Travel Diary-Based Emissions Analysis of Telecommuting for the Puget Sound Demonstration Project

by

Dennis K. Henderson,
Brett E. Koenig, and
Patricia L. Mokhtarian

Research Report
UCD-ITS-RR-94-26

Sponsored by the Washington State Energy Office under Contract No. 94-38-01

November 1994

Institute of Transportation Studies
University of California, Davis
Davis, California 95616
phone: (916) 752-6548
fax: (916) 752-6572

ACKNOWLEDGEMENTS

This research was funded by the Washington State Energy Office under Contract # 94-38-01. The authors would like to thank Rick Kunkle at WSEO for his input regarding many of the critical decisions encountered during this study and for providing the temperature profile data from the Seattle / Tacoma airport readings. Thanks also to Dee Christensen at WSEO for earlier providing us with the travel diaries and giving us free rein in analyzing them. We are grateful to Tom Lusk and Nathaniel Kong at the California Air Resources Board for their advice and technical support in modifying the EMFAC7F and BURDEN7F models. Their assistance is truly appreciated as this research depended on their expertise and generosity. Irena Asmundson provided invaluable support by checking the diary data for errors and preparing the graphics for this report. Michael Bagley provided assistance with consistency checks and preliminary analysis of the travel diary data, as well as earlier work setting up the original versions of EMFAC7F and BURDEN7F.

ABSTRACT

Transportation control measures are often implemented for their environmental benefits, but there is a need to quantify what benefits actually occur. Telecommuting has the potential to reduce the number of daily trips and miles traveled with personal vehicles and consequently, the overall emissions resulting from vehicle activity. This research, sponsored by the Washington State Energy Office (WSEO), studies the emissions impacts of telecommuting for the participants of the Puget Sound Telecommuting Demonstration Project. The California Air Resources Board's emissions models, EMFAC7F and BURDEN7F, are used to estimate the emissions on telecommuting days and non-telecommuting days based on travel diaries completed by program participants. This study, among the first of its kind, represents the most sophisticated application to date of emissions models to travel diary data.

Analysis of the travel diary data and the emissions model output supports the hypothesis that telecommuting has beneficial transportation and air quality impacts. The most important results are that telecommuting decreases the number of daily trips (by 30%), the vehicle miles traveled (by 63%), and the number of cold starts (by 44%), especially those taking place in early morning. These reductions are shown to have a large effect on daily emissions with a 50 to 60% decrease in pollutants generated by a telecommuter's personal vehicle use on a telecommuting day.

Reductions of this magnitude are observed because the telecommuters in this sample are long-distance commuters, with commutes twice as long as the regional average. As telecommuting becomes more widely adopted, and the average commute length for telecommuters becomes more representative of the average, the per-capita impacts on travel and emissions reported here will decrease. Also, there are many factors that should be considered as part of a total assessment of the air quality impacts of telecommuting. These include an analysis of the direct transportation impacts (the only impacts addressed here), as well as the indirect transportation impacts, indirect non-transportation impacts, and region-specific topographical and meteorological factors. However, the net impacts are still expected to be beneficial – a reduction in VMT and emissions.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

As the adoption of telecommuting for the improvement of air quality becomes increasingly widespread it is important to study how personal vehicle use by telecommuters may change with telecommuting and how these changes influence the amount of emissions generated from that activity. Whereas a number of studies have analyzed the transportation impacts of telecommuting, to date few have evaluated the direct emissions impacts which accompany those changes in travel behavior due to telecommuting. This research, sponsored by the Washington State Energy Office (WSEO), follows the State of California Telecommuting Pilot Project as one of the first such analyses.

1.1 Background

Transportation and energy planners have been intrigued with the potential of substituting telecommunications for travel for the past thirty years (see, e.g., Memmott, 1963). The energy crisis of the early 1970s prompted most of the initial research into this area (see, e.g., Lathey, 1975). In the 1980s there was a resurgence of interest in telecommuting among transportation/energy/air quality planners as a possible Transportation Demand Management (TDM) strategy to help decrease congestion and improve air quality (Mokhtarian, 1991).

Several substantive evaluations of the transportation-related impacts of telecommuting have been conducted (Mokhtarian *et al.*, 1994). From these evaluations, a number of findings have begun to emerge, including: reductions in the number of trips made and vehicle miles travelled (VMT) by telecommuters; decreases in trip linking (due to removing the commute trip from the "chain"); spatial shifts in travel (to destinations closer to home); and reductions in peak-period travel.

As research on telecommuting grew, separate parallel efforts were underway to develop computer emissions models to quantify the emissions generated from vehicle activity. Two of the models developed for these purposes are the federal Environmental Protection Agency model, MOBILE, and the California Air Resources Board emission models, EMFAC / BURDEN. While not specifically designed for this purpose, these models (for the first time) provided a tool with which to analyze the emissions impacts of telecommuting and other TDMs.

While several studies on telecommuting gave qualitative support to the hypothesis that telecommuting reduces vehicle emissions, none directly measured those impacts. Finally, an evaluation of the State of California Telecommuting Demonstration Project constituted the first known analysis of the emissions impacts of telecommuting in a specific setting (Sampath, *et al.*, 1991). The present study improves upon the methodology used in the State of California study, making this the most sophisticated application of emissions models with travel diary data to date.

1.2 Research Objectives

This study evaluates the emissions impacts of telecommuting using travel diary data from the Puget Sound (Washington State) Telecommuting Demonstration Project (Quaid and Lagerberg, 1992). The main objective of this research is to determine the impacts of telecommuting on the amount of personal vehicle use, and commensurate emissions, of the telecommuters participating in the study. To these ends, the emissions generated by telecommuters' personal vehicle use on telecommuting days and non-telecommuting days are compared to each other and to the emissions of a non-telecommuting control group.

To estimate the emissions for the analysis, the Puget Sound data are used as input to the California Air Resources Board's emissions models, EMFAC7F and BURDEN7F (CARB, 1993). These are the official models used to estimate emissions in air basins throughout the state of California, and are viewed nationally as representing the current state of the art. The models use temperature profile and vehicle activity data to estimate the emissions caused by vehicle use for an assumed fleet mix. Modifications were made to the models to customize the analysis as much as possible to the characteristics of the Puget Sound, Washington area and of the data itself. The emissions outputs from the BURDEN7F model runs serve as the core of the analysis.

It should be noted that an emissions analysis such as this one depends on the accuracy of the models used. It is generally suspected that the EMFAC and BURDEN models underestimate the amount of emissions caused by vehicle activity, although the extent of this inaccuracy is not well known (Pierson *et al.*, 1990, Pollack *et al.*, 1992). The current (7F) versions of the models, however, are among the most advanced mobile source emissions models available and provide the best estimates of the impacts of telecommuting on vehicle emissions at this time. And although the absolute emissions levels are subject to modeling error, the percent difference in emissions between telecommuting and non-telecommuting days should be a more reliable measure.

The organization of this report is as follows: Section 2 describes the data and outlines the preparation of the data for use in this analysis. Section 3 introduces the emissions models and indicates how they were modified for this study. Development of the input files is also discussed. Section 4 addresses the factors affecting the impacts of telecommuting on air quality, and presents the findings from this study. Each factor is discussed in detail to explain how changes in personal vehicle activity impacts emissions levels. Finally Section 5 summarizes the key findings of this research and relates the findings to those from the State of California Telecommuting Project.

2. PUGET SOUND DATA

2.1 General Description

The Puget Sound Telecommuting Demonstration Project data used in the analysis is composed of travel diary data provided by 104 telecommuters from about 20 public and private organizations and 41 control group members who were (for the most part) comparable non-telecommuting employees of the same organizations. Two-day travel diaries were completed by the project participants and their driving-age household members to document their travel behavior before and after telecommuting. The data were collected in three "waves" with one "Before" telecommuting wave (occurring in late 1990 - early 1991) and two waves occurring about six months and one year, respectively, "After" telecommuting began. The data were organized into a database with detailed information on each trip. Some of the information for each trip includes the origin, destination, total trip time and distance, and the type of mode taken.

In the case of personal auto trips, the vehicle make, model, and year are also included. It is important to note that carpool and vanpool trips were given a different code in the travel diaries, and vehicle information (make, model, and year) was not available for those trips. Thus, this study focuses on "personal vehicle" trips only. It may be reasonable to assume that many if not most ridesharing trips would still have taken place without the telecommuter, and that telecommuting would have no emissions impacts on those trips. However, as further discussed in Section 4, this is clearly an area for additional research.

The input requirements for BURDEN7F demanded that personal vehicles be classified into class/technology groups. Due to the nature of this particular sample, only four out of the thirteen class/technology groups were needed: a light duty automobile class subdivided into catalyst-equipped and non-catalyst-equipped technology groups, and a light duty truck class with the same two subcategories. No motorcycle use was reported in this sample. No medium or heavy duty truck use was reported either, which is to be expected from the information workers who comprise this sample. In general, due to the commercial nature of their use, the activity of these types of vehicles should be largely unaffected by telecommuting.

2.2 Data Cleaning and Preparation

In preparation for the emissions analysis several modifications were made to the Puget Sound travel diary database (Koenig and Mokhtarian, 1993). In addition to the extensive error-checking efforts undertaken, all personal vehicle codes were made to be internally consistent within each household and across each wave (previously, a participant may have listed the same vehicle as #1 in one wave and #2 in the next). This was necessary so that the activity of each vehicle could be monitored throughout the day. Other modifications include the addition of four data fields to each trip record: Date, Day Number, Vehicle Classification, and Cat/Ncat Status. The Date field simply added the date to every trip as recorded in the travel diary. The Day Number variable shows which trips were taken on day 1 and day 2 of each wave. The Vehicle Classification field classifies the automobiles used for each trip as either a Light Duty Automobile (LDA) or a Light Duty Truck (LDT). Finally, the Cat/Ncat variable specifies whether trips were made in a vehicle with or without a catalytic converter (detailed criteria for the cat/non-cat status is provided in Section 3.3).

2.3 Separation of the Data into Analysis Groups

A thorough review of the Puget Sound travel diary data was conducted prior to the beginning of the project. The review was undertaken to assess which type of analysis would be more valuable to perform, a "Before" telecommuting / "After" telecommuting analysis, or a telecommuting day / non-telecommuting day analysis. This review revealed that the participants in the study telecommuted to varying degrees from wave to wave. Half of the participants who telecommuted were doing so six months after the start (i.e. in Wave 2), while the other half were not recorded as telecommuting until one year after the start (in Wave 3). It is not known whether these people were generally telecommuting but happened not to do so during the 2-day travel diary period of Wave 2, or whether they did not begin telecommuting until after the Wave 2 data were collected. Also, some of the telecommuters did not participate in Wave 1 (Before telecommuting), and others had already begun telecommuting when Wave 1 occurred. These two groups had no "Before" measure. Thus, conducting a "Before" / "After" analysis would require the exclusion of a large number of participants and telecommuting trips. To maintain the largest sample of telecommuting data it was decided that a telecommuting day / non-telecommuting day analysis would be preferable.

Further review of the data showed that 32 of the 104 people recruited to telecommute in the study were never recorded as doing so (Table 2.1). Also, 8 of the 41 control group members (supposedly non-telecommuters by design) were recorded as telecommuting over the course of the study.

To best perform the telecommuting day / non-telecommuting day analysis, given these circumstances, it was decided that two emissions analyses would be conducted in parallel. The two analyses, hereafter referred to as Analysis 1 and Analysis 2, allow a thorough evaluation of different subsets of the data. Both allow a comparison of the emissions generated by personal vehicle use on telecommuting days versus non-telecommuting days.

Table 2.1 Distribution of Project Participants who Telecommuted

Recruited as:	**# of people who telecommuted during diary periods**	**# of people who didn't telecommute during diary periods**	**Totals**
Telecommuting Group Members	72	32	104
Control Group Members	8	33	41
Totals	80	65	145

Analysis 1 involves comparing the vehicle emissions of the 72 people who were recruited to telecommute, and did, with the 33 control group members who never telecommuted (Table 2.1). Of the 1227 personal vehicle trips taken by telecommuters, 279 trips took place on 67 telecommuting person-days and 948 trips took place on 257 non-telecommuting person-days (Table 2.2). Emissions for these telecommuting day / non-telecommuting day trips are compared to the emissions produced by the 649 control group personal vehicle trips which occurred on 780 person-days. It is noteworthy that on 41 (38%) telecommuting days no personal vehicle trips were made at all, whereas all of the non-telecommuting days involved at least one trip. To account for different size groups, data are reported in terms of grams of pollutant per person-day. This analysis is perhaps the more robust of the two because it isolates a specific group of telecommuters and controls and compares the telecommuting day emissions and the non-telecommuting day emissions of the same people. Isolating this group of people provides greater certainty in conclusions on whether observed changes in automobile use and emissions are actually due to telecommuting.

Analysis 2 is more encompassing, including two groups representing all trips taken by the 145 participants. This analysis allocates the 310 trips taken on telecommuting days (whether by telecommuting group members or control group members who actually telecommuted) into one group, and the 2306 trips taken on non-telecommuting days into another group, to compare their respective daily emissions (Table 2.3). Although the trips are not from a single consistent set of people, the advantage is the larger sample sizes for each group. This analysis is performed with caution, since it does not permit distinguishing what telecommuters do on their non-telecommuting days from what pure non-telecommuters do. Therefore, Analysis 2 will be used mainly to provide any additional insight to the findings from Analysis 1, rather than as a primary analysis itself.

Table 2.2 Analysis 1 (3 Comparison Groups)

	Telecommuters				**Controls**	
	Telecommuting Days		*Non- Telecommuting Days*			
	# Trips	# Person-days	# Trips	# Person-days	# Trips	# Person-days
Personal vehicle trips	279	67	948	257	649	150
All trips	334	70	1236	280	780	166
No personal vehicle trips made	--	41	--	0	--	0

Table 2.3 Analysis 2 (2 Comparison Groups)

	Telecommuters			
	Telecommuting Days		*Non- Telecommuting Days*	
	# Trips	# Person-days	# Trips	# Person-days
Personal vehicle trips	310	78	2306	580
All trips	386	81	2804	620
No personal vehicle trips made	--	42	--	0

2.4 Data Rejection Based on Study Goals

The goal of this study is to evaluate the direct emission impacts of telecommuting, although other areas of interest were considered. One important hypothesis, for example, is that telecommuting may cause shifts in trip making from one household member to another for a variety of reasons (the increased temporal flexibility of the telecommuter, the lessened ability of the telecommuter to link activities to the work trip, or the potential availability of the telecommuter's usual vehicle to another household member). Also of interest is how telecommuting affects weekend (non-work day) travel. Though these are pertinent questions, the Puget Sound data does not allow them to be addressed with confidence. Participation by household members in filling out surveys and travel diaries was relatively low, and in many cases, the days that trips were recorded did not match between the participants and their household members (making it impossible to tell whether or not the household member's trips were made on a telecommuting day for the participant). Also, with a 2-day diary, not enough weekend data is available on which to base any sound judgements about changes in non-work day travel behavior. The minimum required data for an analysis of this type would be a 4-5 day diary, including one or two weekend days. Given these limitations, this study only addresses the work day emissions impacts of the participants directly recruited for the study, on the specific days for which the data are available. Personal vehicle trips missing vital information that could not be reasonably approximated were also not used (Table 2.4).

