Speed and Temperature Adjustments - As with light-duty vehicles, the heavy-duty emission rates are corrected for average speed and temperature outside of those encountered in the test procedure. (Gasoline vehicles are corrected for both speed and temperature, while diesel vehicles are corrected only for speed. The effect of nonstandard temperature on diesel emissions is assumed to be negligible.) For speed corrections, the basic emission rate is multiplied by the appropriate speed correction factor that is calculated from the speed correction coefficients according to the following formula:

$$SCF = \exp\left(a + bs + cs^2\right) \qquad (3\text{-}33)$$

where:

a,b,c	=	coefficients
s	=	vehicle speed, and
exp	=	exponential function.

Figures 3-21 through 3-23 show a graphical representation of the heavy-duty Diesel and gasoline speed corrections factors for HC, CO, and NO_x, respectively. (The same speed correction factors apply to all model year vehicles).

Temperature correction is only applied to heavy-duty gasoline vehicles. Further, this correction is not operating-mode specific, which is a departure from the light-duty gasoline vehicle methodology. In equation form, the temperature correction factor is represented by:

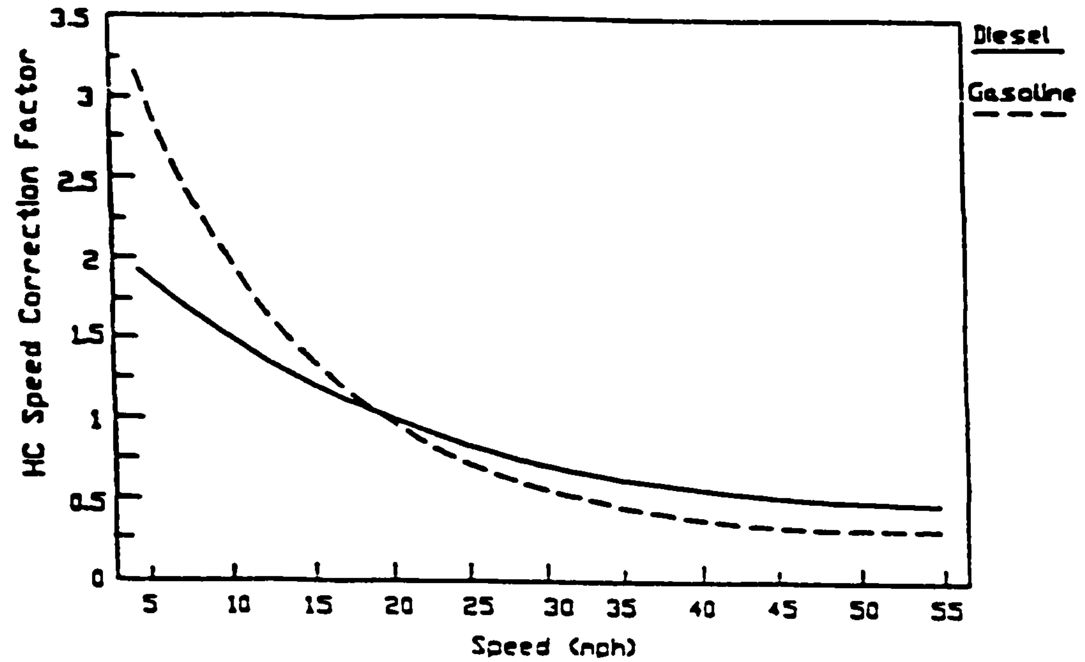


Figure 3-21: Heavy-Duty Vehicle Speed Correction Factors Hydrocarbons

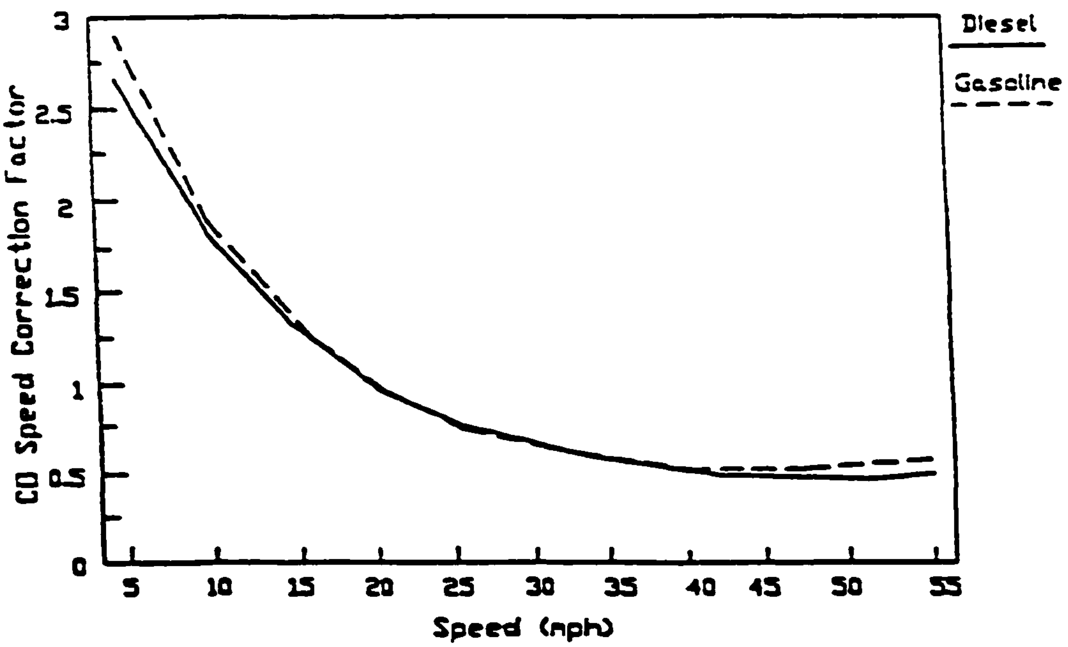


Figure 3-22: Heavy-Duty Vehicle Speed Correction Factors Carbon Monoxide

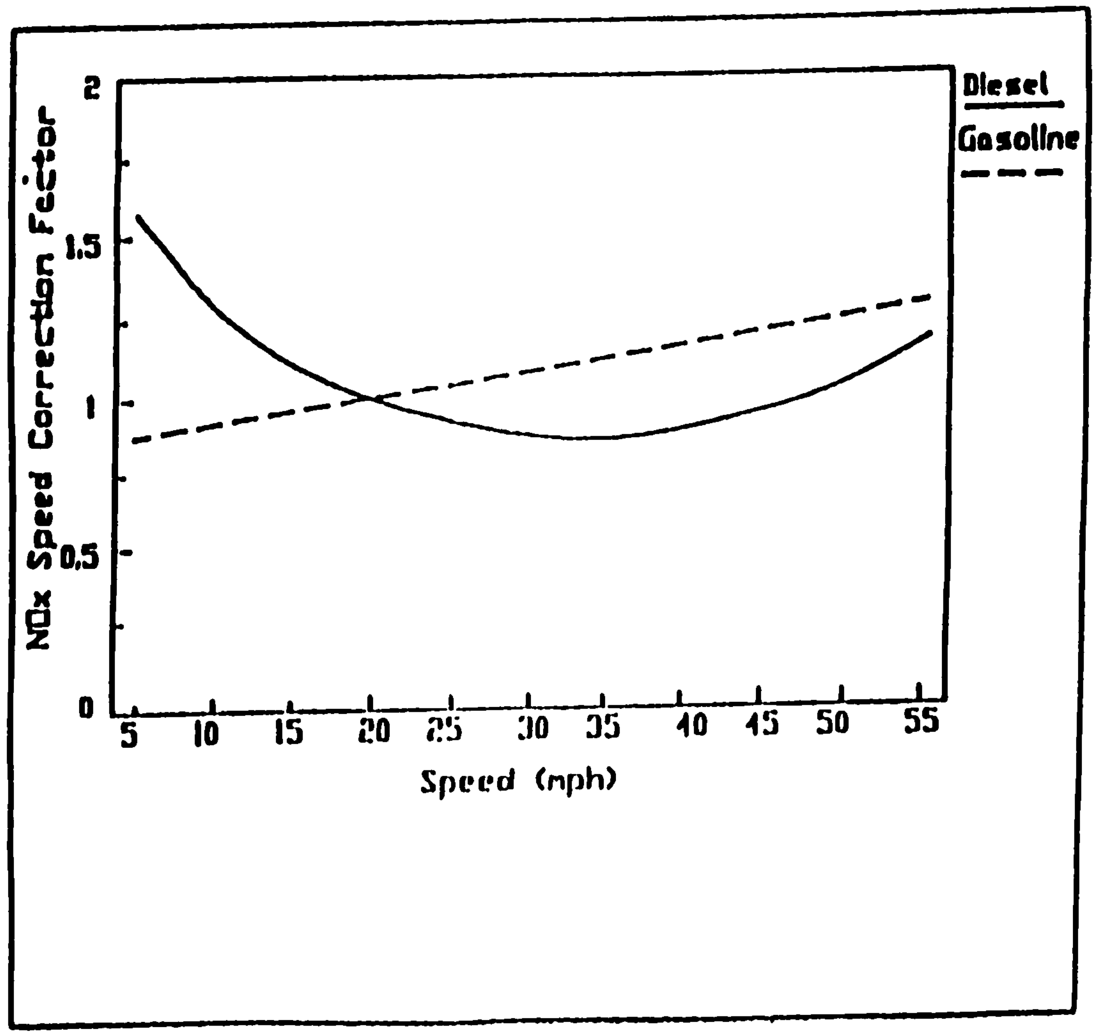


Figure 3-23: Heavy-Duty Vehicle Correction Factors
for Oxides of Nitrogen

$$TCF = \exp\left(a * \left(T - 75^{\circ} F\right)\right) \qquad (3\text{-}34)$$

where

a = coefficient,

T = temperature (°F), and

exp = exponential function.

The value of the coefficient for a particular model year group differs, depending upon whether the temperature range being modeled is above or below 75°F. The heavy-duty gasoline vehicle temperature correction factors for 1985 and later model years are depicted in Figure 3-24 for HC, CO, and $N0_x$ for temperatures below 75°F. Figure 3-24 shows that the impact of temperature is greatest for HC at low temperature.

3.31 Tampering

Tampering effects are accounted for in MOBILE5a. When basic emission rates are developed from surveillance vehicles, the effects of tampering are removed by deleting tampered vehicles from the test sample. An additive emissions impact (in g/mi) and a rate of occurrence have been developed by EPA for each tampered component (including air pump, fuel inlet restrictor, catalyst removal and misfueling), based on tests of tampered vehicles and EPA surveys. Although MOBILE5a contains default tampering rates, these rates can be changed by the user to reflect area-specific tampering rates and antitampering programs. The estimated increase in emissions due to tampering is adjusted to reflect the reduced tampering rates expected under an antitampering program in the development of the tampering offset.

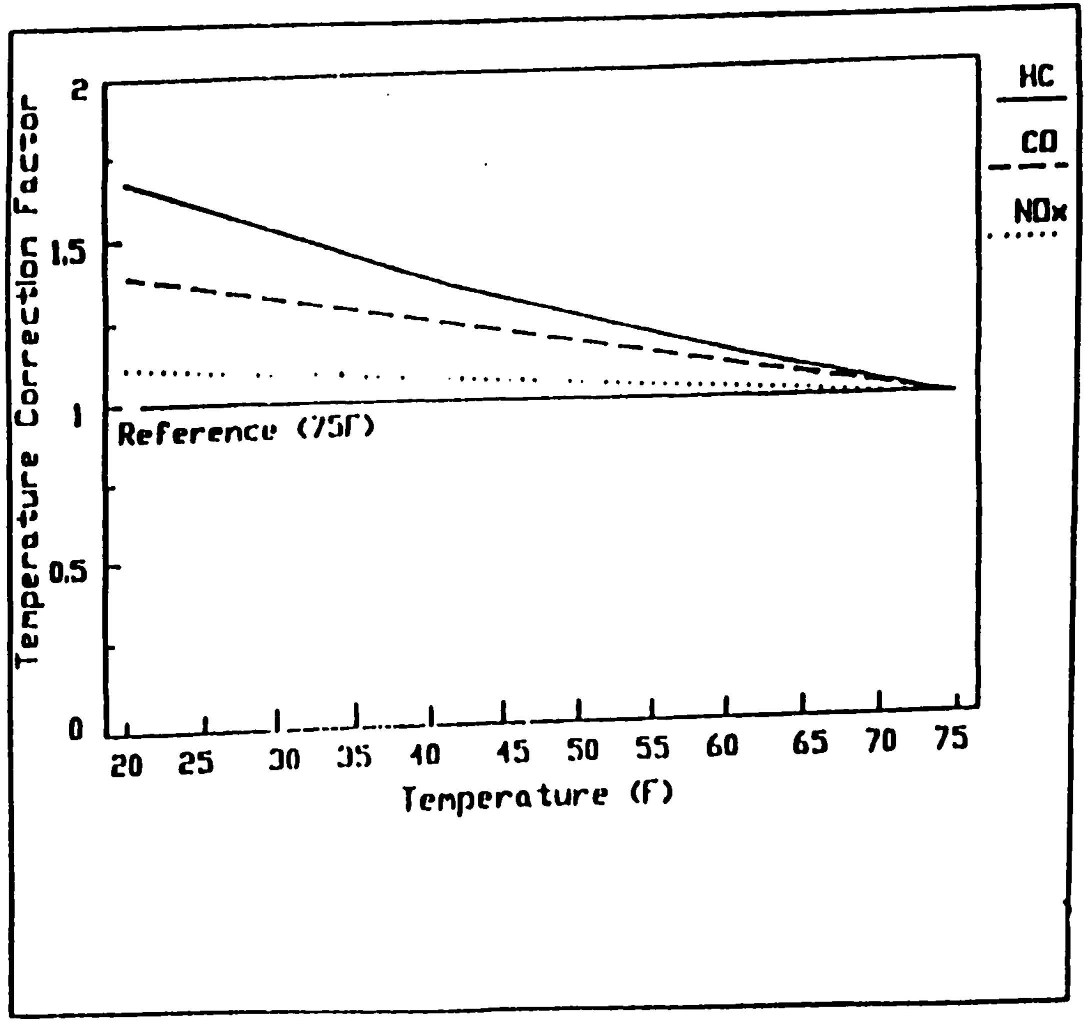


Figure 3-24: Heavy-Duty Gasoline Vehicles Temperature Correction Factors

3.32 Emission Rates Estimated by Fuel Consumption

In MOBILE, the refueling loss factors are calculated for the four gasoline vehicle types (LDGV, LDGT1, LDGT2, and HDGV) in two forms (gram-per-mile and gram-per-gallon). The refueling loss factor is a function of the model year distribution and the fuel efficiency of a vehicle type. This factor is independent of speed. Thus, the refueling loss emission rates can be estimated based on gasoline consumption data by the following equation:

$$ER_k = \frac{RL * GC_k}{(2000\,lb/ton * 453.6\,g/lb)} \qquad (3\text{-}35)$$

where

ER_k	=	Refueling loss emission rate from parish k (ton/day)
RL	=	Refueling loss emission factor (g/gal)
GC_k	=	Gasoline Consumption in parish k (gal/day)

The RL is 3.87 g/gal for the Lake Charles area.

The 1990 state-wide monthly gasoline consumption data for highway usage are available in *Highway Statistics* published by the Federal Highway Administration. For the State of Louisiana, the gasoline consumption data summarized in Table 3-25 are the monthly records from May through August, 1990. The ozone season is May through July for the Lake Charles area. The state wide daily average gasoline consumption rates are calculated under:

The percentages of gasoline sales for the individual parishes with respect to the total state-wide sales are provided by the LaDEQ. The fuel consumption rates (gal/day) of each parish can be calculated by multiplying the parish percentage with the average ozone season daily gasoline consumption data for the state. The results of these refueling loss calculations are shown in Table 3-26.

Table 3-25: The State-Wide Gasoline Consumption for 1990

Month	Day per Month	Amount (1000 gal)
May	31	161,897
June	30	155,810
July	31	156,705
August	31	156,168
Daily Average (May-June) =		5,094,380 gal/day

3.33 Evaporative Emission Factors

In section 3.24.2, six categories of evaporative emissions were presented. This section is designed to present the methodologies used in MOBILE5a for calculating the evaporative emission factors. MOBILE5a modeling process uses a different procedure for modeling evaporative emissions from the procedure presented for exhaust emissions. Note that for the six categories of evaporative emissions cited in section 3-24.2, only hot soak, diurnal, and crankcase emissions are currently regulated by EPA. Refueling losses are regulated by local air pollution control agencies while running and resting loss emissions are regulated through the recently revised evaporative test procedures. Table

Table 3-26: Emission Rates for Refueling Loss

Ozone Nonattainment Area	Ozone Period (Month)	Percent in-Parish (% of LA)	Gas Sales in-Parish (gal/day)	Refuel Factor (g/gal)	Refuel VOC (TPD)
Baton Rouge Area					
Ascension	6-8	1.9	96793	4.07	0.434
East Baton Rouge	6-8	9.9	504344	4.07	2.263
Iberville	6-8	0.7	35661	4.07	0.160
Livingston	6-8	1.8	91699	4.07	0.411
Pointe Coupee	6-8	0.5	25472	4.07	0.114
West Baton Rouge	6-8	0.5	25472	4.07	0.114
Baton Rouge Total	6-8	15.3	779440	4.07	3.497
Lake Charles Area	5-7	4.3	221736	3.87	0.946

Table 3-27: Light-Duty Vehicle Evaporative Emission Standard

Model Year	Diurnal+hotsoak (g/test)	Running Loss (g/mi)	Test Procedure
1971	6.0	-	Carbon Trap
1972-77	2.0	-	Carbon Trap
1978-80	6.0	-	SHED
1981-95	2.0	-	SHED
1996+	2.0	0.05	Enhanced Evaporative

Source: EPA

3-27 shows the LDGVs EPA evaporative emission standards used for certifying vehicles. The standard summarized in Table 3-25 are based on three test procedures - Carbon Trap, SHED and an enhanced evaporative test procedure. An enhanced evaporative test procedure in essence is a modification of the original Sealed Housing Evaporative Determination (SHED) method. Details of the basic function of the evaporative control system used to meet the standards specified in Table 3-25 and the test procedures used to certify vehicles to those standards are contained in the EPA user's guide to MOBILE 4.1 (EPA-AA-TEB-91-01), July 1991.

The evaporative emission factors used in MOBILE5a were derived from the results of EPA's in-use emission factor test program. For the development of the emission factors, the test vehicles were divided into two categories: tampered and non-tampered. The vehicles that had evaporative emission control system malfunctions attributed to deliberate tampering were placed in the category of tampered vehicles. The remaining vehicles were placed in the non-tampered vehicle category. Within each of the above categories, the vehicles were also separated into carbureted and fuel-injected vehicles. The fuel-injected vehicles were further divided into throttle-body-injected (TBI) vehicles and multiport fuel-injected (MPFI) vehicles. The non-tampered emissions estimates are based on the emissions of the vehicles in the emission factor database. Tampered emissions estimates were developed based on a separate testing program in which vehicles were tested in a tampered state.

3.33.1 Hot Soak Emissions

MOBILE5a models hot soak emissions by segregating the vehicle fleet according to fuel delivery system described earlier. However, rather than defining non-tampered and tampered vehicles, a distinction is made as to whether the vehicle has passed the pressure/purge functional evaporative system check. This check is based on EPA pressure and purge tests.

A pressure test is designed to assess the integrity of the fuel tank (including the gas cap) and vapor line leading from the fuel tank to the evaporative canister. Under this procedure, the fuel tank vapor line is disconnected at the canister, a pressure gauge is connected, and the tank is pressurized with nitrogen (through the vapor line) to 14 inches of water. If the pressure drops below 8 inches of water in a two-minute period, the system is considered to be defective. As the name implies, purge testing is intended to identify defects in the evaporative purge system. EPA's procedure consists of placing a flow meter in the vapor purge line between the canister and the engine, and monitoring cumulative flow (in liters) over a dynamometer-based test cycle (i.e., EPA's IM240 test). If the cumulative flow during the test is less than 1.0 liter, the system fails.

It is very difficult to detect evaporative control system defects based on a visual inspection (which was the basic approach in defining tampered and non-tampered vehicles for the MOBILE4 methodology), and the functional checks outlined above provide a much better indication of malfunctioning systems. For that reason, EPA opted to stratify data according to three failure regimes in MOBILE5a: pass pressure/purge, fail pressure, and fail purge. (Vehicles that fail both pressure and purge tests are treated as pressure failures in the model because emissions from pressure failures are generally higher than emissions from purge failures.) The emission data collected for use in MOBILE5a were, therefore, tested according to the pressure/purge procedure prior to emissions measurements.

In order to determine the basic hot soak emission estimates, the emission rate of the passing and failing vehicle are determined separately and the results are weighted by the expected occurrence in the fleet.

Hot soak emissions are adjusted to account for the input RVP and temperature. (The RVP used in determining emission rates is also adjusted downward to account for fuel tank weathering, and the temperature used to determine hot soak emissions is a function of the input minimum and maximum daily temperature.) As an example, the MOBILE5a hot soak emission rate for "passing" multiport fuel-injected vehicles as a function of RVP is shown in Figure 3-25, while the multiplicative temperature correction factor is illustrated in Figure 3-26.

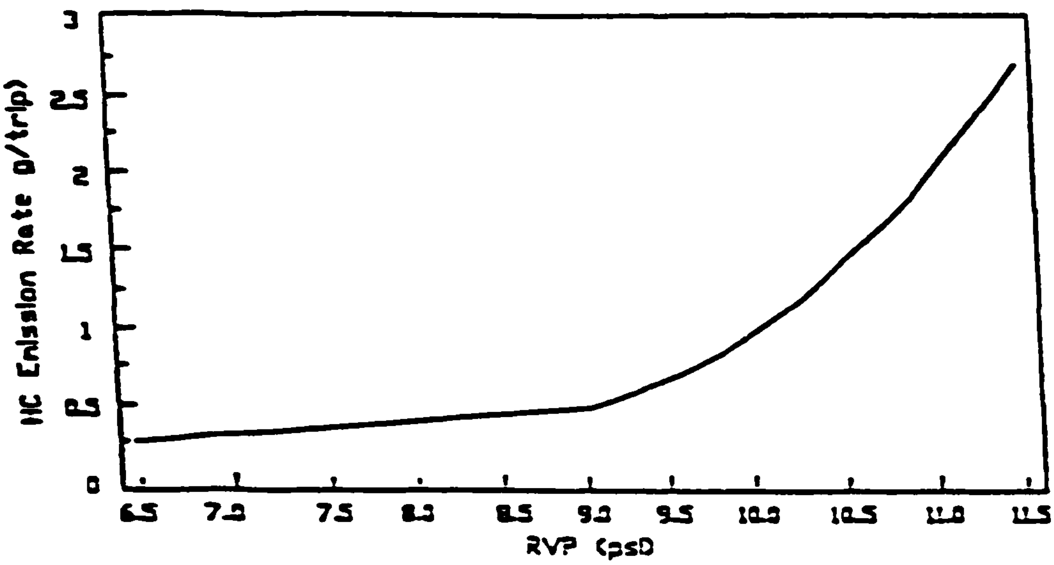


Figure 3-25: MOBILE5a Hot Soak Emissions vs RVP
Multi-Point, Fuel-Injected
"Passing" Vehicles (LDGV)

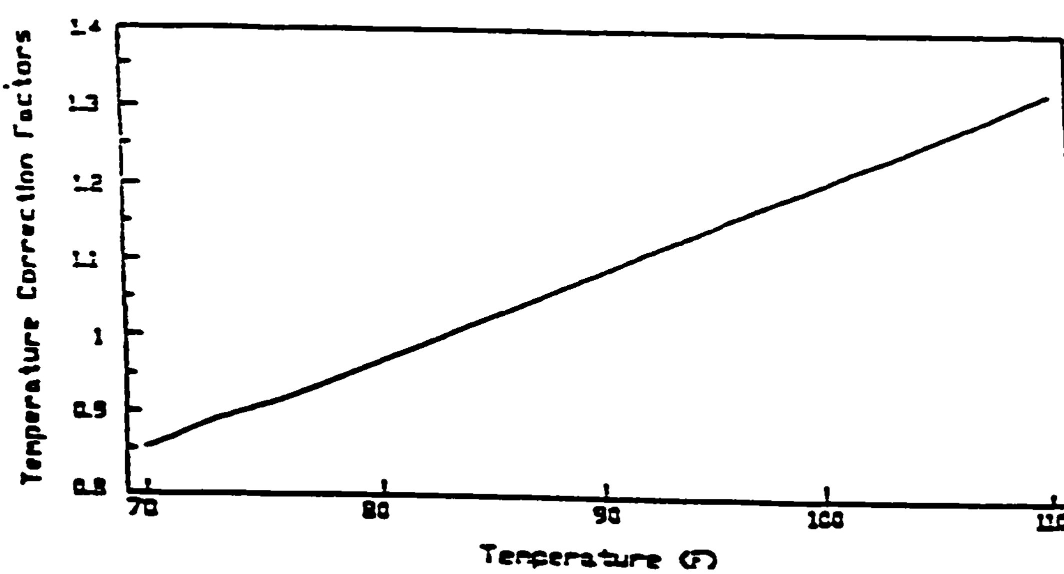


Figure 3-26: MOBILE5a Hot Soak Temperature
Correction Factors Multi-Point,
Fuel-Injection Vehicles (LDGV)

As an example of the weighting procedure, MOBILE5a was run for the 1995 calendar year under typical summer conditions (i.e., 70° - 95° F; 7.8 RVP fuel). For a 1992 model year LDGV, the model predicts 0.3% would be carbureted, 20.2% would have TBI, and 79.5% would be equipped with MPFI. Emission rates from vehicles passing the pressure/purge test are predicted to be as follows:

Carb - 1.996 g/trip

TBI - 0.824 g/trip

MPFI - 0.283 g/trip.

Thus, the composite hot soak emission rate for passing vehicles is calculated as:

HS_{pass}	= 1.966 g/trip * 0.003	(Carb)
	+ 0.824 g/trip * 0.202 * 0.88	(TBI)
	+ 0.283 g/trip * 0.795 * 0.88	(MPFI)
HS_{pass}	= 0.350 g/trip.	

Note that the TBI and MPFI vehicles include a correction factor of 0.88. This accounts for the difference in average fuel tank fill level observed in-use (55%) versus the test procedure fill level (40%). Lower emissions are predicted from the higher fuel tank level because there is less vapor space in the tank, and therefore less vapor generation.

For the hot soak estimates, failed pressure and failed purge emission rates are not stratified according to fuel delivery system. Under the temperature and RVP conditions specified above for this MOBILE run, the hot soak rates are:

$HS_{fail\ purge}$ = 4.305 g/trip, and

$HS_{fail\ press}$ = 4.357 g/trip.

Finally, the above emission rates are composited according to the expected fraction of pass, fail purge, and fail pressure vehicles in the fleet. In this example (i.e., a 1992 model year vehicle analyzed in 1995), the pass/fail regime sizes are:

Pass = 93.15%

Fail Purge = 2.11%

Fail Pressure = 4.74%

Thus, the 1992 model-year hot soak emission rate is:

$$HS_{1992MY} = (0.9315 * 0.350 \text{ g/trip}) + (0.0211 * 4.305 \text{ g/trip}) + (0.0474 * 4.357 \text{ g/trip})$$

$$= 0.623 \text{ g/trip.}$$

3.33.2 Diurnal Emissions

In modeling diurnal losses, MOBILE5a also segregates the fleet according to fuel delivery system and whether the vehicle has passed the pressure/purge functional system check. Emissions are determined as a function of temperature (minimum and maximum, input by the user) and fuel RVP.

The model calculates diurnal rates for "partial" diurnals (i.e., diurnals that are not completed before the vehicle is driven again), full diurnals, and "multiple" diurnals (i.e., cases in which a vehicle sits idle for more than one day). These values are weighted according to their expected occurrence in the fleet to arrive at a single diurnal emission rate in grams/day.

For MOBILE5a, the fraction of vehicles undergoing partial, full, and multiple diurnals was modified to reflect changes in this distribution as a function of vehicle age. This is illustrated in Figure 3-27, which shows the fractional occurrence of diurnal episodes as a function of vehicle age. As seen in the figure, the fraction of full-day and multi-day diurnals increases with vehicle age as these vehicles are used less.

To illustrate, the diurnal emission rates (already weighed for fuel delivery system and pressure/purge failure status) and fraction of each diurnal episode are summarized below for the 1992 model-year LDGV considered in the above example:

Diurnal Episode	Fraction	Emission Rate (g/event
Full-Day	0.3325	2.180
8 a.m. - 11 a.m.	0.3408	0.398
10 a.m. - 3:00 p.m.	0.0747	0.547
8 a.m. - 2 p.m.	0.0390	0.718
Multi-Day	0.1423	7.554
Composite:	0.9293	2.004

It is interesting to note that for this example, the multi-day diurnal episode is the largest contributor to the composite daily emission rate, representing 54% of the composite rate. (Recall that the sum of the diurnal episodes does not equal 1.)

MOBILE5a combines hot soak (HS) and diurnal emissions with crankcase emissions into a single "evaporative" gram per mile emission rate. This is accomplished by multiplying the hot soak emission rate by the number of trips per day and the daily trip fraction: adding this daily hot soak rate to the daily diurnal rate: dividing this sum by the miles per day; and adding the crankcase emissions.

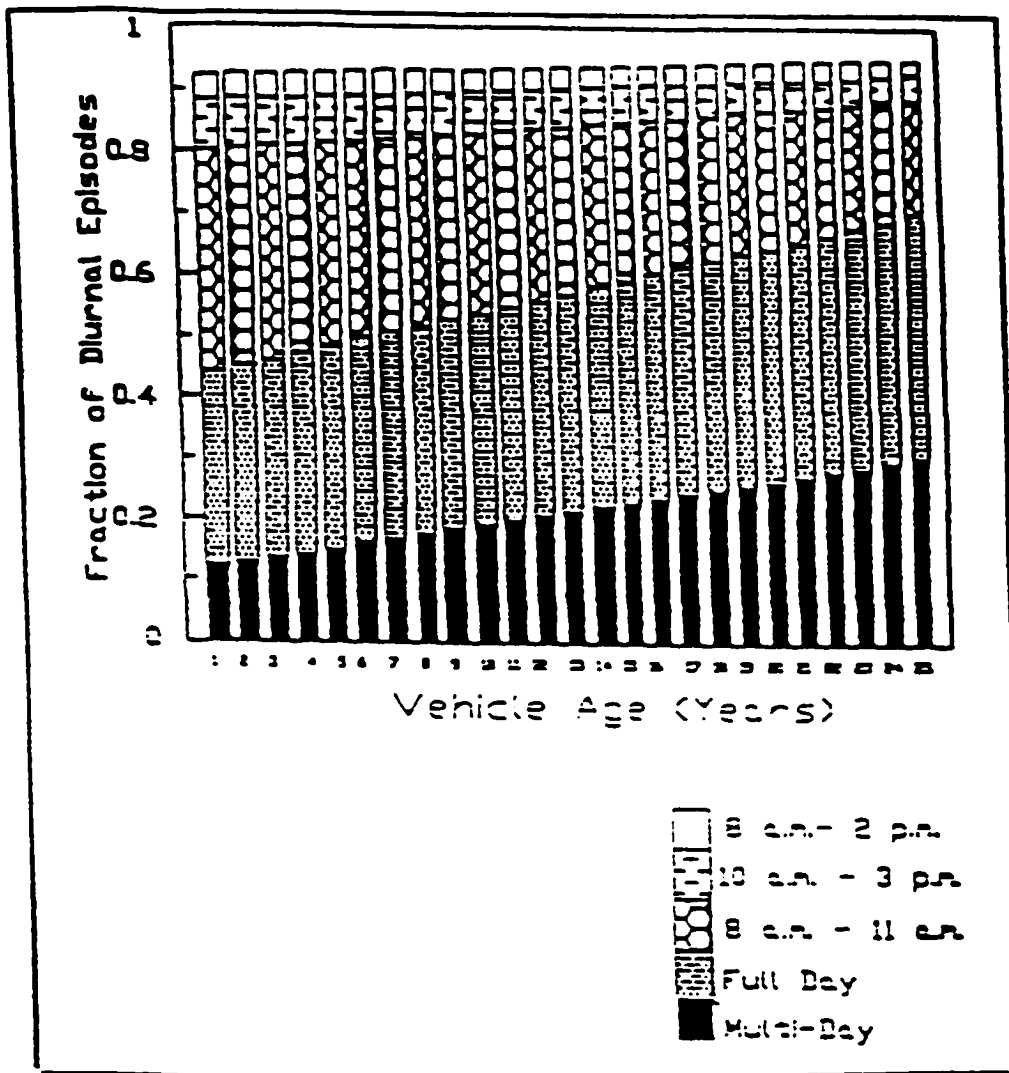


Figure 3-27: Fraction Occurrence of Diurnal
Episodes Used in MOBILE5a

To generate these gram per mile estimates, the following formula is used:

$$BER_E = \frac{\left[\left(HS(g/trip) * trip * fraction\,trips/day\right) + DI\,(g/day)\right]}{CC\,(g/mi)} \qquad (3\text{-}36)$$

$$+ CC(g/mi)$$

where

BER_E	=	Evaporative Basic Emission Rate
HS	=	Hot Soak emission rate (g/trip)
DI	=	Diurnal emission rate (g/day)
CC	=	Crankcase emission rate (g/mile)

Applying equation 3-36 on the example problem presented earlier (i.e., a 1992 model year LDGV in 1995), and also using the average trips per day and miles per day assumed in MOBILE5a will yield the following evaporative emission rate.

$$\frac{\left((0.623\,g/trip * 0.802 * 4.48\,trips/day) + 2.00\,g/day\right)}{34.8\,mi/day} + 0.006\,g/mi$$

$$= 0.128\,g/mi$$

The above calculation is carried out over the 25 model years comprising the fleet. The fleet-average "evaporative" emission rate is then calculated by weighting the model-year-specific values by the assumed travel fraction for each model year.

Figure 3-28 demonstrates graphically the travel parameters used in MOBILE5a to develop LDGV g/mi evaporative emission rates.

3.33.3 Running Losses

Running losses, in g/mi, are calculated by MOBILE with a comparatively simple algorithm. Although a distinction is not made by fuel delivery system, vehicles are stratified according to whether they pass the functional pressure/purge test. Emissions are determined by interpolating among data tables that list running loss emission rates (in g/mi) at four temperatures (80°, 87°, 95°, and 105°F) and four different fuel RVP levels (7.0, 9.0, 10.4, and 11.7). Once emission rates are derived for the two emissions categories, these are weighted according to their expected occurrence in the fleet.

In modeling running losses, MOBILE5a segregates emission rates by pressure/purge failure status. Running loss emission rates from the MOBILE5a model are shown in Figures 3-29 and 3-30 for vehicles passing and failing the pressure/purge test, respectively. (For running losses, pressure failures and purge failures are assumed to have the same emission rate.) These figures indicate that higher temperatures and RVPs result in higher running loss emissions.

3.33.4 Resting Losses

MOBILE5a model calculates resting losses in grams/hour, and emissions are a function of temperature and the type of canister in the evaporative control system (i.e., open bottom versus closed bottom). As an example, MOBILE5a estimates resting loss emissions for a vehicle with an open bottom canister to be 0.29 grams/hour at 100°F, while the value for a closed bottom canister under the same conditions is 0.13 grams/hour. Resting losses are also converted to an equivalent g/mi value by summing emissions throughout the day and dividing by miles/day.