Table 2.4 Trips Not Used in Analyses

	Telecommuters	**Controls**
Original Trip Totals	4045	1355
Unused Trips		
Household members' trips	1742	392
Non-work day trips	45	17
Trips missing distance & time	13	1
New Trip Totals	2245	945

3. PREPARING FOR THE ANALYSIS

An emissions analysis such as this one depends on the accuracy of the emissions models used. There are some questions about the accuracy of most emission models because they rely on aggregate travel and vehicle fleet characteristics to estimate emissions. Because of these simplifying assumptions, current models are able, at best, to provide close approximations of vehicle emissions.

It is generally suspected that the EMFAC and BURDEN models underestimate the amount of emissions caused by vehicle activity, although the extent of the inaccuracy is not well known (Pierson *et al.*, 1990, Pollack *et al.*, 1992). The current (7F) versions of the models, however, are widely regarded as the state of the art in emissions models and provide the best estimates of the impacts of telecommuting on vehicle emissions at this time. As improvements to models are made in the future more accurate emissions analyses will be possible.

Because of the potential for inaccuracy in emissions modeling, the specific emissions figures provided in this report (in grams/person-day) should be used with caution. Despite this, we maintain that the models are still valuable tools to provide a relative comparison of emissions across groups. For this reason, the most meaningful emissions data from this study are the *percent changes* in emissions due to telecommuting rather than the specific emissions figures. These percent changes in emissions, however, are tied to percent changes in VMT and trips. Future telecommuting programs with different travel impacts should expect correspondingly different emissions reductions.

3.1 Introduction to EMFAC7F and BURDEN7F

To model the emissions for these analyses, the latest versions of the California Air Resources Board's emissions models, EMFAC7F and BURDEN7F, are used. The two models are designed to work together to estimate emissions generated from vehicle activity within a specific air basin for a specific vehicle fleet mix. The user specifies the season in which vehicle activity takes place, either summer or winter. These two seasons are when vehicle activity patterns and atmospheric conditions combine to produce the worst air quality.

Based on fleet mix data and temperature range data, EMFAC7F produces an array of emissions factors, or rates at which emissions are generated (i.e. grams/mile), for each vehicle type for a range of speed categories and incremental ambient temperatures. BURDEN7F references these emissions factors, and compiles the emissions inventory for a specific set of vehicle activity data. The emissions inventory is produced by weighting each measure of vehicle activity (VMT, number of cold starts, etc.) with the appropriate emissions factors. The following is a brief discussion of both models. A more in-depth discussion of the models can be found in CARB (1993).

EMFAC7F

The main function of the EMFAC7F model is to calculate emission factors for the thirteen vehicle class/technology groups for each of seven pollutants: total organic gases (TOG), reactive organic gases (ROG), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM), and lead. In this analysis, we report emissions outputs only for TOG, CO, NOx and PM. The SOx and lead outputs are not presented because the vehicle activity in this small sample did not generate measurable amounts of these pollutants. ROG is not presented because it is a subset of TOG. The thirteen vehicle class/technology groups are as follows:

1. Light Duty Automobiles (LDA) – (Non-catalyst, catalyst equipped, and diesel)
2. Light Duty Trucks (LDT) – (Non-catalyst, catalyst equipped, and diesel)
3. Medium Duty Trucks (MDT) – (Non-catalyst, catalyst equipped)
4. Heavy Duty Trucks (HDT) – (Non-catalyst, catalyst equipped, and diesel)
5. Diesel Transit Buses
6. Motorcycles (MCY) – (Non-catalyst)

The emissions produced by these vehicles are modeled as being generated by seven different processes, which are classified into two basic categories: (1) Exhaust emissions which include cold start, hot start, and stabilized running emissions; and (2) Evaporative emissions which include hot soak, diurnal, evaporative running losses, and evaporative resting losses.

For a particular calendar year, EMFAC7F calculates an array of emissions factors for each combination of vehicle class / technology group, emissions process, and pollutant type. These emissions factors are calculated for various ambient temperatures, vehicle speeds, and Reid vapors pressure (which changes with the seasons). To calculate these emissions factors, EMFAC7F uses base emissions data from the federal automobile emissions test cycle, known as the Federal Test Procedure (FTP). The FTP runs vehicles on a standardized acceleration / deceleration test cycle to collect mobile source emissions data. The cycle is designed to represent average driving conditions including average speed, average temperature, and standard acceleration rates. The data from these tests are then converted into base emissions rates in another computer model, CALIMFAC. EMFAC7F modifies the base emissions rates using correction factors to calculate emissions factors for non-FTP speed, temperature, and fuel conditions. The emission factors for each auto class/technology type are weighted by the percentage of vehicle activity contributed by each model year (i.e. the assumed fleet mix), to generate an array of composite emissions factors for each auto class/technology group. These factors represent the rate at which emissions are produced by each process.

BURDEN7F

BURDEN7F's main function is to calculate the emissions inventory. This is accomplished by reading in vehicle activity data and retrieving the correct emissions factor from the files generated by EMFAC7F. BURDEN7F calculates the emissions inventory by weighting vehicle activity by the appropriate emissions factors. The vehicle activity inputs required by BURDEN7F include: total VMT, number of trips, and population for each class of vehicle in the sample; percent of the total VMT occurring in each five mph increment from 0 to 65 mph for each of the six time periods (defined below); the percent of catalyst-equipped starts that were cold starts (by time of day); and the percent of non-catalyst-equipped starts that were cold starts (by time of day). The model approximates emissions for each of the seven processes mentioned earlier: running exhaust, cold start, hot start, diurnal, hot soak, evaporative running losses, and evaporative resting losses. These are summed to obtain sub-totals by vehicle class/technology group for each pollutant.

BURDEN7F estimates the mobile source emissions generated for a specific season during the year (i.e. summer, winter) since the amounts of pollutants generated depend on the Reid vapor pressure which varies with the seasons. The model divides the day into six time periods to account for differences in ambient temperatures throughout the day. These time periods are as follows: 12 midnight to 6 a.m., 6 a.m. to 9 a.m., 9 a.m. to 12 noon, 12 noon to 3 p.m., 3 p.m. to 6 p.m. and 6 p.m. to 12 midnight.

3.2 Modifications to the Models

The EMFAC7F and BURDEN7F models are designed to calculate year-long aggregate emissions inventories for air basins in California. To use the models for our purposes, modifications were made to generate an individual-level 24-hour emissions inventory using the Puget Sound travel diary data. After consulting with the model developers at the California Air Resources Board, several changes were made to the input files and FORTRAN code in the models. In addition, all major input files that make EMFAC7F and BURDEN7F a California-based model were changed using the travel diary data or Puget Sound region data. Changing the input files and FORTRAN code in this way increased the accuracy of the emissions modeling for this study. Due to data limitations, two variables were left unchanged and were assumed to be equivalent for Puget Sound and California State: the sulfur content in fuel, and the inspection and maintenance programs for pollution controlled vehicles.

Modifications were made, as appropriate, to each step of the modeling process as follows. The model's first step is to call the weighting subroutine in EMFAC7F. The subroutine E7FWT calculates composite emissions factors for each class / technology group based on vehicle representation in an assumed fleet by vehicle model year. The assumed fleet (provided in Appendix 1) is generated using default data files containing vehicle sales records, State Department of Motor Vehicles registration information, and estimations of vehicle miles traveled in California from 1957 to 1991. EMFAC7F and BURDEN7F were developed to model year-long emissions for each basin to provide macro-level emissions inventories for use in air quality studies. The models were not intended to provide comparisons among groups. Therefore, the inventories were appropriately based on an average California fleet. However, individual-level analyses such as this present study require sample-specific data - rather than aggregate data - to provide meaningful comparisons across groups within the sample.

Since respondents in this study are primarily information workers, a large proportion (95%) were found to drive catalyst-equipped light-duty autos and trucks. This may differ considerably from the average fleet. Also, telecommuters' and non-telecommuters' vehicles may differ and representation by a single fleet may not be accurate. There are a variety of reasons why telecommuters and non-telecommuters may choose different vehicles. These include socio-demographic differences as well as variables such as commute length. The extent that these choices take place within this sample is unknown, but any variations should be modeled since they have a direct impact on percent changes as well as absolute levels of emissions produced.

These modeling issues are addressed in this study by replacing the average California fleet information with the actual vehicle representation for each group. To allow the generation of accurate weighting functions, the fleet mix file subroutine was de-activated, and the output from the subroutine was generated manually to include vehicles, VMT, and trip information from the telecommuting demonstration project. Now, with the modified code, as EMFAC7F computes the weighting functions, the default California data is completely ignored and the weights are based purely on the actual vehicles of the Puget Sound participants.

To calculate the necessary data and load the fleet mix file, considerable FORTRAN coding and data manipulation were required. Each trip was checked for the household identification number and vehicle identification number, and data was accessed from a reference file to assign the vehicle model year to each trip, allowing tabulations of trip information by vehicle model year. A noteworthy assumption was made in the retrieval of the vehicle year data. Out of the 323 vehicles available to the study participants, 15 were missing a vehicle description, but were used for travel. In most cases these vehicles were recorded in the travel diary as being a "company vehicle". The decision was made to assume that these vehicles were catalyst-equipped light duty autos, since it is reasonable to believe that a large proportion of company cars are such. The year of the inferred vehicles was taken to be the average year of all catalyst-equipped light duty autos in the study (of which there were 217). The calculated average year was 1985.

After each trip record was augmented with the vehicle model year, code was developed to tabulate trip information for each of the four class/technology groups. The fleet mix data required for *each* vehicle year are: percent of the total VMT for that class/technology group, percent of the total trips taken by that class/technology group, percent of the total vehicle population within that class/technology group, and the total VMT accumulated by each model year. The code was executed for each of the five groups (i.e. the three groups in Analysis 1 and the two groups in Analysis 2) so that the fleet mix would precisely match the vehicles in each set of trips. Appendix 1 contains fleet mix input files for each group.

Following the generation of the fleet mix, the second step for EMFAC7F is to calculate the emissions factors for each of three temperature ranges by one degree increments. Low, medium and high temperature ranges are specified by the user and must include the ambient temperatures for the region. Ranges are specified in the user file rather than the temperature profile itself to allow emissions runs for multiple regions at the same time. The temperature profile data is entered into a specific "county" file that is accessed during the emissions inventory for that county (for this analysis, only one "county" – i.e. the Puget Sound region – was modeled). To reflect the actual temperature profile for Puget Sound, data was obtained from the Seattle-Tacoma Airport via WSEO. The data included hourly temperature readings from 1988 through 1991. This data was averaged to represent a summer temperature profile and a winter temperature profile for the previously described time periods of the day. Daily temperatures during the months of June, July, and August were averaged to represent the summer months, and December, January, and February to represent the winter months. An emissions inventory was run for both summer and winter, although the winter emissions inventory is of primary concern to the Washington State Energy Office and therefore is the main focus of this report. For completeness, summer emissions tables are provided in Appendix 3.

The third step in the model run switches from EMFAC7F to BURDEN7F and begins compiling the emissions inventory based on the emissions factors. BURDEN7F accesses the vehicle activity files to compute the total emissions. Output from BURDEN7F is in a tabular form representing emissions per day for the entire sample of trips. The BURDEN7F program is designed to generate year-long emission inventories in units of tons. Internal changes to the FORTRAN code were required to produce output in terms of pounds of pollutant per day– a more useful unit for this individual-level analysis.

3.3 Development of Input Files

The four main types of input data required for the BURDEN7F model are: (1) the cold start fraction of trips made by vehicles with and without catalytic converters for each of the six time periods of the day; (2) the number of trips made and VMT by each vehicle class (LDA, LDT, MDT, HDT, and MCY) for each of the six time periods of the day; (3) VMT fractions by average speed for each of the six time periods; and (4) the average temperatures during each time period for the specific air basin in which the travel took place.

Preparing the Data

To generate the emissions inventory using EMFAC7F and BURDEN7F all of the trip records in the Puget Sound database had to be complete. The data review performed at the onset of the project revealed, however, that several trip records were missing some trip information. In most cases, the missing information was the trip distance (VMT) or the trip time. The trips that were missing both were unusable and were necessarily excluded from the analysis (Table 2.4).

If a trip were missing either trip distance or trip time, but not both, it was possible to estimate the missing data using the average speed of all other trips taken during the same time period. To calculate the missing data, FORTRAN code was developed to compute the average speed of the trips with complete data. To compensate for the varying traffic conditions at different times of the day the program calculated the average speed of trips taken during the six different time periods of the day: 12 midnight to 6 a.m., 6-9 a.m., 9-12 noon, 12-3 p.m., 3-6 p.m., and 6-12 midnight. For additional accuracy, the average speed computed was weighted by VMT, so that the vehicles traveling more miles were more heavily represented. Missing data (time or distance) were estimated by using the appropriate average speed (from one of the six time periods) and inserting the new figure. In this way all trips missing these data were changed into complete records using the average speed of the other trips taken during the same time period (Table 3.1 and 3.2).

As previously indicated (Section 3.2), trips taken by a company car were frequently missing information on the automobile class (i.e. Light Duty Auto, Light Duty Truck etc.), model year, and whether the vehicle had a catalytic converter or not. These automobiles were assumed to be 1985 light duty autos with catalytic converters and were coded as such.

Table 3.1 Analysis 1: Inferred Information and Rejected Trips

	Telecommuters				**Controls** (649 total trips)	
	TC Days (279 total trips)		*Non-TC Days* (948 total trips)			
	No.	%*	No.	%*	No.	%*
Missing Time (Inferred)	0	0.0%	1	0.1%	1	0.2%
Missing Distance (Inferred)	6	2.2%	36	3.8%	43	6.6%
Missing Both (Rejected)	0	0.0%	2	0.2%	1	0.2%

* Percent of total number of trips.

Table 3.2 Analysis 2: Inferred Information and Rejected Trips

	TC days (310 total trips)		*Non-TC Days* (2306 total trips)	
	No.	%*	No.	%*
Missing Time (Inferred)	0	0%	2	0.1%
Missing Distance (Inferred)	8	2.6%	98	4.2%
Missing Both (Rejected)	0	0%	3	0.1%

* Percent of total number of trips.

Data Augmentation

Once the complete data set was developed several steps were taken to prepare the data for the necessary tabulations. FORTRAN programs were written to calculate the number of trips and VMT taken by each vehicle class for each of the six time periods of the day. Other code was written to calculate the percentage of cold starts taken by vehicles with and without catalytic converters. Also required was the distribution of VMT by average speed for the six time periods. It was necessary to create additional fields and append them to the original data to allow these tabulations to be made. For reliability, generation of the needed fields was carried out automatically with FORTRAN code to avoid the possibility of hand calculation errors. The following data augmentation was completed.

1) Each personal vehicle trip was augmented with a field designating whether that vehicle was equipped with a catalytic converter or not. This was accomplished by accessing the vehicle data reference file to compare household ID numbers and mode choice to determine the year of the vehicle. The decision was made to label all vehicles of the 1975 model year and later with a cat-equipped status. In 1975, many auto manufacturers produced vehicles with catalytic converters as standard equipment. Those that did not were still required to meet the same emissions standards, therefore, cat-equipped or not, the vehicles emitted similar levels of pollutants.

2) Average speeds for each trip were converted into a number signifying the appropriate category of the speed distribution data file. The data file groups trips by five mile-per-hour increments as well as by time of day. Thirteen speed groups represent average speeds from 0 to 65 mph.