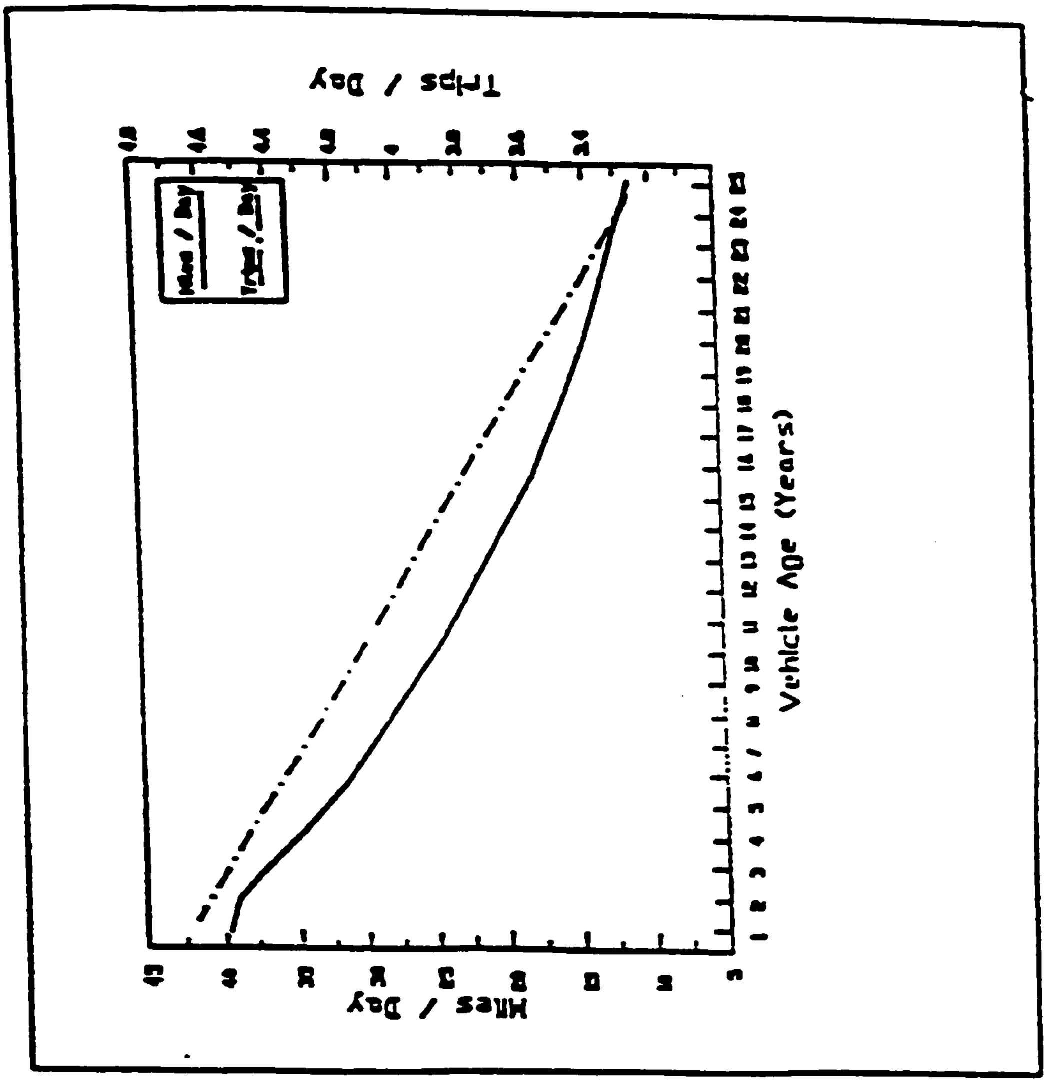


Figure 3-28: Travel Parameters Used in MOBILE5a to Develop LDGV g/mi Evaporative Emission Rates

3.33.5 Crankcase Emissions

Crankcase emissions are largely controlled by positive crankcase ventilation (PCV) systems that have been installed on new vehicles since the early 1960s. Crankcase emissions, therefore, are the result of tampered or defective PCV systems. MOBILE models crankcase emissions by assuming a certain tampering rate (which increases with vehicle age) and multiplying that value by an uncontrolled crankcase emission rate. Overall, crankcase emissions are very small, generally contributing only a few hundredths of a gram per mile to the HC emission rate.

3.34 Modeling of Inspection/ Maintenance (I/M Programs)

On-road motor vehicles have been required to meet increasingly stringent emission standards when new for over 25 years, but they still are significant contributors of ozone precursors and carbon monoxide in most urban areas. Much of this contribution is attributed to vehicles that exceed certification standards in customer service. Although EPA has implemented programs to improve in-use emission control system durability (e.g., in-use recall, 100,000-mile certification standards), a properly designed inspection and maintenance (I/M) program remains one of the most effective means of ensuring that high-emitting vehicles are identified and repaired. Congress recognized the importance of I/M programs in reducing vehicular emissions in urban areas when drafting the Clean Air Act Amendments of 1990, and directed EPA to develop performance requirements and other standards for basic and enhanced I/M programs. These guidelines were

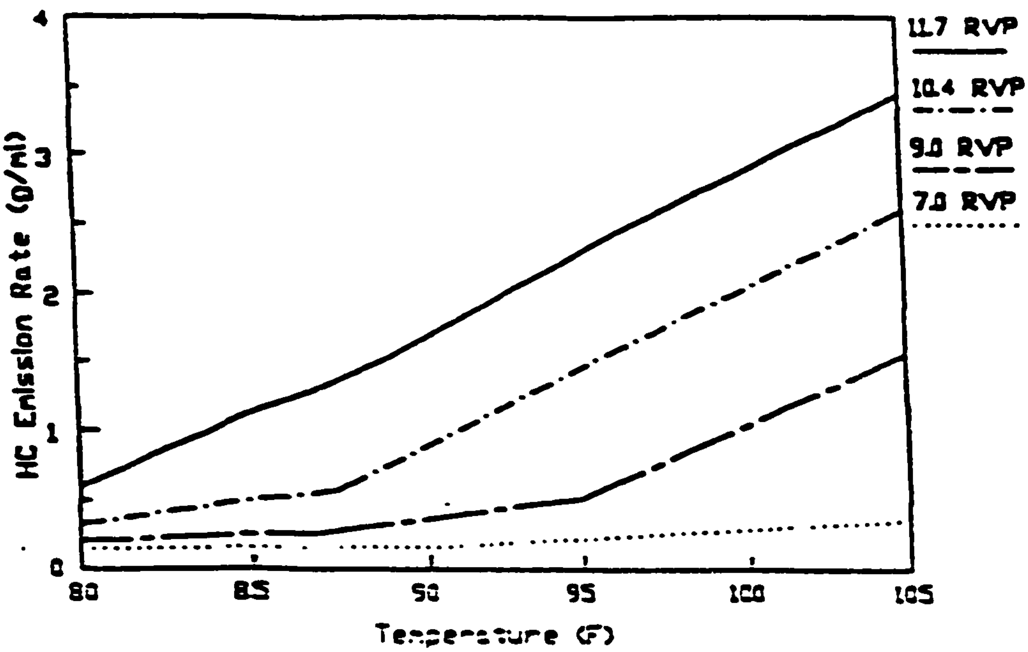


Figure 3-29: MOBILE5a Running Loss Emission on Rates for LDGV Passing the Pressure/Purge Test

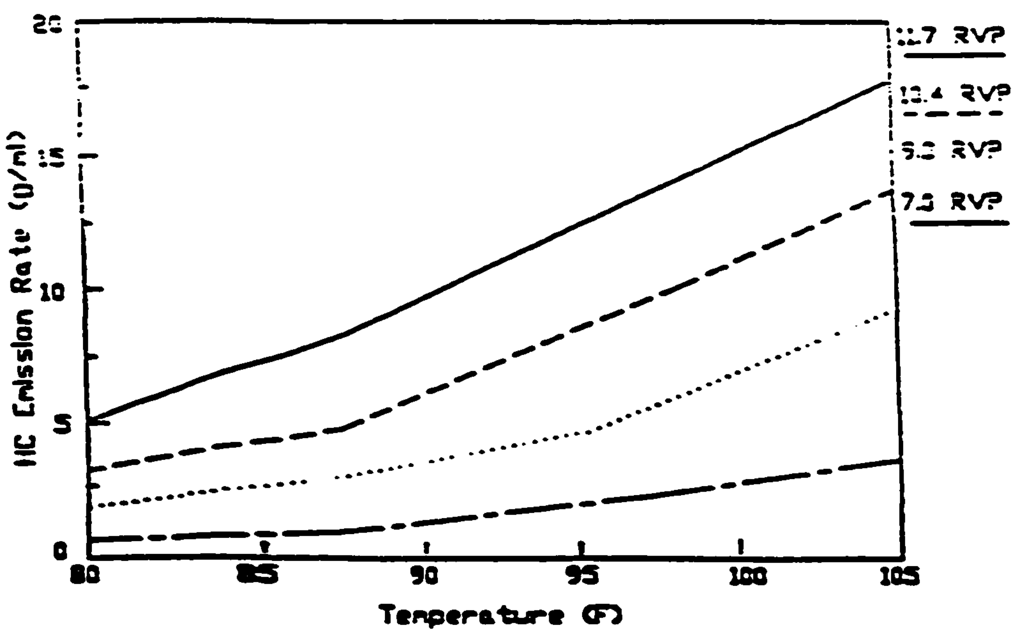


Figure 3-30: MOBILE5a Running Loss Emissions Rates for LDGV Failing the Pressure/Purge Test

published in November 1992, and they specify a number of features associated with both program types.[1]

Below summarizes the methodology MOBILE5a uses to estimate the emission benefits as a result of I/M programs. When an I/M program option is involved in a MOBILE5a run, the base emission rate ("BER" in equation 3-24) is adjusted to reflect the presence of that program. The adjustment takes into account the features of the I/M program being modeled, such as:

- program type (centralized or decentralized),
- inspection frequency (annual or biennial),
- test type (idle, idle/2500,loaded idle,orIM240),emission cutpoints (for IM240),
- waiver rate, and
- compliance rate (i.e., the fraction of vehicles subject to the program that complete the process to the point of receiving a certificate of compliance or a waiver).

To perform the I/M adjustment on the BER, the following methodology is employed:

$$BER_{I/M} = BER_{Non-I/M} * \left\{1 - \left[CRED_{I/M} * (1 - WVR)\right] * ADJ_{Compl}\right\} \qquad (3\text{-}37)$$

where $CRED_{I/M}$ is the I/M credit for the test type, cutpoints, frequency, model year, and vehicle age being considered; WVR is the user-input waiver rate; and ADJ_{Compl} is an adjustment that accounts for the user-input compliance rate. The above calculation is

[1]U.S. Environmental Protection Agency, "Inspection/Maintenance Program Requirements: Final Rule", Federal Register, Vol. 57, number 215, November 5, 1992.

valid for centralized program types; if a decentralized program is specified, the calculation includes an adjustment that reduces the overall effectiveness of the program by 50%.

As an example, consider a calendar year 2000 MOBILE5a run in which an annual, centralized IM240 program is specified with 0.8 g/mi HC and 20.0 g/mi CO cutpoints. Further, assume that the I/M compliance rate is 96% and the waiver rate is 3%. (These are the MOBILE parameters that EPA has chosen for developing the enhanced I/M performance standards.) The non-I/M HC base emission rate for a 1992 model-year LDGV (analyzed in the year 2000) is 2.153 g/mi, and the base emission rate including the effects of the above I/M program is

$$BER_{I/M} = 2.153 * (1 - [0.476 * (1 - 0.03)] * 0.92)$$

$$BER_{I/M} = 2.153 * (1 - 0.425) = 1.238 \text{ g/mi.}$$

Several items are worth noting in the calculation above. First, the I/M credit is reduced from 47.6% to 42.5% when accounting for the effects of the waiver rate and the compliance rate. Second, the adjustment performed to account for the compliance rate is nonlinear (i.e., although the compliance rate was 96% in the above example, the I/M benefits [1]are reduced by 8% rather than 4%). This adjustment inherently assumes that the I/M failure rate of non-complying vehicles will be higher than that of the rest of the fleet.[1]

[1] U.S. Environmental Protection Agency, "MOBILE5a Use Chapter 2, Draft 4a, December 3, 1992.

3.35 Generating Emission Estimates for the Target Area

Having presented the necessary procedures used in MOBILE5a model for determining the emission factors for on-road mobile source emission producing processes, this section presents the procedures used to generate the emission estimates for the research target area. In section 3.22, details of MOBILE5a model user inputs were presented. This section presents the development of the model inputs for the execution of MOBILE5a model software.

(a). Control Flag Settings

The first portion of a MOBILE5a input file consists of a series of control flag settings. These flags are defined in Chapter 2 of the MOBILE4.1 User's Guide. These flags are set based on the data availabilities and the U.S. EPA guidelines. Table 3-28 summarizes the settings used in this analysis.

The emission factors are estimated using a number of MOBILE5a default values. No inspection and maintenance (I/M) program is assumed in the model runs because Louisiana did not have an I/M program in place in 1990. The only locality-specific one time data applied to this analysis are the vehicle registration distributions, anti-tampering program. (ATP), and the local area parameter record. The vehicle registration distributions was earlier shown in Table 3-22.

(b). Anti-Tampering Program

A decentralized anti-tampering program (ATP) has been in place for the ozone non-attainment area of Calcasieu Parish annually since 1986. The MOBILE5a data inputs were provided by the Louisiana Department of Environmental Quality, (LaDEQ). The vehicle types LDGV, LDGT1, and LDGT2 as described on Table 3-27, are subject to the ATP inspection. The program includes vehicles in the model years from 1980 to-date. A maximum allowable year 2020 serves as the last model year. Table 3-28a shows the summary of the ATP parameters used for the emission estimates.

(c). Local Area Parameter (LAP) Record

The LAP record consists of six basic parameters and two optional parameters. Only the six basic parameters are specified in this analysis which include scenario name, minimum and maximum daily temperatures, period-1 and period-2 Reid vapor pressures (RVP), and period-2 RVP start year.

Table 3-28b shows the accumulative monthly ozone exceedances for 1988-1990.

(d). Temperature

The minimum and maximum temperatures used for the emission estimates are based on the procedures described in the Interim Guidance for the Preparation of the Mobile Source Emission Inventories. A copy of the temperature preparations guidance is included in Appendix E. Based on the guidance, the three months of the ozone season

Table 3-28: MOBILE5a Control Flag Settings

Record Number	Variable Name	Content and Code Used
1	PROMPT	1 = prompting, vertical format
2	PROJID	80 characters for title
3	TAMFLG	1 = Use MOBILE5a tapering rates
4	SPDFLG	1 = User inputs one speed for all vehicle types
5	VMFLAG	2 = User inputs VMT mix
6	MYMRFG	3 = User inputs registration distributions; use MOBILE5a annual mileage accumulation rates
7	NEWFLAG	1 = Use MOBILE5a basic emission rates
8	IMFLAG	1 = No I/M program assumed
9	ALHFLG	1 = No corrections to emission factors
10	ATPFLG	2 = ATP assumed
11	RLFLAG	5 = Refueling emissions accounted for in area sources
12	LOCFLG	1 = Different LAP record inputs for each scenario
13	TEMFLG	1 = MOBILE5a calculates temperatures to be used in correction of emission factors from input values of minimum and maximum ambient daily value read as input for ambient daily temperature is over-ridden by calculated values.
14	OUTFMT	3 = 112 column descriptive
15	PRTFLG	4 = All three pollutants
16	IDLFLG	2 = Idle emission factors calculated and printed
17	NMHFLG	3 = VOC emission factors
18	HCFLAG	3 = Sum and components printed, plus evaporative and refueling emission factor information.

Table 3-28a: Summary of the ATP Parameters

FIELD	Content, Variable Name, Code	Values Used
1	Program start year	1986
2	First model year	1980
3	Last model year	2020
4	Vehicle types subject to inspection 1 =NO, 2 = YES)	
	LDGV	2
	LDGT1	2
	LDGT2	2
	HDGV	1
5	Program type (1 = centralized, 2 =	2
	decentralized)	1
6	Inspection frequency (1 = annual, 2 = biennial)	
7	Compliance Rate (%)	90
8	Inspection performed (1 = NO, 2 = YES)	
	Air pump system	2
	Catalyst	2
	Fuel inlet restrictor	2
	Tailpipe lead deposit test	2
	EGR system	1
	Evaporative control system	1
	PVC system	2
	Gas Cap	2

for the ozone exceedances for the year 1988 through 1990 are summarized in Table 3-28b. The three months with the highest ozone exceedances are May, June, and July. Thus, these three months are assigned as the ozone season for the study area.

Temperatures and ozone readings for the 10 dates with the highest observed one-hour ozone concentrations are summarized in Table 3-29 for the Calcasieu Parish.

The resulting ambient temperature calculated from MOBILE5a is 83.0°F for the study area.

(e). Reid Vapor Pressure (RVP)

The RVP value is provided by the U.S. EPA Region VI Office. The wholesale RVP from May through September is 8.3 psi for the New Orleans area which is the nearest city for the source of the data. An RVP value of 8.3 was used in the analysis for the study area.

Table 3-28b: Accumulative Monthly Ozone Exceedances for 1988-1990

Month	Lake Charles Area of Calcasieu
January	0
February	0
March	0
April	1
May	3
June	3
July	2
August	0
September	1
October	1
November	0
December	0

In this analysis, the calendar year of the emission inventories is 1990 which is the same as the start year of the period-2 RVP (the periodd-1 RVP is ignored by the model). The given value, 8.3 psi, is used in the input data file, for both the period-1 and period-2 RVP's. A summary of the local area parameter (LAP) records is shown in Table 3-30 for the study area.

Table 3-29: Temperatures for Calcasieu Parish

Date of Top Ten	Top Ten Readings (ppm)	Daily Minimum Temperature, F	Daily Maximum Temperature, F
5/13/88	0.134	56	85
5/19/88	0.126	66	89
6/2/88	0.124	63	85
6/18/88	0.126	70	93
7/26/88	0.132	73	88
5/28/89	0.131	73	95
6/20/89	0.125	72	93
6/9/90	0.118	73	90
6/11/90	0.114	70	91
7/31/90	0.147	72	92
Average		68.8	90.1

Source: LaDEQ

Table 3-30: LAP Record for Calcasieu Parish

FIELD	Content, Variable Name, Code	Calcasieu Parish
1	Scenario name (SCNAME)	
2	Minimum daily temperature (TEMMIN), in F	68.8
3	Maximum daily temperature (TEMMAX), in F	90.1
4	"Period 1" RVP (RVPBAS)	8.3
5	"Period 2" RVP (IUSRVP	8.3
6	"Period 2" start year (IUSESY)	90

Source: LaDEQ

(f). Scenario Section

In the scenario section, five data fields need to be entered by the user are summarized in Table 3-31.

Based on the above inputs to the MOBILE5a computer model, a run was made for the 1990 base year for the study area. Subsequent runs were made for 1993, 1995, 1996 and 1997 respectively.

The emission factors are described as grams per mile (gm/mi) traveled by a mixture of the eight vehicle types listed in Table 3-23. The grams per mile can be converted in terms of tons per day as will be demonstrated. The emission factors are functions of the speeds which are assigned to the roadways based on their functional classifications. The emission rate for each roadway functional class for the study area is therefore calculated using the following mathematical model:

$$ER_{i,j} = \frac{EF_{i,j} * VMT_j}{2000 lb/ton * 453.6 g/lb} \quad (3\text{-}38)$$

where

$ER_{i,j}$ = Emission rate for pollutant i, road class j (ton/day)

$EF_{i,j}$ = Emission factor for pollutant i, roadway class j (gm/mi)

VMT_j = Vehicle miles traveled for roadway class j (mi/day).

The above procedures were used to quantify the on-road mobile source emissions for the Calcasieu Parish area of Louisiana and the details of the results are presented in Chapter Four.

Table 3-31: Summary of the Scenario Records

FIELD	Content, Variable Name, Code	Values Used
1	Region for which emission factors are to be calculated (IREIN)	Low altitude
2	Calendar year of evaluation (CY)	90
3	Average speed to be used in emission factor calculations (SPD or PSD (8))	One speed for all vehicle types
4	Ambient temperature (AMBT), °F	83.0(Calcasieu Parish)
5	Operating mode fractions (PCCN, PCHC, PCCC) (%) of VMT accumulated by: PCCN - Noncatalyst vehicles in cold start mode PCHC - Catalyst equipped vehicles in hot start mode PCCC - Catalyst equipped vehicles in cold start mode	20.6 27.3 20.6
6	Month of evaluation	July

Source: LaDEQ

3.36 Sensitivity of Emission Rates to Vehicle Speed

In order to address the last objective of this study, a sensitivity analysis of emission rates to vehicular speeds at a given temperature are performed. The process involves the plotting of the relative emission rates at a given temperature on the y-axis versus varying temperatures on the x-axis for the pollutants HC, $N0_x$, and Co. The result is presented in the result section to show how each pollutant is impacted in the study area. The analysis simply shows the relationship between, travel speed and emission rates at a given temperature and it excludes trip-starts, trip-ends and diurnal emissions for the region.

Finally, the VMT trends in the region are analyzed with such variables like the population trends, employment growth rates and economic growths in order to determine their impacts on NAAQS for the study area.

In summary, the following procedures have been performed in sections 3.16 through 3.35:

I. An overview of the air quality modeling techniques and the selection process for the selection of the MOBILE5a modeling technique.

II. The use of equations 3-24, 3-25,3-26, 3-27and 3-28 for determining the emission factors for LDGVs.

III. The use of equations 3-32, 3-33 and 3-34 for determining the emission factors for heavy duty gasoline and diesel vehicles.

IV. The use of equation 3-35 for determining the emission factors due to refueling loss factors.

V. The use of equation 3-39 for determining total emission rate for each pollutant.

VI. A sensitivity analysis procedure to demonstrate the relationship between travel speed and emission rates of each pollutant in the study area.

CHAPTER 4

RESULTS

Based on the procedures established in chapter three, the results of the research investigations are presented in this chapter in four basic sections. The first section presents the results of the TCMs acceptability as perceived by the citizens of Calcasieu parish of Louisiana. The next section presents the forecasted VMTs. The third section shows the cost effectiveness of the most favored TCMs in terms of improving the air quality for the study region. The last section shows the evaluation of the air quality situation for the study region as well as the sensitivity analysis of relative emission rates on speeds.

4.1 The Degree of TCMs Acceptability

Again, based on the procedures established in section 3.5 of chapter three, the results of the transportation control measures (TCMs) in terms of their degrees of acceptability are presented in both Table 4-1 and Figure 4-1 for the research target area. Simply stated, the citizens of Lake Charles area of Calcasieu Parish in Louisiana would like to see implemented for the region, Traffic Flow Improvements that include such measures as adjustments to traffic signal timings, roadway improvements such as the creation of one reversible lanes, all tailored to added highway capacity and improved level of service to the existing highway infrastructure. The other two most favored TCMs are the Improved

Table 4-1: The Distribution of Responses to TCMs by Degree of Acceptability Mean Responses, and Total Number of Responses

DOA	TFI	IPT	ETM	BPP	FWS	ARSI	HOVF	PRFP	EVIC	MAC	ECSC	SEC	PM	VRV	TRO	VLR
1	141	146	195	295	231	233	299	278	394	480	638	628	647	849	793	1204
2	103	125	158	171	208	217	282	308	363	406	430	448	483	334	481	479
3	174	280	335	312	396	439	332	393	460	410	397	392	402	267	379	197
4	789	908	968	750	778	860	825	787	681	622	478	486	445	389	345	181
5	935	672	477	6097	490	380	404	275	306	212	172	154	155	304	156	93
Mean	4.06	3.86	3.64	3.56	3.52	3.44	3.35	3.23	3.12	2.85	2.58	2.57	2.52	2.52	2.35	1.83
Total Number	2142	2131	2133	2137	2103	2129	2142	2041	2104	2130	21155	2108	2132	2143	2154	2154

Note: (a) TRO = Trip Reduction Ordinance; VLR = Vehicle Use Limitations or Restrictions; ETM = Employee Based Transportation Management; IPT = Improved Public Transit; PM = Parking Management; PRFP = Park and Ride or Fringe Parking Facilities; FWS = Flexible Work Schedules; TFI = Traffic Flow Improvements; ARS = Area-wide Sharing Incentives; HOVF = High Occupancy Vehicle Facilities; MAC = Major Activity Centers; SEC = Special Events Control; BPP = Bicycling and Pedestrian Programs; EVIC = Extended Vehicle Idling Control; ESC= Extreme Cold Start Control; VRV = Voluntary Removal of Pre-1980 Vehicles; DOA = Degree of Acceptability; (b) 1 = Highly Unacceptable; 2= Unacceptable; 3 = Undecided; 4 = Acceptable; 5 = Highly Acceptable; DOA = Degree of Acceptability.

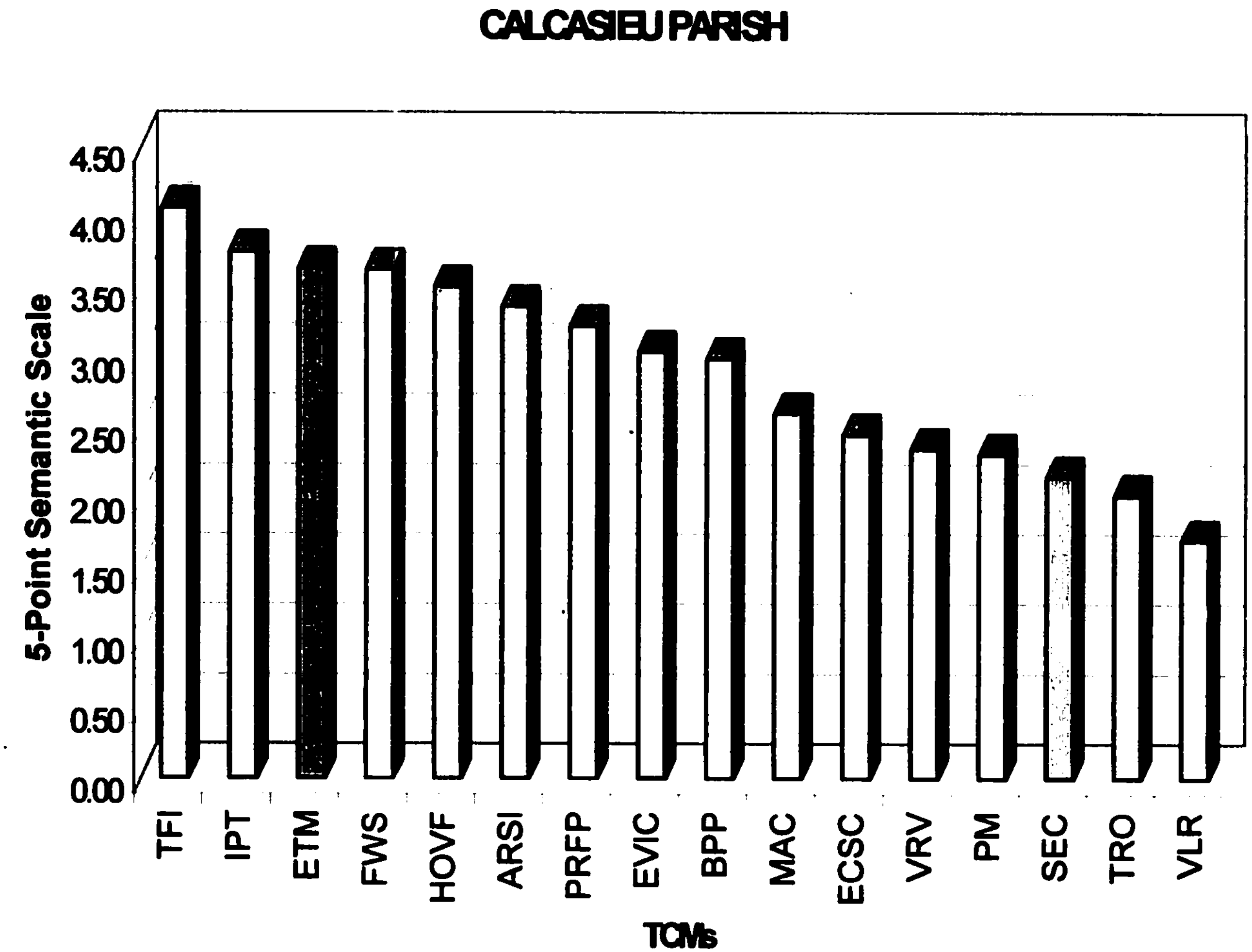


Figure 4-1: Distribution of Degree of Acceptability of TCM [Mean]

Public Transit and the Employer-Based Transportation Management. Table 4-1 and its graphical representation in Figure 4-1 show the distribution of responses to TCMs by degree of acceptability, mean responses and the total number of responses. A plot of a five-point semantic scale on the y-axis versus mean values on the x-axis was made in Figure 4-1 to show the degree of acceptability of a given TCM for Calcasieu Parish of Louisiana. Table 4-2 shows the distribution of responses to TCMs acceptability by rank order while Figure 4-2 shows the distribution of responses to most unfavored TCMs. From Figure 4-2, one can see that the Vehicle Use Limitation or Restriction (VLR) TCM has the highest number of highly unacceptable responses, and this is followed by Voluntary Removal of Pre-1980 Vehicles (VRV). Based on the results of the sixteen TCMs evaluation, the MPO of Lake Charles and the transportation planners of the research target area have been provided with the necessary information for making informed decisions as to what TCMs to implement for air quality benefit. Specifically, single occupancy vehicles (SOVs) and based on literature review, pre-1980 vehicles have been found to pollute more and restrictions on the use of SOVs and the removal of pre-1980 vehicles, therefore, have the potential for significant air quality benefit by reducing mobile source emissions. Stiff opposition to limit the use of SOVs and Pre-1980 vehicles by the citizens of the research area implies that the policy makers for the research area need to design programs to discourage the use of SOVs and programs to market and sell other beneficial TCMs with stiff public opposition. Furthermore, budget constraints and right-of-way limitations may be major constraints for implementing the most favored Traffic Flow Improvement TCM.

Table 4-2 : Distribution of TCMs by Rank Order, Mean Values, and Sample Size

Transportation Control Measures	Mean	Std Dev	Minimum	Maximum	N	Rank
Traffic Flow Improvements	4.06	1.14	1	5	2142	1
Improved Public Transit	3.86	1.13	1	5	2131	2
Employee-based Transportation Management	3.64	1.17	1	5	2133	3
Bicycling and Pedestrian Programs	3.56	1.34	1	5	2137	4
Flexible Work Schedules	3.52	1.25	1	5	2103	5
Area-Wide Ride Sharing Incentives	3.44	1.21	1	5	2129	6
High Occupancy Vehicle Facilities	3.35	1.31	1	5	2142	7
Park and Ride or Fringe Parking Facilities	3.23	1.25	1	5	2041	8
Extended Vehicle Idling Control	3.12	1.33	1	5	2104	9
Major Activity Centers	2.85	1.33	1	5	2130	10
Extreme Cold Start Control	2.58	1.34	1	5	2115	11
Special Events Control	2.57	1.32	1	5	2108	12
Parking Management	2.52	1.31	1	5	2132	13
Voluntary Removal of Pre-1980 Vehicles	2.52	1.50	1	5	2143	13
Trip Reduction Ordinance	2.35	1.31	1	5	2154	15
Vehicle Use Limitations or Restrictions	1.83	1.16	1	5	2154	16

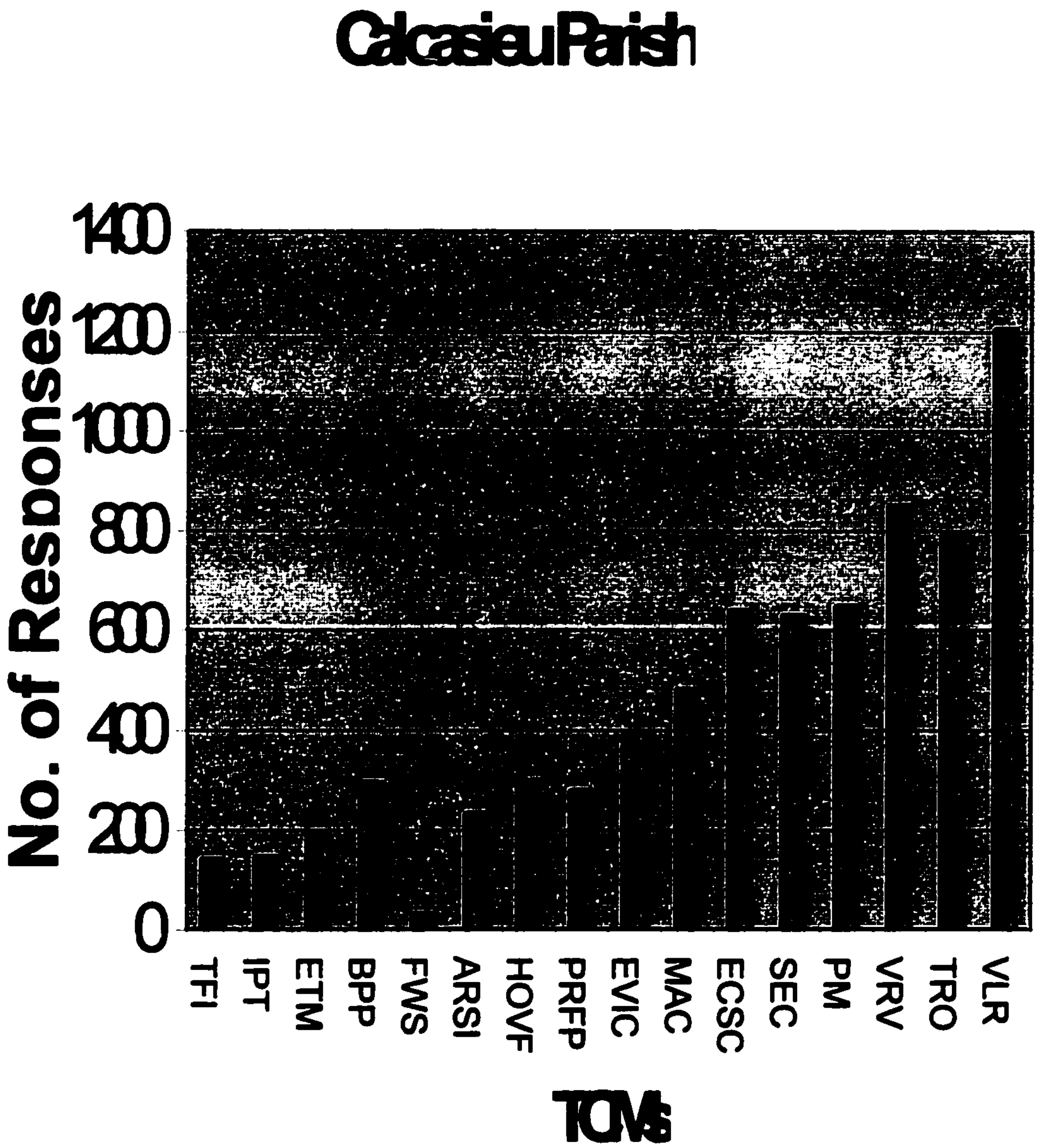


Figure 4-2: Distribution of Responses to TCMs
(Highly Unacceptable)

This is, therefore, to say that the results of the TCM acceptability as presented will have broad implications for Calcasieu Parish if the region is to move from its current nonattainment status to that of attainment status.