3) Each trip record was augmented with its appropriate time slot. As outlined earlier, the six time periods of the day are 12 midnight to 6 a.m., 6-9 a.m., 9-12 noon, 12-3 p.m., 3-6 p.m., and 6-12 midnight. Since some trips overlap time periods, it was necessary to code them such that they could be identified to apportion the VMT for that trip into the two time periods. For example, a trip occurring between 7:30 and 8:00 a.m. was given a "2" signifying the second time period of the day. A trip occurring between 8:00 and 10:00 a.m. was given an "8" signifying a trip that overlaps the second and third time slots.

4) For trips that overlapped time periods, the VMT was apportioned according to time. The proportion of total VMT falling into a given time period was set equal to the proportion of total trip time falling into the same time period. Obviously, the necessary assumption here is that the average speed for each segment was the same.

5) Each trip record was augmented with a field designating a hot or cold start for that trip. A hot start condition was determined by the length of time between trips. For vehicles equipped with a catalytic converter, a hot start is defined as a start occurring within one hour of engine shutdown (CARB, 1993). For vehicles without catalytic converters hot starts are those within four hours of engine shutdown. To produce the data for this field, the assumption was made that the first personal vehicle trip made by a participant on each day of each wave was a cold start. Then, the status of that person's subsequent trips (with the same vehicle) was calculated based on the difference between the origin (departure) time of each trip and the destination (arrival) time of the previous trip.

Creating the Input Files

The above data was tabulated, again using FORTRAN to provide all necessary input for the models. Tabulated data used as model input is provided in Appendix 2. The California data in the input files were replaced with the Puget Sound participants' vehicle activity profile data as the last step in preparation for the model runs.

4. EMISSIONS ANALYSIS

4.1 Factors Affecting Potential Air Quality Impacts of Telecommuting

Air quality may be affected in three different ways as a result of telecommuting. *Direct transportation* impacts are those first-order effects on the participants' travel patterns that are observable from the travel diary data in isolation. *Indirect transportation* impacts include higher-order changes such as effects on household travel, weekend travel, and long-term residential re-location. *Indirect non-transportation* impacts are those related to energy consumption changes due to telecommuting (e.g. lighting or heating at home that wouldn't be used otherwise). All three types of impacts should be considered in a complete analysis of the air quality impacts of telecommuting. Here, the available data permit only the direct transportation impacts of telecommuting to be studied. Even this confined analysis must be performed carefully, since many factors affect the direct air quality impacts of telecommuting and the percent change in emissions levels is, in general, not equal to the percent change in vehicle miles traveled (Mokhtarian, 1991). These factors include: trip length (VMT), number of trips, cold starts, average trip speed, ambient temperature for the trip, and the season in which the vehicle activity takes place.

To explain how these factors affect vehicle emissions, each must be discussed in the context of the emissions processes to which it is related. The seven processes modeled are running exhaust, cold start, hot start, hot soak, evaporative running losses, diurnal, and evaporative resting losses – the first five of which can be influenced by telecommuting. These relationships are discussed in detail below.

Trip length (VMT) is an important factor since increased distance and time cause an increase in running emissions (including running exhaust and evaporative losses). While evaporative emissions contribute only to total organic gases, running exhaust emissions contribute to every pollutant in varying degrees. For TOG and CO, running emissions are low in comparison to cold start emissions for short-to-moderate length trips (less than 20 miles). However, running emissions are the dominant contribution to oxides of nitrogen (NOx), and are the only contributor to particulate matter (PM) emissions. If telecommuting causes a reduction in number of trips as well as VMT through the elimination or reduction of commute (and possibly other) trips, reductions in overall emissions are expected. However, if shorter trips are made and overall VMT decreases, but the number of trips with cold starts increases, NOx and PM should decrease, while TOG and CO would increase.

The ***number of trips*** is important as it relates to engine start-up emissions (cold start and hot start) and engine shut-down emissions (hot soak). After engine shut-down at the end of each trip (whether a cold or hot start trip) a hot soak occurs. This causes evaporative TOG losses from the fuel system resulting from hot engine temperatures. Therefore if telecommuting decreases the overall number of trips, hot soak (TOG) emissions will decrease.

Cold start emissions are greater than hot start emissions by an order of magnitude, and thus are a major concern. As just mentioned, cold starts are the dominant contributor to TOG and CO emissions for short-to-moderate length trips, as well as a major contributor to NOx. Even with a reduction in VMT and number of trips, emissions could actually increase if telecommuting caused a shift in travel behavior resulting in a higher number of trips that begin with a cold start. Since the cold start exhaust is a major contributor to emissions, a very important measure in this study is the number of cold starts per person-day and how it changes with telecommuting.

In general, there is a U-shaped relationship between ***speed*** and running emissions (CARB, 1990). Higher speeds mean *lower* emissions rates up to approximately 50-60 mph, beyond which higher speeds lead to *higher* emissions rates. The impact of telecommuting on travel speeds is ambiguous: other things being equal, higher travel speeds are likely if more trips are made at off-peak (uncongested) times of the day; alternatively, lower speeds will occur if trips are shifted from the freeways to the surface streets, where vehicle travel is typically slower (Sampath, *et al.*, 1991). Emissions are also influenced by vehicle accelerations, with higher emissions occurring on trips with more accelerations and decelerations than on equally long trips with constant speeds. For the purposes of this study, the data do not allow accelerations and decelerations to be determined; only the average speed for the trip can be calculated from distance and time. While EMFAC7F and BURDEN7F do not model the emissions impacts due to acceleration and deceleration in detail, the FTP test procedures used to determine the baseline emissions factors used by EMFAC7F do include standardized acceleration / deceleration test cycles, so these impacts on emissions are modeled to some extent.

The ***ambient temperature*** affects vehicle emissions for each pollutant emitting process. Evaporative emissions – TOG losses related to changes in ambient temperature – increase as temperature increases. These impacts are included in the models, although their overall contribution to the impacts due to telecommuting is expected to be small. By contrast, cold start emissions are very sensitive to ambient temperature. In general, cold start emissions increase as ambient temperature decreases. Thus, if telecommuting causes a shift in trips to later times of the day when temperatures are higher, reductions in cold start emissions could be significant.

Ambient temperatures are also related to ***the season*** for which the analysis is performed. Typically, summer temperatures are higher than winter, resulting in a decrease in cold start emissions. However, the Reid vapor pressure (RVP) also depends on the season. In the summer, the RVP is lower, which decreases evaporative losses significantly. Because of these outside factors the authors caution that comparing emissions across seasons may show changes in emissions levels that are unrelated to vehicle activity.

Other factors related to the climate and topography of the air basin will also affect the air quality impacts of telecommuting. For example, mountain ranges, wind patterns, or the existence of a temperature inversion layer may form barriers against the natural dispersion of pollutants. Obviously, these are beyond the scope of this analysis. Here, it is only the production of pollutants by personal vehicles that is studied. But it is important to point out that the *effects* of these emissions are a function of many other factors. The same absolute levels of personal vehicle emissions may have very different effects from one basin to the next, depending on these other factors.

4.2 Presentation of the Results

As previously discussed, the main focus of this project is to identify the changes in personal vehicle use due to telecommuting, and what the emissions impacts of those changes are. While extensive modifications were made to improve the accuracy of the emissions outputs, the potential for modeling inaccuracy (Section 3) means that the *percent difference* in emissions between groups is the most reliable measure.

Output from the models represents emissions for all vehicle activity in the sample (in units of pounds). These numbers are then divided by the number of person-days represented by the sample and converted by the appropriate factor to yield an emissions output in terms of grams of pollutant per person per day (or grams per person-day). In this context, a person-day is defined as a day on which a participant in the study kept a record of his or her trips. This study focuses on the impact of telecommuting on personal vehicle travel and emissions. Thus, trips involving travel by other modes (such as transit or walk) have been excluded from the analysis. Emissions for these modes are either absolutely zero (e.g. for walk) or zero at the margin (e.g. for transit, assuming the bus will be traveling with or without the telecommuter on board). Consequently, person-days involving *only* trips by modes other than personal vehicles have been excluded from the denominator of the ratio of grams of pollutant to person-days.

However, the 41 telecommuting days on which no trips of any kind were recorded *are* included in the denominator, as the reduction of travel due to telecommuting is precisely one of the impacts we are attempting to measure. To the extent that a given telecommuter would virtually never travel by personal vehicle (e.g. the telecommuter doesn't own a car, and takes transit or walks everywhere), we are slightly overstating the impacts of telecommuting by including such a case (because the reduction in travel due to telecommuting would have no emissions impact). However, the impact of such cases (if any in fact exist) is expected to be negligible.

While beyond the scope of this study, an examination of the effects of telecommuting on mode choice is important. These effects (Mokhtarian, 1991) could be either positive (telecommuters may replace auto trips with walk or bike trips close to home; they may have a heightened awareness of the impacts of travel on air quality and congestion and switch to alternate modes as a result) or negative (telecommuting may reduce transit use and disrupt or dissolve established ridesharing arrangements). Future work with these and other data should provide useful insight into mode choice impacts.

To provide a common basis for comparison of impacts, all trips were treated as though they took place in the same season. In the winter months, levels of carbon monoxide are of greatest concern. This is the worst case season for Puget Sound, Washington, and is most important to the study sponsor, the Washington State Energy Office. Thus, average winter temperatures and the corresponding Reid vapor pressure were used for this analysis.

It was expected that an assessment of the impacts of telecommuting on fuel consumption would be conducted as part of this study. Internal code problems in the models did not allow the generation of accurate numbers. Upon investigation of these problems, it was discovered that fuel efficiencies are only roughly averaged within the code anyway. The code uses a table look up method and bases fuel consumption on an overall reported average for each class / technology group and each vehicle model year. The fuel consumption rate is then assigned to each class / technology group depending on the representation of each model year in the assumed fleet. For a individual-level analysis of this type, an ideal model would include speed as well as class / technology group, with fuel use calculated on a trip by trip basis, rather than using average fuel efficiencies based on an assumed fleet mix.

Oxides of sulfur were not represented in the output of the models. The reported values were zero. With the participants' fleet mix primarily comprising catalyst-equipped vehicles, and constituting a fairly small sample, not enough SOx was produced to be measurable in pounds (the units of the BURDEN7F output).

4.3 Emissions Analysis Findings

Analysis 1 begins with an examination of the differences between controls and telecommuters (on their non-telecommuting days) to assess the extent to which the controls are a useful comparison group. This is followed by a comparison of telecommuters on their telecommuting (TC) days with non-telecommuting (NTC) days. The impacts of the factors affecting emissions levels (described in Section 4.1) are discussed in detail. Table 4.1 summarizes the travel and emissions impacts of telecommuting for Analysis 1. Table 4.2 presents the percent differences among groups for the same indicators as in Table 4.1. For Analysis 2, levels of vehicle activity and emissions are compared for TC days and NTC days for the pooled sample (not distinguishing between telecommuters and controls). Although this is not considered to be the primary analysis, it serves to strengthen confidence in the findings from Analysis 1. Supporting tables and figures for this section begin on page 35.

Analysis 1

Before assessing the changes in emissions due to telecommuting, it is important to check the extent to which the telecommuters and controls are comparable, independent of telecommuting. Comparing telecommuters on NTC days with the control group reveals two critical differences. First, telecommuters make 15% *fewer* trips than controls (3.69 versus 4.33 per person per day). This translates into 11% fewer cold starts and 21% fewer hot starts. Second, telecommuters have a 57% *higher* daily VMT (52.00 versus 33.11 miles per person-day). Both differences are statistically significant at a less than 0.005% level. The higher VMT for telecommuters on NTC days is due to the fact that, on average, their commute length is 2.5 times longer than the controls'. Commute length was not specifically requested in the diaries and therefore was not available for those participants who never drove directly between home and work. The average commute length difference is based on the participants for whom home-to-work trip distances were available (55 out of 73 telecommuters and 29 out of 31 controls). As for the smaller number of trips, it may be that because telecommuters spend considerably more time on a single trip – the commute – they have less time to spend on other discretionary trips than do the controls.

These two differences will act in opposite directions on emissions. Particulate matter emissions, which are almost exactly correlated with VMT, are 58% *higher* for the telecommuters (on NTC days) than for the controls. Oxides of nitrogen (NOx) are sensitive both to running time and to cold and hot starts, with the net result being 15% *higher* for telecommuters. Total organic gases (TOG) and carbon monoxide (CO), on the other hand, are most highly sensitive to cold starts. Thus, these pollutants are 22 and 24% *lower*, respectively, for telecommuters (NTC days), since they are making fewer cold starts. To more clearly illustrate the impact of cold starts, Table 4.1 shows that for the telecommuting group (on NTC days) cold starts produced 53.2% of the TOG, 71.9% of the CO, and 17.7% of the NOx. Control group cold starts produced 60.3%, 83.4%, and 26.9%, respectively.

Finally, it should be noted that, on average, trip speeds are higher for telecommuters on NTC days (32.47 mph) than for the controls (27.42 mph). It is likely that, due to their longer commutes, a higher proportion of telecommuters' NTC day travel is on freeways, for which average speeds will be higher than for surface streets. This higher average speed for telecommuters means that their emissions *rates* (gm/mi) are slightly lower than the controls'. However, the model classifies speed into five-mph categories. Since the average speeds for telecommuters' NTC days and for the controls fall into adjacent categories (30-35 and 25-30, respectively), and running emissions only represent part of the overall emissions levels, the impact due to the difference in speed is likely to be small.

Ultimately, the conclusion to be drawn is that the control group will not serve as a very useful comparison to the telecommuters, due to these important differences. When measures such as number of trips are already lower on NTC days than for controls, they will only be even lower on TC days. But it is worth noting that even measures that are higher on NTC days than for the controls (VMT, NOx, and PM) are much lower on TC days than for the controls. This provides additional qualitative support for the effectiveness of telecommuting.

We turn now to the comparison of telecommuters' TC days and NTC days. This analysis reveals several important transportation and emissions-related findings. Tables 4.1 - 4.8 and Figures 4.1 - 4.6 show that VMT, number of trips and daily emissions have dramatically decreased as a result of telecommuting. Telecommuters made significantly (30%) fewer trips on their TC days than on their NTC days. Average VMT per person-day decreased by 63% on TC days from 52 miles per day to 19 miles per day. Emissions findings include reductions in the number of cold starts by 44% (significant at $\alpha \leq 0.005$) and hot starts by 1% (not significant). Each pollutant of major concern was considerably reduced on TC days. Total organic gas and carbon monoxide decreased by approximately 47%, while oxides of nitrogen decreased by 59%. The decrease in particulate matter emissions was exactly proportional to the reduction in VMT (63%).

The following discussion of results (referencing Table 4.2) relates these decreases in emissions levels to changes in travel behavior due to telecommuting. The first area of interest is *VMT*. The savings of 63% in VMT for this particular sample of telecommuters is larger than would be expected from a more representative sample since their 48-mile (round trip) commute was observed to be twice as long as the regional average (Kunkle, *et al.,* 1994). Over time, as telecommuting becomes more widespread, commute lengths of telecommuters are expected to fall closer to the regional average and the VMT reductions are expected to decrease. Nonetheless, from an emissions standpoint, the sharp decrease in VMT for this sample led to substantially reduced running emissions (especially running exhaust). Emissions of PM and NOx, which are primarily running exhaust-related, decreased in parallel to the VMT reductions. CO and TOG emissions are less directly related to running emissions and, consequently, were only slightly affected by the change in VMT.

The next area of interest is the 30% decrease in the number of *vehicle trips* due to telecommuting. Cold start trips, which decreased by 44%, are one of the largest contributors to emissions and are discussed in detail below. Hot start trips remained statistically equivalent between TC and NTC days. Thus, there is a higher *proportion* of hot starts on TC days, even though the *number* of hot starts did not increase. On NTC days, the proportion was 32% hot starts to 68% cold starts, whereas on TC days the proportion was 46% hot starts to 54% cold starts. If the total number of trips remained constant but telecommuting shifted some of those trips from cold starts to hot starts, emissions would still be reduced since hot starts generate far lower emissions than cold starts. In this sample, however, the decrease in emissions is entirely due to the decrease in number of trips (predominantly cold starts), not to the increase in the proportion of hot starts. Hot soak emissions – the evaporative TOG emissions which occur when a vehicle is parked after a period of hot running – decreased by 38%. However, hot soak emissions contribute to only about 10% of all TOG emissions and consequently were a relatively minor part of the TOG savings due to telecommuting.

An analysis of the pollutant emitting processes reveals that one of the primary indicators of how emissions are impacted by telecommuting is how *cold starts* are effected (Tables 4.1- 4.5 and 4.7 - 4.8). Of particular importance are the difference in the number of cold starts and the times of the day when they occur. Table 4.7 shows the distribution of cold starts throughout the day. The total at the bottom of each column represents the total number of cold starts per person-day for that particular group. Analysis of the table reveals two important findings. First, on TC days, the absolute number of cold starts per person-day is lower for four out of the six time periods, compared to NTC days. The overall 44% decrease in the number of cold starts is one of the primary reasons why telecommuters produced much lower emissions on TC days than NTC days. TOG and CO emissions were most affected, as cold starts contribute to well over half of the emissions for both pollutants.

The second important finding is that the distribution of cold start trips for telecommuters on TC days shifted to warmer times of the day. To quantify the savings in emissions caused by this cold start shift another emissions inventory was performed to isolate the effects of time-of-day (TOD) shift alone. This was accomplished by imposing the NTC day distribution on the TC day cold start totals and re-running the emissions inventories. The new emissions totals represent purely the effect of having a smaller number of cold starts on a TC day, holding time-of-day distribution constant. The difference between the old and the new totals represents the effect of the TOD shifts. Table 4.8 shows the savings in grams per person-day resulting from TOD shifts. For TOG and CO, these savings represent 10 to 12% of the total grams saved as a result of telecommuting. For NOx, TOD shifts represent 2.2% of the savings. For TOG and CO, this is a significant contribution to reducing emissions levels, and shows the importance of TOD shifts in cold starts. However, the absolute decrease in the number of cold starts is the largest contributor to the savings in cold start emissions.

Speeds do not seem to be greatly affected by telecommuting in this case. The average daily speed for telecommuting days is 27.74 mph, compared to 32.47 mph on non-telecommuting days. As with the control group, this is probably due to a lower proportion of travel taking place on freeways on TC days than on NTC days. An analysis similar to the one done for the time of day distribution was performed to assess the extent of these impacts. The NTC day speed distribution was imposed on the TC day travel activity and the emissions model was re-run. The findings from the model runs show that the impacts of slower speeds are negligible (less than five percent of the overall emissions levels).

Analysis 2

Analysis 2 supports these same results by looking at a larger sample, including all participants in the study without regard to the classification under which they were recruited (Tables 4.9 - 4.15 and Figures 4.7 - 4.12). For Analysis 2, emissions reductions are roughly 10 percentage points lower than in Analysis 1 (see Tables 4.9 and 4.10 and compare Tables 4.1 and 4.2). The reduction in the total number of trips was 5 percentage points higher for Analysis 2 (35%) than for Analysis 1 (30%). VMT decreased by a *smaller* margin (57% for Analysis 2 compared to 63% for Analysis 1). Cold starts were reduced by about the same margin (45% versus 44%), and average trip speeds still fell into adjacent categories (28.46 mph for TC-days and 30.70 mph for NTC-days).

There are two primary reasons why Analysis 2 shows a smaller decrease in emissions than Analysis 1. Though the smaller reduction in VMT accounts for some of the difference (especially for NOx), the TOG and CO emissions are more heavily influenced by cold starts. The second reason is obtained by comparing the time of day distributions of cold starts between the two analyses (Table 4.7 and Table 4.15). Though the number of cold starts per person-day and the temporal distribution of cold starts for NTC days are roughly the same as for Analysis 1, on Analysis 2 TC days there were a higher proportion of cold starts in the time frame of 6:00 to 9:00 a.m. and fewer cold starts from 9:00 a.m. to 3:00 p.m. It is the colder ambient temperature in the morning that caused the higher levels of emissions for the telecommuting group in Analysis 2. This illustrates the significance of the time-shift of cold start trips and the emissions output sensitivity to this shift.

4.4 Distance / Cold Start Ratio

As demonstrated in the preceding discussion, the relative efficiency of a particular TDM compared to others can be assessed by examining the % reductions in emissions for each pollutant of concern. To decrease vehicle emissions, TDMs typically focus on reducing either the distance traveled (VMT) or the number of (cold start) trips, or both. Distance (VMT) is a surrogate for running emissions, which is the major contributor to PM and NOx, and the number of cold starts is a surrogate for cold start emissions, which is the major contributor to TOG and CO. Using these surrogates permits a rough assessment of the emissions impacts of various TDMs without requiring the extensive effort of air quality modeling. A ratio may be defined to help facilitate this type of investigation.

We define the **D**istance / **C**old Start Ratio, or "**D / C Ratio**" as:

$$\text{D / C Ratio} = \frac{\text{\% reduction in VMT}}{\text{\% reduction in number of cold starts}}$$

It is useful to analyze both the fraction form of the D / C Ratio and the single number resulting from the quotient. This allows more information to be obtained from the ratio, as it provides a comparison measure to be used across various TDMs as well as insight into the relative savings of each pollutant. Provided that the implementation of a TDM results in a reduction of both VMT and number of cold starts, a benefit to air quality should be realized. This will likely be the case for many TDMs. Some TDMs, however, including center-based telecommuting and compressed work schedules, have been hypothesized to increase the number of cold start trips. In analyzing these cases the only useful expression of the measure is in fraction form as it allows the numerator and denominator to be examined independently. It is important to note that the numerator and denominator of the ratio represent average per-capita reductions and that the aggregate (or overall, region-wide) impacts are determined by scaling these reductions up by the number of program participants. Thus, a comparison of the aggregate effectiveness of two TDM measures must take into account the number of people likely to be affected by each measure, not just the per capita impacts.

A study of the ratio expressed as the quotient (a single number) provides information internal to the TDM itself, i.e. which processes and pollutants achieved proportionately greater reductions. A ratio with a quotient of 1 indicates that the percent savings in VMT and number of cold starts are equal and each pollutant is reduced at comparable levels. A value less than 1 indicates proportionately higher reductions in cold starts, with therefore the highest emissions reductions observed for TOG and CO. A value greater than 1 indicates proportionately higher reductions in VMT, resulting in higher reductions for PM and NOx. Thus, a higher value of the quotient is not necessarily "better", it only indicates the relative emphasis between the two processes for a particular TDM. Similarly, no tradeoff is necessary for shifting the D / C Ratio higher or lower. The ratio can be increased by increasing the % reduction in VMT while holding % reduction in cold starts constant, thus increasing PM and NOx savings without sacrificing TOG and CO savings. The ratio can be lowered in a similar fashion by holding the reduction in VMT constant and increasing the % reduction in number of cold starts.

A study of the numerator and denominator of the ratio expressed as a fraction provides a useful measure across TDMs. For example, a ratio of 75 / 50 shows that the reduction of VMT was 75%, while the reduction in the number of cold starts was 50%. This hypothetical TDM can be compared to a second TDM whose D / C Ratio is, say, 25 / 25. The quotients of the two TDMs are 1.5 and 1, respectively. If TOG is the pollutant of concern, an analysis of the quotient would show that the latter TDM had a better relative reduction in TOG (since it had a *lower* quotient). However, looking at the fraction it is obvious that the first TDM would be more effective, since it caused higher percent reductions in both VMT (numerator) and the number of cold starts (denominator). It is important to distinguish these two different expressions of the D / C Ratio since they each convey useful information when interpreted correctly.

In this current study the D / C Ratio has a value of 63 / 44 = 1.43, meaning that the percent reduction in VMT is equal to 1.43 times the percent reduction in the number of cold starts. While this indicates a significant (44%) decrease in the number of cold starts (CO and TOG), the ratio also shows that telecommuting was even *more* effective (63% decrease) at reducing VMT (NOx and PM). The numerator and denominator values obtained here will be useful in future studies of telecommuting and other TDMs to investigate the effectiveness of various programs.

5. CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Cold start activity and VMT are important factors in determining levels of personal vehicle emissions. The results of this analysis indicate that telecommuting has beneficial transportation and air quality impacts for both of those indicators. The most important results (from Analysis 1) are that telecommuting decreases the number of daily trips (by 30%), the vehicle miles traveled (by 63%), and the number of cold starts (by 44%), especially those taking place in early morning (before 9:00 a.m.). These reductions are shown to have a large effect on daily emissions with a 50 to 60% decrease in pollutants generated by the telecommuter's personal vehicle use on telecommuting days. These findings are supported by those from the State of California Telecommuting Pilot Project analysis (Sampath *et al.*, 1991). The percent savings in daily emissions are comparable between the two studies, as are the reductions in number of trips and VMT.

It is important to realize that reductions of this magnitude are observed because the telecommuters in this sample are long-distance commuters. With commutes twice as long as the regional average, a disproportionate amount of their daily travel is spent on commuting. As telecommuting becomes more widely adopted, and the average commute length for telecommuters becomes more representative of the average for the region as a whole, the per-capita impacts on travel and emissions reported here will decrease. However, the net impacts are still expected to be beneficial – a reduction in VMT and emissions.

Future research on the emissions impacts of telecommuting will benefit from improvements to the EMFAC / BURDEN models. It is expected that the upcoming (7G) versions of the models will increase predicted emissions levels to be more consistent with field-measured pollutant concentrations (Washington, 1994). These advances will improve the estimates of emissions levels allowing for more accurate comparisons of the emissions benefits of telecommuting and other TDMs.

Finally, a number of interesting research questions remain regarding the transportation-related impacts of telecommuting. One of particular relevance to the subject of this paper is the transportation and emissions impacts of telecommuting from a center compared to telecommuting from home. Center-based telecommuting by definition requires a commute of some kind (albeit shorter than the trip to the conventional workplace), and therefore may involve a cold start. Policy-makers are reluctant to fully support telecommuting centers as a TDM until more is known empirically about their effectiveness in reducing emissions. Multiple projects are currently underway to evaluate center-based telecommuting by comparing VMT, number of trips, commute mode choices and trip linking characteristics of telecenter users with those of home-based telecommuters and non-telecommuters of the same organization. These and other studies will continue to provide useful new insights into the travel and air quality-related impacts of telecommuting.

6. REFERENCES

California Air Resources Board (CARB) (1990) *Derivation of the EMFAC7E Emission and Correction Factors for On-Road Motor Vehicles.* State of California Air Resources Board, Mobile Source Division, Inventory Analysis Branch. Sacramento, California.

California Air Resources Board (CARB) (1993) *Methodology for Estimating Emissions from On-Road Motor Vehicles. Volumes I, II, and III.* State of California Air Resources Board, Technical Support Division. Sacramento, California.

Koenig, B. and P. L. Mokhtarian (1993) "Puget Sound Telecommuting Demonstration Project – Travel Data Set Review and Modifications," unpublished Technical Memorandum to the Washington State Energy Office. Institute of Transportation Studies, University of California, Davis, September.

Kunkle, R. and B. Lagerberg (1994) *Travel Characteristics and Impacts of Telecommuting*, Research Report # 92-247. Washington State Energy Office. September.

Lathey, C. (1975) *Telecommunications Substitutability for Travel: An Energy Conservation Potential.* United States Department of Commerce, Office of Telecommunications. Washington, DC.

Memmott III, F. W. (1963) "The substitutability of communications for transportation" *Traffic Engineering*, Vol. 33, No. 5 (February).

Mokhtarian, P. L. (1991) "Telecommuting and Travel: State of Practice, State of the Art", *Transportation* 18(4): 319 - 342.

Mokhtarian, P. L., S. L. Handy, and I. Salomon (1994) "Methodological Issues in the Estimation of Travel, Energy, and Air Quality Impacts of Telecommuting", forthcoming *Transportation Research A*.

Pierson, W.R., A.W. Gertler and R.L. Bradow (1990) "Comparison of the SCAQS Tunnel Study with Other On-Road Vehicle Emission Data", *Journal of the Air and Waste Management Association* 40: 1495-1504.

Pollack, A. K., J. G. Heiken, R. A. Gorse (1992) "Comparison of Remote Sensing Data and Vehicle Emission Models: The Proportion of Emissions From High Emitting Vehicles", Proceedings of the 85th Annual Meeting of the Air and Waste Management Association. June 21 - 26, 1992.

Quaid, M. and B. Lagerberg (1992) "Puget Sound Telecommuting Demonstration: Executive Summary," Program Research, Washington State Energy Office, Olympia, Washington.

Sampath, S., S. Saxena, and P. L. Mokhtarian (1991) "The Effectiveness of Telecommuting as a Transportation Control Measure," Proceedings of the ASCE Urban Transportation Division National Conference on Transportation Planning and Air Quality. Santa Barbara, California, July 28-31, 1991, pp. 347-362. Research Report # UCD-ITS-RR-91-10. Institute of Transportation Studies, University of California, Davis.

Washington, S. (1994) "A Cursory Analysis of EMFAC7G: Reconciling Observed and Predicted Emissions", Research Report # UCD-ITS-RR-94-8. Institute of Transportation Studies, University of California, Davis. May

Table 4.1 Analysis 1: Travel and Emissions Impacts of Telecommuting (per person-day)

	Telecommuters		Controls
	TC Days # people = 72 # person-days = 108	Non-TC Days # people = 71 # person-days = 257	# people = 33 # person-days = 150
# of personal vehicle trips	2.58**	3.69	4.33**
VMT (personal vehicles)	19.22**	52.00	33.11**
# of cold starts	1.41**	2.50	2.82**
# of hot starts	1.18	1.19	1.51***
Average mph (weighted by VMT)	27.74**	32.47	27.42**
Total Organic Gas*	28.79	54.75	70.24
Carbon Monoxide*	233.10	437.25	577.64
Oxides of Nitrogen*	18.77	46.09	40.09
Particulate Matter*	4.08	11.00	6.97
% TOG produced by Cold Starts	51.8%	53.2%	60.3%
% CO produced by Cold Starts	74.7%	71.9%	83.4%
% NOx produced by Cold Starts	24.2%	17.7%	26.9%

* Measured in gm / person-day. Statistical tests could not be performed on these measures, because the model does not produce emissions by individual and therefore standard deviations could not be computed.