4.2 Vehicle Miles of Travel (VMT) Estimates

Using the methodology demonstrated in chapter three, and applying equations 3-7 through 3-12, a mathematical regression model was developed and used to forecast the VMT for the year 1990 through 2021. To ensure for the validity of the model, equations 3-13 through 3-19 were used in testing of the statistical significance of the model as a good predictor model. Details for the validity of the predicting model are demonstrated and shown in Appendix D of this document. Table 4-3 shows the daily vehicle miles of travel (DVMT) by highway functional classification for the research target area.

The CAAA of 1990 requires that both VMT and vehicle trips growth rates in non-attainment areas match the population growth rates. Table 4-4 shows the annual population growth rates for the research target area. In terms of the 1990 CAAA, Table 4-5 column 4 shows the DVMT the region needs to eliminate in order to attain or remain in attainment status for NAAQS.

Table 4-5 shows the annual VMT growth rates for Calcasieu Parish area of Louisiana. In terms of the 1990 CAAA, Table 4-5 column 4 shows the DVMT the region needs to eliminate in order to attain or remain in attainment status for NAAQS.

Based on the fact that the study area is classified as "marginal" in terms of meeting the ambient air quality standards for ozone under the 1990 CAAA, the area is not required to meet the strict outcome of the results presented in Table 4-5. Furthermore,

Table 4-3: Daily Vehicle Miles of Travel by Functional Classification

Year	FC-01 DVMT	FC-02 DVMT	FC-06 DVMT	FC-07 DVMT
1990	787,448	46,812	121,080	379,513
1991	804,337		122,252	391,433
1992	821,225		123,425	403,353
1993	838,114	50,053	124,597	415,273
1994	855,002		125,769	427,193
1995	871,891		126,942	439,112
1996	888,779	53,294	128,114	451,032
1997	905,668	54,375	129,287	452,952
1998	922,557	55,455	130,459	474,872
1999	939,451	56,144	131,632	406,790
2000	56,340	57,216	132,804	498,710
2003	1,007,007	60,432	136,321	534,470
2005	1,040,785	62,577	138,666	558,310
2008	1,091,452	65,793	142,183	594,070
2010	1,125,230	67,937	144,528	617,910
2013	1,175,897	71,153	148,045	653,670
2015	1,209,675	73,298	150,390	677,510
2021	1,311,009	79,730	157,424	749,030

Year	FC-08 DVMT	FC-09 DVMT	FC-11 DVMT	FC-14 DVMT
1990	95388	161300	921815	394853
1991	97459		938907	397145
1992	99530		955999	399437
1993	101601		973091	401729
1994	103672		990182	404021
1995	105743		1007274	406313
1996	107814	179749	1024366	408605
1997	109885	183684	1041458	410897
1998	111956	187706	1058550	413189
1999	114027	190267	1075648	415478
2000	116098	193509	1092740	417770
2003	122311	203235	1144016	424646
2005	126453	209719	1178200	429230
2008	132666	219444	1229476	436106
2010	136808	225928	1263660	440690
2013	143021	235654	1314936	447566
2015	148163	242138	1349120	452150
2021	159589	261589	1451672	465902

Table 4-3: contd

Year	FC-16 DVMT	FC-17 DVMT	FC-19 DVMT
1990	314860	2367	17011
1991	323156		
1992	331452		
1993	339748	2370	
1994	348004		
1995	356341		
1996	364637		17145
1997	372933	2381	17172
1998	381229	2383	17199
1999	389526	2385	17219
2000	397822	2387	17242
2003	422711	2393	17312
2005	439303	2397	17358
2008	64192	2404	17428
2010	480874	2408	17474
2013	505673	2414	17544
2015	522265	2419	17590
2021	572042	2431	17729

Note: FC = Functional Classification

Table 4-4: Annual Population Growth Rates for Calcasieu Parish Area of Louisiana

Period	Percent Annual Growth Rate
1990-1997	0.621
1998-2003	0.609
2004-2008	0.607
2009-2013	0.607
2014-2021	0.613

Source: MPO of Calcasieu Parish

Table 4-5: Distribution of Annual VMT, Growth Rates, and Excess DVMT

Period	DVMT	Percent Annual Growth Rates	Excess DVMT
1990-1997	3,242,447 - 3,680,692	1.67	34,662
1998-2003	3,755,555 - 4,074,854	1.42	30,458
2004-2008	4,138,926 - 4,395,214	1.24	26,199
2009 -2013	4,459,286 - 4,715,573	1.15	24,214
2014-2021	4,770,645 - 5,228,147	1.17	26,623

while the excess VMT presented in Table 4-5 may serve as a good target of VMT to eliminate in order to achieve air quality benefits for the region, it must be emphasized that additional air quality analyses are required before a conclusion can be reached regarding the nonattainment status of the research target area.

4.3 Comparative Evaluation of the Four Most Favored TCMs

In section 4.1, it was shown that the most acceptable TCMs are Traffic Flow Improvements, Improved Public Transit, and Employer-Based Transportation Management. The scope of this analysis is therefore limited to the air quality impacts and cost-effectiveness of the three TCMs. However, the HOV Lanes TCM which was not on the top list will also be evaluated to enable the MPO of Calcasieu to better assess their strategies to use HOV Lanes as a viable TCM option for the region.

In order to analyze the travel impacts of a given TCM, the baseline travel characteristics data presented in both Table 3-17 and 3-18 are used as input data for the

TCM Tools Software. A great deal of the input data were primary data collected from the employee survey (ES). The TCM Tools Software was developed for San Diego Association of Governments by Sierra Research, Inc. The software is Lotus 1-2-3 spreadsheet based software that is designed to estimate the effect of each TCM on the travel parameters such as trips, VMT and speed that influence emissions. The software has three modules - transportation module, emission module, and cost-effectiveness module. Only the transportation module component was used in this research. This module works by combining information on local travel estimates with assumptions about how travelers will respond to individual TCMs. Details regarding the use of the software and the software itself can be obtained by contacting San Diego Association of Governments in California. A brief explanation relating to the formulas and assumptions the spreadsheet uses for the TCMs analyzed are contained in Appendix D of this document.

To determine the probable induced traffic due to any improved traffic flow, a TRANPLAN and Traffic Assignment computer simulations program was run by the MPOs office for the study area. The result provided an induced traffic for two percent, five percent and eight percent speed increases for a typical road net-work in the area over the base scenario. The induced VMT of 4980 for 5% speed increase was used as input data in the Transportation Travel Impact Module. Also for the HOV TCM, an impact study was conducted assuming a 40-mile HOV freeway. The travel and the emissions impacts of the four specified TCMs are presented in Table 4-6. The results show the peak and off-peak trip reductions, the total estimated VMT reductions, speed increases and the estimated reduction in daily commute trips for each scenario as well as the estimates of

Table 4-6: Travel and Emissions Impacts of TCMs

TCM Specific	Peak Trip Reductions		Off-Peak Trip Reduction		Total VMT Reduction		Speed Increases		Daily Commute Trip Reduction	Reduction in Emission in percent		
	Number	% of Peak VMT	Number	% of Off-Peak	Number	% of Total VMT	Peak	Off-Peak		HC	CO	NO_x
Traffic Flow Improvement	(4,980.00)	(0.76)	0.00	0.00	(46,926.00)	(1.56)	5.00	0.40	(1,644.00)	a	a	a
Improved Public Transit[a]	25.00	0.00	49.00	0.00	599.00	0.02	0.01	0.01	8.00	0.2	0.2	0.02
Employer-Based Transp. Mgr.	131.00	0.02	52.00	0.00	1,011.00	0.03	0.06	0.00	134.00	0.0	0.0	0.03
HOV Lanes[b]	23,800.00	3.61	0.00	0.00	201,369.00	6.67	42.91	0.00	7,835.00	6.67	6.67	6.67

Note: (a) This TCM has no emissions impacts due to induced traffic
(b) This TCM impacts are for a 40-mile freeway and 200 induced vehicle trips.
(*) Minus implies trip or VMT increases

estimated reduction in daily commute trips for each scenario as well as the estimates of the emissions impacts. Table 4-6 demonstrates that although Traffic Flow Improvement tactics proved beneficial, HOV lanes has shown to be the most favored TCM, this because Traffic Flow Improvement has no air quality benefit due to induced traffic associated with the improvement. Furthermore, HOV lanes TCM seemed to offer the most air quality benefit from the above analysis. Finally, note that the strategies, as shown in Table 4-6, that are primarily intended to improve speeds such as traffic signals and capacity increases, are not appropriate for meeting the goals of reducing VMT or vehicle trips.

4.3.1 Emissions Impacts of TCMs

Based on extensive literature review, emission impacts of TCMs are stated as percent reductions in mobile source emissions. This approach is followed for the study area. Where TCMs affect VMT and trips, the proportional effect on emissions was assumed to be equal to that of the VMT. On the other hand, where there is significant traffic flow improvements, a better usable estimate can be found in the literature. Note that according to MOBILE 5a, as previously indicated, 30 percent of VOC emissions for an 11 mile trip are due to the cold start and the hot start which when applied can slightly reduce the VOC estimates shown in Table 4-6. Based on the decreases in VMT, reductions in emissions are estimated by applying the emissions factors for the underlying years. This approach can be used to determine the expected emissions reductions for 1993 through year 2021. Note that the analysis for the year 1993 through 1996 was considered adequate for determining probable cost-effectiveness. Table 4-7 presents travel and emission impacts of the four TCMs based on extensive literature review.

Table 4-7: Travel and Emission Impacts of TCMs Based on Literature Review

TCM Specific	% Reduction in VMT	Percent Reduction in Trips	% Reduction in VOC Emission
Traffic Flow Improvements	<0.1	<0.1	0.4
Public Transit Improvements	1.0	0.8	0.9
Employer-Based Transp. Mgt.[1]	1.4	1.1	1.3
HOV Lanes	1.4	0.5	1.1

Source: Apogee Research, Inc.

4.3.2 Cost-Effectiveness

This chapter also presents the cost estimates and the cost-effectiveness for the four TCMs being analyzed. At this juncture, it is important to present an overview of the term (costs) as used by an accountant and as used by an economist. For an accountant, the historical or explicit costs of items which are regarded as the ordinary expenses of a firm constitute costs. To an economist, costs include both the explicit and implicit costs. The implicit cost is the opportunity cost or the cost of the resources owned and used by the firm's owner. This is to say that an economic cost may not necessarily be equal to an accountant's cost. An accountant's cost also include transfer payments. Costs as used in this report reflect the accounting definition. The costs involved in implementing a TCM can be desegregated into three cost sectors: public, private and individual. For each sector, the cost, revenue, and avoided costs of the TCM are determined. Costs can include capital expenditures, operating and maintenance expenses, administrative and enforcement cost, subsidy payments, user fees, etc. Avoided costs would include costs that implementation of the TCM would save. Travel costs and productivity costs are also legitimate TCM costs but they are not included in the foregoing estimates. Travel costs are costs to travelers in terms of their time and convenience for switching from their preferred mode of travel. Productivity costs are costs to firms due to reduced access for employers, customers, suppliers, and others.

4.3.3 Engineering Economic Analysis versus Cost-Effectiveness

In most engineering feasibility project evaluations, an economic analysis may be performed using a technique known as the benefit-cost ratio method of analysis. This method simply indicates that if the associated benefit exceeds the cost of a proposed project, the project is recommended for implementation all things being equal. On the other hand, cost-effectiveness analysis does not consider whether the benefits of the stated outcome outweigh the costs, nor does it consider net costs. Cost-effectiveness, however, examines the size of the costs and allows comparisons of the relative costs of different ways to achieve a result.

This study analyzes the relative costs to the state and to the people of Calcasieu Parish of alternative methods for reducing emissions given the three most acceptable TCMs and the HOV Lanes TCM. Emphasis is placed on costs incurred by the government or by a firm acting at the direction of the government. Note that government here may be the federal, state or local government. The benefits of emissions reduction are not addressed and as such, any travel benefits that may be generated by a given TCM is overlooked.

4.3.4 Cost-Effectiveness Data

Based on an extensive literature review, a number of cost data considered appropriate for the TCMs being evaluated are compiled and used to determine the cost-effectiveness of a given TCM. This is necessary in the absence of usable cost data for the area being studied. The travel impacts study indicated that for the traffic flow improvements, the benefit realized by the increase in speed was outweighed by the latent traffic demand and as such, the TCM was not effective in reducing mobile source emission for the study area. The cost estimate for this TCM was not investigated for the above reason.

In the case of public transit improvement, literature indicates a practical vehicle round trip avoided cost in the range of $8 to $13 per occurrence[1] An average round trip cost of $10.50 was chosen for the cost-effectiveness analysis. Note that costs here include capital, operating expenses, and operating subsidies. Fare payments are regarded as benefits and are not included. The costs are considered borne by the government.

For the employer-based transportation management TCM which includes employer sponsored area-wide ridesharing, the cost estimates are based on the administrative expenses of operating and promoting area-wide ridesharing. The costs involved in implementing a TCM can be desegregated into three cost sectors: public, private and individual. This program may be supported by the government or by a business enterprise.

Literature provides annual costs per new carpooler or van-pooler in the range of $76 to $120.[2] For this study, the annual cost of $84 per new carpool member is considered appropriate.[3] Converting the yearly cost per new car-pooler of $84 to daily cost yields $0.23 per new car-pooler (365 days per year). Assuming an average carpool vehicle occupancy of 2.9, it was determined that for each new carpool member, 65.5% of a round trip is avoided. The cost per round trip avoided is computed using the following relationship:

$$1-1/(1+b)^{1}$$

where b = the percent increase in the average vehicle occupancy expressed in decimal

Here, there is 190% increase, so that b= 1.9 which yields $0.35 ($0.23/.655) per round trip avoided. For HOV lanes, the costs are estimated on the basis of providing capital cost for additional lanes. From the literature review, the costs for vehicle round trips avoided range from $2.30 to $6.00. The mid value cost of $4.15 is again considered adequate for this study area.

The cost data was used by simply dividing costs per unit by the ton(s) of mobile source emissions reduced to determine the cost per ton of each pollutant reduced. The computed values served as the daily cost-effectiveness for the TCMs analyzed. Tables 4-8 and 4-9 present the cost data and the cost-effectiveness of the TCMs being analyzed.

Literature tends to indicate that most studies do not use the same year for determining the emissions impacts of travel and trip reductions. The reason for this has been due to Technological changes in the vehicle fleet composition which improves over time such that a typical car pollutes less. For this reason, four cost effectiveness numbers for each TCM being evaluated has been shown in Table 4-9 for the years 1990, 1993, 1995, and 1996 respectively. The year 1990 is chosen as the base year for comparison.

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[1]Apogee Research, Inc.

Table 4-8: Cost per Vehicle Round-Trip Avoided

TCM Specific	Cost-Effectiveness
Traffic Flow Improvements	N/A
Public Transit Improvements	$10.50
Employer-Based Transp. Mgt.	$ .35
OV Lanes	$ 4.15

Table 4-9: Daily Cost-Effectiveness of TCMs

TCM Specific	Mobile Source	1990 ($/ton)	1993 ($/ton)	1995 ($/ton)	1996 ($/ton)
Traffic Flow Improvements	HC or VOC	N/A	N/A	N/A	N/A
	CO	N/A	N/A	N/A	N/A
	NO_x	N/A	N/A	N/A	N/A
Public Transit Improvement	HC or VOC	$3,461.00	4567.00	5010.00	5216.00
	CO	435.00	518.00	563.00	585.00
	NO_x	2541.00	2790.00	2934.00	3018.00
Employer-Based Transp. Mgt.	HC or VOC	77.00	101.00	111.00	116.00
	CO	10.00	12.00	13.00	13.00
	NO_x	56.00	62.00	65.00	67.00
HOV Lanes	HC or VOC	4.00	5.00	6.00	6.00
	CO	1.00	1.00	1.00	1.00
	NO_x	3.00	3.00	3.00	4.00

From Table 4-9, it can be seen that the cost-effectiveness of travel changes decreases rapidly with time.

4.3.5 Remarks on Cost-Effectiveness Estimates

Caution should be exercised while using the cost-effectiveness figures shown in Table 4-9. Cost-effectiveness varies depending on the size of the impacts one seeks from a TCM. The results presented above demonstrate particular circumstances and should not be extrapolated for different conditions. The cost data used for the study area while based on reasonable scale, may differ significantly for example if spending were pushed well above the indicated levels.

4.4 Evaluation of the Air Quality Situation for the Study Area

The procedures presented in chapter three for air quality analysis using MOBILE5a computer software were used in reaching the results presented in this section. The user supplied input data presented in table 3-21/3-21a were used in the air quality modeling process for the region. Specifically equations 3-24, 3-25, 3-26 through equation 3-38 were used in arriving at the emission factors, values which were aggregated to arrive at composite emission factor values for VOC, CO, and NO_x respectively, presented in Table 4-10. Table 4-10 presents the emissions factors from the EPA MOBILE 5a modeling software in terms of grams per mile. Table 4-10 also shows the various mobile source emission factors in terms of their associated roadway functional system, VMT and average speed. A selected few samples of the computer input data and output information of MOBILE 5a runs are shown in Appendix E.

Table 4-10: Emissions Factor from EPA MOBILE5a

1990: Func. Classification	VMT (mi/Day)	Average Speed (mph)	HC or VOC (gm/mi)	CO (gm/m)	No_x (gm/m)
01	787,448	61.9	3.076	42.593	8.409
02	46,812	51.60	2.558	18.944	5.247
06	121,080	44.0	2.739	19.762	4.372
07	379,513	47.0	2.641	19.383	3.947
08	95,388	45.7	2.706	20.035	2.958
09	161,300	27.0	3.755	29.954	2.815
11	921,815	51.7	2.506	18.320	5.054
14	394,853	32.7	2.970	21.837	3.294
16	314,860	36.6	3.104	23.309	2.834
17	2,367	34.4	3.209	24.203	2.578
19	17,011	27.0	3.743	29.620	2.492
TOTAL	3,242,447				

Table 4-10: contd.

1993: Func. Classification	VMT (mi/Day)	Average Speed (mph)	HC or VOC gm/mi	CO gm/mi	NO_x gm/mi
01	838,114	58.5	2.035	23.786	6.319
02	50,053	49.5	1.889	15.373	3.962
06	124,597	49.5	1.902	15.473	4.093
07	415,273	45.0	1.996	16.269	3.237
08	101,601	36.0	2.284	19.135	2.545
09	170,816	27.0	2.775	24.056	2.558
11	973,091	54.0	1.821	15.024	4.649
14	401,729	40.5	2.119	17.334	2.949
16	339,748	36.0	2.302	19.247	2.568
17	2,370	36.0	2.287	19.059	2.382
19	17,080	27.0	2.763	23.865	2.310
TOTAL	3,434,472				

Table 4-10: contd.

1995: Func. Classification	VMT (mi/Day)	Average Speed (mph)	HC or VOC (gm/mi)	CO (gm/mi)	NO_x (gm/mi)
01	871,891	61.8	1.944	27.702	6.350
02	51,856	51.6	1.646	13.825	3.876
06	126,942	44.9	1.740	14.371	3.480
07	439,112	49.4	1.676	14.123	3.222
08	105,743	45.8	1.729	14.664	2.504
09	177,300	27.0	2.438	21.623	2.422
11	1,007,274	51.6	1.617	13.540	3.951
14	406,313	39.0	1.903	16.081	2.749
16	356,341	36.0	2.006	17.254	2.445
17	2,376	34.4	2.064	17.873	2.271
19	17,126	27.0	2.419	21.543	2.216
TOTAL	3,562,274				

Table 4-10: contd.

2000: Func. Classification	VMT (mi/day)	Average Speed (mph)	HC or VOC (gm/mi)	CO (gm/mi)	NO_x (gm/mi)
01	956,340	61.7	1.504	17.932	4.962
02	57,216	54.8	1.322	10.347	3.457
06	132,804	44.7	1.420	10.953	2.844
07	498,710	49.3	1.357	10.497	2.668
08	116,098	45.8	1.405	11.032	2.155
09	193,509	27.0	2.017	18.106	2.105
11	1,092,740	51.5	1.318	10.107	3.192
14	417,770	38.8	1.565	12.667	2.336
16	397,822	37.3	1.613	13.320	2.132
17	2,387	34.4	1.700	14.393	1.999
19	17,242	27.0	2.010	18.101	1.959
TOTAL	3,882,638				

Table 4-10: contd.

2003: Func. Classification	VMT (mi/Day)	Average Speed (mph)	HC or VOC gm/mi	CO gm/mi	NO_x gm/mi
01	1,007,007	63.0	1.371	15.404	4.510
02	60,432	58.5	1.205	12.024	3.418
06	136,321	49.5	1.218	8.812	2.723
07	534,470	45.0	1.286	9.571	2.285
08	122,311	36.0	1.503	12.385	1.947
09	203,235	27.0	1.850	16.865	1.954
11	1,144,016	50.6	1.195	8.586	2.777
14	424,646,	39.4	1.407	11.049	2.1466
16	422,711	39.0	1.421	11.299	1.988
17	2,393	36.2	1.493	12.286	1.878
19	17,312	27.0	1.845	16.878	1.839
TOTAL	4,074,854				

Table 4-10: contd.

2005: Func. Classification	VMT (mi/Day)	Average Speed (mph)	HC or VOC gm/mi	CO (gm/mi)	NO_x (gm/mi)
01	1,040,785	61.1	1.261	12.585	4.019
02	62,577	54.6	1.145	8.294	2.927
06	138,666	44.4	1.240	9.053	2.438
07	558,310	48.8	1.175	8.383	2.293
08	126,453	45.7	1.217	8.949	1.941
09	209,719	27.0	1.782	16.514	1.903
11	1,178,200	51.4	1.144	8.097	2.715
14	429,230	38.2	1.381	10.963	2.074
16	439,303	37.2	1.410	11.436	1.932
17	2,397	34.4	1.489	12.571	1.832
19	17,358	27.0	1.779	16.559	1.799
TOTAL	4,202,998				

Table 4-10: contd

2008 Func. Classification	VMT (mi/day)	Average Speed(mph)	HC or VOC gm/mi	CO gm/mi	NO_x gm/mi
01	1,091,452	61.1	1.205	11.700	3.799
02	65,793	58.5	1.170	10.359	3.104
06	142,183	49.5	1.118	7.914	2.487
07	594,070	45.0	1.179	8.682	2.119
08	132,666	36.0	1.382	11.617	1.839
09	219,444	27.0	1.716	16.326	1.840
11	1,229,476	50.5	1.099	7.722	2.527
14	436,106	39.3	1.296	10.269	2.004
16	464,192	39.3	1.296	10.370	1.878
17	2,404	36.0	1.379	11.602	1.783
19	17,428	27.0	1.712	16.367	1.745
TOTAL	4,395,214				

Table 4-10: contd.

2010: Func. Classification	VMT (mi/day)	Average Speed (mph)	HC or VOC (gm/mi)	CO gm/mi	NO_x (gm/mi)
01	1,125,230	61.1	1.179	11.207	3.704
02	67,937	54.6	1.074	7.713	2.735
06	144,528	44.4	1.165	8.510	2.287
07	617,910	48.8	1.100	7.787	2.165
08	136,808	45.7	1.138	8.365	1.855
09	225,928	27.0	1.687	16.261	1.818
11	1,263,660	51.4	1.071	7.512	2.536
14	440,690	38.2	1.297	10.470	1.970
16	480,784	37.2	1.322	10.942	1.848
17	2,408	34.4	1.398	12.134	1.759
19	17,474	27.0	1.681	16.293	1.727
TOTAL	4,523,357				

Table 4-10: contd.

2013: Func. Classification	VMT mi/day	Average Speed (mph)	Hcor VOC (gm/mi)	CO gm/mi	NO_x (gm/mi)
01	1,175,897	60.5	1.136	10.470	3.536
02	71,153	58.5	1.113	9.629	2.960
06	148,045	49.5	1.065	7.496	2.376
07	653,670	45.0	1.122	8.269	2.039
08	143,021	36.0	1.318	11.274	1.784
09	235,654	27.0	1.645	16.112	1.785
11	1,314,936	50.1	1.047	7.312	2.390
14	447,566	39.2	1.237	9.932	1.935
16	505,673	39.5	1.228	9.922	1.823
17	2,414	35.6	1.325	11.425	1.733
19	17,544	27.0	1.639	16.155	1.700
TOTAL	4,715,573				

Table 4-10: contd.

2015 Func. Classification	VMT (mi/day)	Avg. Speed (mph)	HC or VOC (gm/mi)	CO (gm/mi)	NO_x (gm/mi)
01	1,209,675	60.1	1.124	10.197	3.464
02	73,298	53.3	1.044	7.466	2.558
06	1520,390	43.6	1.144	8.488	2.208
07	677,510	48.3	1.066	7.541	2.077
08	147.,163	45.3	1.107	8.224	1.814
09	242,138	27.0	1.642	16.129	1.781
11	1,349,120	50.9	1.039	7.285	2.426
14	452,150	38.3	1.254	10.229	1.924
16	522,265	37.6	1.270	10.587	1.812
17	2,419	34.3	1.358	11.991	1.727
19	17,590	27.0	1.634	16.167	1.697
TOTAL	4,843,718				

Table 4-10: contd.

2020 Func. Classification	VMT (mi/day)	Avg. Speed (mph)	HC or VOC (gm/mi)	CO (gm/mi)	NO_x (gm/mi)
01	1,294,120	57.8	1.069	8.877	3.224
02	78,658	58.5	1.096	9.582	2.921
06	156,252	49.5	1.049	7.466	2.344
07	737,110	45.0	1.104	8.237	2.015
08	157,518	36.0	1.297	11.242	1.768
09	258,347	27.0	1.620	16.082	1.768
11	1,434,580	49.7	1.033	7.284	2.333
14	463,610	39.1	1.219	9.936	1.914
16	563,746	39.6	1.206	9.858	1.806
17	2,429	35.7	1.300	11.353	1.720
19	17,706	27.0	1.614	16.130	1.687
TOTAL	164,076				

Table 4-11: Daily Regional Emissions for HC, Co and NO_x

1990: Func. Class.	HC or VOC Grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/ day	CO Tons/ day	NO_x Tons/ day
1.00	2,422,190.00	33,382,283.00	6,621,650.00	2.67	36.80	7.30
2.00	119,745.00	886,807.00	245,623.00	0.13	0.98	0.27
6.00	331,638.00	2,392,783.00	529,362.00	0.37	2.64	0.58
7.00	1,002,294.00	7,356,100.00	1,497,938.00	1.10	8.11	1.65
8.00	258,120.00	1,911,099.00	282,158.00	0.28	2.11	0.31
9.00	605,682.00	4,831,580.00	454,060.00	0.67	5.32	0.50
11.00	2,310,068.00	16,887,650.00	4,658,853.00	2.55	18.62	5.14
14.00	1,172,713.00	8,622,805.00	1,300,646.00	1.29	9.50	1.43
16.00	977,325.00	7,339,072.00	892,313.00	1.08	8.09	0.98
17.00	7,596.00	57,289.00	6,102.00	0.01	0.06	0.01
19.00	63,672.00	503,866.00	42,391.00	0.07	0.56	0.05
TOTAL	9,271,043.00	84,170,935.00	16,531,095.00	10.22	92.78	18.22

Table 4-11: contd.

1993: Func. Class.	HC or VOC Grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/ day	CO Tons/ day	NO_x Tons/ day
1.00	1,705,562.00	19,935,380.00	5,296,042.00	1.88	21.97	5.84
2.00	94,550.00	769,465.00	198,310.00	0.10	0.85	0.22
6.00	236,983.00	1,927,889.00	509,976.00	0.26	2.13	0.56
7.00	828,885.00	6,756,076.00	1,344,239.00	0.91	7.45	1.48
8.00	232,057.00	1,944,135.00	258,575.00	0.26	2.14	0.29
9.00	474,014.00	4,109,150.00	436,947.00	0.52	4.53	0.48
11.00	1,771,999.00	14,619,719.00	4,523,900.00	1.95	16.12	4.99
14.00	851,264.00	6,963,570.00	1,184,699.00	0.94	7.68	1.31
16.00	782,100.00	6,539,130.00	872,473.00	0.86	7.21	0.96
17.00	5,420.00	45,170.00	5,645.00	0.01	0.05	0.01
19.00	47,192.00	407,614.00	39,455.00	0.05	0.45	0.43
TOTAL	7,030,025.00	64,017,298.00	14,670,260.00	7.75	70.57	16.17

Table 4-11: contd.

1995: Func. Classification	HC or VOC grams/day	CO grams/day	NOx grams/day	HC or VOC Tons/ day	CO Tons/ day	NOx Tons/day
01	1,694,956	24,153,124	5,536,508	1.87	26.62	6.10
02	85,355	716,909	200,994	0 .09	0 .79	0 .222
06	220,879	1,824,283	441,758	0.24	2.01	0.49
07	735,952	6,201,579	1,414,819	0.81	6.84	1.56
08	182,830	1,550,615	264,780	0.20	1.71	0.29
09	432,257	3,833,758	429,421	0.48	4.23	0.47
11	1,628,762	13,638,490	3,979,740	1.80	15.03	4.39
14	773,214	6,533,919	1,116,954	0.85	7.20	1.23
16	714,820	6,148,308	871,254	0.79	6.78	0.96
17	4,904	42,466	5,396	0.005	0.05	0.006
19	41,428	368,945	37,951	0.05	0.41	0.004
TOTAL	6,515,357	65,012,396	14,299,575	7.18	71.66	15.76

Table 4-11: contd.

2000: Func. Class.	HC or VOC grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/day	CO Tons/day	NO_x Tons/day
01	1,438,335	171,219,089	4,745,559	1.59	18.90	5.23
02	75,640	592,013	197,795	.083	.653	.218
06	465,81	359,302	93,284	.051	.396	.103
07	676,749	5,234,958	1,330,558	.746	5.77	1.47
08	163,117	1,280,793	250,191	.180	1.41	.276
09	390,307	3,503,674	407,336	.430	3.86	.449
11	1,440,231	11,044,323	3,488,026	1.59	12.17	3.84
14	653,810	5,298,989	975,910	.721	5.83	1.08
16	641,686	5,298,989	848,156	.707	5.84	.935
17	4,057	34,356	4,771	.004	.038	.005
19	34,656	312,097	33,777	.038	.344	.037
TOTAL						

Table 4-11: contd.

2003: Func. Class.	HC or VOC Grams/day	CO Grams/day	NO_x grams/day	HC or VOC Tons/day	Co Tons/day	NO_x Tons/day
1	138,607	15,511,936	4,541,602	1.52	17.1	5.01
2	77,655	726,634	206,557	0.09	0.8	0.22
6	166,039	1,201,261	371,202	0.18	1.32	0.41
7	687,328	5,115,412	1,221,26	0.76	5.64	1.35
8	183,833	1,514,822	238,140	0.2	1.67	0.26
9	375,985	3,427,558	397,121	0.41	3.78	0.44
11	1,367,099	9,022,521	3,176,932	1.51	0.95	3.5
14	597,477	4,691,914	911,290	0.66	5.17	1.005
16	600,672	4,776,212	840,349	0.66	5.26	0.93
17	3,573	29,400	4,494	0.004	0.03	0.005
19	31,941	292,192	31,837	0.04	0.32	0.04
TOTAL	5,472,209	46,309,862	11,941	6.03	51.93	13.16

Table 4-11: contd.

2005: Func. Class.	HC or VOC gram/day	CO grams/day	NO_x grams/day	HC or VOC Tons/ day	CO Tons/day	NO_x Tons/ day
1	1,274,600	13,098,279	4,182,915	1.4	14.44	4.61
2	71,651	519,014	183,163	0.08	0.57	0.2
6	171,946	1,255,343	338,068	0.19	1.38	0.37
7	656,014	4,680,313	1,280,205	0.72	5.16	1.41
8	153,893	1,131,628	245,445	0.17	1.25	0.27
9	373,719	3,463,300	399,095	0.41	3.82	0.44
11	1,347,861	9,539,885	3,198,813	1.49	10.52	3.53
14	592,767	4,705,648	890,223	0.65	5.19	0.98
16	619;417	5,023,069	848,733	0.68	5.54	0.94
17	3,569	30,133	4,391	0.004	0.03	0.005
19	30,880	287,431	31,227	0.03	0.32	0.03
TOTAL	5,293,317	4,373,484	11,602,278	5.84	48.21	12.79

Table 4-11: contd.

2008: Func. Class.	HC or VOC grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/day	CO Tons/day	NO_x Tons/ day
1	1,315,200	12,769,988	4,146,426	1.45	14.08	4.57
2	76,978	681,550	204,221	0.08	0.75	0.23
6	158,961	1,125,236	353,609	0.18	1.24	0.39
7	780,409	5,157,716	1,258,834	0.86	5.69	1.39
8	183,344	1,541,181	243,973	0.2	1.7	0.27
9	376,566	3,582,643	403,777	0.42	3.95	0.45
11	1,351,194	9,494,014	3,106,886	1.49	10.47	3.42
14	565,193	4,478,373	873,956	0.62	4.94	0.96
16	601,593	4,813,671	871,753	0.66	5.31	0.96
17	3,315	27,891	4,286	0.004	0.03	0.005
19	29,837	285,244	30,412	0.03	0.31	0.03
TOTAL	5,442,590	43,957,507	11,498,133	6	48.45	12.67

Table 4-11: contd.

2010: Func. Class.	HC or VOC grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/day	CO Tons/day	NO_x Tons/ day
1	1,335,819	12,311,819	4,157,972	1.47	13.57	4.58
2	79,193	685,132	210,613	0.09	0.76	0.23
6	157,668	1,109,745	351,755	0.17	1.22	0.39
7	733,418	5,405,197	1,332,833	0.81	5.96	1.47
8	188,502	1,612,419	255,149	0.21	1.78	0.28
9	387,651	3,796,857	420,642	0.43	4.19	0.46
11	1,376,738	9,614,812	3,142,607	1.52	10.6	3.46
14	553,639	4,445,226	866,040	0.61	4.9	0.95
16	620,966	5,017,288	921,842	0.68	5.53	1.02
17	3,199	27,580	4,183	0.004	0.03	0.005
19	28,755	283,423	29,825	0.03	0.31	0.03
TOTAL	5,465,548	44,309,321	11,693,551	6.02	48.84	12.89

Table 4-11: contd.

2013: Func. Class.	HC or VOC grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/day	CO Tons/day	NOx Tons/ day
01	1,335,819	12,311,642	4,157,972	1.47	13.57	4.58
02	79,193	685,132	210,613	0.09	0.76	0.23
06	157,668	1,109,745	351,755	0.17	1.22	0.39
07	733,418	5,405,197	1,332,833	0.81	5.96	1.47
08	188,502	1,612,419	255,149	0.21	1.78	0.28
09	387,651	3,796,857	420,642	0.43	4.19	0.46
11	1,376,738	9,614,812	3,142,697	1.52	10.59	3.46
14	553,639	4,445,226	866,040	0.61	4.90	0.95
16	620,966	5,017,288	921,842	0.68	5.53	1.02
17	3,199	27,580	4,183	0.004	0.03	0.005
19	28,755	283,423	29,825	0.03	0.31	0.03
TOTAL	5,465,548	44,309,521	11,693,551	6.02	48.84	12.89

Table 4-11: contd.