**Statistically different from Telecommuters on Non-TC days at $\alpha \leq 0.005$.

***Statistically different from Telecommuters on Non-TC days at $\alpha \leq 0.1$.

Table 4.2 Analysis 1: Percent Differences Among Groups

	% Difference between Non-TC Days and TC Days	% Difference between Controls and TC Days	% Difference between Controls and Non-TC Days
# of personal vehicle trips	-30.01	-40.42	-14.78
VMT (personal vehicles)	-63.04	-41.95	57.05
# of cold starts	-43.60	-50.00	-11.35
# of hot starts	-0.84	-21.85	-21.20
Average mph	-14.57	1.20	18.42
Total Organic Gas	-47.42	-59.01	-22.05
Carbon Monoxide	-46.69	-59.65	-24.30
Oxides of Nitrogen	-59.28	-53.18	14.97
Particulate Matter	-62.91	-41.46	57.82

Table 4.3 Analysis 1: Total Organic Gases

(in gm/person-day)	**Telecommuters**		**Controls**
	TC Days	Non-TC Days	
Running Exhaust	4.21	10.91	9.42
Cold Start Exhaust	14.90	29.13	42.33
Hot Start Exhaust	0.72	0.71	1.09
Diurnal Evaporation	0.29	0.21	0.18
Hot Soak Evaporation	2.90	4.74	8.00
Running Losses	4.80	8.44	8.70
Resting Losses	0.88	0.62	0.55
Total Organic Gas Emissions	28.79	54.75	70.24

Table 4.4 Analysis 1: Carbon Monoxide

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Running Exhaust	46.80	110.19	76.02
Cold Start Exhaust	174.18	314.60	481.56
Hot Start Exhaust	12.12	12.47	20.00
Total Carbon Monoxide Emissions	233.10	437.26	577.64

Table 4.5 Analysis 1: Oxides of Nitrogen

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Running Exhaust	11.99	35.97	25.91
Cold Start Exhaust	4.55	8.17	10.79
Hot Start Exhaust	2.23	1.96	3.45
Total NOx Emissions	18.77	46.09	40.09

Table 4.6 Analysis 1: Particulate Matter

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Exhaust	0.25	0.58	0.33
Tire-wear	3.83	10.42	6.64
Total Particulate Matter Emissions	4.08	11.00	6.97

Table 4.7 Analysis 1: Number and Percent of Cold Starts Per Person-day, by Time of Day

	Telecommuters		Controls
	TC Days	Non-TC Days	
12:00 midnight - 6:00 a.m.	0.01 (1.0%)	0.14 (5.6%)	0.01 (0.35%)
6:00 a.m. - 9:00 a.m.	0.28 (19.9%)	0.84 (33.5%)	0.96 (34.0%)
9:00 a.m. - 12:00 noon	0.20 (14.2%)	0.14 (5.6%)	0.28 (9.9%)
12:00 noon - 3:00 p.m.	0.25 (17.7%)	0.16 (6.4%)	0.23 (8.2%)
3:00 p.m. - 6:00 p.m.	0.44 (31.2%)	0.86 (34.3%)	0.97 (34.4%)
6:00 p.m. - 12:00 midnight	0.23 (16.3%)	0.37 (14.7%)	0.37 (13.1%)
Total # Cold Starts	1.41 (100%)	2.50 (100%)	2.82 (100%)

Table 4.8 Analysis 1: Cold Start Time of Day Shift Impacts

	TC Days (1)	NTC Days (2)	TC Days with NTC trip time distribution (3)	TOD savings (1) - (3) (4)	% Total savings due to shift in cold start trips (4) / [(2)-(1)]
TOG*	28.79	54.75	31.35	2.56	9.6%
CO*	233.10	437.25	256.46	23.86	11.7%
NOx*	18.77	46.09	19.36	0.59	2.2%