2015: Func. Class.	HC or VOC grams/day	CO grams/day	NO_x grams/day	HC or VOC Tons/day	CO Tons/day	NO_x Tons/ day
1	1,359,675	12,335,056	4,190,314	1.5	13.6	4.62
2	76,523	547,243	187,496	0.68	0.6	0.21
6	172,046	1,276,510	332,061	0.19	1.41	0.37
7	722,226	5,109,103	1,407,188	0.8	5.63	1.55
8	162,909	1,210,269	266,954	0.18	1.33	0.29
9	397,591	3,905,444	431,248	0.44	4.3	0.48
11	1,401,736	9,828,339	3,272,965	1.55	10.83	3.61
14	566,996	4,625,042	869,937	0.62	5.1	0.96
16	663,277	5,529,220	946,344	0.73	6.09	1.04
17	3,285	29,006	4,178	0.004	0.03	0.005
19	28,742	284,378	29,850	0.03	0.31	0.03
TOTAL	5,555,006	44,679,610	11,938,535	6.12	49.25	13.16

Table 4-11: contd.

2020: Func. Classification	VMT (mi/Day)	Average Speed (mph)	Hcor VOC (gm/mi)	CO (gm/mi)	NO_x (gm/mi)
01	1,294,120	57.8	1.069	8.877	3.224
02	78,658	58.5	1.096	9.582	2.921
06	156,252	49.5	1.049	7.466	2.344
07	737,110	45.0	1.104	8.237	2.015
08	157,518	36.0	1.297	11.242	1.768
09	258,347	27.0	1.620	16.082	1.768
11	1,434,580	49.7	1.033	7.284	2.333
14	463,610	39.1	1.219	9.936	1.914
16	563,746	39.6	1.206	9.858	1.806
17	2,429	35.7	1.300	11.353	1.720
19	17,706	27.0	1.614	16.130	1.687
TOTAL	5,164,076	464.9	13.607	116.047	23.500

As shown in Table 4-11, the total mobile source emissions for the research target area are just calculated in grams per day of a specific pollutant and then using equation 3B38, the grams per day are converted to tons per day. Again, Table 4-11 shows the details of the daily regional emissions for HC, CO and NO_x. regional emissions for the HC or VOC, CO, and NO_x by roadway functional classifications for the years 1990 through 2020.

4.4.1 Calcasieu Parish Air Quality Conformity Analysis

In reference to sections 1.7 and 1.8 of this document, Calcasieu parish is required under the 1990 CAAA to confirm to the State Implementation Plan (SIP) and the State Transportation Improvement Program (TIP)y the region is to move from its non-attainment status to that of attainment status in ambient air quality standard. As indicated earlier, Calcasieu parish, which includes the Lake Charles Urbanized Area was classified as "marginal" in terms of meeting the national ambient air quality standard for ozone. As a result, Calcasieu Parish is required to perform conformity analysis in accordance with the applicable provisions of the federal transportation conformity rule. This research effort has performed the air quality conformity analysis starting from the base year of 1990 through year 2020 for the region. Note that in performing the analysis the guidelines presented in the paper: "A VMT for Air Quality Purposes, prepared by the Federal Highway Administration (FHWA), and; Section 187, A VMT Forecasting and Tracking Guidance, prepared by EPA was followed closely". In order to ensure that the metropolitan transportation plan for any given year does lead to increased mobile source emissions, the

LaDEQ and the LaDOTD sets a motor vehicle emission budgets (MVEBs) that non-attainment areas can use as a guide for determining conformity to both SIP and TIP. Table 4-12 presents the analysis/budget year, MVEBs and the modeled emissions. For conformity, the modeled emissions must be equal or less than the budgeted emissions.

Table 4-12: Emission Analysis Summary (Tons/Day)

Analysis/ Budget year	MVEB for VOC (Tons/day)	Modeled Emission for VOC (Tons/day)	MVEB NO_x (Tons/day)	Modeled Emission NO_x (Tons/day)
1990	12.20	10.22	19.90* (base yr.)	18.22
1993	9.22	7.75	17.93	16.17
1995	8.77	7.18	17.72	15.76
2000	7.96	6.29	16.31	*/13.95
2003	7.96	6.03	16.31	13.16
2005	7.78	5.84	15.67	12.79
2008	8.21	6.00	15.66	12.67
2010	8.21	5.03	16.53	12.88
2013	8.21	6.02	16.53	12.89
2015	8.21	6.12	16.53	13.16
2020	8.21	6.43	16.53	13.53

***Source: Louisiana Department of Environmental Quality (LaDEQ), A State Implementation Plan, Redesignation of Calcasieu Parish to Ozone Attainment, December 20, 1995**

Based on the above analysis, the modeled emissions for both VOC and NO_x have consistently been lower than the motor vehicle emissions budget for the region and as such, the region is compliance with SIP and TIP provisions for attaining the ambient air quality standards as mandated by the provisions of the 1990 CAAA. All the results obtained indicate emission reductions of VOC and NO_x from 12.20 tons per day and 19.90 tons per day base year levels to 6.43 and 13.53 tons per day respectively for VOC and NO_x. Specifically, the mobile source VOC emissions decrease from 12.2 tons per day in base year 1990 during the ozone season to 8.21 tons per day in the horizon year of 2020 amounts to a change of 32.7%. NO_x emissions also decreased over the same period from 19.9 tons per day in the base year to 13.53 tons per day in the horizon year and that amounts to a change of 32.0%. Note that since the research region is cited for ozone non-attainment, no attempt is made to analyze the impact of CO pollutants in the region.

4.4.2 Sensitivity of Emission Rates to Vehicle Speeds

In order to determine the impacts of speeds on the various mobile source emissions, a plot of relative emission rate at a given temperature on the y-axis and speed on the x-axis is made for HC, NO_x and CO and shown in figure 4-3. For the horizon year of 2020 and for the temperature of 85.2□F , the result of the sensitivity analysis of emission rate to vehicle speeds, confirmed the earlier research findings by both EPA and CARB that a significant relationship does exist between travel speed and emission rates after controlling for trip-start, trip-end and diurnal emissions. Although the speed-specific rates do still include the effects of acceleration, deceleration, cruise and idling, figure 4-3 provides an approximate mapping of the relationship between emissions for hydrocarbon, NO_x, CO, and speed for the research target area. Although CO emissions are significantly higher on a grams per mile basis than both HC and NO_x . Figure 4-3 shows that at least within certain ranges of speeds, emission rates for all three primary pollutants are sensitive to speeds.

No attempt was made, however, in this investigation, to determine the extent to which the speed sensitivity is a function of the number of acceleration episodes implicit in a particular speed and the extent to which the emission rate is sensitive to the cruise speed itself. From literature review, however, most of the variations in rates across speeds are explained by the presence of acceleration periods and very little variability exists across most normal driving ranges of cruise speed.

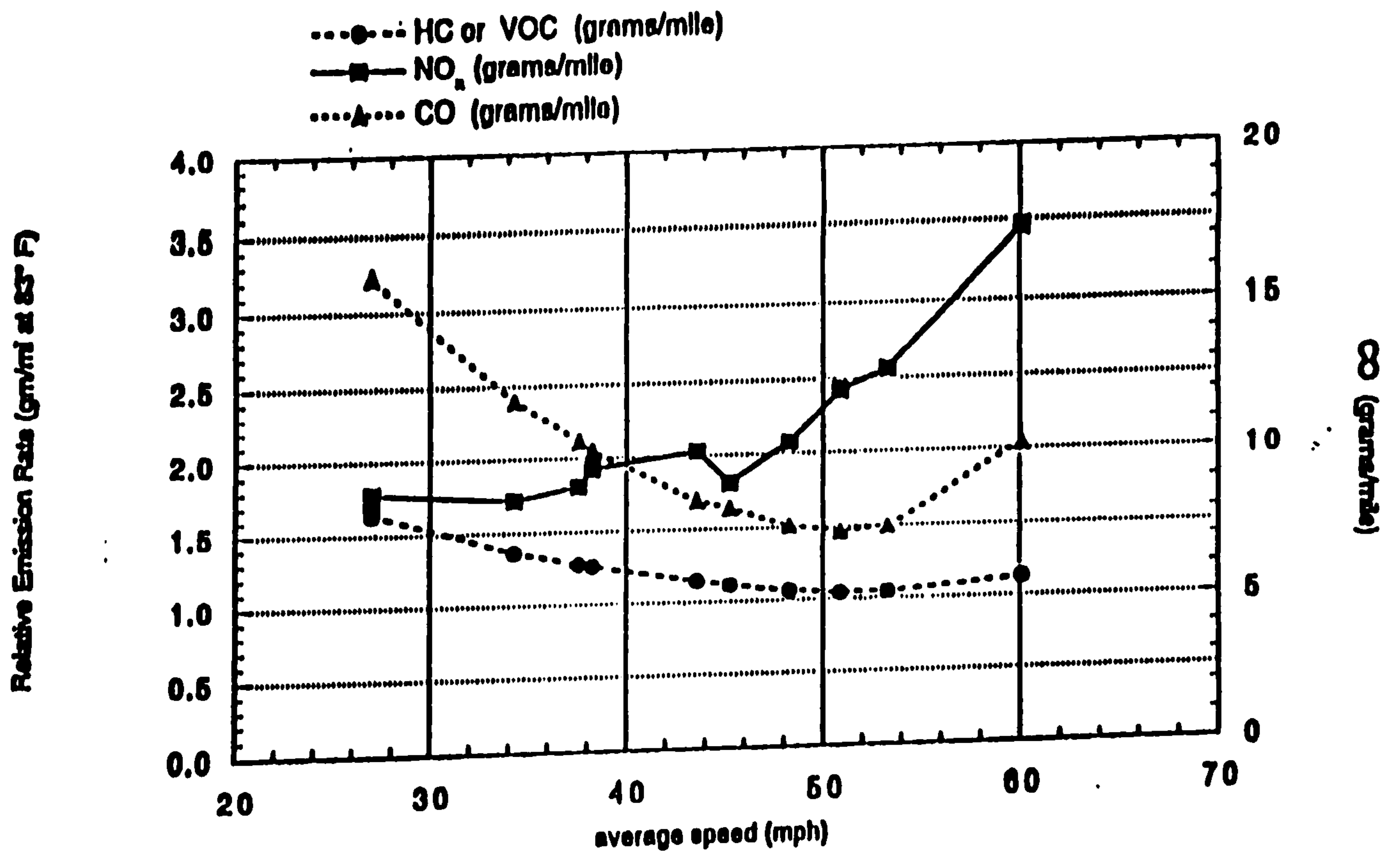

Figure 4-3: Sensitivity of Emission Rate to Vehicle Speed

CHAPTER 5

CONCLUSION

Based on the results of the findings presented in chapter four, it is concluded that the objectives set forth in this investigation have to some degree been addressed. The details of the results presented also concluded that the research target area has been shown to move from its EPA designated status of non-attainment in ambient air quality standards for ozone, to that of attainment status. Although the Federal Regulation Code (CFR) 40 parts 52 and 81 of May 1997 shows that the EPA has now re-designated Calcasieu Parish to attainment status, according to CFR 40 parts 52 and 81 the region is required to conform to EPA specified conformity maintenance plan that is designed to enable the region to remain in attainment status. Appendix E has also the details of the Federal Register Notices on Calcasieu re-designation.

Furthermore, TCMs can be compared in three basic way as follows:

- Relative degree of acceptability of a TCM to be implemented,
- Relative effectiveness of TCMs in reducing mobile source emissions, and
- Relative cost-effectiveness of TCMs in reducing mobile source emissions.

All of the above measures serve to identify the most attractive TCM and to place limits on what might be expected in terms of likely improvements.

5.1 Degree of Acceptability of TCMs

This investigation clearly demonstrated that a TCM that may appear very attractive to the residents of non-attainment area may not be cost-effective at reducing mobile source emissions. However, it is necessary that the MPOs and the city officials be aware of the degree of acceptability of a given TCM for ease of implementation. For instance, the analysis on TCMs showed that the traffic flow improvements TCM was the most acceptable TCM, but in evaluating its travel and its emissions impacts, it was found that it increased emissions due to induced or latent traffic demand.

5.2 Effectiveness of TCMs

The TCMs analyzed here are few and a comprehensive analysis of the other TCMs should be done in order to offer the region a range of TCM options to adopt. The relative effectiveness of the ones analyzed can be grouped as strong or weak. A TCM is strong if its mobile source emissions impact equals or exceeds 3%; it is weak if the impact is equal or less than 1%. The study noted that in order to effectively control the mobile source emissions for the region, the VMT/vehicle trips growth rates do not exceed the population growth rate.

Based on the analysis performed in Table 4-5, the specified excess DVMT tend to portray the region indicate that the region was still in non-attainment status until subsequent analysis proved otherwise. One explanation for this phenomenon in the fact that technology is better efficient vehicle fleet, and reformulated fuels, and other controls have contributed significantly to lesser on-road mobile source emissions than was the case when the 1990 CAAA took effect.

5.3 VMT Estimating Procedure

The study investigation noted that while home survey may provide a better VMT estimate and trips estimate than the HPMS method, it is rather difficult to associate the VMT so estimated with the roadway functional classifications used to estimate emissions form EPA MOBILE 5a. A combination of home survey and HPMS VMT procedures are encouraged where feasible. The study used the HPMS and TRANPLAN for the VMT forecasts used in the MOBILE 5A model.

5.4 Air Quality Analysis/ Sensitivity Analysis

Although the air quality analysis result shows that the region to have moved to attainment status by use of MVEB comparative method, it is possible to arrive at a different conclusion Y Build or no Build method were used. Under the Build or No Build method, all transportation improvement programs are required not to violate the EPA emissions limit on NAAQS. Furthermore, the sensitivity analysis concluded that HC, NO_x, and CO emissions are sensitive to speed at a given temperature. There was no sensitivity analysis performed on emission rates varying temperatures designed to confirm any relationship between emission rates and temperature for the region. Furthermore, literature review shows that research on emission rates long ago established that rates vary significantly by vehicle type but no effort in this study was done to demonstrate such relationship for the study region due to time constraint.

5.5 Areas for Future Research Efforts

Based on extensive literature review, the TCMs air quality benefits seemed to be marginal in terms of solving the air quality problems. Furthermore, interviews with a number of citizens of the study area tend to suggest that the prevailing air quality problem for the area are not due to mobile source emissions but in some cases due to point source emissions. Presently, the area has a number of petro-chemical industries within and outside its borders and from neighboring state of Texas. Research is needed to investigate the percentage of pollutants that can be attributed to both point sources and mobile sources; the socio-economic impacts of mitigating the air quality problems should also be investigated for the region.

The merits of market-oriented TCMS in addition to the sixteen CAAA TCMs should be investigated for the area. Having determined the degrees of acceptability of the sixteen CAAA TCMs by the residents of the study area, a follow-up study should be conducted on the cost-effectiveness of each TCM including market-oriented TCMs to enable the MPOs, the city and the state officials to make reasonable decisions on what TCM or combinations of TCMs offer (s) the best merit for mitigating mobile source problems for the region under investigation.

5.6 Remarks

For the air quality analysis, only the vehicle distribution for the years 1991 and less were used in estimating the various on-road mobile source emission rates. Vehicle distribution data for 1992 and above model year vehicles were not available. Based on the literature review, the later model year vehicles have been found to pollute less due to advancement in technology. It is therefore concluded that the various emission rates used in the analysis are at best conservative and should be used with caution since the actual rates may be lower. However, lower emission rates further confirm the region is in attainment status in ambient air quality standards as earlier demonstrated.

Appendices

Appendix A Questionnaire on TCM and Human Use Committee Review Approval Memorandum

A-1 Questionnaire on TCM for Lake Charles, Louisiana

Instructions: Please carefully read the following scenarios presented below which describes each of the sixteen (16) Transportation Control Measures. Next, respond to each scenario by filling in your personal choice of 1,2,3,4 or 5 in the space provided. The numbers 1,2,3,4 and 5 are explained as follows: 1=Highly Unacceptable 2=Unacceptable 3=Undecided 4=Acceptable and 5=Highly Acceptable.

Scenarios:

1) If Trip Reduction Ordinances (TCM #1), such as the imposition of toll and increased parking fees, were introduced in your area, please indicate your degree of acceptability of this approach to discourage single-occupant automobile trips and reduce congestion. [ ]

2) What is your degree of acceptability if Vehicle Use Limitations or Restrictions (TCM #2) (i.e. use of vehicle on Monday and not on Tuesday or other alternate days) are implemented in the Lake Charles area? [ ]

3) If Employer-Based Transportation Management Programs (TCM #3) such as free parking or vanpooling, are introduced in your area, what would be your degree of acceptability? [ ]

4) What would be your degree of acceptability if an Improved Public Transit System (TCM #4), which includes reduced fares and more buses along, the route, were implemented in the Lake Charles area? [ ]

5) Suppose a Parking Management Program (TCM #5), which includes high cost for parking personal vehicles and free parking for vanpools or carpools, is implemented, please indicate how acceptable it would be to you. [ ]

6) What would be your degree of acceptability if Park and Ride or Fringe Parking Facilities (TCM #6) were established in your area? [ ]

7) If Flexible Work Schedules (TCM #7) (i.e. would allow you to come and go at your convenience with your employer's agreement) were put in place by your employer, what would be your level of acceptability? [ ]

8) Suppose the transportation supervisors in the Lake Charles area decided to introduce Traffic Flow Improvements (TCM #8), such as roadway expansion to reduce your travel time, indicate how acceptable they would be to you. [ ]

9) If Area Wide Sharing Incentives (TCM #9) which may reduce travel time and provide you with monetary compensation were adopted in your area, what would be your level of acceptability? [ ]

10) If High-Occupancy Vehicle Facilities (TCM #10) that would allow priority use of special lanes and save you travel time and cost were established in the Lake Charles area, please indicate your degree of acceptability. [ ]

11) What would be your degree of acceptability if Major Activity Centers (TCM #11) were developed in the Lake Charles area where legislation would prohibit parking of personal vehicles and allowing carpools and vanpools in certain areas? [ ]

12) If Special Event Controls were implemented to facilitate non-automotive travel (TCM #12) (such as restriction of the use of private cars), how acceptable would these be? [ ]

13) TCM #13 calls for the establishment of Bicycling and Pedestrian Programs. These would include the restriction of private automobiles and encouragement of the use of bicycles and footpaths. How acceptable would the TCM be to you. [ ]

14) If Extended Vehicle Idling Controls (TCM #14) were established, what would be your degree of acceptability? [ ]

15)How acceptable is Extreme Cold Start Controls (TCM #15) which would require you to install a system to preheat your car before starting in cold weather to reduce air pollution? [ ]

16) If legislation was introduced to require the Removal of All Pre-1980 Vehicle (TCM #16) to improve air quality, what would your degree of acceptability? [ ]

A-2 Human Use Committee Review Approval Memorandum

LOUISIANA TECH
UNIVERSITY

RESEARCH & GRADUATE SCHOOL

MEMORANDUM

TO: Benedict N. Nwokolo

FROM: Deby Hamm, Graduate School

SUBJECT: HUMAN USE COMMITTEE REVIEW

DATE: June 22, 1999

In order to facilitate your project, an EXPEDITED REVIEW has been done for your proposed study entitled:

"An empirical investigation on the impacts of ground-level ozone concentrations on national ambient air quality standards: the case of Lake Charles, LA

Proposal #1-QC

The proposed study procedures were found to provide reasonable and adequate safeguards against possible risks involving human subjects. The information to be collected may be personal in nature or implication. Therefore, diligent care needs to be taken to protect the privacy of the participants and to assure that the data are kept confidential. Further, the subjects must be informed that their participation is voluntary.

Since your reviewed project appears to do no damage to the participants, the Human Use Committee grants approval of the involvement of human subjects as outlined.

You are requested to maintain written records of your procedures, data collected, and subjects involved. These records will need to be available upon request during the conduct of the study and retained by the university for three years after the conclusion of the study.

If you have any questions, please give me a call at 257-2924.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM
P.O.BOX • RUSTON, LA 71272-0029 • TELEPHONE (318)257-2924
FAX (318)257-4487 • email: research@LaTech.edu
AN EQUAL OPPORTUNITY UNIVERSITY

Appendix B Employee Survey

Survey Related To Transportation Control Measures for Lake Charles, Louisiana

Please shade the appropriate area to the right that corresponds to your response below:

(A) DEMOGRAPHIC

1. My sex is: (1) Female (2) Male

2. My age is: (1) < or = 29 (2) 30-39 (3) 40-49
(4) 50-59 (5) 60 and over

3. My marital status is: (1) Single (2) Married
(3) Widowed (4) Divorced (5) Separated

4. The number of people who currently reside in my home:
(1) 1 (2) 2 (3) 3 (4) 4 or more

5. The number of people in my home who have a valid driver's license: (1) 1 (2) 2 (3) 3 (4) 4 or more

6. The number of dependents under 18 years of age currently residing with me:
(1) 0 (2) 1 (3) 2 (4) 3

7. The highest education level of the head of the household:
(1) Less than high school (2) High school diploma
(3) Some college or Associate's Degree
(4) Bachelor's Degree (5) Master's or Ph.D.

8. The present occupation of the head of the household is:
(1) Household manager (2) Skilled/Clerical
(3) Unskilled/semi-skilled (4) Professional
(5) Student/unemployed
(9) Other:________________

(B) CAR OWNERSHIP

9. How many motor vehicles (excluding motorcycles, etc.) do you and your family currently own and/or have the use of?
(1) 0 (2) 1 (3) 2 (4) 3 (5) 4 or more

(C) INCOME

10. Income per year:
    (1) less than $10,000 (2) $10,001 - $20,000
    (3) $20,001 - $30,000 (4) $30,001 - $40,000
    (5) more than $40,000

(D) TRAVEL CHARACTERISTICS

11. Work Trips (Distance from work to home):
    (1) 0-5 miles (2) 6-10 miles (3) 11-20 miles
    (4) more than 20 miles

12. What is the approximate time you usually leave home?

    ____

13. Average travel time (home to work):
    __________ minutes

14. How do you commute to work?
    (1) By car alone (2) Car pool (3) Van pool
    (4) Mass Transit (5) Walk

15. Miles traveled by your vehicle(s) per week for work/school for commuting:
    (a) Vehicle 1: (1) 0-40 miles per week (2) 41-70 (3) 71-140
    (4) more than 140 miles
    (b) Vehicle 2: (1) 0-40 (2) 41-70 (3) 71-140 (4) more than 140
    (c) Vehicle 3: (1) 0-40 (2) 41-70 (3) 71-140 (4) more than 140

16. Miles traveled by your vehicle(s) per week for family business (shopping, errands, banking):
    (a) Vehicle 1: (1) 0-20 (2) 21-35 (3) 36-70 (4) more than 70
    (b) Vehicle 2: (1) 0-20 (2) 21-35 (3) 36-70 (4) more than 70
    (c) Vehicle 3: (1) 0-20 (2) 21-35 (3) 36-70 (4) more than 70

17. Miles traveled by your vehicle(s) per week for civic/religious activities:
    (a) Vehicle 1: (1) 0-5 (2) 6-10 (3) 11-20 (4) more than 20
    (b) Vehicle 2: (1) 0-5 (2) 6-10 (3) 11-20 (4) more than 20
    (c) Vehicle 3: (1) 0-5 (2) 6-10 (3) 11-20 (4) more than 20

18. Miles traveled by your vehicle(s) per week for social/recreational activities:
    (a) Vehicle 1: (1) 0-40 (2) 41-70 (3) 71-140 (4) more than 140
    (b) Vehicle 2: (1) 0-40 (2) 41-70 (3) 71-140 (4) more than 140
    (c) Vehicle 3: (1) 0-40 (2) 41-70 (3) 71-140 (4) more than 140

19. What is your commuting style?
    (1) I drive alone to work/school.
    (2) I carpool or share a ride to work/school.
    (3) I walk or ride public transit to work/school.

(E) TRAFFIC PATTERN

20. Give the name and address of your work:

    ____
    ____
    ____

21. If you use a car:
    (a) What are the usual routes you travel?
        ____
        ____
    (b) Main routes:
        ____
        ____
        ____

(F) EMPLOYMENT CHARACTERISTICS

22. Your work schedule is:
    (1) Normal hours (7:00 am - 5:00 pm)
    (2) Normal hours plus shift
    (3) Normal hours plus overtime
    (4) Full time (5) Part time
    ____________ Not applicable

23. Do you need your car during working hours?
    (1) Yes (2) No

(G) PARKING AVAILABILITY

24. Is parking provided by your employer?
    (1) Yes (2) No

25. What is the cost of parking?
    (1) Free (2) $___/day

(H) MODAL CHOICE

26. At what cost will you consider van pooling?
    (1) $0 saving per month (2) $1-9 saving/month
    (3) $10-20 saving/month (4) $21-30 saving/month (5)more than $30

27. At what level of service would you van pool?
    (Level or services is defined as wait time and convenience.)
    (1) Less travel time than auto (0-10 minutes)
    (2) More travel time than auto (0-10 minutes)
    (3) More travel time than auto (11-20 minutes)

28. Will you consider joining a van pool?
    (a) If present mode of travel is by auto:
        (1) Yes (2) No
    (b) If present mode of travel is by car pool:
        (1) Yes (2) No
    (c) If present mode of travel is by mass transit:
        (1) Yes (2) No

29. Give any additional comments on van pooling:

    ____

    ____

(I) DRIVING HABITS

30. I observe the posted speed limits: (1) Yes (2) No

31. I drive at a steady speed: (1) Yes (2) No

32. I accelerate smoothly and moderately: (1) Yes (2) No

33. I never let the engine idle for more than one minute:
    (1) Yes (2) No

34. I ease off the accelerator when going downhill:
    (1) Yes (2) No

35. I avoid streets with frequent stops: (1) Yes (2) No

36. I anticipate speed changes and stops by slowing down early to avoid last-second breaking: (1) Yes (2) No

37. I plan my trips when making errands so that I don't retrace my path:
    (1) Yes (2) No

38. I make all consecutive daily errands in one trip rather than return home between destinations: (1) Yes (2) No

Appendix C Sample Size Determination and Baseline Travel for Transportation Control Measures

C-1 Sample Size Determination

In determining a simple random sample (SRS) necessary for a population of 142,619 residents, the procedures discussed in Kalton (1983) were used. To determine the appropriate sample size, a precision of 2% was specified. That is, the initial specification calls for an estimation (percentage of residents who will demonstrate a high degree of acceptability to any of the Transportation Control Measures) that is within 2% of the population percentage with 95% probability. Thus 1.96 SE(p) = 2%, where p is the sample percentage and SE (p) is the standard error of the sample percentage. Assuming the use of simple random sampling (SRS) initially and ignoring the finite population correction (fpc), then

$$SE(p) = \sqrt{\frac{PQ}{n'}}$$

Where P is the population percentage, Q = 100-P and n' is the initial sample size. Thus

$$1.96\sqrt{\frac{PQ}{n'}} = 2$$

$$n' = (1.96)^2 PQ / 2^2$$

Suppose 15%<P<35% and we choose P = 35%, then

$$n' = \frac{(1.96)^2 (35)(65)}{2^2} = \frac{3.8416 \times 2275}{4} = 2185$$

A revised sample size is needed to take into account the fpc term and with N = 142,619 and using the formula:

$$n = Nn'/(N+n)$$

$$n = \frac{142{,}619 \times 2185}{(142{,}619 + 2185)} = \frac{142{,}619 \times 2185}{144{,}804} = 2152$$

The information from census blocks provided by the Imperial Calcasieu Regional Planning and Development Commission in Lake Charles was used to proportionately allocate the sample size within each block based on the population of each block.

C-2 Baseline Travel Characteristics Input Data for Transportation Control Measures

(A) Data from ES Used to Calculate VMT

Another objective of this study was to determine the effectiveness of the most favored TCM to decrease mobile source emissions if implemented. Data from the ES are, therefore, important in allowing for the calculation of estimates of variables such as total vehicle miles traveled (VMT) by residents in the study area and number of work and non-work trips taken as a total or average measure. In the case of VMT, the information collected for vehicle miles traveled by households with at least three cars for work and non-work purposes was used. The following Tables (C-1 to C-25) present data used to calculate estimates of total VMT for work, school, shopping, business, civic/religious, and social/recreational activities from the employee survey information. Note that N/A, as used in the Tables C-1 through C-25, indicates Not Applicable.

C-2.1 Vehicle Miles Traveled for Work and Non-Work Activities by Veh. #1

(a) Miles Traveled by Vehicle 1 From Home to Work (HBW):

Table C-1: Distribution of HBW Vehicle Miles of Travel by Veh. #1

Distance Traveled (miles)	Label	Frequency	Percent	Cum. Percent
No Response	0[a]	27	6.0	6.0
0-40	1	175	38.7	44.7
41-70	2	116	25.7	70.4
71-140	3	91	20.1	90.5
>140	4	43	9.5	100.0
	Total	452	100.0	

Total VMT = Sum of Frequency Value x Avg. Dists. Traveled

Total VMT = 175(20) + 116(55.5) + 91(105.5) + 43(141)
= 3500 + 6438.00 + 9600.5 + 6063
= 25,601.50 (N_b = 425)

Note: (a) 0 stands for number of no response
(b) N stands for total number of responses

(b) Miles Traveled by Vehicle 1 to School from Home (HBS):

Table C-2: Distribution of HBS Vehicle Miles Traveled by Veh. #1

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
No Response	0	180	39.8	39.8
0-40	1	197	43.6	83.4
41-70	2	10	2.2	85.6
71-140	3	5	1.1	86.7
>140	4	5	1.1	87.8
N/A	5	55	12.2	100.0
	Total	452	100.0	

Total VMT = 197(20) + 10(55.5) + 5(105.5) + 5(141)
= 3940 + 555 + 527.50 + 705
= 5727.50 (N = 217)

(c) Miles Traveled by Vehicle 1 to Shop from Home (HBSH):

Table C-3: Distribution of HBSH Vehicle Miles Traveled by Veh. #1

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	27	6.0	6.0
0-20	1	217	48.8	54.0
21-35	2	123	27.2	81.2
36-70	3	67	14.8	96.0
>70	4	17	3.8	99.8
N/A	5	1	2	100.0
	Total	452	100.0	

Total VMT = 217(10) + 123 (28) + 67(53) + 17(71)
= 2170 + 3444 + 3551 + 1207
= 10,372 (N = 424)

(d) Miles Traveled by Vehicle 1 for Business from Home (HBB):

Table C-4: Distribution of HBB Vehicle Miles of Travel by Veh. #1

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
No Response	0	28	6.2	6.2
0-20	1	179	39.6	45.8
21-35	2	89	19.7	65.5
36-70	3	98	21.7	87.2
>70	4	54	11.9	99.1
N/A	5	4	0.9	100.0
		452	100.0	

Total VMT = 179(10) + 89(28) + 98(53) +54(71)
= 1790 + 2492 + 5194 + 3834
= 13,310 (N = 420)

(e) Miles Traveled by Vehicle 1 for Civic from Home (HBC):

Table C-5: Distribution of HBC Vehicle Miles of Travel by Veh #1

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
No Response	0	43	9.5	9.5
0-5	1	185	40.9	50.4
6-10	2	101	22.3	72.8
11-20	3	64	14.2	86.9
>20	4	53	11.7	98.7
N/A	5	6	1.3	100.0
	Total	452	100.0	

Total VMT = 185(2.5) + 101(8) + 64 (15.5) + 53(21)
= 462.5 + 808 + 992 +1113.0
= 3,375.5 (N = 403)

(f) Miles Traveled by Vehicle 1 for Social from Home (HBSO):

Table C-6: Distribution of HBSO Vehicle Miles of Travel by Veh. #1

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	32	7.1	7.1
0-40	1	287	63.5	70.6
41-70	2	86	19.0	89.6
71-140	3	34	7.5	97.1
>140	4	13	2.9	100.0
	Total	452	100.0	

Total VMT = 287(20) + 86(55.5) + 34(105.5) + 13(141)
= 5740 + 4773 + 3587 + 1833
= 15,933.0 (N = 407)

C-2.2 Vehicle Miles Traveled for Work and Non-Work Activities by Veh. #2

(a) Miles Traveled by Vehicle 2 to Work from Home (HBW):

Table C-7: Distribution of HBW Vehicle Miles of Travel by Veh. #2

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	161	35.6	35.6
0-40	1	141	31.2	66.8
41-70	2	65	14.4	81.2
71-140	3	62	13.7	94.9
>140	4	22	4.9	99.8
N/A	5	1	.2	100.0
		452	100.0	

Total VMT = 141(20) + 65(55.5) + 62(105.5) + 22(141)
= 2820 + 3607.5 + 6541 + 3102
= 16,070.5 (N = 291)

(b) Miles Traveled by Vehicle 2 to School from Home (HBS):

Table C-8: Distribution of HBS Vehicle Miles Traveled by Veh. #2

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	243	53.8	53.8
0-40	1	129	28.5	82.3
41-70	2	13	2.9	85.2
71-140	3	5	1.1	86.3
>140	4	4	.9	87.2
N/A	5	58	12.8	100.0
	Total	452	100.0	

Total VMT = 129(20 + 12(55.5) + 5(105.5) + 4(141)
= 2580 + 721.5 + 527.5 + 564
= 4,393 (N = 151)

(c) Miles Traveled by Vehicle 2 to Shop from Home (HBSH):

Table C-9: Distribution of HBSH Vehicle Miles of Travel by Veh. #2

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	186	41.2	41.2
0-20	1	164	36.3	77.4
21-35	2	55	12.2	89.6
36-70	3	34	7.5	97.1
>70	4	11	2.4	99.6
N/A	5	2	.4	100.0
	Total	452	100.0	

Total VMT = 164 (10) + 55(28) + 34(53) + 11(71)
= 1640 + 1540 + 1802 + 781
+ 5,763 (N = 264)

(d) Miles Traveled by Vehicle 2 for Business from Home (HBB):

Table C-10: Distribution of HBB Vehicle Miles of Travel by Veh. #2

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	185	40.9	40.9
0-20	1	134	29.6	70.6
21-35	2	52	11.5	82.1
36-70	3	56	12.4	94.5
>70	4	20	4.4	98.9
N/A	5	5	1.1	100.0
	Total	452	100.0	

Total VMT = 134(10) + 52(28) + 56(53) + 20(71)
= 1340 + 1456 + 2968 + 1420
= 7184 (N = 262)

(e) Miles Traveled by Vehicle 2 for Civic
from Home (HBC):

Table C-11: Distribution of HBC Vehicle Miles
of Travel by Veh. #2

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	200	44.2	44.2
0-5	1	130	28.8	73.0
6-10	2	48	10.6	83.6
11-20	3	33	7.3	90.9
>20	4	34	7.5	98.5
N/A	5	7	1.5	100.0
	Total	452	100.0	

Total VMT = 130(2.5) + 48(8) + 33(15.5) + 34(21)
= 325 + 384 + 511.5 + 714
= 1934.5 (N = 245)

(f) Miles Traveled by Vehicle 2 for Social
from Home (HBSO):

Table C-12: Distribution of HBSO Vehicle
Miles of Travel by Veh. #2

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	164	36.3	36.3
0-40	1	210	46.5	82.7
41-70	2	53	11.7	94.7
71-140	3	19	4.2	98.7
>140	4	5	1.1	99.8
N/A	5	1	.2	100.0
	Total		100.0	

Total VMT = 210(20) + 53(55.5) + 19(105.5) + 5(141)
= 4200 + 2941.5 + 2004.5 +705
+ 9851 (N = 287)

C-2.3 Vehicle Miles Traveled for Work and Non-Work Activities by Veh. #3

(a) Miles Traveled by Vehicle 3 to Work from Home (HBW):

Table C-13: Distribution of HBW Vehicle Miles of Travel by Veh. #3

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	371	82.1	82.1
0-40	1	43	9.5	91.6
41-70	2	13	2.9	94.5
71-140	3	19	4.2	98.7
>140	4	6	1.3	100.0
	Total	452	100.0	

Total VMT = 43(20) + 13(55.5) + 19(105.5) + 6(141)
= 860 + 721.50 + 2004.5 + 846
= 4432 (N = 75)

Note: (b) Miles Traveled by Vehicle 3 to School: Total VMT = 0.