* gm / person-day

Figure 4.1 Analysis 1: Vehicle Miles Travelled

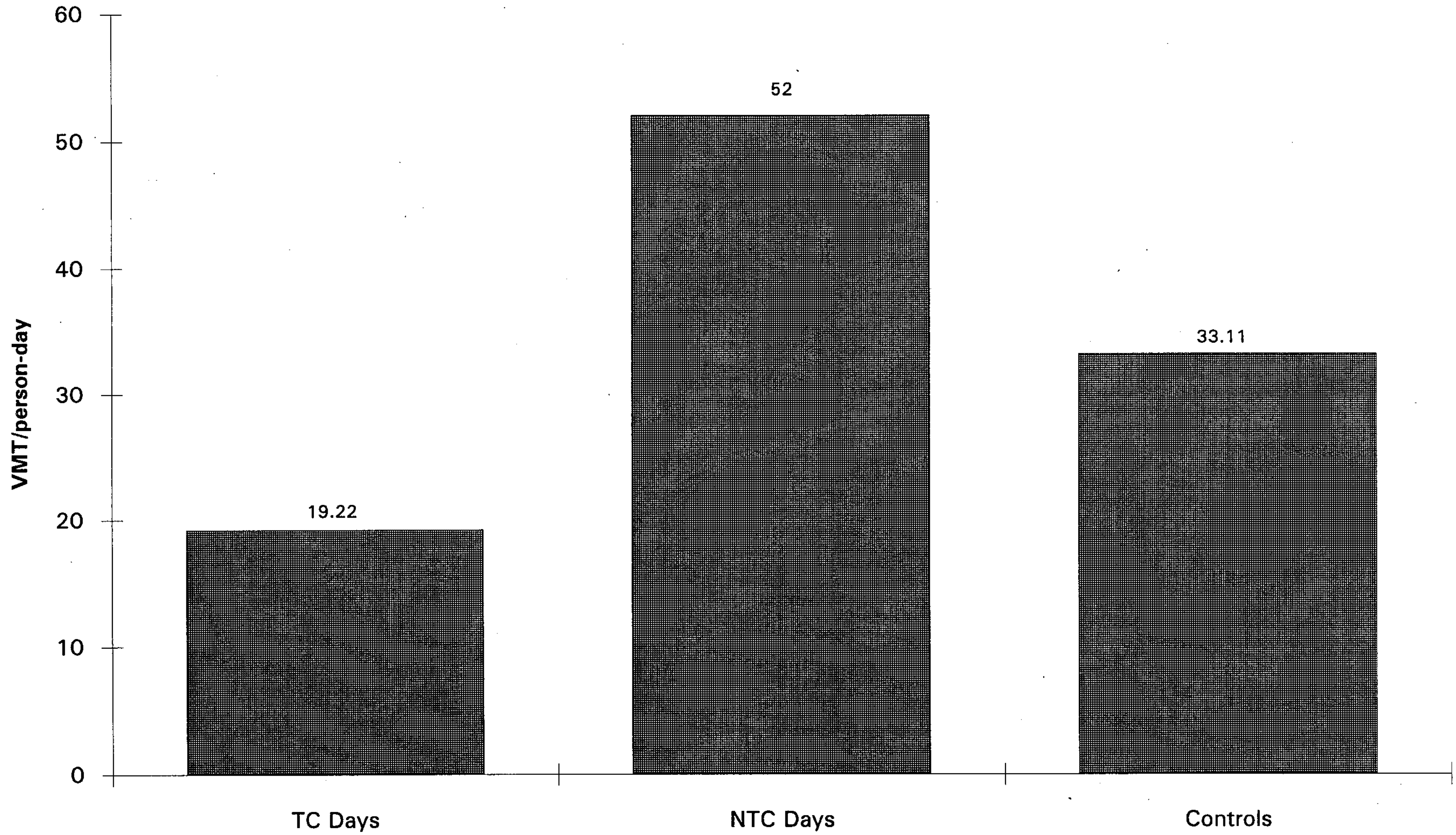


Figure 4.2 Analysis 1: Cold Start and Hot Start Trips

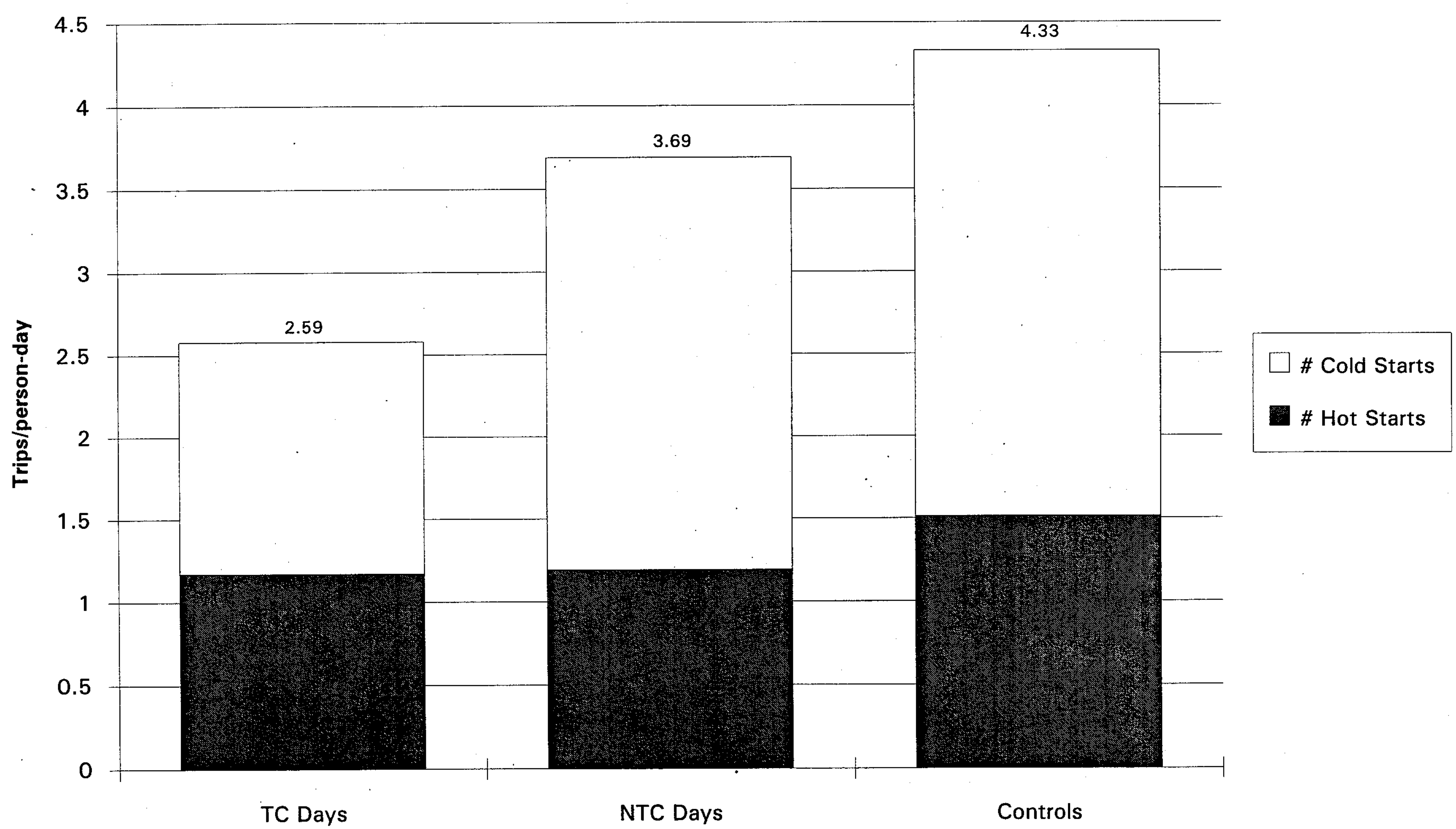


Figure 4.3 Analysis 1: Total Organic Gases

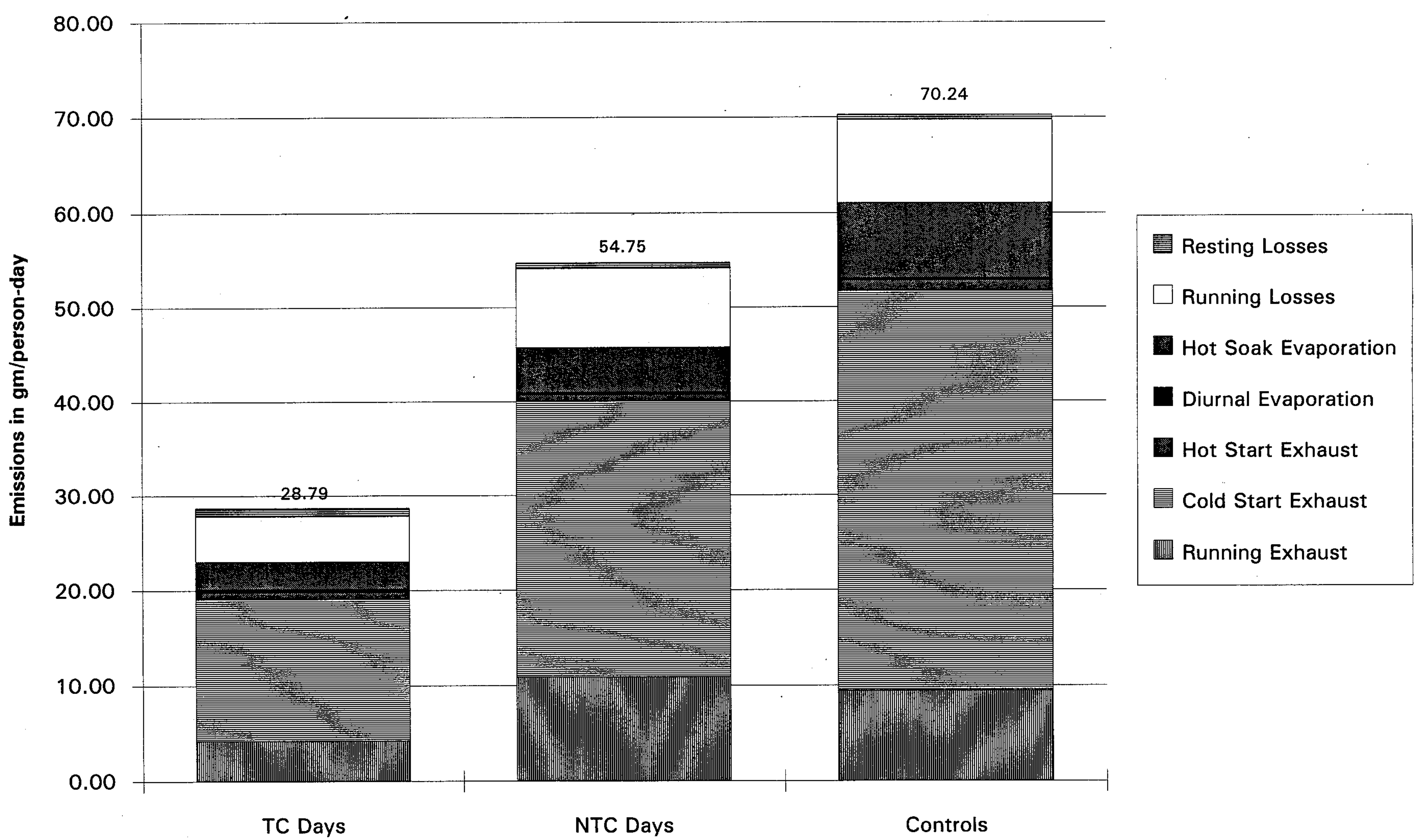


Figure 4.4 Analysis 1: Carbon Monoxide

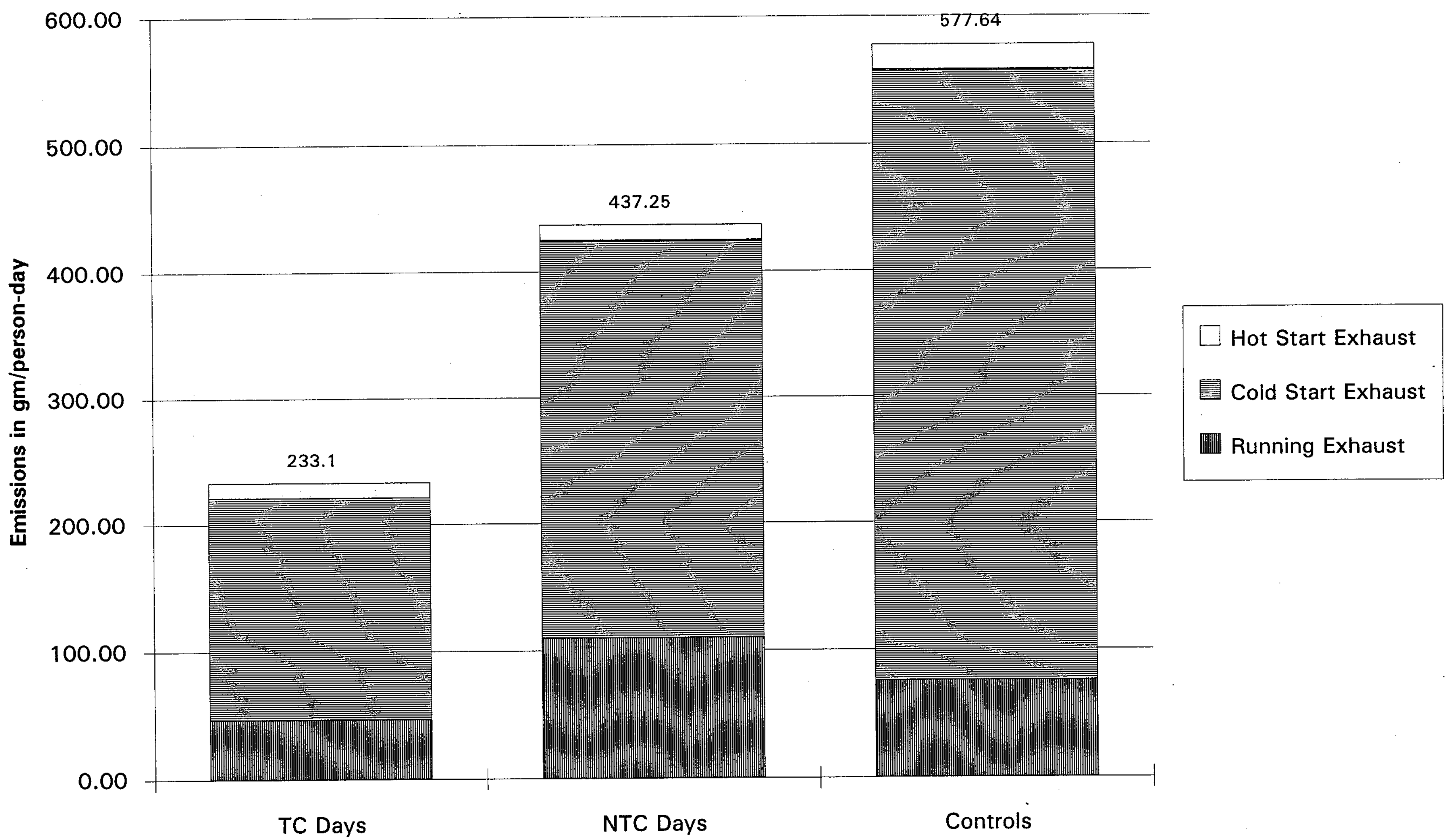


Figure 4.5 Analysis 1: Oxides of Nitrogen

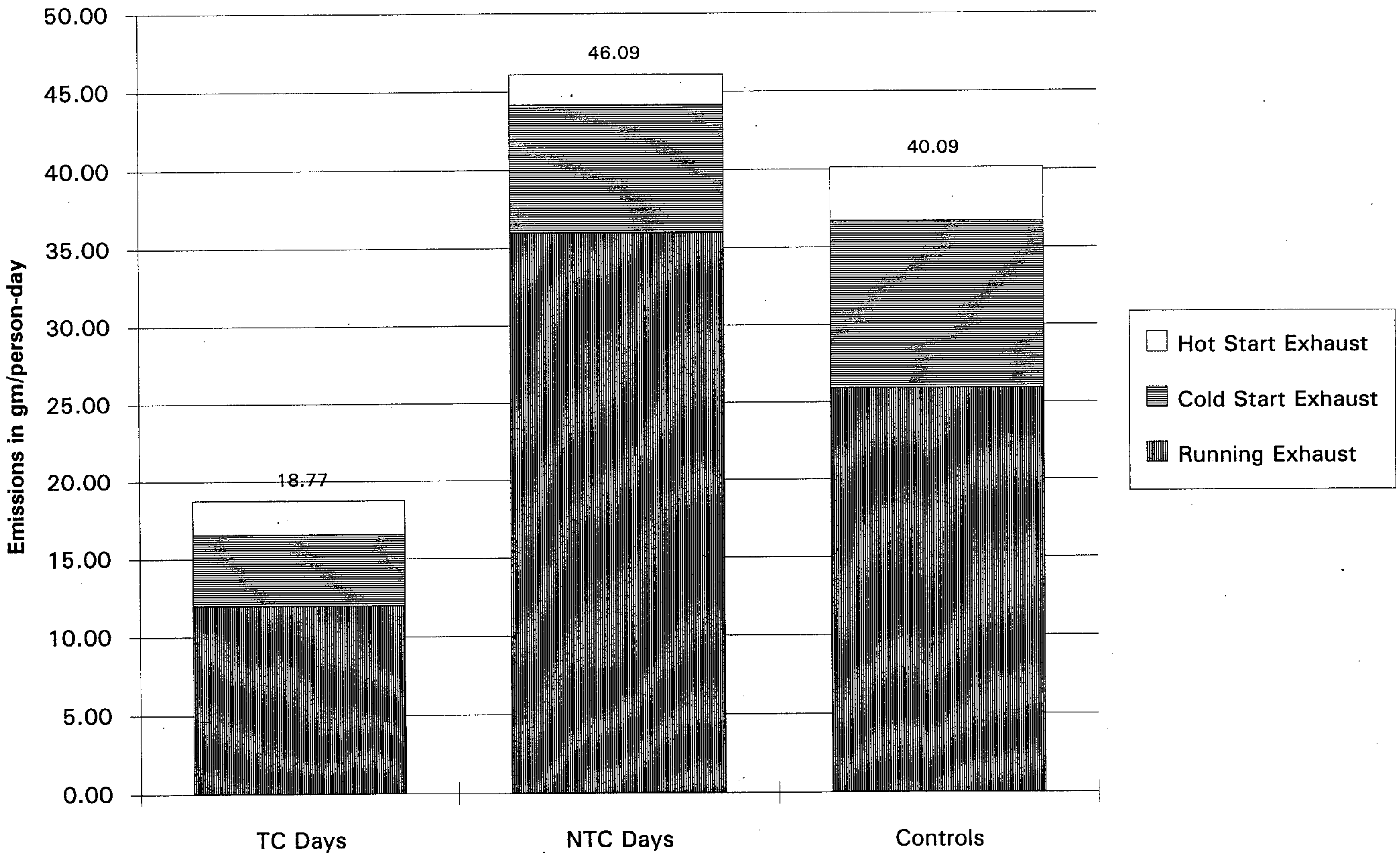


Figure 4.6 Analysis 1: Particulate Matter

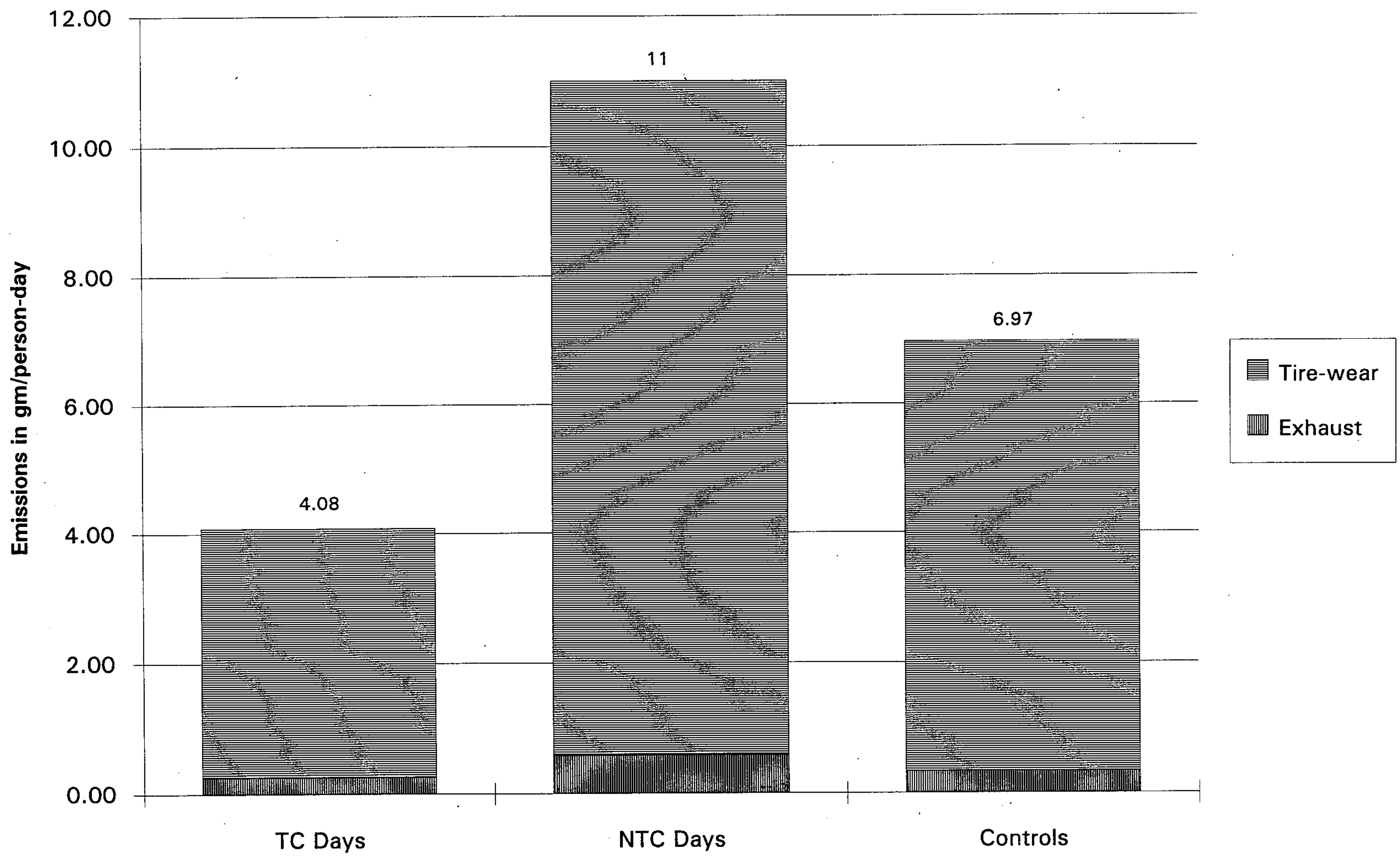


Table 4.9 Analysis 2: Travel and Emissions Impacts of Telecommuting (per person-day)

	Telecommuting Days # people = 80 # person-days = 120	Non-Telecommuting Days # people = 145 # person-days = 580
# of personal vehicle trips	2.58**	3.98
VMT (personal vehicles)	20.06**	46.95
# of cold starts	1.44**	2.60
# of hot starts	1.14	1.37
Average mph (weighted by VMT)	28.46***	30.70
Total Organic Gas*	35.00	58.64
Carbon Monoxide*	275.54	458.61
Oxides of Nitrogen*	22.38	43.96
Particulate Matter*	4.28	9.92
% TOG produced by Cold Starts	47.6%	54.6%
% CO produced by Cold Starts	65.4%	76.0%
% NOx produced by Cold Starts	22.0%	20.5%

* Measured in gm / person-day. Statistical tests could not be performed on these measures, because the model does not produce emissions by individual and therefore standard deviations could not be computed.

**Statistically different from Non-Telecommuting days at $\alpha \leq 0.005$.

***Statistically different from Non-Telecommuting days at $\alpha \leq 0.1$.

Table 4.10 Analysis 2: Percent Differences Among Groups

	% Difference Between Non-TC days and TC days
# of personal vehicle trips	-35.18
VMT (personal vehicles)	-57.27
# of cold starts	-44.62
# of hot starts	-16.79
Average mph	-7.30
Total Organic Gas	-40.30
Carbon Monoxide	-39.92
Oxides of Nitrogen	-49.09
Particulate Matter	-56.85

Table 4.11 Analysis 2: Total Organic Gases

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	7.39	10.17
Cold Start Exhaust	16.67	32.03
Hot Start Exhaust	0.68	0.86
Diurnal Evaporation	0.27	0.18
Hot Soak Evaporation	3.45	5.88
Running Losses	5.57	8.93
Resting Losses	0.95	0.58
Total Organic Gas Emissions	35.00	58.64

Table 4.12 Analysis 2: Carbon Monoxide

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	83.48	95.73
Cold Start Exhaust	180.13	348.48
Hot Start Exhaust	11.89	14.40
Total Carbon Monoxide Emissions	275.54	458.61

Table 4.13 Analysis 2: Oxides of Nitrogen

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	15.23	32.16
Cold Start Exhaust	4.92	9.00
Hot Start Exhaust	2.23	2.81
Total NOx Emissions	22.38	43.96

Table 4.14 Analysis 2: Particulate Matter

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Exhaust	0.27	0.53
Tire-wear	4.01	9.40
Total Particulate Matter Emissions	4.28	9.92

Table 4.15 Analysis 2: Number and Percent of Cold Starts Per Person-day, by Time of Day

	Telecommuting Days	Non-Telecommuting Days
12:00 midnight - 6:00 a.m.	0.02 (1.4%)	0.09 (3.5%)
6:00 a.m. - 9:00 a.m.	0.33 (23.4%)	0.87 (33.6%)
9:00 a.m. - 12:00 noon	0.19 (13.5%)	0.19 (7.3%)
12:00 noon - 3:00 p.m.	0.23 (16.3%)	0.18 (6.9%)
3:00 p.m. - 6:00 p.m.	0.47 (33.3%)	0.86 (33.2%)
6:00 p.m. - 12:00 midnight	0.17 (12.1%)	0.40 (15.4%)
Total # Cold Starts	1.41 (100%)	2.59 (100%)

Figure 4.7 Analysis 2: Vehicle Miles Travelled

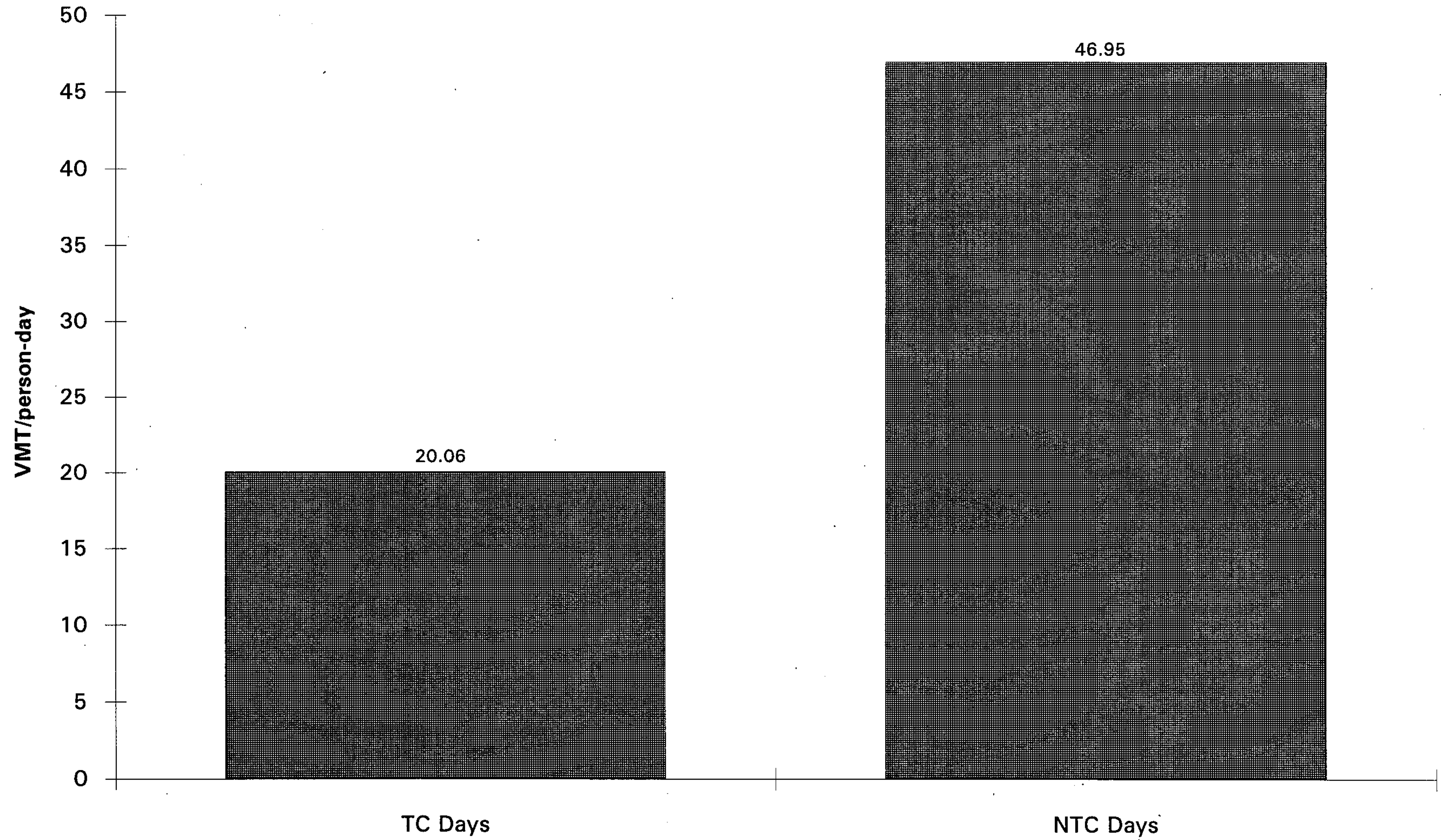


Figure 4.8 Analysis 2: Cold Start and Hot Start Trips

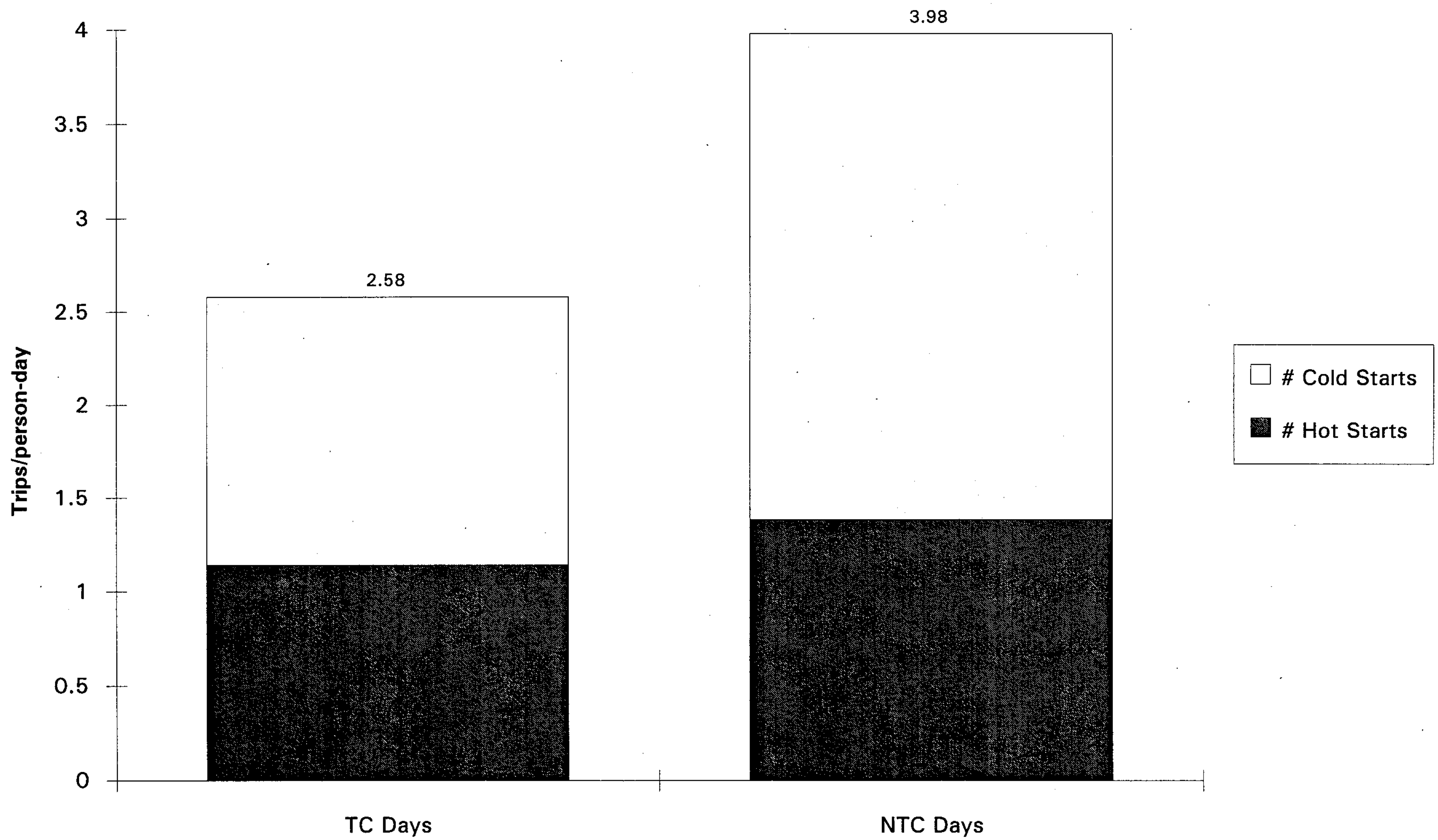


Figure 4.9 Analysis 2: Total Organic Gases

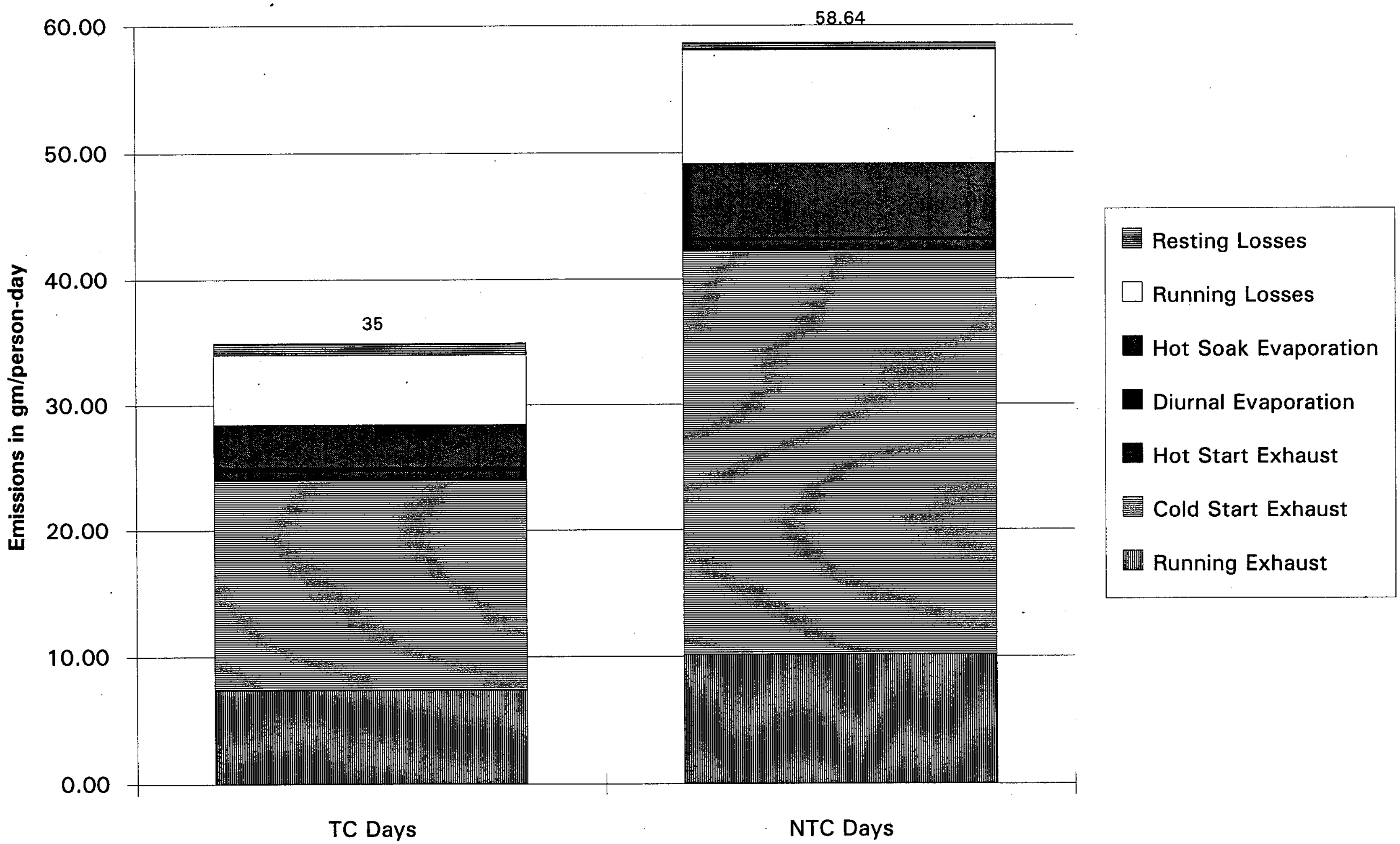


Figure 4.10 Analysis 2: Carbon Monoxide

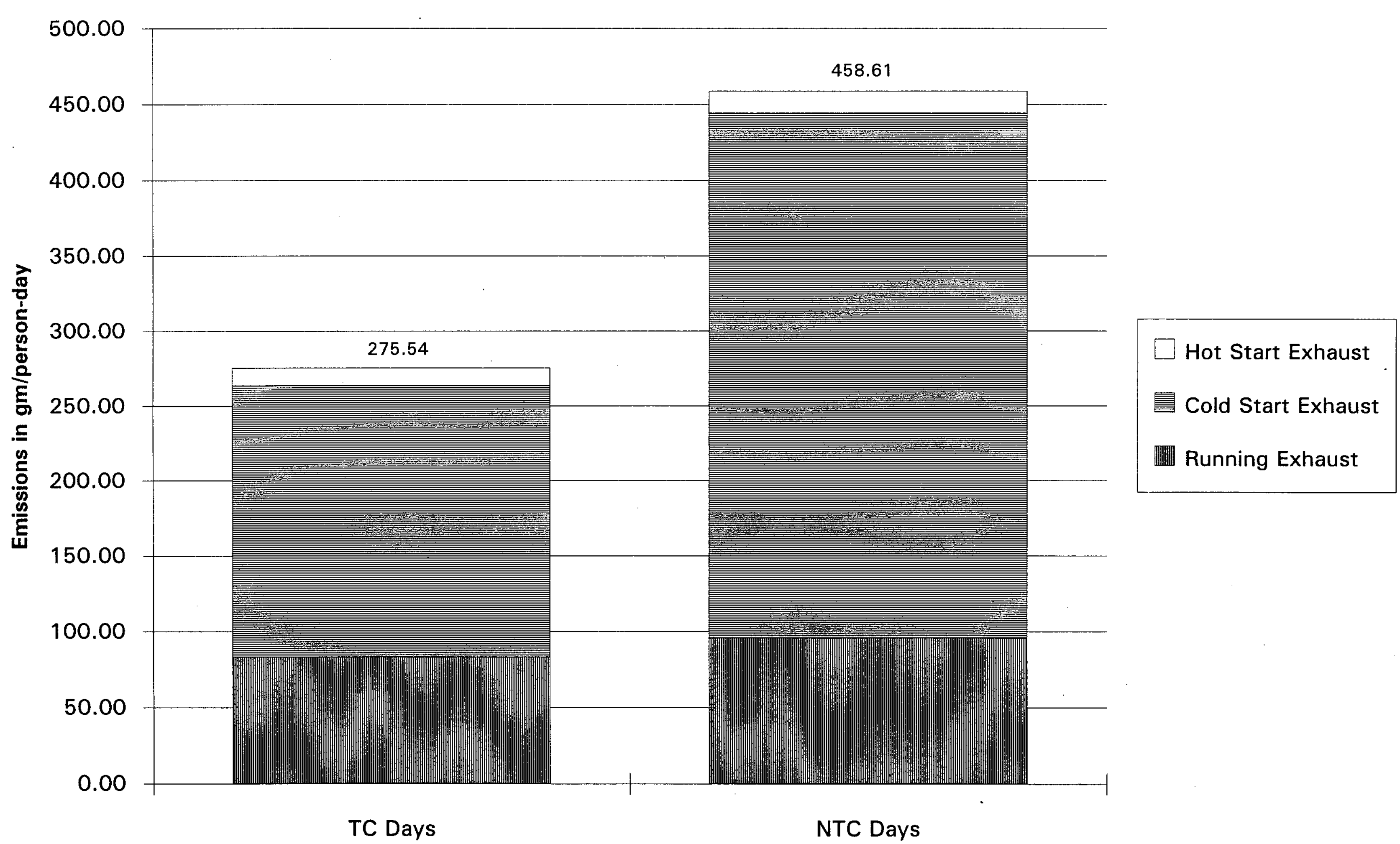


Figure 4.11 Analysis 2: Oxides of Nitrogen

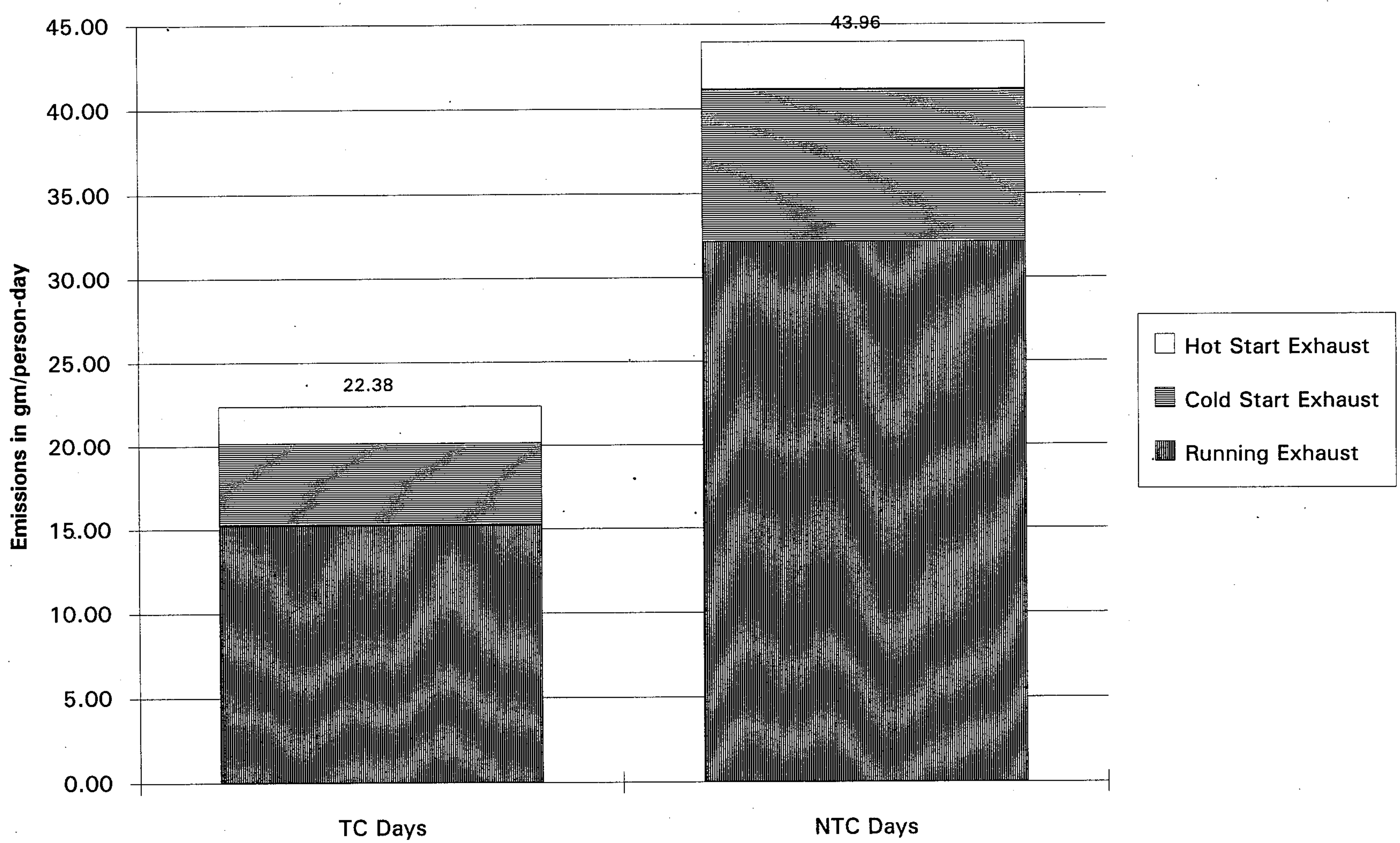
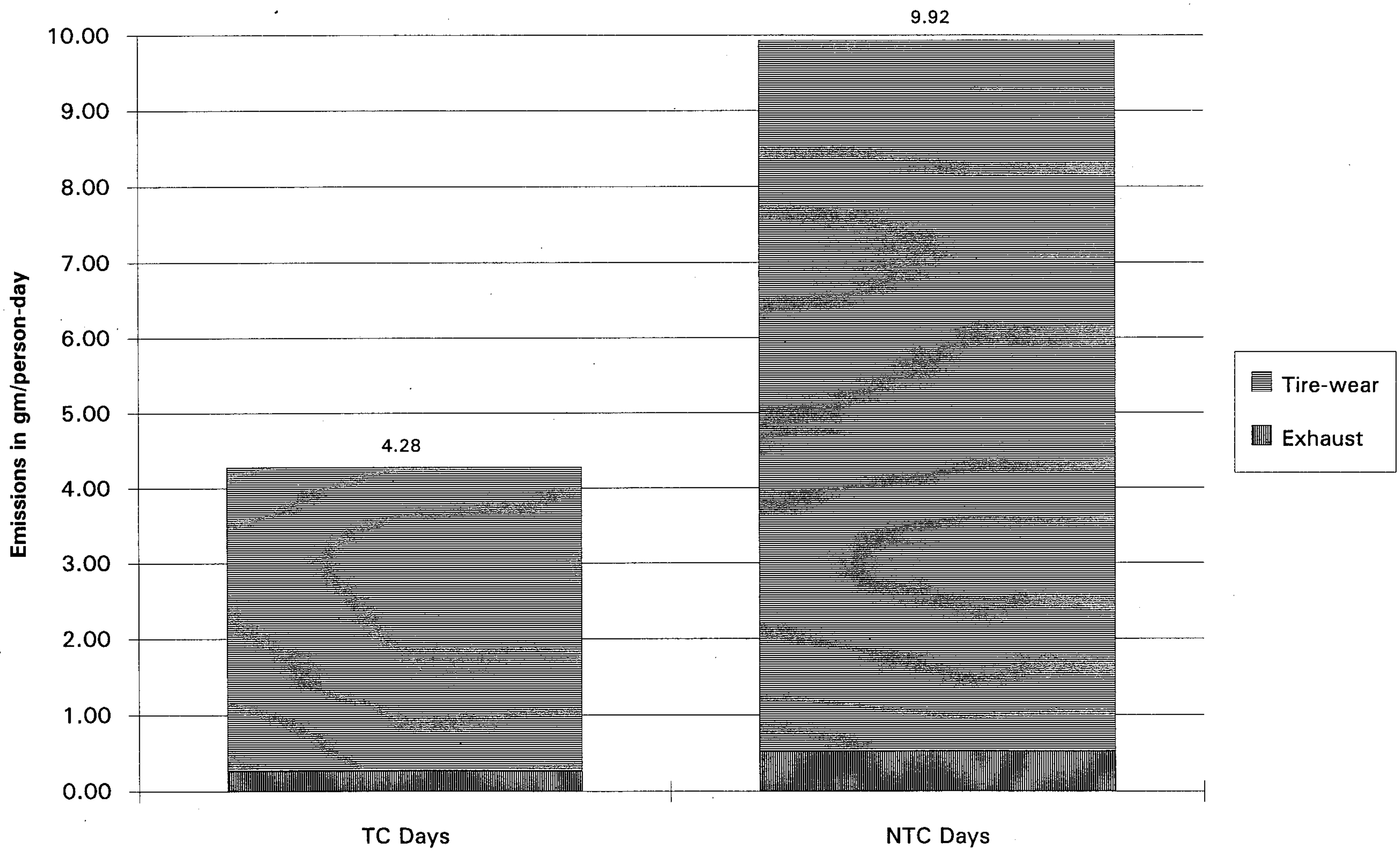


Figure 4.12 Analysis 2: Particulate Matter



APPENDIX 1

FLEET MIX INPUT FILES

This Appendix contains the fleet mix input files required by EMFAC7F to generate the emissions weighting factors based on representation of vehicle class/technology group by model year. Each column of input represents vehicle activity fractions by model year. The four columns to the right of the model year represent VMT fraction, trip fraction, population fraction, and cumulative mileage. The VMT fraction, for example, is the percent of the total miles traveled by that class/technology group that were made by vehicles of each model year. The activity fractions by technology group at the end of each section are VMT fraction, trip fraction, and population fraction. These are the fractions of the totals for the entire class that were made by each technology group within that class. For example, LDA/NCAT VMT fraction is the percent of LDA VMT that was made by LDAs without catalytic converters. First, the default California fleet mix is included, then the three fleet mix input files for Analysis 1.

1991 California Default Fleet Mix (Output from E7FWT)

LDA1 NCAT 1 1

1957	0.00416	0.00416	0.00504	247307.
1958	0.00354	0.00354	0.00424	242679.
1959	0.00446	0.00446	0.00529	238001.
1960	0.00613	0.00613	0.00719	233271.
1961	0.00789	0.00789	0.00914	228486.
1962	0.01281	0.01281	0.01467	223644.
1963	0.02008	0.02008	0.02270	218743.
1964	0.03060	0.03060	0.03414	213780.
1965	0.04299	0.04299	0.04731	208751.
1966	0.04671	0.04671	0.05069	203653.
1967	0.04911	0.04911	0.05252	198483.
1968	0.05877	0.05877	0.06189	193236.
1969	0.06908	0.06908	0.07160	187908.
1970	0.07379	0.07379	0.07521	182494.
1971	0.08715	0.08715	0.08727	176989.
1972	0.10794	0.10794	0.10613	171386.
1973	0.12852	0.12852	0.12392	165679.
1974	0.12522	0.12522	0.11829	159860.
1975	0.01378	0.01378	0.01274	153920.
1976	0.02366	0.02366	0.02136	147849.
1977	0.02685	0.02685	0.02333	141635.
1978	0.02008	0.02008	0.01660	135178.
1979	0.03669	0.03669	0.02874	128390.
1980	0.00000	0.00000	0.00000	121226.
1981	0.00000	0.00000	0.00000	113629.
1982	0.00000	0.00000	0.00000	105528.
1983	0.00000	0.00000	0.00000	96821.
1984	0.00000	0.00000	0.00000	87507.
1985	0.00000	0.00000	0.00000	77586.
1986	0.00000	0.00000	0.00000	67058.
1987	0.00000	0.00000	0.00000	55923.
1988	0.00000	0.00000	0.00000	44181.
1989	0.00000	0.00000	0.00000	31832.
1990	0.00000	0.00000	0.00000	18876.
1991	0.00000	0.00000	0.00000	5313.

Activity Fractions
0.057113 0.057113 0.103878

LDA1 CAT 1 2

1957	0.00000	0.00000	0.00000	247307.
1958	0.00000	0.00000	0.00000	242679.
1959	0.00000	0.00000	0.00000	238001.
1960	0.00000	0.00000	0.00000	233271.
1961	0.00000	0.00000	0.00000	228486.
1962	0.00000	0.00000	0.00000	223644.
1963	0.00000	0.00000	0.00000	218743.
1964	0.00000	0.00000	0.00000	213780.
1965	0.00000	0.00000	0.00000	208751.
1966	0.00000	0.00000	0.00000	203653.
1967	0.00000	0.00000	0.00000	198483.
1968	0.00000	0.00000	0.00000	193236.