(c) Miles Traveled by Vehicle for Shop from Home (HBSH):

Table C-14: Distribution of HBSH Vehicle Miles of Travel by Veh. #3

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	372	82.3	82.3
0-20	1	54	11.9	94.2
21-35	2	15	3.3	97.6
36-70	3	10	2.2	99.8
N/A	5	1	.2	100.0
	Total	452	100.0	

Total VMT = 54(10)+ 15(28) + 10(53)
= 540 + 420 + 530
= 1490 (N = 79)

(d) <u>Miles Traveled by Vehicle 3 for Business from Home (HBB):</u>

Table C-15: Distribution of HBB Vehicle Miles of Travel by Veh. #3

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	366	81.0	81.0
0-20	1	47	10.4	91.4
21-35	2	17	3.8	95.1
36-70	3	14	3.1	98.2
>70	4	4	.9	99.1
N/A	5	4	.9	100.0
	Total	452	100.0	

Total VMT = 47(10) + 17(28) + 14 (53) + 4(71)
= 470 + 476 + 742 + 284
= 1972 (N = 82)

(e) <u>Miles Traveled by Vehicle 3 for Civic from Home (HBC):</u>

Table C-16: Distribution of HBC Vehicle Miles of Travel by Veh. #3:

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
		370	81.9	81.9
0-5	0	47	10.4	92.3
6-10	1	14	3.1	95.4
11-20	2	5	1.1	96.5
>20	3	10	2.2	98.7
N/A	4	6	1.3	100.0
	5	452	100.0	

Total VMT = 47(2.5) + 14(8) + 5(15.5) + 10(21)
= 117.5 + 112 + 77.5 + 210
= 517 (N=76)

(f) Miles Traveled by Vehicle 3 for Social from Home (HBSO):

Table C-17: Distribution of HBSO Vehicle Miles of Travel by Veh. #3

Distance Traveled (miles)	Value	Frequency	Percent	Cum. Percent
	0	367	81.2	81.2
0-40	1	60	13.3	94.5
41-70	2	16	3.5	98.0
71-140	3	4	.9	98.9
>140	4	5	1.1	100.0
	Total	452	100.0	

Total VMT = 60(20) + 16(55.5) + 4(105.5) + 5(141)
= 1200 + 888.0 + 422 + 705
= 3215 (N =85)

(B) VMT Estimation Procedures

Requirements for TCM Program Inputs:

(1) Total VMT

(2) Total Number of Trips

(3) % of VMT in Peak Period

(4) % of VMT in Off-Peak Period

Work Trip Analysis:

Household sample size = 425

Survey data based on 1, 2, and 3 car ownership

Total Daily Vehicle miles from weekly travel:

Car No 1:	Travel per day	(25601.5/5) =	5120.3
Car No 2:	Travel per day	(16070.5/5) =	3214.1
Car No 3:	Travel per day	(4432/5) =	886.4

(a) Total Daily Vehicle Miles for 425 households = 9920.8

VMT/day = 9221

Note: Assumption is that home to work is based on a 5-day week.

Number of persons in the sample households:

(survey information)

1 person/home = 14.35%

2 person/home = 30.490%

3 person/home = 18.834%

4 or more persons/home = 36.323%

Total number of respondents = 446 homes

Using the above distributions compute the number of persons for the commute or work trips as:

14.35% of 425 = 60.988 homes x 1 person/home = 60.99

30.490% of 425 = 129.583 homes x 2 persons/home = 259.17

18.834% of 425 = 80.485 homes x 3 persons/home = 240.134

36.323% of 425 = 154.373 homes x 4 persons/home = 617.491

(a) Total Number of persons in the sample = 1178.0 persons

Estimate of Daily VMT per person = 9221/1178

Daily Commute VMT per person = 7.828 VMT/person

= 8

Total area population = 142,619 (1990 Census)

Total daily commute VMT = 8 VMT/person x 142,619 persons

Daily commute VMT = 1,140,958 VMT

Daily commute transit VMT = 569.4*

(b) Total = 1,140,958 + 569.4

= 1,141,527.4 VMT

* Data supplied by Lake Charles Transit Authority

<u>Non-Work VMT Calculations</u>:

<u>Home to School VMT:</u>

Car No 1: Travel per day (5727/5) = 1145.5

Car No 2: Travel per day (4393/5) = 878.6

Car No 3: Travel per day 0 = <u>0</u>

Total Daily VMT = 2024.1

Note: Assumption is that home to school is based on a 5-day week.

Calculation of Total No. of persons in the sample of 217:

14.35% of 217 = 31.14 homes x 1 person/home = 31.14 persons

30.490% of 217 = 66.163 homes x 2 persons/home = 132.327 persons

18.834% of 217 = 40.87 homes x 3 persons/home = 122.609 persons

36.323% of 217 = 78.821 homes x 4 persons/home = 315.284 persons

Total Number of persons = 602

Average Daily VMT for school per person = 2024.1/602

= 3.367

= 3.4

(c) Total home to school VMT for the area = 3.4 x 142,619

= 484,904.6

Home to Shop VMT:

Car No. 1: Travel per day (10372/7) = 1481.714

Car No. 2: Travel per day (5763/7) = 823.286

Car No. 3: Travel per day (1490/7) = 212.857

Total Daily VMT: 2517.857

Note: Assumption is that home to shop is based on a 7-day week.

Calculation of Total No. of persons in the sample of 424:

14.35% of 424 = 60.844 homes x 1 person/home = 60.844 persons

30.439% of 424 = 129.061 x 2 persons/home = 258.125 persons

18.834% of 424 = 79.856 x 3 persons/home = 239.568 persons

36.323% of 424 = 154.01 x 4 persons/home = 616.038 persons

Total Number of persons = 1175 persons

Average home-shop VMT/person = 2518.0/1175

= 2.144

= 2

(d) Total Home-shop VMT for the area = 2 x 142,619

= 285,238

Home to Business VMT:

Car No. 1: Travel per day = (13,310/7) = 1901.429

Car No. 2: Travel per day = (7184/7) = 1026.286

Car No. 3: Travel per day (1972/7) = 281.714

Total Daily VMT = 3209.429

Note: Assumption is that home to business is based on a 7-day week.

Calculation of Total No. of Persons in the sample of 420:

14.35% of 420 = 60.27 homes x 1 person/home = 60.27 persons

30.490% of 420 = 128.058 homes x 2 persons/home = 256.116 persons

18.834% of 420 = 79.103 x 3 persons/home = 237.308 persons

36.323% of 420 = 152.557 x 4 persons/home = 610.226 persons

Total No. of persons = 1164

Average Home-Business VMT/person = 3209.429/1164

= 2.758

= 3

Total Home-Business VMT for the area = 3 x 142,619

= 427,857

Home-Civic VMT:

Car No. 1: Travel per day = (3375.5/7) = 482.214

Car No. 2: Travel per day = (1934.5/7) = 276.357

Car No. 3: Travel per day = (517/7) = 73.587

Total daily VMT = 832.429

Note: Assumption is that home to civic events is based on a 7-day week.

Calculation of Total Number of persons in the sample of 403:

14.35% of 403 = 57.831 homes x 1 person/home = 57.831 persons

30.490% of 403 = 122.875 homes x 2 persons/home = 245.749 persons

18.834% of 403 = 79.901 homes x 3 persons/home = 227.703 persons

36.323% of 403 = 146.382 homes x 4 persons/home = 585.527 persons

Total No. of persons = 1117

Average Home-Civic VMT/person = 832.429/1117

= .75

(e) Total Home-Civic VMT for the area = .75 x 142,619

= 106,964

Home to Social VMT:

Car No. 1: Travel per day = (15,933/7) = 2,276.143

Car No. 2: Travel per day = (9851/7) = 1,407.286

Car No. 3: Travel per day = (3215/7) = 459.286

Total Daily VMT = 4142.714

Note: Assumption is that home to social function is based on a 7-day week.

Calculation of Total Number of persons in the sample of 407:

14.35% of 407 = 58.405 x 1 person/home = 58.405 persons

30.490% of 407 = 124.094 homes x 2 person/home = 248.189 persons

18.834% of 407 = 74 homes x 3 persons/home = 223.724 persons

36.323% of 407 = 147.835 homes x 4 persons/home = <u>591.338</u> persons

Total No. of persons = 1122

Average Daily VMT person = 4142.714/1122

= 3.695

= 4

(f) Total Daily VMT for the area = 4 x 142,619

= 570,476

Total Work Daily VMT = 1,140,958 VMT

Total Non-Work VMT [(d) + (e) + (g) + (h)]:

484,905 + 285,238 + 427,857 = 106,964 + 570,476 = 1,875,440

Total Commute & Non-commute = 1,140,958 = 1,875,440

= 3,016,398 VMT

Transit VMT = 1,121

(1) Total VMT = 3,016,398 + 1,121

= 3,017,519

2. <u>Determination of the Number of Trips</u>:
<u>Number of Work Trips:</u>

From the 1990 Nationwide Personal Transportation Survey (NPTS), the daily vehicle trips per household was calibrated using a mathematical regression model. The average daily vehicle trips was computed as 4.637 trips per household.

For the research target area, the

Household work sample size = 425 households

Household total persons in the sample = 1178 persons

Sample work trips = 425 households x 4.637 trips/household

= 1970.725 trips

Work trips/person = 1970.725 trips/1178 persons

= 1.67

Population total work trips = 1.673 trips/person x 142,619 persons

= 238,593.233

Total work trips + transit trips = 238,594 + 32* = 238,626 trips

*Data supplied by the Lake Charles Transit Authority

Non-work Trips:

Home to School Daily Trips:

Sample household number = 217 homes

Total persons in household = 602 persons

Total trips in the sample = 4.637 x 217 homes

= 1006.229 trips

Trips per person = 1006.229 trips/602 persons

= 1.671

Total trips = 1.671 trips/person x 142,619 persons

= 238,384.342 trips

Home to Shopping Daily Trips:

Sample household size = 424 homes

Sample total person = 1175 persons

Sample total trips = 4.637 trips/household x 424 households

= 1966.088 trips

Trips per person = 1966.088/1175

= 1.673 trips per person

Population home/shopping trips/day = 1.673 x 142,619

= 238,639.57

Total Daily home/School Trips = 238,640 trips

Home to Business Daily Trips:

Sample household size = 420 homes

Sample total persons = 1164

Sample total trips = 4.637 trips/household x 420 households

= 1947.54 trips

Trips per person = 1947.54 trips/1164 person

= 1.673

Population Home/Business Daily Trips = 1.673 x 142.619

Total daily trips = 238,622.171

Home to Civic Daily Trips:

Sample household size = 403 homes

Sample total persons = 1117 persons

Sample total trips = 4.637 trips/household x 403 households

= 1868.711 trips

Trips per person = 1868.711/1117 person

= 1.673 trips/person

Total Daily Trips = 1.673 x 142,619

Home/Civic Daily Trips = 238,597.757

Home to Social Daily Trips:

Sample household size = 407

Sample total persons = 1122 persons

Sample total trips = 4.637 trips/household x 407 households

= 1887.259 trips

Trips per person = 1887.259 tirps/1122 person

= 1.682 trips/person

Daily Total Home/Social Trips = 1.682 trips/person x 142,619 persons

Total Daily Trips = 239,892.149

Non-Commute Daily Trips:

238,384.342 (Home to School)

238,639.57 (Home to Shopping)

238,622.171 (Home to Business)

238,597.757 (Home to Civic Events)

239,892.149 (Home to Social Events)

31.000 (Transit: 63-32)

1,194,166.989

Total Non-Commute trips = 1,194,167/day

Total Commute trips = 238,626/day

(2) Total Daily Trips = 1,194,167 + 238,626

= 1,432,793 trips

Total Daily Non-Commute VMT = 1,875,976.60

Total Daily Commute VMT = 1,141,542.4 miles

Total Daily Commute and Non-Commute VMT = 3,017,519 VMT

Commute Vehicle Trips:

From total commute trips divide by the prevailing load factor of 1.077 calibrated from NPTS[1]

238,626/1.077 = 221,565.5 vehicle trips

Non-Commute Vehicle Trips:

Non-Commute person trips = 1,194,167

Load factor = 1.077

Non-commute Veh. Trips = 1,194,167/1.077

= 1,108,790

Total Commute and Non-Commute Vehicle Trips = 221,566 + 1,108,790

Total Vehicle Trips = 1,330,356

Note: Tables D-18 through D-22 & D-24 - D-25 are data analysis from Employee Survey.

[1] Hu, P. S. and J. Young. Summary of Travel Trends. 1990 Nationwide Personal Transportation Survey (Washington, DC: Federal Highway Administration, HPM-40, 1990).

Table C-18: Commute Trips for HBW Trips

Vehicle Number	VMT per day
1.	5120.3
2.	3214.1
3.	886.4
Daily VMT for 425 households = 9221 VMT	

Table C-19: Distribution of Persons by Household

Number of Persons/Household	Frequency	Percent
One	64	14.35
Two	136	30.49
Three	84	18.84
Four or More	162	36.32
Total	446	100.0%

Table C-20: Distribution of Commuting Trips by Mode

Mode	Frequency	Percent
Drive Alone	411	94.7
Carpool	22	5.1
Vanpool	1	0.2
Total	434	100.0%

Table C-21: Distribution of Commuting Distances

Range of Distances	Frequency	Percent
0-5 miles	129	29.4
6-10 miles	153	34.9
11-20 miles	127	28.9
21 or more miles	30	6.8
Total	439	100.0%

Total Distance = Total Frequency x Mid-point Distance

Total Dist. = 129(2.5 miles) + 153(8) + 127(15.5) + 30(21) = 4145

Average Trip Length = (4145 miles)/439 = 9.4 miles

Peak Period 6 a.m. = 9 a.m. (From MPO's office in Lake Charles)

3 p.m. – 6 p.m.

Table C-22: Distribution of Commute Trips by Time

Time	Frequency	Cum. Percent
6 a.m. – 7 a.m.	75	23.81
7:01 a.m. – 7:30 a.m.	88	51.75
7:31 a.m. – 8:00 a.m.	107	85.71
8:01 a.m. – 8:30 a.m.	29	94.92
8:31 a.m. - 9:00 a.m.	9	97.78
9:01 a.m. – 9:30 a.m.	1	98.10
9;31 a.m. – 12:40 p.m.	4	99.37
>12:40 p.m.	2	100.00

Note: 97.78 % VMT occur within the morning peak period and the figure is assumed to hold during the evening peak period when the commuters return home.

Peak VMT = 0.9778 (1,141,527.4)

Peak VMT = 1,116,185.5

Off Peak VMT = Total VMT – Peak VMT

= 3,017,519 – 1,116,185.5

Off Peak VMT = 1,901,333.5

<u>Drive-Alone Share of Commute Person Trips:</u>

Drive-Alone = 94.7%

Total Commute Person Trips = 239,376

Drive-Alone Share = .947(239,376) trips

= 226,689.1 trips

Commute Vehicle Trips:

Commute Daily Trips = 238,594

Load Factor (Calibrated from NPTS) = 1.077

Commute Vehicle Trips = 238,594/1.077

= 221,537.75

Transit Trips = 32

Total Vehicle Commute Trips = 221,567.75

Total Non-Commute Vehicle Trips:

Non-Commute person trips = 1,194,136

Load Factor = 1.077

Non-Commute Vehicle trips = 1,194,136/1.007

Non-Commute Vehicle trips = 1,108,761.37

Add Transit Non-Commute trips = 31

Total Non-Commute Vehicle Trips = 1,108,792.37

Percent of all Trips in Peak Period:

Peak period commuting trips = .9778(239,376)

= 234,061.85

Add Peak Period Non-Commuting Trips:
Home-School Trips = 238,384

Home-Civic/Religious Trips = 238,598

Total Peak Period Trips = 711,043.85

Total Person Trips = 1,434,230

Percent of all trips in peak period

= 711,043.85/1,434,230 x 100
= 49.58%

Percent of All Trips that are Commute Trips:

Total Commute Trips = 239,376

Total Person Trips = 1,434,230

Percent of all trips that are commute
= (239,376/1434,230) x 100
= 16.69%

Percent of all Trips that are Non-Commute Trips:

Total Daily Person Trips = 1,434,230

Total Daily Person Commute Trips = - 239,376

Total Non-Commute Person Trips = 1,194,854

Percent of all trips that are non-commute

= (1,194,854/1,434,230) x 100

= 83.31%

Percent of Commute Trips in Peak Period:

Total commute Trips = 239,376

Peak Period Commute Trips = 234,061.85

Percent of commute trips in peak period

= (234,061.85/239,376) x 100

= 97.78%

Percent of Non-Commute Trips in Peak Period:

Total non-commuting peak period trips = 476,982.0

Total non-commuting person trips = 1,434,230

Percent of non-commute trips in peak period

= (476,982/1,434,230) x 100

= 33.26%

Percent of Peak Trips That Are Commute Trips:

Total peak trips = 711,043.85

Total commute peak trips = 234,061.85

Percent of peak trips that are commute

= (234,061.85/711,043.85) x 100

= 32.92%

Percent of Off-Peak Trips That Are Commute Trips:

Total off-peak trips = 1,434,230 – 711,043.85

= 723,186.15

Total off-peak commute trips = 239,376 = 234,061.85

= 5,314.15

Percent of off-peak trips that are commute

= (5,314.15/723,186.15) x 100

= 0.73%

Table C-23: Average Vehicle Trip Length
(miles)

Purpose	1969	1977	1983	1990	Calibrated 1993
Home to work	9.4	9.1	8.5	11.0	
Home to shoping	4.4	5.0	5.3	5.1	
Home to personal business	6.5	6.8	6.7	7.4	
Home-soc./recr.	13.1	10.3	10.5	11.8	
Home-other	8.9	8.4	7.9	9.0	
Avg. non-com. Trip length	8.23	7.63	7.6	8.33	8.0

Source: 1990 Nationwide Personal Transportation Survey

Average daily commute out-of-pocket costs per vehicle:

Daily gasoline vehicle = $2.00

Daily parking fee = 1.40

Daily vanpooling/carpooling cost = 4.68

Total Daily costs = $8.08

Percent of all Trips that are Transit:

Total person trips = 1,434,230

Total transit trips = 1,500 (Lake Charles Transit Authority)

Percent of all trips that are transit

= (1,500/1,434,230) x 100

= 0.1046%

<u>Percent of all Commute Trips that are Transit:</u>

Total commute trips = 239,376

Total transit commute trips = 782

Percent of commute that are transit

= (782/239,376) x 100

= 0.3267%

<u>Commute Trip Share of Transit:</u>

Total Transit commute share = 782 trips

<u>Total Transit vehicle miles = 1121 VMT</u>

Total commute daily trips = 238,594 = 782 for transit

= 239,376

Total non-commute daily trips = 1,194,136 + 718 for transit

= 1,194,854

Total daily person trips = 239,376 + 1,194,854

= 1,434,230 trips

Total commute VMT = 1,140,958 + 569.4 for transit

= 1,141,527.4 VMT

Total non-commute VMT = 1,875,440 + 551.6 for transit

= 1,875,991.6

Total VMT = 1,141,527.4 + 1,875,991.6

= 3,017,519 VMT

Table C-24: Distribution of Commute Trips by Distance

Distance	Frequency	Percent
0-5 miles	129	29.39
6-10 miles	153	34.85
11-20 miles	127	28.93
>20 miles	30	6.83
Total	439	100.00%

Table C-25: Distribution of Non-Commute Trips Less than 5/miles by Number of Vehicles and 1 mile by Sample Size (N)

Non-Commute	Vehicle 1	Vehicle 2	Vehicle 3	N
School	197	129		368
Shop	217	164	54	767
Business	179	134	47	764
Civic	185	130	47	724
Social	287	210	60	779
Total	1065	767	208	3402

Frequency = (1065 + 767 + 208)/3402

= 2040/3402

= 59.97%

Average cost of gas/gallon = ($1.12 + 1.30 + 1.20)/3

= $1.21

Average cost per mile to drive = $0.24/mile

(Govt. rate)
Average commute out-of-pocket costs per veh per trip

= $5.00*

* Default value from TCM Tools Model Documentation

Commute Trips on Freeways:

Total household number = 452

62 households use freeway

(62/452) x 100 = 13.72%

Calculation for TCM on – Transit Service Increases

Actual Transit VMT = 1121 (Lake Charles Transit Authority)

Assume 25% Increase in VMT = .25 (1121)

= 281 VMT

Employer-Based Transportation Management TCM:

(Employee Transit Pass Subsidy)

Pass Subsidy = $1310.25 (Lake Charles Transit Authority)

Cost of Operations = $.24/ml. (Louisiana government approved rate)

Driver wages = $6.00/hr

Assumed percent of cost = 8.5%

Appendix D VMT Forecasting Model Computer Output

year	vmt01	vmt02	vmt06	vmt07	vmt08	vmt09	vmt11	vmt14	vmt16	vmt17	vmt19	Sum
1990	787448	46812	121080	379513	95388	161300	921815	394853	314860	2367	17011	3242447
1991	804337		122252	391433	97459		938907	397145	323156			3074689
1992	821225		123425	403353	99530		955999	399437	331452			3134421
1993	838114	50053	124597	415273	101601		973091	401729	339748	2370		3246576
1994	855002		125769	427193	103672		990182	404021	348004			3253843
1995	871891	50073	126942	439112	105743	181624	1007274	406313	356341			3545313
1996	888779	53294	128114	451032	107814	179749	1024366	408605	364627		17145	3623525
1997	905668	54375	129287	462952	109885	183684	1041458	410897	372933	2381	17172	3690692
1998	922557	55455	130459	474872	111956	187706	1058550	413189	381229	2383	17199	3755555

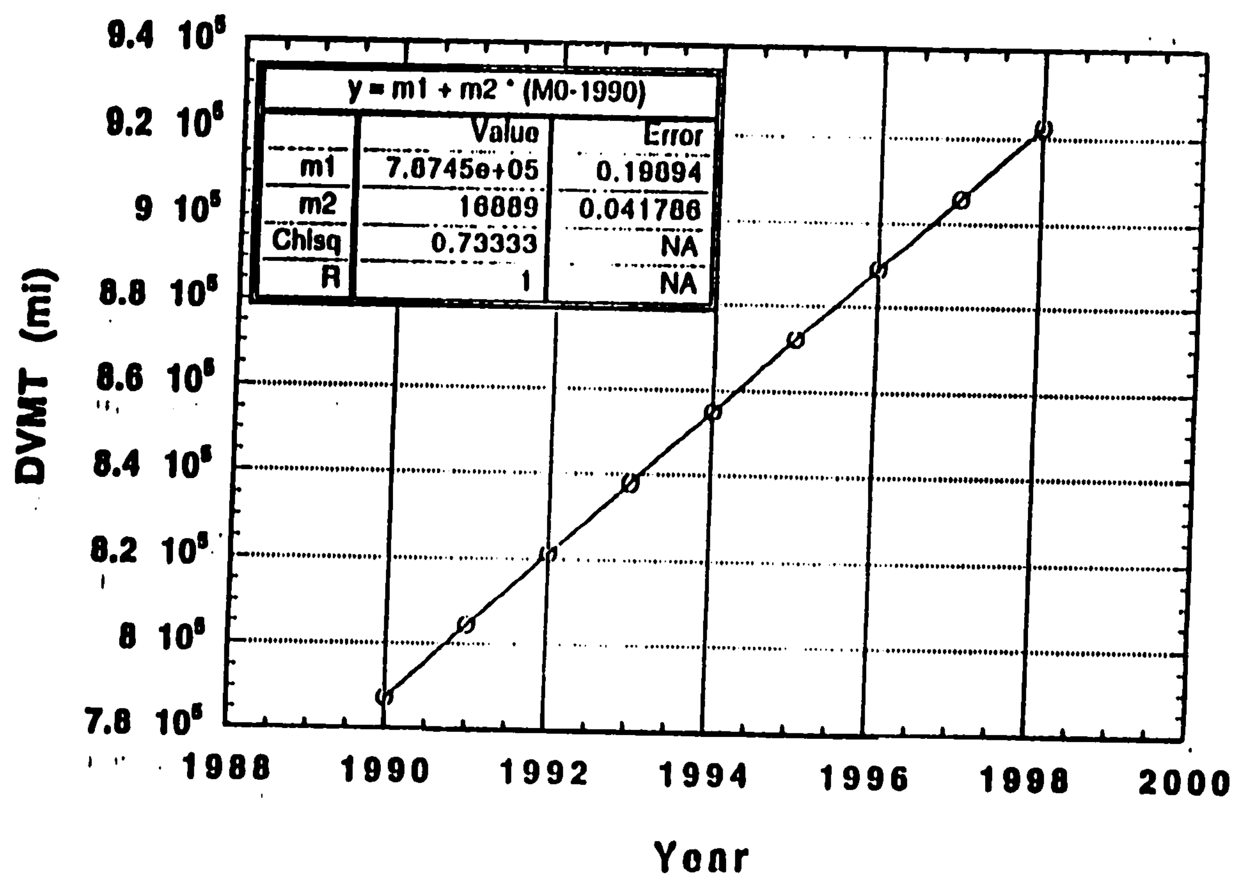

Figure D-1: DVMT for Principal Arterial Rural Interstate (FC-01)

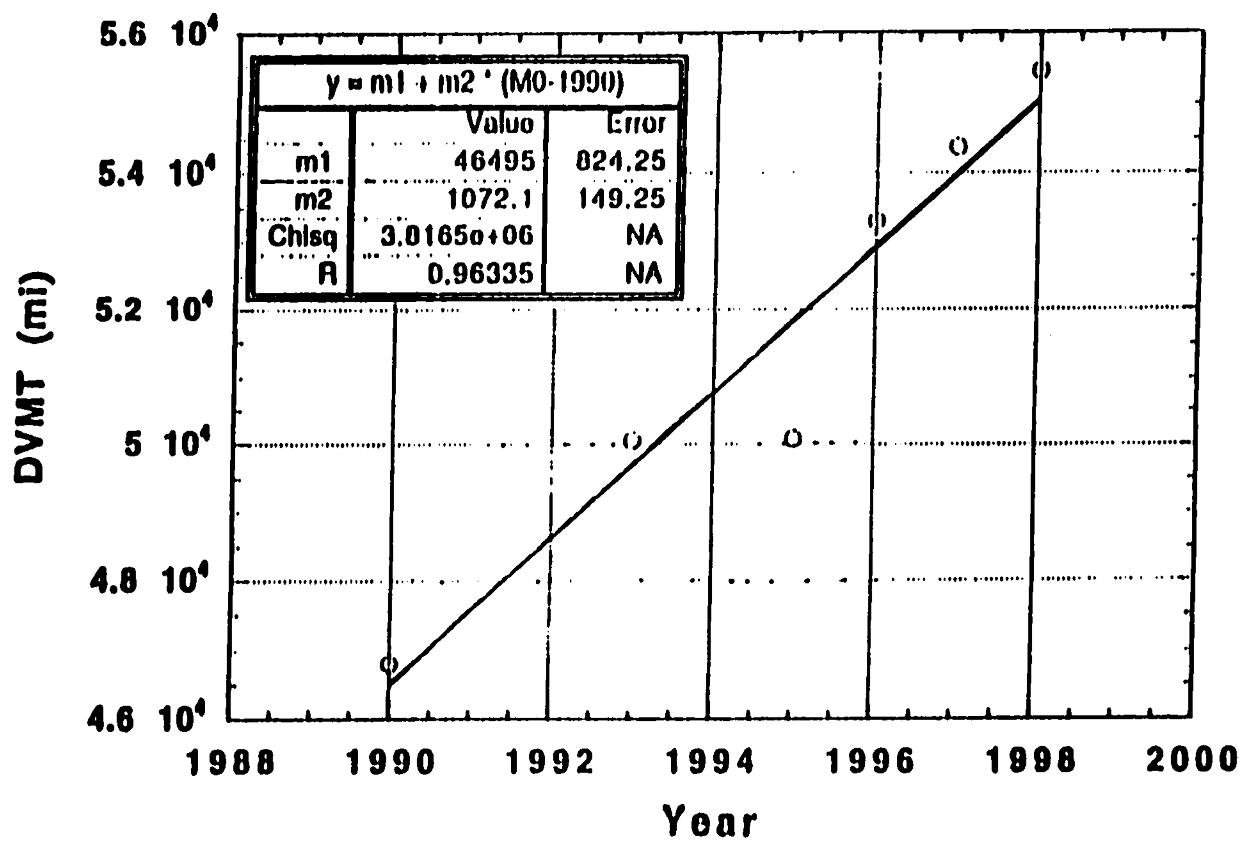

Figure D-2: DVMT for Rural Principal Arterial System (FC-02)

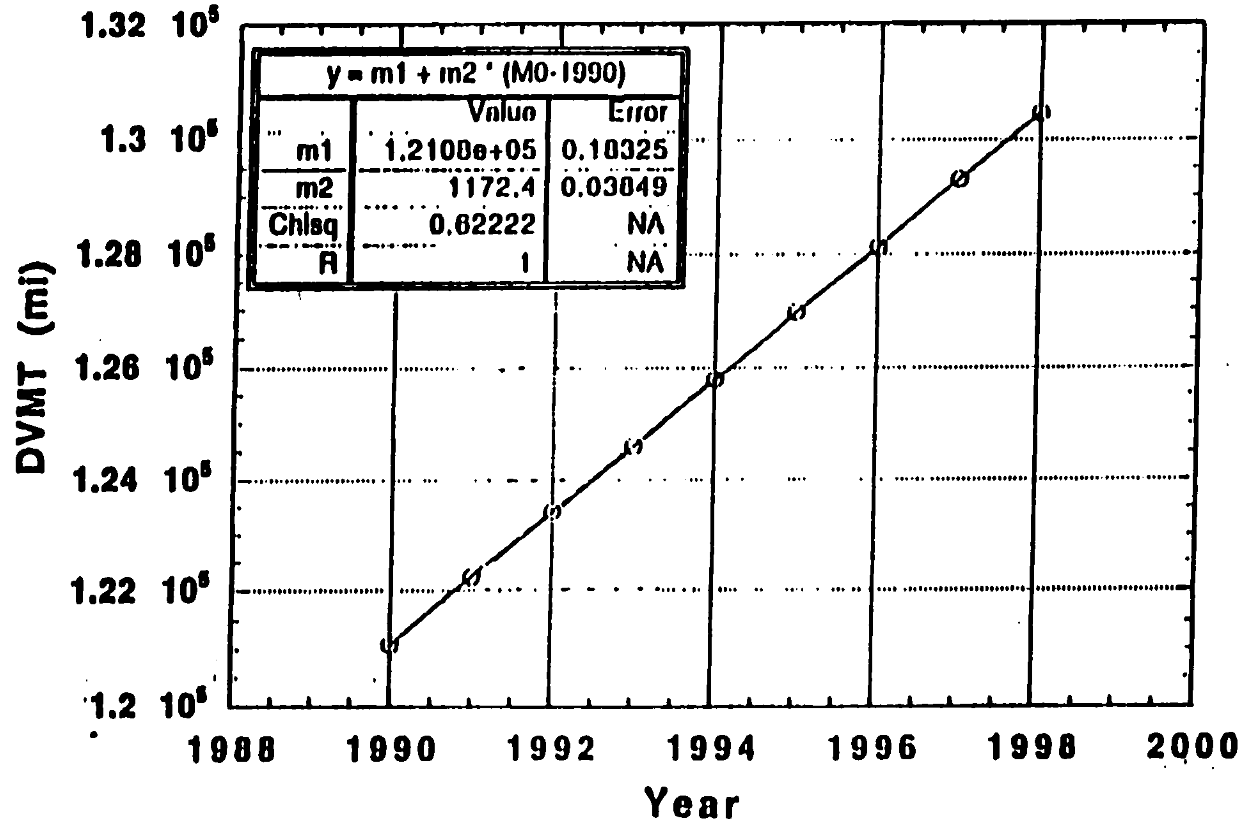

Figure D-3: DVMT for Minor Arterial System (FC-06)

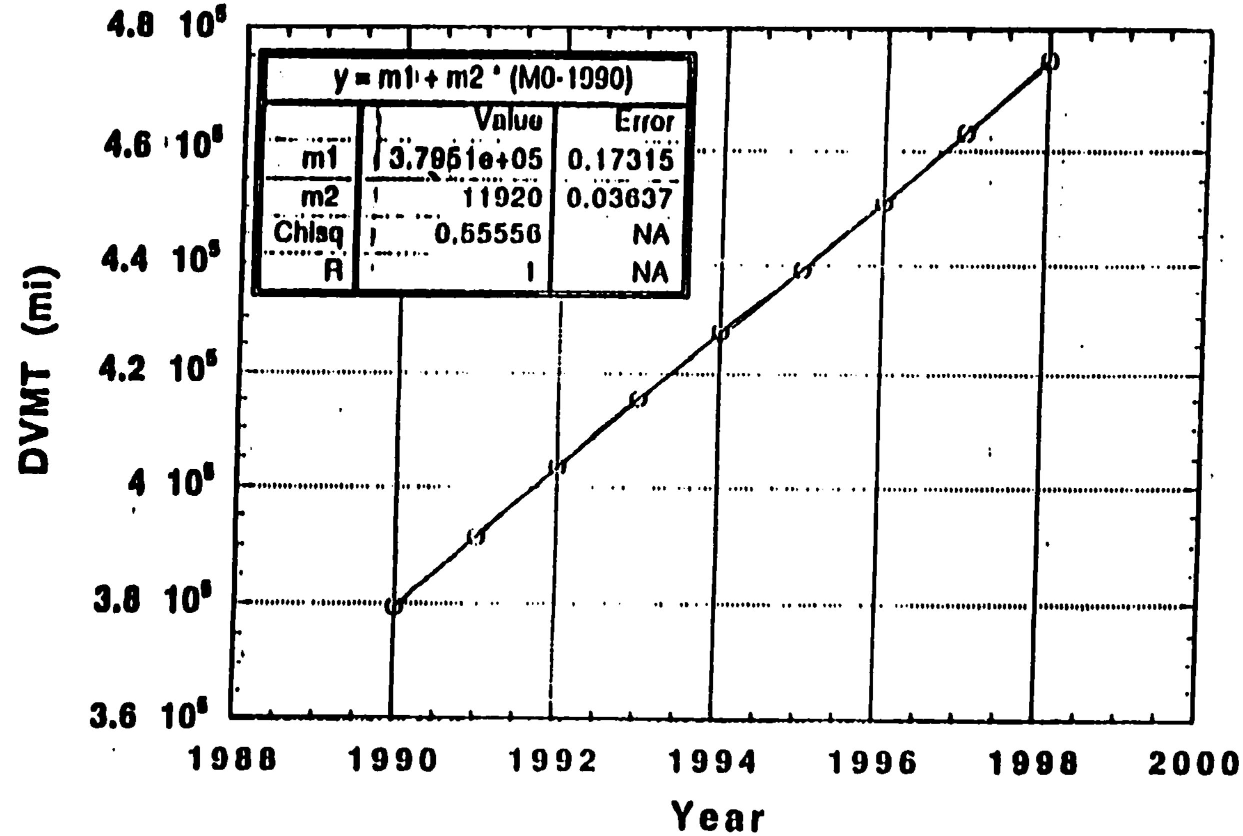

Figure D-4: DVMT for Urban Major Collector System (FC-07)

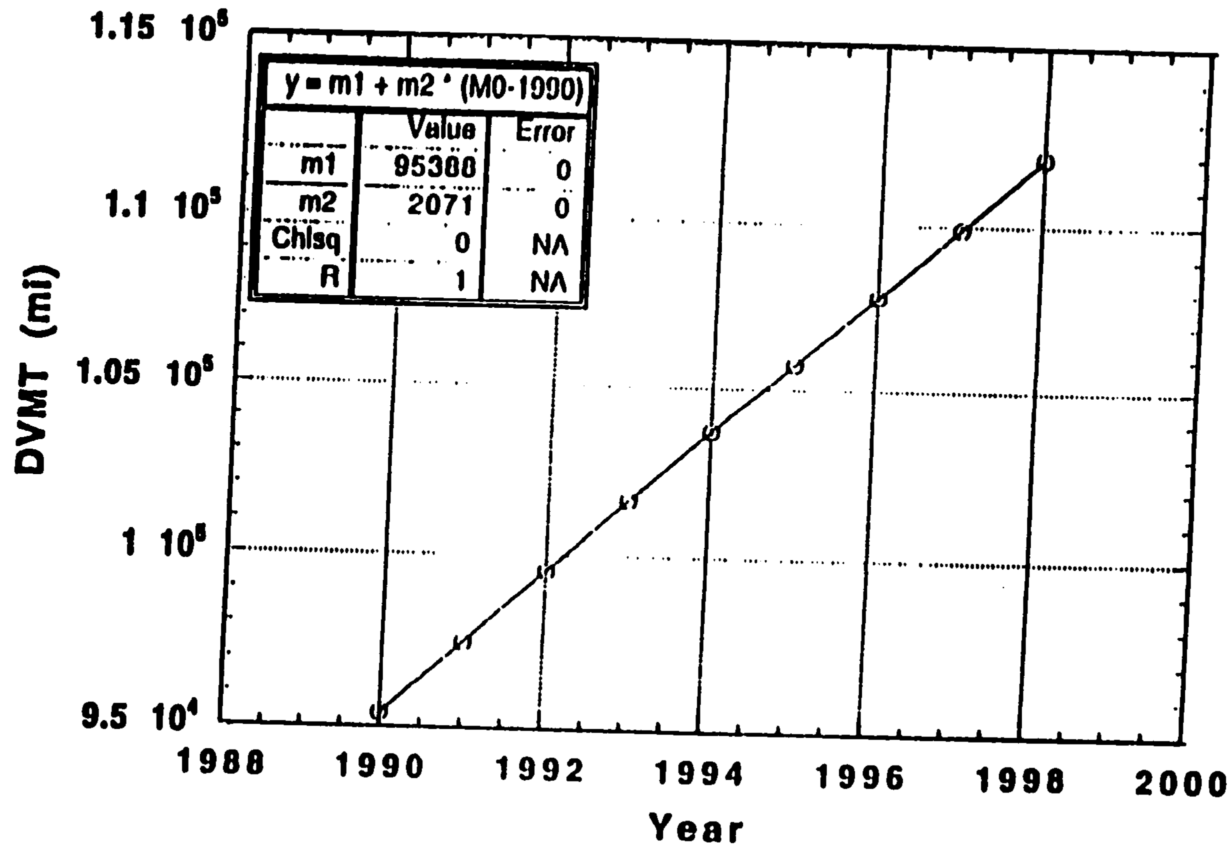

Figure D-5: DVMT for Rural Minor Collector System (FC-08)

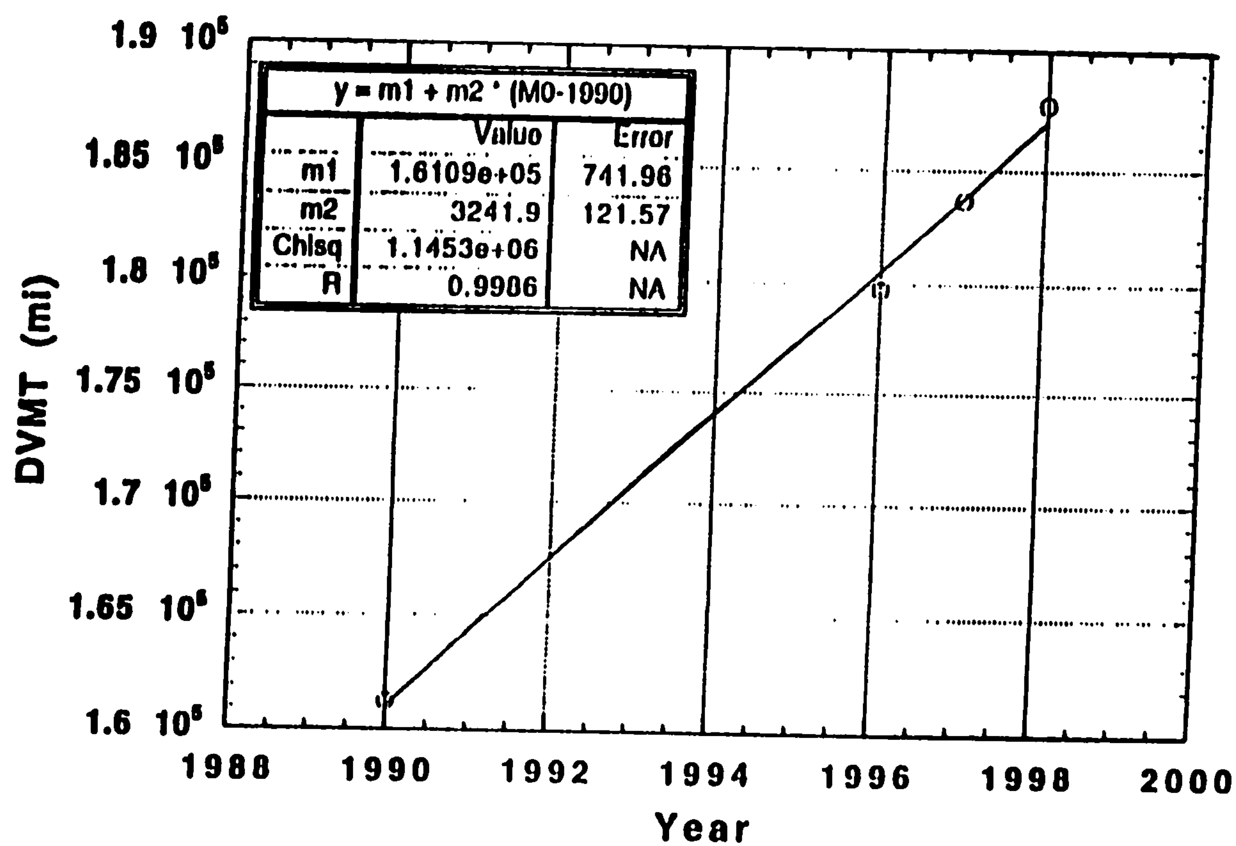

Figure D-6: DVMT for Rural Local Roadway System (FC-09)

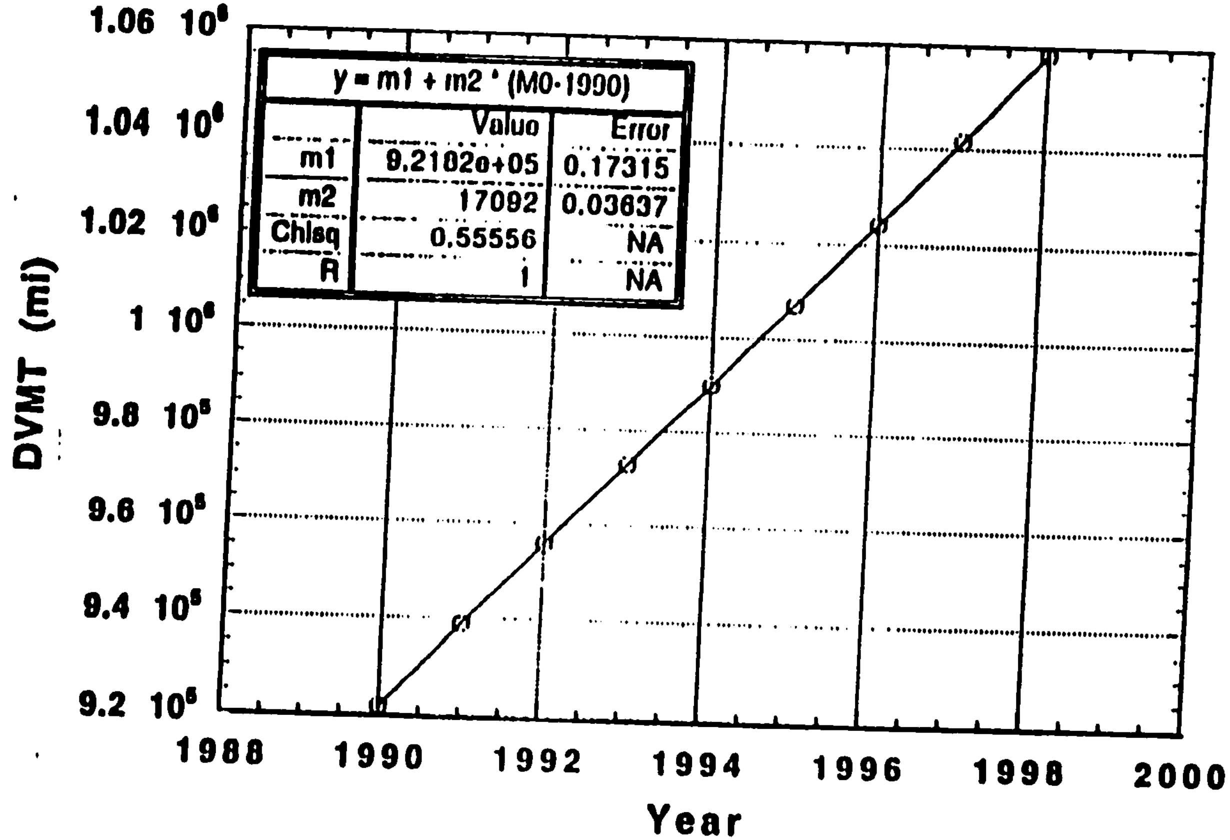

Figure D-7: DVMT for Urban Interstate (State) System (FC-11)

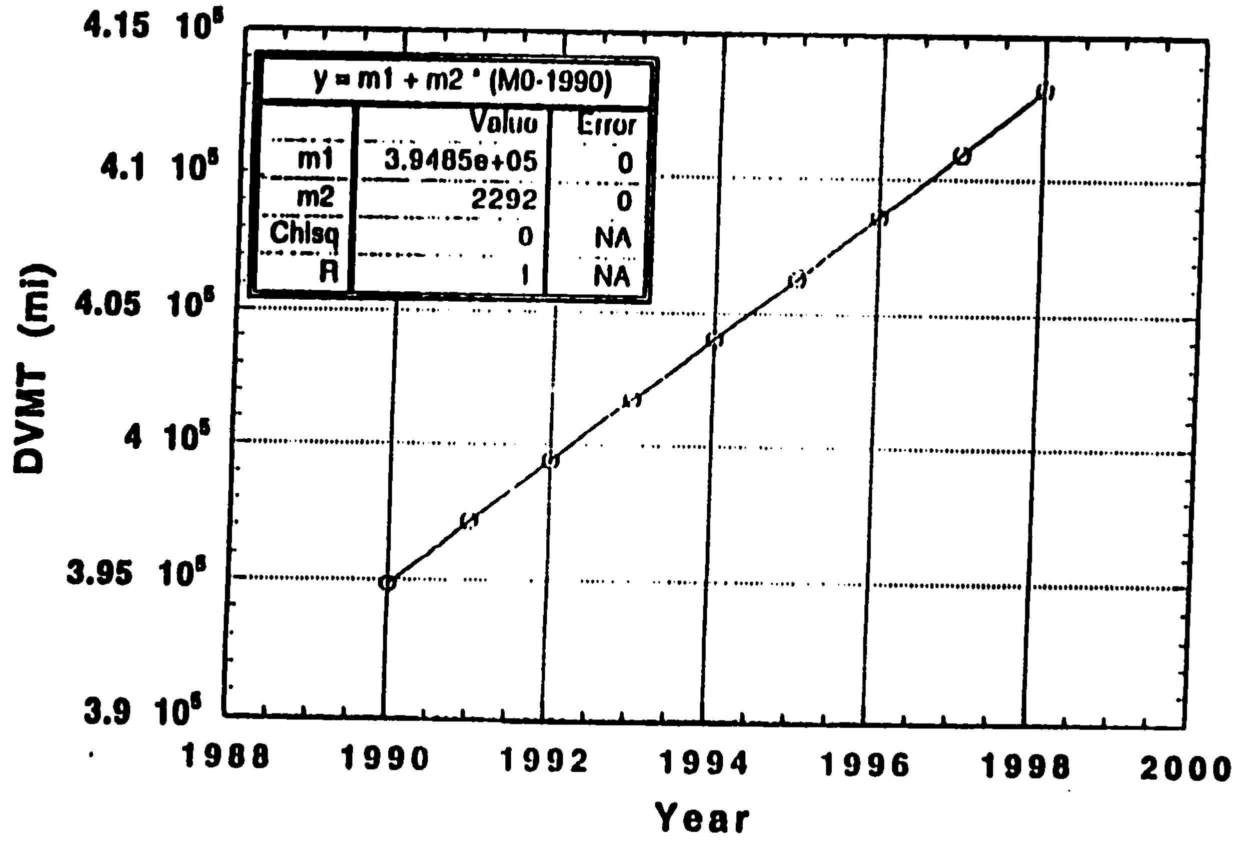

Figure D-8: DVMT for Urban Principal Arterial Road System (FC-14)

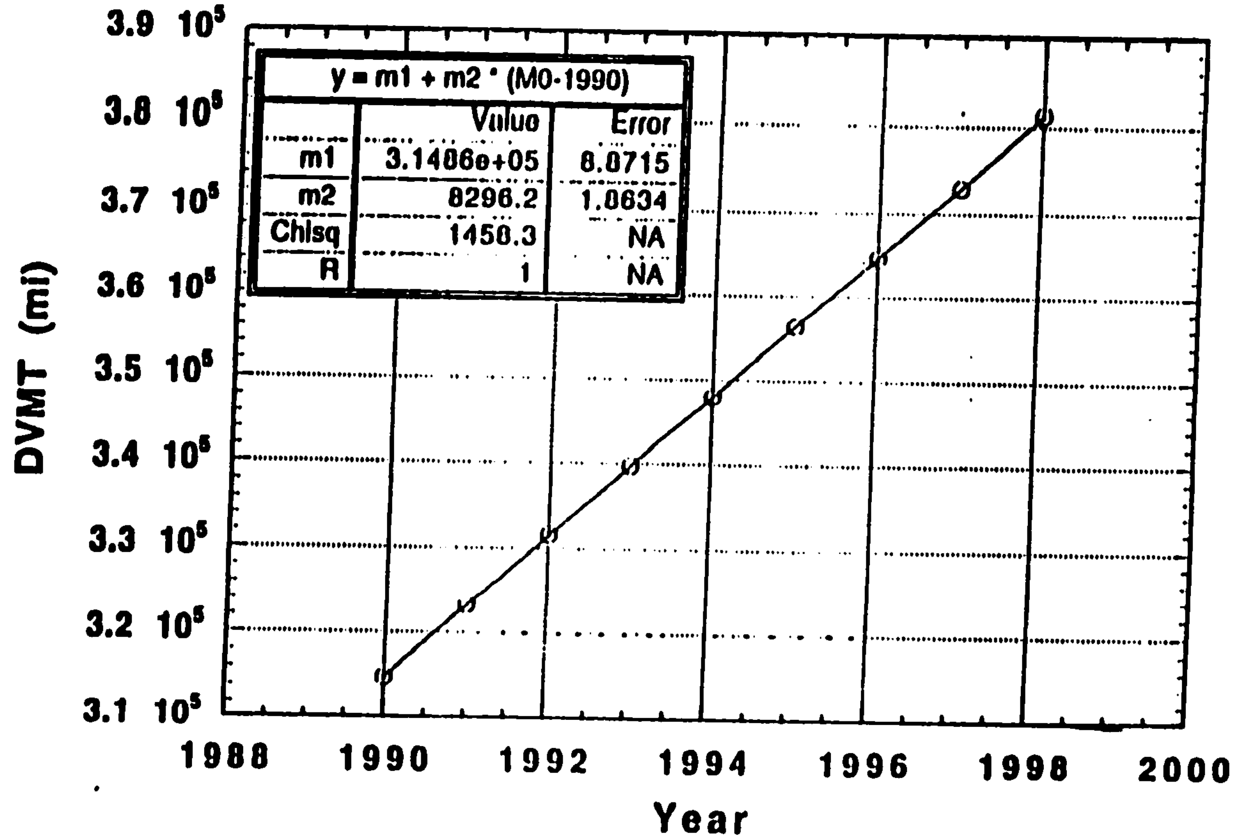

Figure D-9: DVMT for Urban Minor Arterial Road System (FC-16)

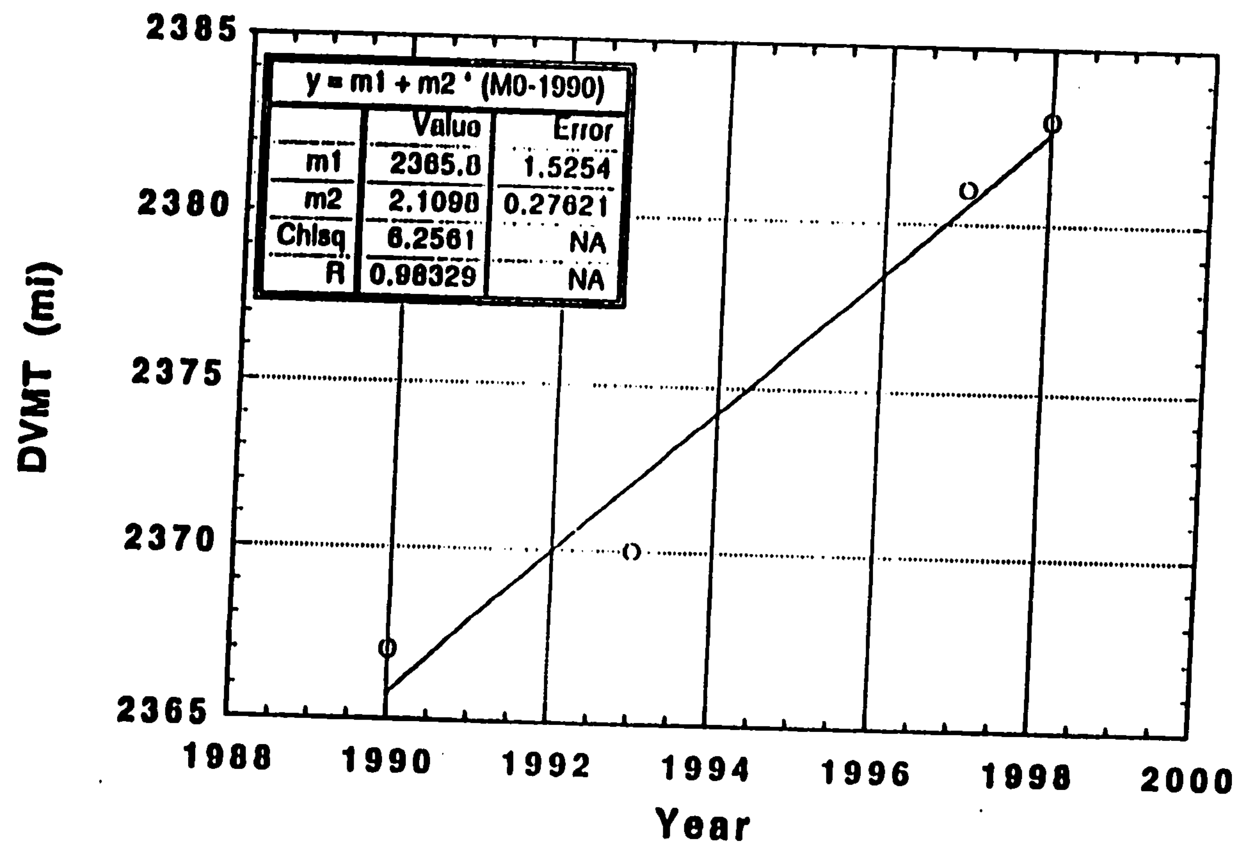

Figure D-10: DVMT for Urban Collector (State) System (FC-17)

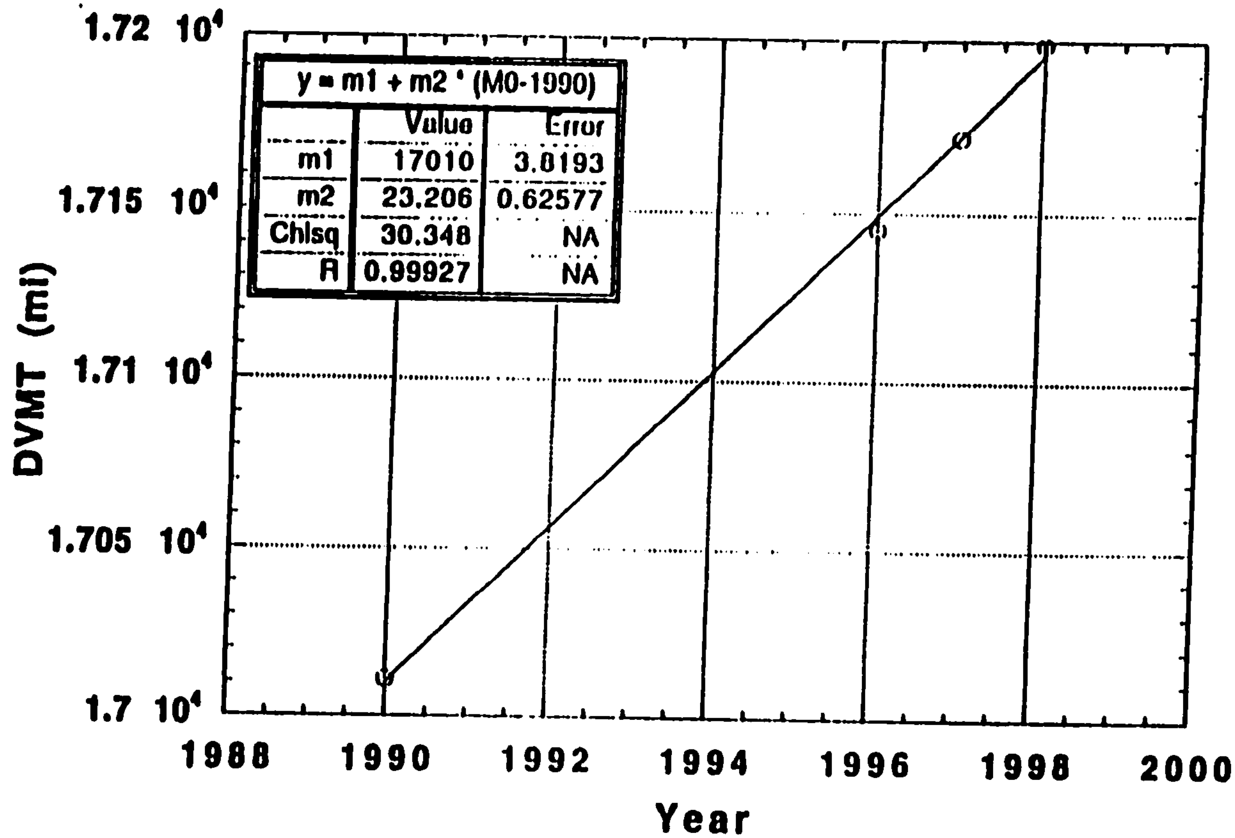

Figure D-11: DVMT for Urban Collector (State) System (FC-19)

Appendix E Input and Output Data from EPA MOBILE5a, Temperature Preparation Methodology, and EPA Speed-Time Profiles Used in Speed Corrections Factors

E-1 Input and Output Data from EPA MOBILE5a

```
1 - (PROMPT) No prompting, vertical format
    (PRLJID) LAKE CHARLES MOBILE INVENTORY 1990 (BASE)
1 - (TAMFLG) Use MOBILE5 tampering rates
1 - (SPDFLG) One average speed for all vehicle types
2 - (VMFLAG) Input one VMT mix for each scenario
3 - (MYMRFG) Input registration distributions by age
1 - (NEWFLG) use MOBILE5 basic emission rates
1 - (IMFLAG) No I/M program is assumed to be operating
1 - (ALHFLG) No corrections to EFs for A/C, Towing, etc.
2 - (ATPFLG) Model effects of anti-tampering program
5 - (RLFLAG) Zero-out refueling emissions completely

1 - (LOCFLG) One LAP record input for each scenario
1 - (TEMFLG) Temperatures calculated by MOBILE5
3 - (OUTFMT) 112 column descriptive
4 - (PRTFLG) All three pollutants HC, CO, and NOx
2 - (IDLFLG) Idle emission factors calculated and printed
3 - (NMHFLG) Volatile organic compounds (VOC)
3 - (HCFLAG) Print total EFs and Component(exclude refueling)
0.0530.0520.0570.0590.0530.0580.0600.0620.0460.051
0.0540.0530.0620.0580.0500.0380.0240.0220.0200.015
0.0100.0080.0070.0060.022
0.0560.0570.0540.0650.0520.0640.0550.0650.0440.047
0.0480.0400.0580.0480.0420.0320.0220.0240.0200.017
0.0110.0100.0090.0080.031
0.0550.0560.0630.0660.0510.0630.0640.0650.0440.046
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0.0120.0110.0110.0080.031
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0.0100.0080.0070.0060.022
0.0560.0570.0640.0660.0520.0640.0650.0650.0440.047
0.0480.0400.0550.0480.0420.0320.0220.0240.0200.017
0.0110.0100.0090.0080.031
0.0550.0560.0630.0660.0510.0630.0640.0650.0440.047
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0.0130.0140.0210.0210.0320.0700.0760.0560.0680.116
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0.0000.0000.0000.0000.000
86 80 20 2221 21 090. 22222222
```

E-1 Input and Output Data from EPA MOBILE5a contd.

```
1 90 61.9 85.2 20.6 27.3 20.6 7
FC 01/RU INTERST C 68.8 90.1  8.3  7.8 92 1 1
.561.208.054.014.001.003.157.002
1 90 53.6 85.2 20.6 27.3 20.6 7
FC 02/RU PAL ART C 68.8 90.1  8.3  7.8 92 1 1
.552.265.063.014.001.003.100.002
1 90 44.0 85.2 20.6 27.3 20.6 7
FC 06/RU MIN ART C 68.8 90.1  8.3  7.8 92 1 1
.534.264.069.019.001.003.107.003
1 90 49.0 85.2 20.6 27.3 20.6 7
FC 07/RU MAJ COL C 68.8 90.1  8.3  7.8 92 1 1
.557.287.066.015.001.003.068.003
1 90 45.7 85.2 20.6 27.3 20.6 7
FC 08/RU MIN COL C 68.8 90.1  8.3  7.8 92 1 1
.591.323.045.009.001.003.027.001
1 90 27.0 85.2 20.6 27.3 20.6 7
FC 09/RU LOCAL    C 68.8 90.1  8.3  7.8 92 1 1
.596.323.033.010.001.003.033.001
1 90 51.7 85.2 20.6 27.3 20.6 7
FC 11/UR INTERST C 68.8 90.1  8.3  7.8 92 1 1
.635.192.048.012.001.003.108.001
1 90 38.7 85.2 20.6 27.3 20.6 7
FC 14/UR PAL ART C 68.8 90.1  8.3  7.8 92 1 1
.614.252.057.015.001.003.054.004
1 90 36.6 85.2 20.6 27.3 20.6 7
FC 16/UR MIN ART C 68.8 90.1  8.3  7.8 92 1 1
.626.274.047.018.001.003.027.004
1 90 34.4 85.2 20.6 27.3 20.6 7
FC 17/UR COLLECT C 68.8 90.1  8.3  7.8 92 1 1
.650.255.042.003.001.003.016.005
1 90 27.0 85.2 20.6 27.3 20.6 7
FC 19/UR LOCAL    C 68.8 90.1  8.3  7.8 92 1 1
.702.239.027.006.001.003.017.005
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1 (PRLJID) LAKE CHARLES MOBILE INVENTORY 1990 (BASE)
MOBILE5a (26-Mar-93)
0Functional Check Program Description:

0Check Start (Jan1)	Model Yrs Covered	Vehicle Classes Covered LDGV	LDGT1	LDGT2	HDGV	Inspection Type	Freq	Comp Rate
ATP 1986	1980-2020	Yes	Yes	Yes	No	Test & Repair	Annual	90.0%

0Air pump system disablements:	Yes	Catalyst removals:	Yes
Fuel inlet restrictor disablements:	Yes	Tailpipe lead deposit test:	Yes
EGR disablement:	Yes	Evaporative system disablements:	Yes
PCV system disablements:	Yes	Missing gas caps:	Yes

0VOC HC emission factors include all evaporative HC emission factors, except for refueling emissions.
0

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 01/RU INTERST Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	61.9	61.9	61.9		61.9	61.9	61.9	61.9	61.9	
VMT Mix:	0.561	0.208	0.054		0.014	0.001	0.003	0.157	0.002	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	3.09	3.68	4.61	3.87	4.83	0.34	0.48	1.50	10.71	3.076
Exhaust HC:	2.05	2.55	3.14	2.67	1.59	0.34	0.48	1.50	3.58	2.116
Evaporat HC:	0.83	0.94	1.22	1.00	2.87				6.52	0.781
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.11	0.11	0.17	0.12	0.26					0.097
Rating L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.082
Exhaust CO:	43.93	56.74	65.45	58.54	81.30	0.96	1.12	7.68	29.98	42.393
Exhaust NOX:	3.68	4.24	5.10	4.41	7.87	2.55	2.99	32.23	1.55	8.409

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	3.93	3.79	5.48	4.32	10.58	11.37
WtDiurnal	9.37	12.91	18.89	14.81	34.08	27.30
Multiple	18.46	22.88	23.15	22.97	36.67	
Crankcase	0.03	0.05	0.17	0.07	0.12	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.11	0.10	0.10	0.10	0.14	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No

0FC 02/RU PAL ART — Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 1 RVP: 8.3 — Period 2 RVP: 7.0 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	53.6	53.6	53.6		53.6	53.6	53.6	53.6	53.6	
VMT Mix:	0.552	0.265	0.063		0.014	0.001	0.003	0.100	0.002	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	2.43	2.83	3.56	2.97	4.93	0.35	0.50	1.56	9.52	2.558
Exhaust HC:	1.35	1.66	2.03	1.73	1.60	0.35	0.50	1.56	2.39	1.498
Evaporat HC:	0.83	0.94	1.22	0.99	2.87				6.52	0.837
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.14	0.14	0.22	0.16	0.34					0.136
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.087
Exhaust CO:	17.95	22.12	25.15	22.70	63.88	0.83	0.97	6.67	11.27	18.944
Exhaust NOX:	2.85	3.32	3.95	3.44	7.45	1.93	2.25	24.31	1.26	5.247

0Evaporative Emissions by Component — Weathered RVP: 8.0 — Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	3.93	3.79	5.48	4.32	10.58	11.37
WtDiurnal	9.37	12.91	18.89	14.81	34.08	27.30
Multiple	18.46	22.88	23.15	22.97	36.67	
Crankcase	0.03	0.05	0.17	0.07	0.12	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.11	0.10	0.10	0.10	0.14	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 — I/M Program: No — Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes — Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No

0FC 06/RU MIN ART — Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 1 RVP: 8.3 — Period 2 RVP: 7.0 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	44.0	44.0	44.0		44.0	44.0	44.0	44.0	44.0	
VMT Mix:	0.534	0.264	0.069		0.019	0.001	0.003	0.107	0.003	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	2.58	2.96	3.75	3.13	5.33	0.40	0.56	1.75	9.59	2.739
Exhaust HC:	1.44	1.74	2.14	1.82	1.87	0.40	0.56	1.75	2.46	1.605
Evaporat HC:	0.83	0.94	1.22	1.00	2.87				6.52	0.850
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.21	0.20	0.31	0.22	0.47					0.197
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.087
Exhaust CO:	18.90	22.73	26.26	23.46	58.39	0.83	0.97	6.61	12.05	19.762
Exhaust NOX:	2.24	2.65	3.11	2.75	6.96	1.57	1.84	19.81	1.04	4.372

0Evaporative Emissions by Component — Weathered RVP: 8.0 — Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Hot Soak	3.93	3.79	5.40	4.32	10.58				11.37	
WtDiurnal	9.37	12.91	18.89	14.81	34.08				27.30	
Multiple	18.46	22.88	23.15	22.97	36.67					
Crankcase	0.03	0.05	0.17	0.07	0.12				0.00	
Refuel	0.00	0.00	0.00	0.00	0.00					
Resting	0.11	0.10	0.10	0.10	0.14				0.17	

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 07/RU MAJ COL Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	49.0	49.0	49.0		49.0	49.0	49.0	49.0	49.0	
VMT Mix:	0.557	0.287	0.066		0.015	0.001	0.003	0.068	0.003	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	2.45	2.86	3.60	2.99	5.00	0.37	0.52	1.63	9.52	2.641
Exhaust HC:	1.35	1.66	2.03	1.73	1.69	0.37	0.52	1.63	2.39	1.508
Evaporat HC:	0.83	0.94	1.22	0.99	2.07				6.52	0.875
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.17	0.17	0.27	0.19	0.41					0.167
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.091
Exhaust CO:	17.95	22.12	25.15	22.69	59.66	0.81	0.95	6.50	11.27	19.383
Exhaust NOX:	2.38	2.81	3.30	2.90	7.21	1.72	2.01	21.68	1.10	3.947

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/ml, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Hot Soak	3.93	3.79	5.40	4.32	10.58				11.37	
WtDiurnal	9.37	12.91	18.89	14.81	34.08				27.30	
Multiple	18.46	22.88	23.15	22.97	36.67					
Crankcase	0.03	0.05	0.17	0.07	0.12				0.00	
Refuel	0.00	0.00	0.00	0.00	0.00					
Resting	0.11	0.10	0.10	0.10	0.14				0.17	

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 08/RU MIN COL Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	45.7	45.7	45.7		45.7	45.7	45.7	45.7	45.7	
VMT Mix:	0.591	0.323	0.045		0.009	0.001	0.003	0.027	0.001	

0Composite Emission Factors (Gm/Mile)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
VOC HC:	2.53	2.92	3.69	3.01	5.23	0.39	0.54	1.70	9.56	2.706
Exhaust HC:	1.40	1.70	2.09	1.75	1.80	0.39	0.54	1.70	2.43	1.536
Evaporat HC:	0.83	0.94	1.22	0.97	2.87				6.52	0.881
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.20	0.19	0.30	0.20	0.45					0.195
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.094
Exhaust CO:	18.47	22.43	25.74	22.04	58.46	0.82	0.96	6.54	11.69	20.035
Exhaust NOX:	2.26	2.67	3.13	2.73	7.05	1.61	1.88	20.35	1.05	2.958

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Hot Soak	3.93	3.79	5.48	4.32	10.58				11.37	
WtDiurnal	9.37	12.91	18.89	14.81	34.08				27.30	
Multiple	18.46	22.88	23.15	22.97	36.67					
Crankcase	0.03	0.05	0.17	0.06	0.12				0.00	
Refuel	0.00	0.00	0.00	0.00	0.00					
Resting	0.11	0.10	0.10	0.10	0.14				0.17	

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No

0FC 09/RU LOCAL Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	27.0	27.0	27.0		27.0	27.0	27.0	27.0	27.0	
VMT Mix:	0.596	0.323	0.033		0.010	0.001	0.003	0.033	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	3.58	3.97	5.04	4.07	7.36	0.59	0.83	2.62	10.62	3.755
Exhaust HC:	2.23	2.60	3.21	2.65	3.57	0.59	0.83	2.62	3.49	2.404
Evaporat HC:	0.83	0.94	1.22	0.96	2.87				6.52	0.874
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.42	0.34	0.52	0.36	0.81					0.384
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.093
Exhaust CO:	28.56	32.48	38.53	33.04	81.90	1.23	1.44	9.85	20.65	29.954
Exhaust NOX:	2.09	2.41	2.85	2.45	6.10	1.51	1.76	19.02	0.88	2.815

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Hot Soak	3.93	3.79	5.48	4.32	10.58				11.37	
WtDiurnal	9.37	12.91	18.89	14.81	34.08				27.30	
Multiple	18.46	22.88	23.15	22.97	36.67					
Crankcase	0.03	0.05	0.17	0.06	0.12				0.00	
Refuel	0.00	0.00	0.00	0.00	0.00					
Resting	0.11	0.10	0.10	0.10	0.14				0.17	

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 11/UR INTERST Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	51.7	51.7	51.7		51.7	51.7	51.7	51.7	51.7	
VMT Mix:	0.635	0.192	0.048		0.012	0.001	0.003	0.108	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	2.44	2.84	3.57	2.99	4.98	0.36	0.50	1.58	9.52	2.506
Exhaust HC:	1.35	1.66	2.03	1.74	1.61	0.36	0.50	1.58	2.39	1.468
Evaporat HC:	0.83	0.94	1.22	0.99	2.87				6.52	0.807
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.15	0.15	0.24	0.17	0.37					0.143
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.087
Exhaust CO:	17.95	22.12	25.15	22.73	61.75	0.02	0.96	6.57	11.27	18.320
Exhaust NOX:	2.66	3.11	3.60	3.22	7.35	1.83	2.14	23.10	1.20	5.054

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	3.93	3.79	5.48	4.32	10.58	11.37
WtDiurnal	9.37	12.91	18.09	14.01	34.08	27.30
Multiple	18.46	22.88	23.15	22.97	36.67	
Crankcase	0.03	0.05	0.17	0.07	0.12	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.11	0.10	0.10	0.10	0.14	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 14/UR PAL ART Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	38.7	38.7	38.7		38.7	38.7	38.7	38.7	38.7	
VMT Mix:	0.614	0.252	0.057		0.015	0.001	0.003	0.054	0.004	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	2.79	3.16	4.01	3.31	5.71	0.44	0.61	1.93	9.78	2.970
Exhaust HC:	1.60	1.90	2.34	1.90	2.17	0.44	0.61	1.93	2.65	1.741
Evaporat HC:	0.83	0.94	1.22	0.99	2.87				6.52	0.885
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.27	0.23	0.36	0.26	0.55					0.251

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Rating L HC:      0.10      0.09      0.00      0.09      0.11                                    0.61     0.093
Exhaust  CO:     20.74     24.30     28.54     25.00     60.61      0.89      1.03      7.08     13.67    21.837
Exhaust NOX:      2.19      2.60      3.04      2.60      6.69      1.48      1.73     18.72      1.01     3.294
0Evaporative Emissions by Component                  Weathered RVP:   8.0              Hot Soak Temp: 86.5 (F)
 (Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr)     Running Loss Temp: 87.2 (F)
                                                                                    Resting Loss Temp: 80.2 (F)
 Hot Soak         3.93      3.79      5.48      4.32     10.50                                   11.37
 WtDiurnal        9.37     12.91     18.89     14.01     34.00                                   27.30
 Multiple        18.46     22.88     23.15     22.97     36.67
 Crankcase        0.03      0.05      0.17      0.07      0.12                                    0.00
 Refuel           0.00      0.00      0.00      0.00      0.00
 Resting          0.11      0.10      0.10      0.10      0.14                                    0.17
________________________________________________________________________________________________________________
0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990           I/M Program: No        Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
                     Anti-tam. Program: Yes      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                      Reformulated Gas: No
0FC 16/UR MIN ART                                 Minimum Temp:  69. (F)          Maximum Temp:  90. (F)
                          Period 1 RVP:  8.3      Period 2 RVP:  7.8          Period 2 Start Yr: 1992
0  Veh. Type:       LDGV      LDGT1     LDGT2     HDGT      HDGV      LDDV      LDDT      HDDV      MC     All Veh
                   ______    ______    ______    ______    ______    ______    ______    ______    ______   ______
 Veh. Speeds:      36.6      36.6      36.6                36.6      36.6      36.6      36.6      36.6
     VMT Mix:      0.626     0.274     0.047               0.010     0.001     0.003     0.027     0.004
0Composite Emission Factors (Gm/Mile)
 VOC      HC:      2.90      3.26      4.14      3.39      5.91      0.46      0.64      2.02      9.89     3.104
 Exhaust  HC:      1.68      1.98      2.46      2.05      2.34      0.46      0.64      2.02      2.76     1.819
 Evaporat HC:      0.03      0.94      1.22      0.98      2.87                                    6.52     0.912
 Refuel L HC:      0.00      0.00      0.00      0.00      0.00                                             0.000
 Runing L HC:      0.29      0.25      0.38      0.27      0.59                                             0.278
 Rating L HC:      0.10      0.09      0.08      0.09      0.11                                    0.61     0.096
 Exhaust  CO:     21.72     25.26     29.79     25.93     62.57      0.92      1.08      7.37     14.55    23.309
 Exhaust NOX:      2.17      2.57      3.01      2.64      6.59      1.47      1.71     18.51      0.99     2.834
0Evaporative Emissions by Component                  Weathered RVP:   0.0              Hot Soak Temp: 86.5 (F)
 (Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr)     Running Loss Temp: 87.2 (F)
                                                                                    Resting Loss Temp: 80.2 (F)
 Hot Soak         3.93      3.79      5.48      4.32     10.58                                   11.37
 WtDiurnal        9.37     12.91     18.89     14.01     34.08                                   27.30
 Multiple        18.46     22.88     23.15     22.97     36.67
 Crankcase        0.03      0.05      0.17      0.06      0.12                                    0.00
 Refuel           0.00      0.00      0.00      0.00      0.00
 Resting          0.11      0.10      0.10      0.10      0.14                                    0.17
________________________________________________________________________________________________________________
0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 1990           I/M Program: No        Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
                     Anti-tam. Program: Yes      Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                      Reformulated Gas: No
```

0FC 17/UR COLLECT Minimum Temp: 69. (F) Maximum Temp: 90. (F)

Period 1 RVP: 8.3 Period 2 RVP: 7.0 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	34.4	34.4	34.4		34.4	34.4	34.4	34.4	34.4	
VMT Mix:	0.660	0.265	0.042		0.008	0.001	0.003	0.016	0.005	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	3.02	3.38	4.30	3.51	6.15	0.48	0.68	2.13	10.02	3.209
Exhaust HC:	1.78	2.09	2.59	2.16	2.54	0.48	0.68	2.13	2.89	1.907
Evaporat HC:	0.83	0.94	1.22	0.90	2.87				6.52	0.904
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.31	0.27	0.41	0.29	0.63					0.300
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.098
Exhaust CO:	22.93	26.50	31.34	27.17	65.37	0.97	1.13	7.76	15.63	24.203
Exhaust NOX:	2.15	2.54	2.90	2.60	6.48	1.46	1.71	18.41	0.97	2.578

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)

(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)

Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	3.93	3.79	5.40	4.32	10.58	11.37
WtDiurnal	9.37	12.91	18.89	14.01	34.08	27.30
Multiple	18.46	22.88	23.15	22.97	36.67	
Crankcase	0.03	0.05	0.17	0.06	0.12	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.11	0.10	0.10	0.10	0.14	0.17

0Emission factors are as of July 1st of the indicated calendar year.

0User supplied veh registration distributions.

0Cal. Year: 1990 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low

Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

Reformulated Gas: No

0FC 19/UR LOCAL Minimum Temp: 69. (F) Maximum Temp: 90. (F)

Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	27.0	27.0	27.0		27.0	27.0	27.0	27.0	27.0	
VMT Mix:	0.702	0.239	0.027		0.006	0.001	0.003	0.017	0.005	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	3.58	3.97	5.04	4.08	7.36	0.59	0.83	2.62	10.62	3.743
Exhaust HC:	2.23	2.60	3.21	2.66	3.57	0.59	0.83	2.62	3.49	2.361
Evaporat HC:	0.83	0.94	1.22	0.97	2.87				6.52	0.890
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.42	0.34	0.52	0.36	0.81					0.393
Rsting L HC:	0.10	0.09	0.08	0.09	0.11				0.61	0.098
Exhaust CO:	28.56	32.48	38.53	33.09	81.90	1.23	1.44	9.85	20.65	29.620
Exhaust NOX:	2.09	2.41	2.85	2.45	6.10	1.51	1.76	19.02	0.88	2.492

0Evaporative Emissions by Component Weathered RVP: 8.0 Hot Soak Temp: 86.5 (F)

(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)

Resting Loss Temp: 80.2 (F)

Hot Soak	3.93	3.79	5.48	4.32	10.50	11.37
WtDiurnal	9.37	12.91	10.89	14.01	34.00	27.30
Multiple	18.46	22.88	23.15	22.97	36.67	
Crankcase	0.03	0.05	0.17	0.06	0.12	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.11	0.10	0.10	0.10	0.14	0.17

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1 - (PROMPT) No prompting, vertical format
    (PRJID)  LAKE CHARLES MOBILE INVENTORY 2005 (NO BUILD)
1 - (TAMFLG) Use MOBILE5 tampering rates
1 - (SPDFLG) One average speed for all vehicle types
2 - (VMFLAG) Input one VMT mix for each scenario
3 - (MYMRFG) Input registration distributions by age
1 - (NEWFLG) use MOBILE5 basic emission rates
1 - (IMFLAG) No I/M program is assumed to be operating
1 - (ALHFLG) No corrections to EFs for A/C, Towing, etc.
2 - (ATPFLG) Model effects of anti-tampering program
5 - (RLFLAG) Zero-out refueling emissions completely
1 - (LOCFLG) One LAP record input for each scenario
1 - (TEMFLG) Temperatures calculated by MOBILE5
3 - (OUTFMT) 112 column descriptive
4 - (PRTFLG) All three pollutants HC, CO, and NOx
2 - (IDLFLG) Idle emission factors calculated and printed
3 - (NMHFLG) Volatile organic compounds (VOC)
3 - (HCFLAG) Print total EFs and Component(exclude refueling)
0.0530.0520.0570.0590.0530.0580.0600.0620.0460.051
0.0540.0530.0620.0580.0500.0380.0240.0220.0200.015
0.0100.0080.0070.0060.022
0.0560.0570.0640.0660.0520.0640.0650.0650.0440.047
0.0480.0400.0580.0480.0420.0320.0220.0240.0200.017
0.0110.0100.0090.0050.031
0.0550.0560.0630.0660.0510.0630.0640.0650.0440.046
0.0470.0400.0580.0490.0420.0330.0220.0240.0210.017
0.0120.0110.0110.0050.032
0.0550.0560.0630.0660.0510.0630.0640.0650.0440.047
0.0470.0400.0580.0490.0420.0330.0220.0240.0210.017
0.0120.0110.0110.0050.031
0.0530.0520.0570.0590.0530.0580.0600.0620.0460.051
0.0540.0530.0620.0580.0500.0380.0240.0220.0200.015
0.0100.0080.0070.0060.022
0.0560.0570.0640.0660.0520.0640.0650.0650.0440.047
0.0480.0400.0580.0480.0420.0320.0220.0240.0200.017
0.0110.0100.0090.0050.031
0.0550.0560.0630.0660.0510.0630.0640.0650.0440.047
0.0470.0400.0580.0490.0420.0330.0220.0240.0210.017
0.0120.0110.0110.0050.031
0.0130.0140.0210.0210.0320.0700.0760.0550.0690.116
0.1030.4050.0000.0000.0000.0000.0000.0000.0000.000
0.0000.0000.0000.0000.000
85 80 20 2221 21 090. 22222222
1 05 61.2 85.2 20.6 27.3 20.6 7
FC 01/RU INTERST C 68.8 90.1  8.3  7.8 92 1 1
.549.221.054.014.001.003.157.001
1 05 45.6 85.2 20.6 27.3 20.6 7
FC 02/RU PAL ART C 68.8 90.1  8.3  7.8 92 1 1
.541.277.063.014.001.003.100.001
1 05 43.0 85.2 20.6 27.3 20.6 7
FC 06/RU MIN ART C 68.8 90.1  8.3  7.8 92 1 1
.524.276.069.019.001.003.107.001
1 05 48.5 85.2 20.6 27.3 20.6 7
FC 07/RU MAJ COL C 68.8 90.1  8.3  7.8 92 1 1
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.547.299.066.015.001.003.068.001
1 05 45.6 85.2 20.6 27.3 20.6 7
FC 08/RU MIN COL C 68.8 90.1  8.3  7.8 92 1 1
.580.334.045.009.001.003.027.001
1 05 27.0 85.2 20.6 27.3 20.6 7
FC 09/RU LOCAL   C 68.8 90.1  8.3  7.8 92 1 1
.585.334.033.010.001.003.033.001
1 05 51.3 85.2 20.6 27.3 20.6 7
FC 11/UR INTERST C 68.8 90.1  8.3  7.8 92 1 1
.624.203.048.012.001.003.108.001
1 05 37.3 85.2 20.6 27.3 20.6 7
FC 14/UR PAL ART C 68.8 90.1  8.3  7.8 92 1 1
.605.264.057.015.001.003.054.001
1 05 35.9 85.2 20.6 27.3 20.6 7
FC 16/UR MIN ART C 68.8 90.1  8.3  7.8 92 1 1
.618.285.047.018.001.003.027.001
1 05 34.2 85.2 20.6 27.3 20.6 7
FC 17/UR COLLECT C 68.8 90.1  8.3  7.8 92 1 1
.650.279.042.008.001.003.016.001
1 05 27.0 85.2 20.6 27.3 20.6 7
FC 19/UR LOCAL   C 68.8 90.1  8.3  7.8 92 1 1
.692.253.027.006.001.003.017.001
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1 (PRLJID) LAKE CHARLES MOBILE INVENTORY 2005 (NO BUILD)
MOBILE5a (26-Mar-93)
0Functional Check Program Description:

0Check Start (Jan1)	Model Yrs Covered	Vehicle Classes Covered LDGV	LDGT1	LDGT2	HDGV	Inspection Type	Freq	Comp Rate
ATP 1986	1980-2020	Yes	Yes	Yes	No	Test & Repair	Annual	90.0%

0Air pump system disablements: Yes Catalyst removals: Yes
Fuel inlet restrictor disablements: Yes Tailpipe lead deposit test: Yes
EGR disablement: Yes Evaporative system disablements: Yes
PCV system disablements: Yes Missing gas caps: Yes
0VOC HC emission factors include all evaporative HC emission factors, except for refueling emissions.
0

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 01/RU INTEREST Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 9.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	61.2	61.2	61.2		61.2	61.2	61.2	61.2	61.2	
VMT Mix:	0.549	0.221	0.054		0.014	0.001	0.003	0.157	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.28	1.35	1.65	1.41	1.40	0.26	0.33	0.95	6.65	1.263
Exhaust HC:	0.96	1.04	1.35	1.10	0.52	0.26	0.33	0.95	2.27	0.908
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.180
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.07	0.06	0.08	0.06	0.08					0.055
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.040
Exhaust CO:	12.99	14.71	19.30	15.63	16.01	0.83	0.89	6.21	26.90	12.660
Exhaust NOX:	2.45	2.59	3.27	2.73	5.64	1.81	1.92	11.78	1.57	4.031

0Evaporative Emissions by Component Weathered RVP: 7.5 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No

0PC 02/RU PAL ART

Period 1 RVP: 8.3 — Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 2 RVP: 7.8 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	45.6	45.6	45.6		45.6	45.6	45.6	45.6	45.6	
VMT Mix:	0.541	0.277	0.063		0.014	0.001	0.003	0.100	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.18	1.25	1.51	1.30	1.53	0.29	0.38	1.07	5.98	1.215
Exhaust HC:	0.81	0.90	1.15	0.95	0.59	0.29	0.38	1.07	1.59	0.879
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.192
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.12	0.10	0.13	0.11	0.13					0.101
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.042
Exhaust CO:	8.50	9.66	12.24	10.14	11.01	0.72	0.77	5.38	11.20	8.764
Exhaust NOX:	1.74	1.73	2.17	1.81	5.07	1.17	1.24	7.63	1.08	2.396

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.40	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 — I/M Program: No — Anti-tam. Program: Yes — Reformulated Gas: No
Ambient Temp: 85.2 / 85.2 / 85.2 (F) — Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 — Altitude: 500. Ft.

0PC 06/RU MIN ART

Period 1 RVP: 8.3 — Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 2 RVP: 7.8 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	43.0	43.0	43.0		43.0	43.0	43.0	43.0	43.0	
VMT Mix:	0.524	0.276	0.069		0.019	0.001	0.003	0.107	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.23	1.30	1.57	1.35	1.58	0.31	0.39	1.12	6.02	1.269
Exhaust HC:	0.85	0.94	1.20	0.99	0.63	0.31	0.39	1.12	1.63	0.924
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.193
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.13	0.11	0.14	0.12	0.15					0.110
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.042
Exhaust CO:	9.20	10.32	13.03	10.06	11.83	0.73	0.79	5.49	11.75	9.394
Exhaust NOX:	1.73	1.72	2.17	1.81	4.98	1.13	1.20	7.34	1.07	2.419

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Hot Soak	0.99	0.94	1.04	0.97	2.90				11.13	
WtDiurnal	2.03	2.39	2.72	2.40	11.21				9.01	
Multiple	4.70	4.44	4.61	4.50	19.43					
Crankcase	0.01	0.01	0.01	0.01	0.01				0.00	
Refuel	0.00	0.00	0.00	0.00	0.00					
Resting	0.05	0.05	0.05	0.05	0.05				0.17	

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 07/RU MAJ COL Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.0 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	40.5	40.5	40.5		40.5	40.5	40.5	40.5	40.5	
VMT Mix:	0.547	0.299	0.066		0.015	0.001	0.003	0.068	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.13	1.21	1.46	1.25	1.49	0.20	0.36	1.03	5.96	1.176
Exhaust HC:	0.78	0.87	1.11	0.91	0.56	0.20	0.36	1.03	1.57	0.839
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.199
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.10	0.09	0.12	0.10	0.12					0.094
Resting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.044
Exhaust CO:	7.93	9.11	11.59	9.56	12.00	0.72	0.77	5.35	10.79	8.382
Exhaust NOX:	1.77	1.76	2.22	1.84	5.18	1.24	1.31	8.06	1.12	2.273

0Evaporative Emissions by Component Weathered RVP: 7.5 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Hot Soak	0.99	0.94	1.04	0.97	2.90				11.13	
WtDiurnal	2.03	2.39	2.72	2.40	11.21				9.01	
Multiple	4.70	4.44	4.63	4.50	19.43					
Crankcase	0.01	0.01	0.01	0.01	0.01				0.00	
Refuel	0.00	0.00	0.00	0.00	0.00					
Resting	0.05	0.05	0.05	0.05	0.05				0.17	

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 08/RU MIN COL Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.0 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	45.6	45.6	45.6		45.6	45.6	45.6	45.6	45.6	
VMT Mix:	0.580	0.334	0.045		0.009	0.001	0.003	0.027	0.001	

0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.18	1.25	1.51	1.28	1.53	0.29	0.38	1.07	5.98	1.218
Exhaust HC:	0.81	0.90	1.15	0.93	0.59	0.29	0.38	1.07	1.59	0.860
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.204
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.12	0.10	0.13	0.11	0.13					0.109
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.046
Exhaust CO:	8.50	9.66	12.24	9.96	11.81	0.72	0.77	5.38	11.20	8.973
Exhaust NOX:	1.74	1.73	2.17	1.78	5.07	1.17	1.24	7.63	1.08	1.940

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F)

(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.

0User supplied veh registration distributions.

0Cal. Year: 2005 — I/M Program: No — Anti-tam. Program: Yes — Reformulated Gas: No

Ambient Temp: 85.2 / 85.2 / 85.2 (F) — Operating Mode: 20.6 / 27.3 / 20.6 — Region: Low — Altitude: 500. Ft.

0FC 09/RU LOCAL — Minimum Temp: 69. (F) — Maximum Temp: 90. (F)

Period 1 RVP: 8.3 — Period 2 RVP: 7.8 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	27.0	27.0	27.0		27.0	27.0	27.0	27.0	27.0	
VMT Mix:	0.585	0.334	0.033		0.010	0.001	0.003	0.033	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.77	1.77	2.17	1.81	2.23	0.45	0.58	1.65	6.65	1.782
Exhaust HC:	1.29	1.34	1.70	1.38	1.17	0.45	0.58	1.65	2.26	1.329
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.203
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.23	0.19	0.23	0.19	0.25					0.205
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.046
Exhaust CO:	16.44	17.18	21.24	17.54	16.55	1.08	1.16	8.10	19.81	16.514
Exhaust NOX:	1.67	1.70	2.14	1.74	4.39	1.10	1.16	7.14	0.91	1.903

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F)

(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 11/UR INTERST Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	51.3	51.3	51.3		51.3	51.3	51.3	51.3	51.3	
VMT Mix:	0.624	0.203	0.040		0.012	0.001	0.003	0.108	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.12	1.20	1.45	1.25	1.45	0.27	0.35	1.00	5.96	1.144
Exhaust HC:	0.78	0.87	1.11	0.92	0.54	0.27	0.35	1.00	1.57	0.831
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.189
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.09	0.08	0.11	0.09	0.11					0.081
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.042
Exhaust CO:	7.93	9.11	11.59	9.58	12.40	0.72	0.77	5.39	10.79	8.096
Exhaust NOX:	1.92	1:95	2.45	2.04	5.20	1.32	1.40	8.59	1.22	2.708

0Evaporative Emissions by Component Weathered RVP: 7.5 Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) Running Loss Temp: 87.2 (F)
Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 I/M Program: No Ambient Temp: 85.2 / 85.2 / 85.2 (F) Region: Low
Anti-tam. Program: Yes Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.
Reformulated Gas: No
0FC 14/UR PAL ART Minimum Temp: 69. (F) Maximum Temp: 90. (F)
Period 1 RVP: 8.3 Period 2 RVP: 7.8 Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	37.3	37.3	37.3		37.3	37.3	37.3	37.3	37.3	
VMT Mix:	0.605	0.264	0.057		0.015	0.001	0.003	0.054	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.37	1.42	1.73	1.47	1.73	0.34	0.44	1.25	6.16	1.405
Exhaust HC:	0.96	1.04	1.33	1.09	0.74	0.34	0.44	1.25	1.77	1.017
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.202
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.16	0.13	0.16	0.14	0.18					0.141

	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.045
Exhaust CO:	11.07	12.09	15.15	12.63	12.50	0.80	0.86	5.98	13.60	11.277
Exhaust NOX:	1.72	1.72	2.16	1.88	4.77	1.07	1.14	6.97	1.03	2.069

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 — I/M Program: No — Anti-tam. Program: Yes — Reformulated Gas: No
Ambient Temp: 85.2 / 85.2 / 85.2 (F) — Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 — Altitude: 500. Ft.
0PC 16/UR MIN ART — Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 1 RVP: 8.3 — Period 2 RVP: 7.8 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	35.9	35.9	35.9		35.9	35.9	35.9	35.9	35.9	
VMT Mix:	0.610	0.285	0.047		0.018	0.001	0.003	0.027	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.41	1.46	1.77	1.50	1.78	0.35	0.46	1.29	6.21	1.447
Exhaust HC:	1.00	1.07	1.37	1.12	0.78	0.35	0.46	1.29	1.82	1.040
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.209
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.16	0.14	0.17	0.14	0.19					0.152
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.046
Exhaust CO:	11.62	12.61	15.77	13.05	12.81	0.82	0.89	6.16	14.21	11.928
Exhaust NOX:	1.71	1.72	2.16	1.78	4.72	1.07	1.13	6.94	1.02	1.927

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 — I/M Program: No — Anti-tam. Program: Yes — Reformulated Gas: No
Ambient Temp: 85.2 / 85.2 / 85.2 (F) — Region: Low
Operating Mode: 20.6 / 27.3 / 20.6 — Altitude: 500. Ft.

0PC 17/UR COLLECT

Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 1 RVP: 8.3 — Period 2 RVP: 7.8 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	34.2	34.2	34.2		34.2	34.2	34.2	34.2	34.2	
VMT Mix:	0.650	0.279	0.042		0.008	0.001	0.003	0.016	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.47	1.50	1.03	1.55	1.84	0.37	0.47	1.35	6.28	1.495
Exhaust HC:	1.04	1.12	1.42	1.15	0.84	0.37	0.47	1.35	1.89	1.080
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.206
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.17	0.15	0.10	0.15	0.20					0.163
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.047
Exhaust CO:	12.34	13.30	16.60	13.71	13.27	0.86	0.92	6.42	15.04	12.650
Exhaust NOX:	1.71	1.72	2.16	1.77	4.66	1.06	1.13	6.91	1.00	1.832

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

	LDGV	LDGT1	LDGT2	LDGT	HDGV	MC
Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Resting	0.05	0.05	0.05	0.05	0.05	0.17

0Emission factors are as of July 1st of the indicated calendar year.
0User supplied veh registration distributions.
0Cal. Year: 2005 — I/M Program: No — Ambient Temp: 85.2 / 85.2 / 85.2 (F) — Region: Low
Anti-tam. Program: Yes — Operating Mode: 20.6 / 27.3 / 20.6 — Altitude: 500. Ft.
Reformulated Gas: No

0PC 19/UR LOCAL

Minimum Temp: 69. (F) — Maximum Temp: 90. (F)
Period 1 RVP: 8.3 — Period 2 RVP: 7.8 — Period 2 Start Yr: 1992

0 Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	All Veh
Veh. Speeds:	27.0	27.0	27.0		27.0	27.0	27.0	27.0	27.0	
VMT Mix:	0.692	0.253	0.027		0.006	0.001	0.003	0.017	0.001	
0Composite Emission Factors (Gm/Mile)										
VOC HC:	1.77	1.77	2.17	1.81	2.23	0.45	0.58	1.65	6.65	1.779
Exhaust HC:	1.29	1.34	1.70	1.38	1.17	0.45	0.58	1.65	2.26	1.317
Evaporat HC:	0.20	0.20	0.19	0.20	0.77				3.78	0.204
Refuel L HC:	0.00	0.00	0.00	0.00	0.00					0.000
Runing L HC:	0.23	0.19	0.23	0.19	0.25					0.211
Rsting L HC:	0.05	0.04	0.04	0.04	0.04				0.61	0.047
Exhaust CO:	16.44	17.10	21.24	17.57	16.55	1.08	1.16	8.10	19.81	16.559
Exhaust NOX:	1.67	1.70	2.14	1.75	4.39	1.10	1.16	7.14	0.91	1.799

0Evaporative Emissions by Component — Weathered RVP: 7.5 — Hot Soak Temp: 86.5 (F)
(Hot Soak: g/trip, Diurnals: g, Crankcase: g/mi, Refuel: g/gal, Resting: g/hr) — Running Loss Temp: 87.2 (F) — Resting Loss Temp: 80.2 (F)

Hot Soak	0.99	0.94	1.04	0.97	2.90	11.13
WtDiurnal	2.03	2.39	2.72	2.48	11.21	9.81
Multiple	4.70	4.44	4.63	4.50	19.43	
Crankcase	0.01	0.01	0.01	0.01	0.01	0.00
Refuel	0.00	0.00	0.00	0.00	0.00	
Heating	0.05	0.05	0.05	0.05	0.05	0.17

E-2 Temperature Preparation Methodology

Temperature is normally calculated from the most recent three-year period for validated ozone and/or CO monitoring data exists at the time the emission inventory is due. For 1990 inventories, the period to be used for temperature determination will be 1988-1990. The temperatures use din the 1990 inventory must also be used for all projection inventories.

Consider the three-year period as a whole, the analyst should determine the consecutive three-moth period with the highest frequency of NAAQS exceedances days occurring in the inventory area. The same consecutive three-month period will apply for each year, with a total of nine moths used to determine temperature. If the months containing the highest frequency of exceedances are not consecutive or if two or more sets of consecutive months have the same frequency, the analyst should use the month of June, July, and August for ozone modeling and the months of November, December, and January for carbon monoxide modeling.

The analyst should the list the 10 highest concentrations – not necessarily exceedances – that occurred in the inventory area during those nine months and the dates of those concentrations. Exceptions to this procedure are listed below:

- More than 10 highest concentrations may be needed to identify 10 unique dates.
- If the 10^{th} ranked level occurs on more than one day, all of those days should be included in the temperature calculation.

- For the entire MSA monitoring network, if only two years of validated monitoring data exists for an MSA, the analyst should list the seven highest values.
- If only one year of data exists for the entire MSA monitoring network, the analyst should list the four highest values.

The ten highest ozone concentrations for each site in a country and the dates on which they occurred are contained in the Aerometric Information Retrieval System (AIRS) AMP440/maximum Values Report. Eight-hour average CO concentrations and the dates on which they occurred can be found in the AIRS ANP350 raw data report. The AMP355/Standard Report contains CO values that exceed the NAAQS. These reports are available from EPA's National Air Data Branch. Be sure to specify the year(s) and counties of interest and indicate that the request is for preparation of a SIP emission inventory, to avoid being charged the normal processing fee. To obtain copies of these report, contact Tom Link at FTS 629-5456 or (919) 541-4546.

E-3 EPA Speed-Time Profiles Used in Speed Corrections Factors

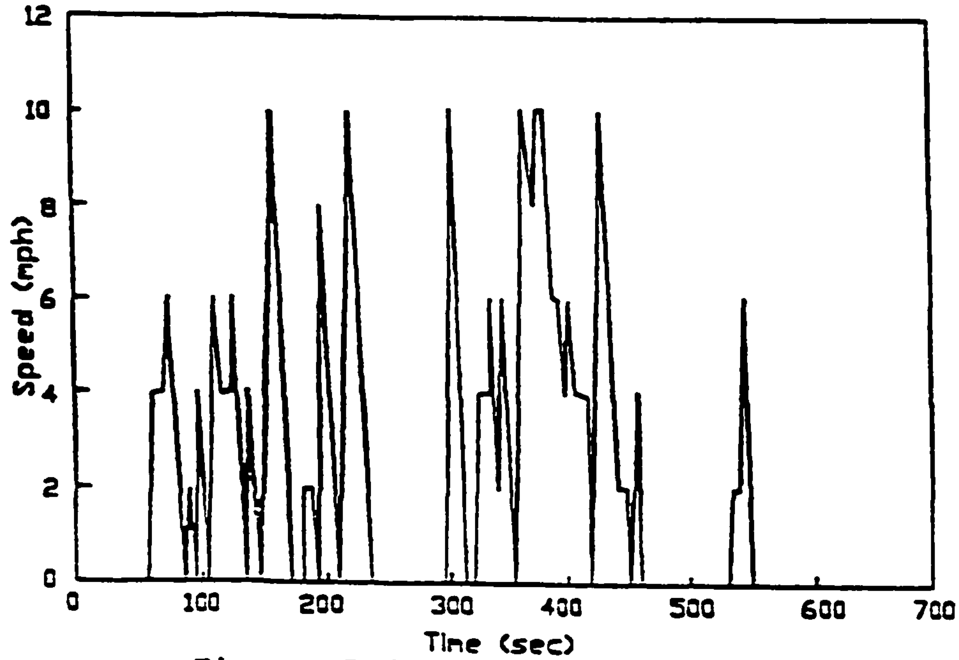

Figure E-1: EPA Low Speed Cycle
Source: EPA
(2.5 mph)

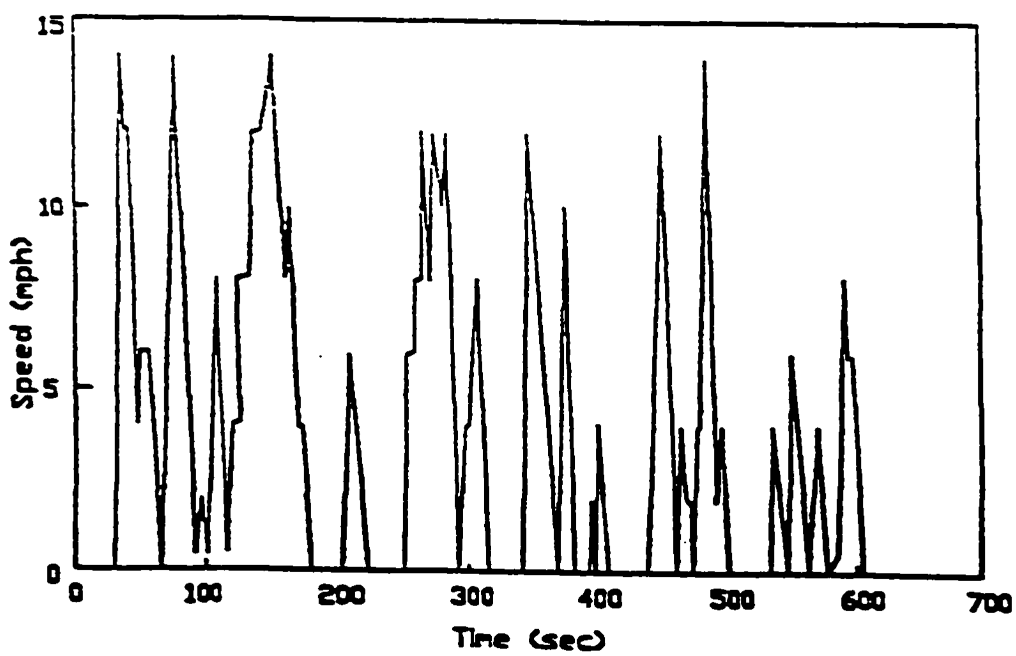

Figure E-2: EPA Low Speed Cycle
Source: EPA
(3.6 mph)

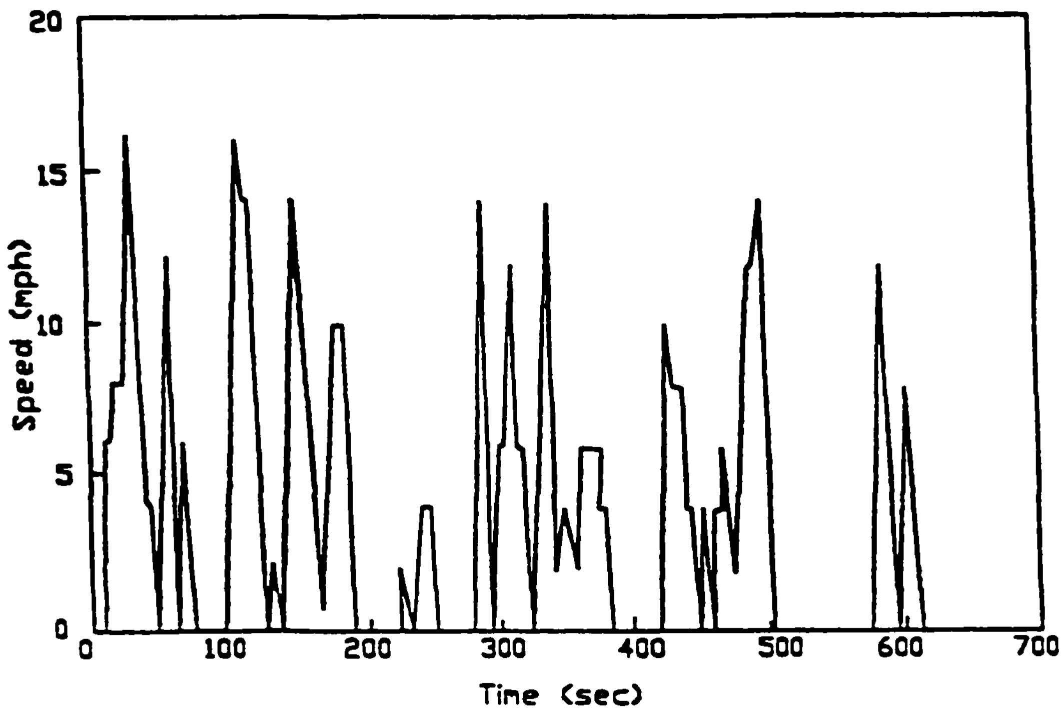

Figure E-3: EPA Low Speed Cycle
Source: EPA
(4.0 mph)

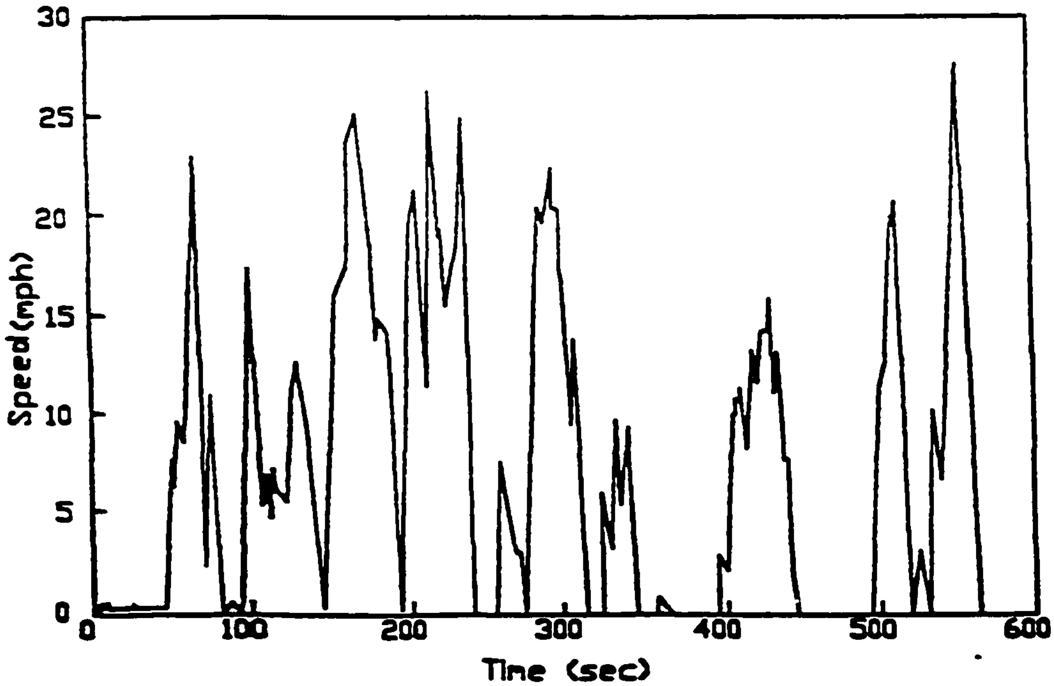

Figure E-4: New York City Cycle
Source: EPA

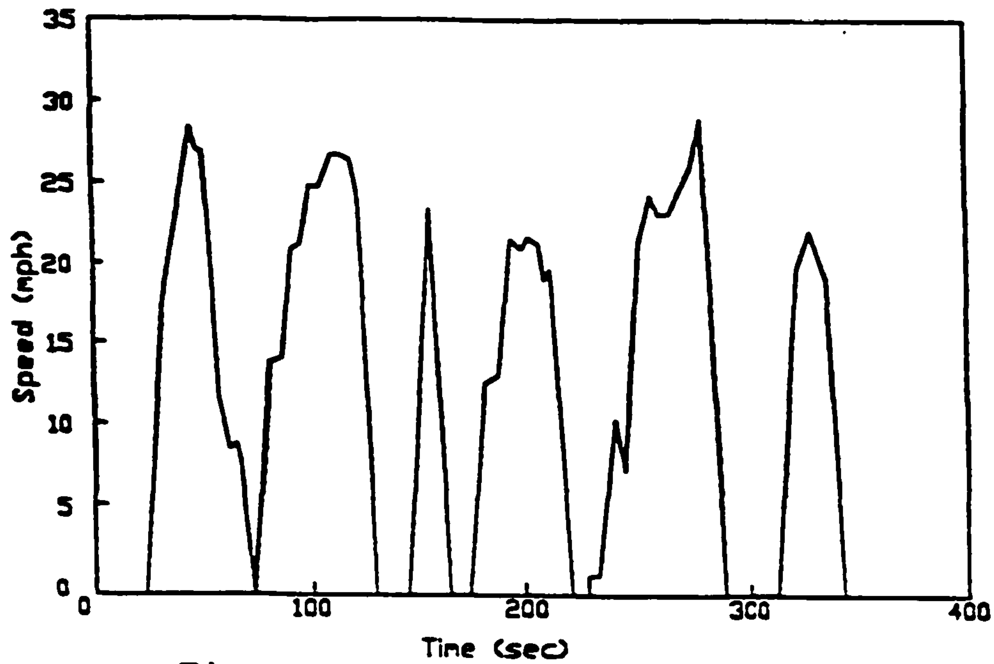

Figure E-5: Speed Correction Cycle 12
Source: EPA

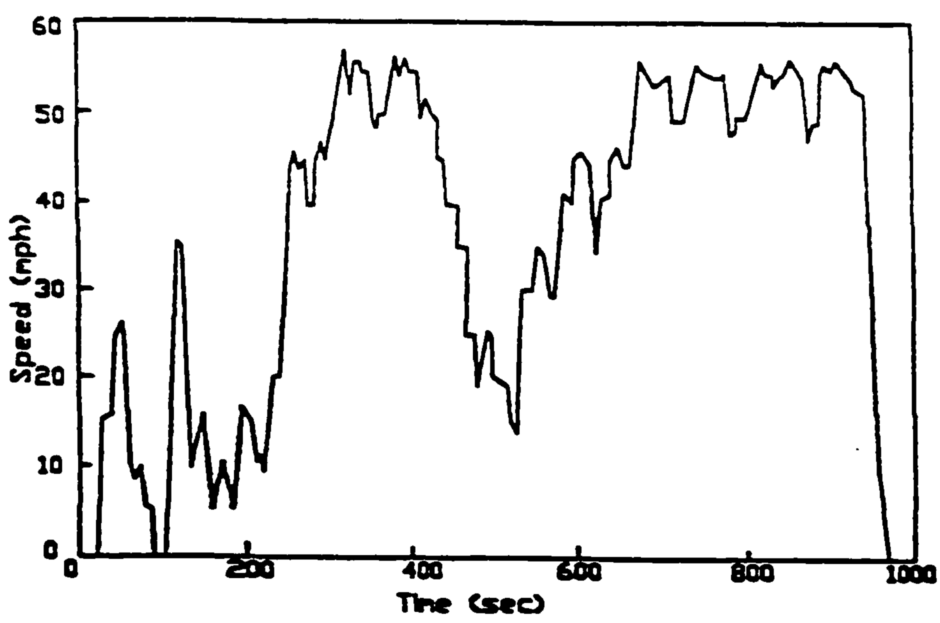

Figure E-6: Speed Correction Cycle 36
Source: EPA

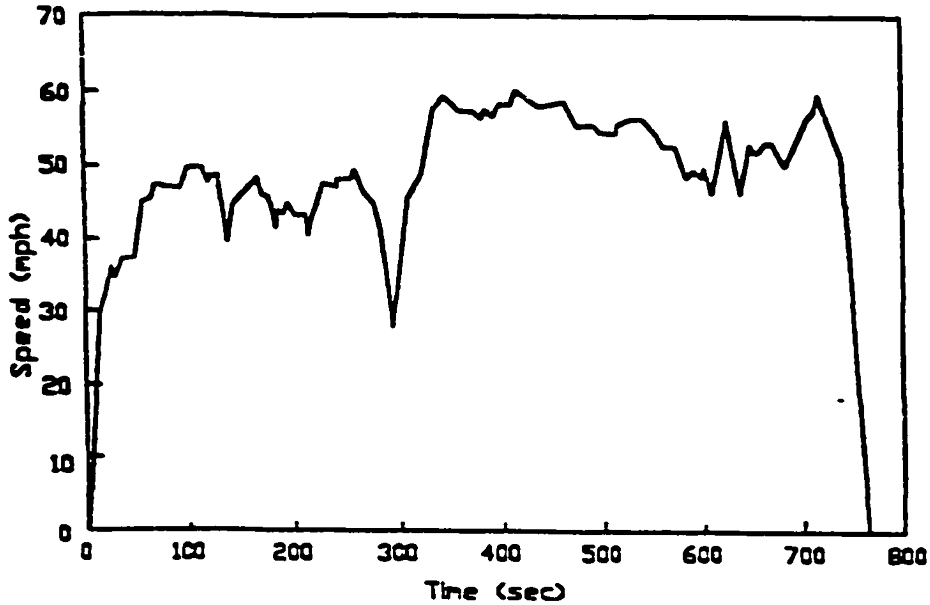

Figure E-7: Highway Fuel Economy Test
Source: EPA

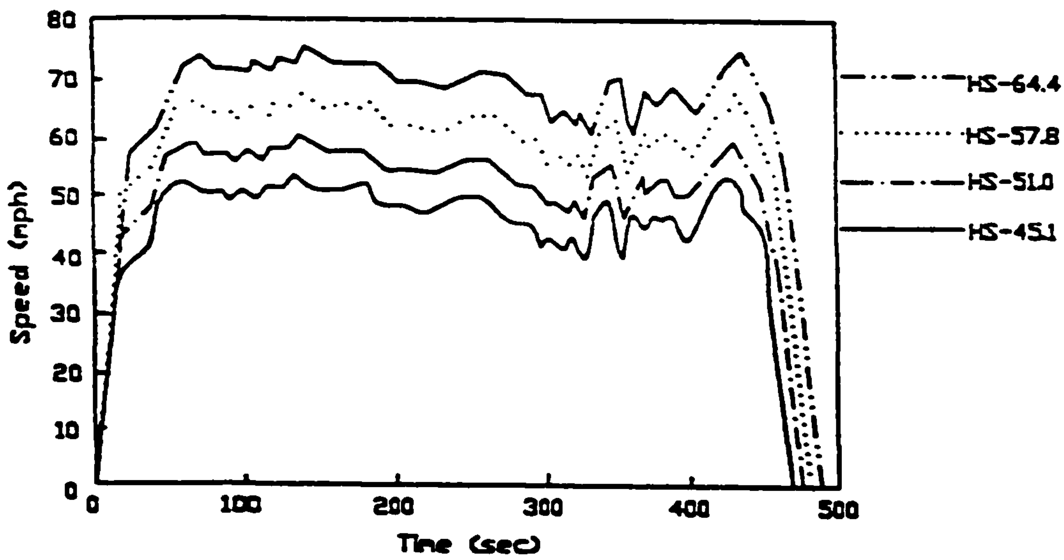

Figure E-8: CARB High Speed Cycles
Source: EPA

Appendix F Procedures Used to Calculate Travel Impacts of TCMs

F-1 Traffic Flow Improvements

F-1.1 Traffic Signal Improvements **Description** Improve traffic signal timing and coordination. This strategy will increase speeds, and possibly induce an increase in the number of trips.

For this TCM, the user inputs the estimated changes in trips and speeds by time period.

Baseline Travel Characteristics – Supplied by User

- Total peak VMT
- Total off peak VMT
- Average commute trip length
- Average non-commute trip length
- Percent of peak trips that are commute trips
- Percent of off peak trips that are commute trips

TCM-Specific Parameters – Supplied by User

- Reduction in peak trips
- Reduction in off-peak trips
- Percent change in peak speeds
- Percent change in off-peak speeds

Assumptions in the Spreadsheet

- Speeds are input directly, not calculated according to the change in VMT

Calculations in the Spreadsheet

- Reduction in total trips = (Reduction in peak trips) + (Reduction in off-peak trips)
- Reduction in peak VMT = (Reduction in peak trips) * [(Percent of peak trips that are commute trips) * (Average commute trip length) + (1-(Percent of peak trips that are commute trips)) * (Average non-commute trip length)}
- Reduction in off-peak VMT = (Reduction in off-peak trips) * [(Percent of off-peak trips that are commute trips) * (Average commute trip length) + (1-(Percent of off-peak trips that are commute trips)) * (Average non-commute trip length)]
- Reduction in total VMT = (Reduction in peak VMT) + (Reduction in off-peak VMT)

F-1.2 Capacity Increases **Description** Make improvements to the roadway such that the roadway capacity is increased. This strategy will increase speeds, and possibly induce an increase in the number of trips. For this TCM, the user inputs the estimated changes in trips and speeds by time period.

Baseline Travel Characteristics – Supplied by User

- Total peak VMT
- Total off peak VMT
- Average commute trip length
- Average non-commute trip length
- Percent of peak trips that are commute trips
- Percent of off peak trips that are commute trips

TCM-Specific Parameters – Supplied by User

- Reduction in peak trips

- Reduction in off-peak trips
- Percent change in peak speeds
- Percent change in off-peak speeds

Assumptions in the Spreadsheet

- Speeds are input directly, not calculated according to the change in VMT

Calculations in the Spreadsheet

- Reduction on total trips = (Reduction in peak trips) + (Reduction in off-peak trips)
- Reduction in peak VMT = (Reduction in peak trips) * [(Percent of peak trips that are commute trips) * (Average commute trip length) + (1-Percent of peak trips that are commute trips)) * (Average non-commute trip length)]
- Reduction in off-peak VMT = (Reduction in off-peak trips) * [(Percent of off-peak trips that are commute trips) * (Average commute trip length) + (1-Percent of off-peak trips that are commute trips)) * (Average non-commute trip length)]
- Reduction in total VMT = (Reduction in peak VMT) + (Reduction in off-peak VMT)

F-2 Improved Public Transit TCM

F-2.1 Transit Service Increases Description Improvements to the transit system in terms of either an increase in route miles or fare, which are directly input by the user. Changes in route miles or fare can be implemented individually or in combination.

Baseline Travel Characteristics – Supplied by User

- Total person trips

- Commute trip share of transit
- Percent of commute trips in peak period
- Percent of non-commute trips in peak period
- Percent of peak trips that are commute trips
- Percent of peak trips that are non-commute trips
- Average commute trip length
- Average non-commute trip length
- Total peak VMT
- Total off-peak VMT
- Total transit vehicle miles
- Percent of all trips that are transit

TCM-Specific Parameter – Supplied by User

- Increase in transit vehicle miles
- Average percent fare decrease
- Percent of transit ridership increase that equals the trips reduction

Assumptions in the Spreadsheet

- Elasticity of transit use with respect to service
- Elasticity of transit use with respect to cost
- Elasticity of speed with respect to volume

Calculations in the Spreadsheet

- Reduction in total trips = [((Increase in transit vehicle miles)/(Total transit vehicle miles) * (Elasticity of transit use with respect to service)) + ((Average percent fare decrease) * (Elasticity of transit use with respect to cost)] * (Percent of transit ridership increase that equals the trip reduction) * (Total person trips) * (Percent of all trips that are transit)

- Reduction in peak trips = [(Commute trip share of transit) * (Percent of commute trips in peak period) + (1-(Commute trips share of transit) * (Percent of non-commute trips in peak period)] * (Reduction in total trips)
- Reduction in off-peak trips = (Reduction on total trips) – (Reduction in peak trips)
- Reduction in peak VMT = (Reduction in peak trips) * ([(Percent of peak trips that are commute trips) * (Average commute trips length) + (1-(Percent of peak trips that are commute trips)) * (Average non-commute trip length)]
- Reduction n off-peak VMT = (Reduction in off-peak trips) * ([(Percent of off-peak trips that are commute trips) * (Average commute trip length) + (1-(Percent of off-peak trips that are commute trips)) * (Average non-commute trip length)]
- Reduction in total VMT = (Reduction in peak VMT) + (Reduction in off-peak VMT)
- Percentage change in peak speeds = (Reduction in peak VMT)/(Total peak VMT) * (Peak elasticity of speed with respect to volume)
- Percentage change in off-peak speeds = (Reduction in off-peak VMT)/(Total off-peak VMT) * (Off-peak elasticity of speed with respect to volume)

F-3 Employer-Based Transportation Management

F-3.1 Employee Transit Pass Subsidy Description Subsidies for transit passes given by an employer to their employees to encourage the use of public transportation. For this TCM, the user inputs the percent of the subsidy that is provided for a monthly transit pass.

Baseline Travel Characteristics – Supplied by User

- Total commute person trips
- Drive-alone share of commute person trips
- Percent of commute trips in peak period
- Average commute trip length
- Total peak VMT
- Total off-peak VMT

TCM-Specific Parameters – Supplied by User

- Percent of cost of a monthly transit pass subsidized
- Percent of employees affected
- Percent of transit ridership that equals the trip reduction

Assumptions in the Spreadsheet

- Elasticity of transit use with respect to cost
- Elasticity of speed with respect to volume
- This TCM only affects commute trips

Calculations in the Spreadsheet

- Reduction in total trips = (Total commute person trips) * (Drive-alone share of commute person trips) * (Price elasticity for transit) * (Percent subsidy of cost of monthly transit pass) * (Percent of employees affected) * (Percent of transit ridership that equals the trip reduction)

- Reduction in peak trips = (Percent of commute trips in peak period) * (Reduction in total trips)
- Reduction in off-peak trips = (Reduction in total trips) – (Reduction in peak trips)
- Reduction in peak VMT = (Reduction in peak trips) * (Average commute trip length)
- Reduction in off-peak VMT = (Reduction in off-peak trips) * (Average commute trip length)
- Reduction in total VMT = (Reduction in peak VMT) + (Reduction in off-peak VMT)
- Percentage change in peak speeds = (Reduction in peak VMT)/(Total peak VMT) * (Peak elasticity of speed with respect to volume)
- Percentage change in off-peak speeds = (Reduction in off peak VMT)/(Total off-peak VMT) * (Off-peak elasticity of speed with respect to volume)

F-3.2 <u>Ridesharing</u> Description Ridesharing involves programs that promote and provide incentives for commuters to share rides in carpools, vanpools, and subscription bus services. For this TCM, the user inputs information on the targeted percent increase in non-drive-alone modes as a result of this strategy for those employees affected.

Baseline Travel Characteristics – Supplied by User

- Drive alone share of commute person trips
- Total commute person trips
- Percent of commute trips in peak period
- Average commute trip length
- Total peak VMT
- Total off-peak VMT

TCM-Specific Parameters – Supplied by User

- Percent increase in non-drive-alone modes
- Percent of maximum VMT reduction realized due to circuity of ridesharing or access to transit
- Percent of new carpool riders that still make a trip, not including carpool driver
- Average carpool size
- Percent of employees affected

Assumptions in the Spreadsheet

- Elasticity of speed with respect to volume

Calculations in the Spreadsheet

- Reduction in person trips = (1-(Drive-alone share of commute trips)) * (Percent increase in non-drive-alone modes) * (Total commute person trips) * (Percent of employees affected)
- Reduction in total trips = (1-(Percent of new carpool riders that still make a trip)) * (Reduction in person trips) – ((Reduction in person trips)/(Average size of carpool))
- Reduction in peak trips = (Percent of commute trips in peak period) * (Reduction in total trips)
- Reduction in off-peak trips = (Reduction in total trips) – (Reduction in peak trips)
- Reduction in peak VMT = (Reduction in peak trips) * (Average commute trip length) * (Percent of maximum VMT reduction realized due to circuity of ridesharing or access to transit)
- Reduction in off-peak VMT = (Reduction in off-peak trips) * (Average commute trip length) * (Percent of maximum VMT reduction realized due to circuity of ridesharing or access to transit)
- Reduction in total VMT = (Reduction in peak VMT) + (Reduction in off-peak VMT)
- Percentage change in peak speeds = (Reduction in peak VMT)/(Total peak VMT) * (Peak elasticity of speed with respect to volume)
- Percentage change in off-peak speeds = (Reduction in off peak VMT)/(Total off-peak VMT) * (Off-peak elasticity of speed with respect to volume)

F-4 High Occupancy Vehicle Lanes Description Add a lane to an existing roadway that is restricted to high occupancy vehicles during the peak periods and is not used as a lane during the off-peak periods. For this TCM, the user inputs the lane characteristics and any induced trips that may occur as a result of increases in available capacity in the mixed flow lanes.

Baseline Travel Characteristics – Supplied by User

- Total peak VMT
- Total commute vehicle trips
- Percent of peak trips that are commute trips
- Average commute trip length
- Average non-commute trip length
- Percent of all trips in peak period
- Percent of VMT on freeways

TCM-Specific Parameters – Supplied by User

- Miles of freeway affected
- Number of hours in peak periods
- Number of existing lanes on freeway
- Induced number of vehicle trips on mixed flow lanes due to additional capacity
- Percent of freeways affected

Assumptions in the Spreadsheet

- Peak elasticity of speed with respect to volume
- Average mode shift from drive alone per mile of HOV lane per hour
- Only peak period travel is affected

Calculations in the Spreadsheet

- Reduction in peak trips = [(Miles of freeway affected) * (Average mode shift from drive alone per mile of HOV lane per hour) * (Number of hours in peak periods)] – (Induced number of vehicle trips on mixed-flow lanes due to additional capacity)
- Reduction in off-peak trips = 0
- Reduction in total trips = (Reduction in peak trips)
- Reduction in peak VMT = (Number of park-and-ride lot spaces) * (Average utilization rate) * [(Percent of commute trips in the peak period) * (Percent of park-and-ride lot use that is commute trips) * ((Average commute trip length) – Average length of trip to lot) + (Percent of non-commute trips in the peak period) * ((1-(Percent of park-and-ride lot use that is commute)) * ((Average non-commute trip length) – (Average length of trip to lot))]
- Reduction in off-peak VMT = (Reduction in total VMT) – (Reduction in peak VMT)
- Percentage change in off-peak speeds = (reduction in off-peak VMT)/(Total off-peak VMT) * (Off-peak elasticity of speed with respect to volume)

Appendix G Glossary of Terms

This section contains the definitions of key terms used through out this document. They are presented to provide clarity and a common meaning to some of the key terms. Some terms that are less commonly used are defined within the text.

Area source - Small stationary and non-transportation pollution sources that are too small and/or numerous to be included as point sources but may collectively contribute significantly to air pollution (i.e., dry cleaners).

Area-wide ride sharing incentives - Carpooling is a travel arrangement in which two or more people travel together in the same vehicle which is owned by one of the travelers. compensation to the owner of the vehicle is limited to the cost of operating the vehicle for carpooling activities. Vanpooling, on the other hand, generally is a travel arrangement involving a group of people (usually 8 or more). The van may or may not be owned by one of the carpool members.

Bicycling and pedestrian programs - Bicycle lanes and storage facilities can be used to discourage occupancy automobile trips and increase the interface between various transportation modes -- primarily bicycles and mass transit or bicycles and carpools/vanpools. There are three types of bicycle lanes as defined by AASHTO. Class I bicycle lanes provide a separate path for exclusive use of bicycles. Class II lane designates a portion of a roadway for preferential or exclusive use for bicycles and class III is a shared roadway for both bicycles and vehicular travel.

CAAA - The Clean Air Act 0Amendments of 1990.

CO - Carbon monoxide - a criteria pollutant - a product of incomplete fuel combustion.

Carbon monoxide (CO) - A colorless, odorless, tasteless gas formed in large part by incomplete combustion of fuel. Human activities (i.e., transportation or industrial processes) are largely the source for CO contamination.

Emissions budget - The part of the State Implementation Plan (SIP) that identifies the allowable emissions levels, mandated by the National Ambient Air Quality Standards (NAAQS), for certain pollutants emitted from mobile, stationary, and area sources. The emissions levels are used for meeting emission reduction milestones, attainment, or maintenance demonstrations.

Employer-based transportation management - Employers may sponsor programs designed to encourage employees to carpool or use transit. Economic incentives are those generally promoted by employers. Beyond the savings to employees who carpool or used transit, employers can provide more direct incentives such as inexpensive or free parking for carpoolers, the sponsorship of vanpools or provision of transit passes to employees designed to discourage single-occupancy vehicles.

Extended vehicle idling controls - Motor vehicles emit more air pollution while idling than while operating at normal speeds. This implies that vehicle idling can be a major source of air pollution.

Methods of Control:

(i) Rerouting rail alignments to avoid at-grade crossing;

(ii) Separating highway and rail alignments at existing crossings;

(iii) Improving alternative traffic routes, including signs, to nearby grade separated crossings; and

(iv) Installing signs at rail crossing informing motorists to turn off their engines.

Extreme cold start controls - Cold starts are related to trip volume but not to trip lengths. Cold start emissions account for a high proportion of total pollution generated for short trips (60% for a five mile trips and 50% for a ten-mile trip). The number of trips taken per vehicle matters a great deal even when VMT is constant.

Flexible work schedules - These measures are intended to reduce demand for the transportation system in peak periods, thereby shortening travel time, improving speeds and reducing emissions. Additional effects of staggered work hours and flex time could be a shift from automobiles to transit since the latter will be less crowded. These modal shifts have the effect of reducing emissions levels.

Fugitive dust - Windblown soil and road dust; the greatest source of PM_{10}.

HC - Hydrocarbons - gaseous compounds made of carbon and hydrogen (used interchangeably with VOC).

High-occupancy vehicle facilities - Lanes for high-occupancy vehicles (HOVs) are roadway lanes dedicated for either the entire day or for certain peak periods to exclusive use by carpools, vanpools, and buses. Vehicles in these lanes may move with the flow of traffic or against it (in the later case, the lanes are termed "contra-flow").

Highway vehicles - Cars, vans, buses, trucks, and motorcycles.

Improved Public Transit - This measure includes both the system management actions and the long-range transit improvements. Specifically, system operating policies which affect the amount and quality of transit service. Policy variables include fares, headway, speeds, feeder services and system hours of operation. Long-range transit planning strategy embodies a statement of need and policy direction with corridors or subareas of deficiency identified.

Inspection and Maintenance Program (I/M) - An emissions testing and inspection program implemented by states in nonattainment areas to ensure that the catalytic or other emissions control devices on in-use vehicles are properly maintained.

Major Activity Centers - This measure is used to create special zones within which the presence of automobiles is restricted or prohibited. Most often these auto-restricted zones are in congested areas of the downtown, but other locations are possible. This measure encourages modal shifts to transits which are allowed access to downtown. Air quality is improved by this measure, as emissions of air pollutants are reduced when VMT is reduced.

Mobile source - Mobile sources include motor vehicles, aircraft, seagoing vessels, and other transportation modes. The mobile source related pollutants are carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and small particulate matter (PM_{10}).

NAAQS - The National Ambient Air Quality Standards - Federally established standards for pollutant concentrations that States, cities and towns must meet by specified deadlines.

NO_x - Nitrogen oxides - a collective term for all compounds of nitrogen and oxygen (includes nitrogen monoxide, nitrogen dioxide, etc).

Nonattainment areas - Areas that have failed to meet the NAAQS.

Off-highway sources - Aircraft, trains, boats, off-road recreational vehicles, farm and construction equipment, and yard tools.

Oxygenated gasoline - Gasoline enriched with oxygen bearing liquids to reduce CO production by permitting more complete combustion.

Park and ride or fringe parking facilities - This is a travel arrangement wherein commuters drive from their homes to a designated parking lot on the fringe of the urban area, park their cars for the day, ride high occupancy vehicles (HOVs) to their places of employment, and return to these parking lots in the evening to drive their cars home. This measure is designed to reduce automobile congestion on major thoroughfares leading to large employment centers and downtowns.

Parking Management - Within this category are controls on aggregate parking supply, preferential parking for HOVs, public policies to increase the cost of parking, and parking requirements in zoning codes. By making parking less plentiful and/or more costly, these measure are meant to create a disincentive to driving -- thereby reducing trips, diverting them to transit, or increasing auto occupancy rates.

Particulate matter (PM) - Any material that exists as solid or liquid in the atmosphere. Particulate matter may be in the form of fly ash, soot, dust, fog, fumes, etc.

Parts per million (ppm) - A measure of air pollutant concentrations.

Point & area sources - Stationary sources of emissions, including electric utilities, factories, petroleum refineries; dry cleaners, and so forth

Precursors - Pollutants that contribute to the formation of other pollutants; HC and NO_x are precursors of ozone.

PSI - Pollutant Standards Index; a composite calculation of PM_{10}, sulfur dioxide, CO, ozone, and nitrogen dioxide used to measure air quality.

Reformulated gasoline - Gasoline specifically developed to reduce undesirable combustion products.

Reid Vapor Pressure (RVP) - A measure of fuel volatility.

Small particulate matter (PM_{10}) - Particulate matter which is less than 10 microns in size. A micron is one millionth of a meter. Particulate matter this size is too small to be filtered by the nose and lungs.

Special Event Controls - Programs ordinances to facilitate non-automotive travel, provision and utilization of mass transit, as part of transportation planning and development applicable to new shopping centers, and other vehicle activity.

Stage II Vapor Recovery Program - This program is designed to reduce HC emissions during refueling operations.

State Implementation Plan (SIP) - A plan mandated by the CAAA that contains procedures to monitor, control, maintain, and enforce compliance with the NAAQS.

Stationary source - Relatively large, fixed sources of emissions (ie., chemical process industries, petroleum refining and petrochemical operations, or wood processing).

Traffic Flow Improvements - These measures consist of adjustments in traffic signals, widening of roadways, creation of one-way streets, widening of intersections, and institution of reversible lanes. Each of these actions is designed to increase the speed of traffic and to reduce delays (and to a lesser extent travel time) by increasing capacity. Generally, as traffic flow is improved through an increase in capacity, the amount of pollutants emitted by vehicles is lessened. This benefit results from increase in speed and fewer delays.

Transportation control measures (TCMs) - Any measure in a SIP directed toward reducing emissions of air pollutants from transportation sources by improving traffic flow, reducing congestions, or reducing vehicle use.

Transportation Hydrocarbons (HC) - Colorless gaseous compounds originating from evaporation and the incomplete combustion of fossil fuels.

Transportation Improvement Program (TIP) - Also known as a transportation program, a TIP is a program of transportation projects drawn from or consistent with the transportation plan and developed pursuant to Title 23, U.S.C. (United States Code) and the Federal Transit Act.

Transportation Plan - This is a long-range plan that identifies facilities that should function as an integrated metropolitan transportation system, and developed pursuant to Title 23 U.S.C. (United States Code) and the Federal Transit Act. It gives emphasis to those facilities that serve important national and regional transportation functions, and includes a financial plan that demonstrates how the long-range plan can be implemented.

Trip Reduction Ordinances - Road pricing measures are typically used in heavily traveled corridors and congested areas to discourage single-occupant automobile trips and to reduce congestion by imposing economic disincentives on the use of vehicles for such trips. Generally, these are measures that encourage people to shift to carpools, vanpools, or transit because they will save travel time and cost. This shift in travel modes, in turn, reduces congestion and increases operative speeds. An additional benefit is a reduction in the emission of air pollutants.

Vehicle miles traveled (VMT) - The sum of distance traveled by all motor vehicles in a specified region.

Vehicle use limitations or restrictions - These measures include no-drive days and auto-restricted or pedestrian zones. Going beyond voluntary programs by imposing mandatory no-drive days -- which might be implemented, for example, on the basis of restricting cars with certain license plate numbers on specific days. Auto-restricted or pedestrian zones, which would be located in downtown shopping areas.

VOC - Volatile organic compounds - gaseous compounds made of carbon and hydrogen (used interchangeably with HC).

Voluntary removal of pre-1980 vehicles - Old cars and poorly tuned cars are known to be a major pollution source and addressing this problem may help reduce emissions problems. The pre-1980 model year light duty vehicles and pre-1980 model light duty trucks fall into this category of old vehicles. The state of California, for instance, is experimenting with "bounty" programs, in which owners (often low-income people) are paid about $700 to take older vehicles off the road.

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VITA

Benedict Nweke Nwokolo was born in Enugwu-Ukwu, Nigeria, on December 8, 1950. He came to America on January 4, 1976 and by December 1979, he received a Bachelor of Science degree in Civil Engineering at Purdue University, West Lafayette campus, Indiana. After his B. S. degree, he entered a graduate school at Jackson State University in January 1980, and in December 1980, he received an MBA degree. With a Federal Government of Nigeria scholarship, he entered another graduate program in Civil Engineering at Mississippi State in Starkville, Mississippi in 1981. He received another master's degree in Civil Engineering in December 1982. In 1983, he came back to Jackson State to teach as an instructor and as an Assistant Research Director in the School of Technology. In 1984, he secured a position as an Assistant Project Leader/Assistant Professor at Alcorn State University, Lorman, Mississippi. During the same year, he received another master's degree in Computer Science at Jackson State University, Mississippi.

Benedict Nwokolo served Alcorn State University until July 1987. He came to Grambling State University, Grambling, Louisiana, in August of 1987 as an Assistant Professor and was promoted to the rank of an Associate Professor of Engineering in 1998. During his tenure at Grambling State, he received several federally sponsored research projects in the amount of about three million dollars. He entered the doctoral program at Louisiana Tech University in 1994 as a part-time student and was able to complete the requirements for the degree of Doctoral of Engineering in Civil Engineering in May of 1999. Currently, Benedict Nwokolo is the Principal Investigator of a half a million-dollar research project on the air quality for the Baton Rouge, Louisiana nonattainment area in terms of national ambient air quality standards.