1969	0.00000	0.00000	0.00000	187908.
1970	0.00000	0.00000	0.00000	182494.
1971	0.00000	0.00000	0.00000	176989.
1972	0.00000	0.00000	0.00000	171386.
1973	0.00000	0.00000	0.00000	165679.
1974	0.00000	0.00000	0.00000	159860.
1975	0.00759	0.00759	0.01344	153920.
1976	0.01062	0.01062	0.01837	147849.
1977	0.01662	0.01662	0.02766	141635.
1978	0.02305	0.02305	0.03649	135178.
1979	0.02451	0.02451	0.03676	128390.
1980	0.02852	0.02852	0.04033	121226.
1981	0.03086	0.03086	0.04094	113629.
1982	0.03539	0.03539	0.04368	105528.
1983	0.04750	0.04750	0.05480	96821.
1984	0.06218	0.06218	0.06734	87507.
1985	0.07723	0.07723	0.07882	77586.
1986	0.09168	0.09168	0.08847	67058.
1987	0.09654	0.09654	0.08834	55923.
1988	0.10878	0.10878	0.09465	44181.
1989	0.11980	0.11980	0.09935	31832.
1990	0.12947	0.12947	0.10257	18876.
1991	0.08965	0.08965	0.06798	5313.

Activity Fractions
0.924354 0.924354 0.877929

LDA1 DSL 1 3

1957	0.00000	0.00000	0.00000	261215.
1958	0.00000	0.00000	0.00000	257152.
1959	0.00000	0.00000	0.00000	253045.
1960	0.00000	0.00000	0.00000	248892.
1961	0.00000	0.00000	0.00000	244691.
1962	0.00000	0.00000	0.00000	240440.
1963	0.00000	0.00000	0.00000	236137.
1964	0.00000	0.00000	0.00000	231780.
1965	0.00000	0.00000	0.00000	227365.
1966	0.00000	0.00000	0.00000	222890.
1967	0.00000	0.00000	0.00000	218351.
1968	0.00000	0.00000	0.00000	213745.
1969	0.00000	0.00000	0.00000	209068.
1970	0.00000	0.00000	0.00000	204315.
1971	0.00000	0.00000	0.00000	199482.
1972	0.00000	0.00000	0.00000	194563.
1973	0.00000	0.00000	0.00000	189553.
1974	0.00000	0.00000	0.00000	184326.
1975	0.00320	0.00320	0.00582	178867.
1976	0.00468	0.00468	0.00813	173157.
1977	0.00724	0.00724	0.01184	167176.
1978	0.02619	0.02619	0.03981	160818.
1979	0.08014	0.08014	0.11281	153979.
1980	0.05927	0.05927	0.07689	146593.
1981	0.11552	0.11552	0.13733	138578.
1982	0.11134	0.11134	0.12032	129833.
1983	0.08853	0.08853	0.08742	120213.
1984	0.09198	0.09198	0.08332	109684.
1985	0.11691	0.11691	0.09753	98207.
1986	0.14200	0.14200	0.10947	85745.
1987	0.15300	0.15300	0.10931	72259.
1988	0.00000	0.00000	0.00000	57707.
1989	0.00000	0.00000	0.00000	42046.
1990	0.00000	0.00000	0.00000	25231.
1991	0.00000	0.00000	0.00000	7220.

Activity Fractions
0.018533 0.018533 0.018192

LDT NCAT 4 1

1957	0.00000	0.00000	0.00000	195770.
1958	0.00000	0.00000	0.00000	195770.
1959	0.00000	0.00000	0.00000	195770.
1960	0.00000	0.00000	0.00000	195770.
1961	0.00000	0.00000	0.00000	195770.
1962	0.00000	0.00000	0.00000	195770.
1963	0.00000	0.00000	0.00000	195770.
1964	0.00000	0.00000	0.00000	195770.
1965	0.00000	0.00000	0.00000	195770.
1966	0.00000	0.00000	0.00000	195640.
1967	0.07261	0.07261	0.08485	192640.
1968	0.07261	0.07261	0.08485	188466.
1969	0.07261	0.07261	0.08485	184292.
1970	0.07261	0.07261	0.08485	180118.
1971	0.07261	0.07261	0.08485	175944.
1972	0.07472	0.07472	0.08577	171760.
1973	0.09129	0.09129	0.09775	167360.
1974	0.11256	0.11256	0.11243	162642.
1975	0.07899	0.07899	0.07361	157586.
1976	0.02392	0.02392	0.02079	152166.
1977	0.05132	0.05132	0.04161	146355.
1978	0.06810	0.06810	0.05151	140126.
1979	0.05824	0.05824	0.04109	133447.
1980	0.07783	0.07783	0.05122	126289.
1981	0.00000	0.00000	0.00000	118614.
1982	0.00000	0.00000	0.00000	110388.
1983	0.00000	0.00000	0.00000	101569.
1984	0.00000	0.00000	0.00000	92115.
1985	0.00000	0.00000	0.00000	81980.
1986	0.00000	0.00000	0.00000	71116.
1987	0.00000	0.00000	0.00000	59470.
1988	0.00000	0.00000	0.00000	46985.
1989	0.00000	0.00000	0.00000	33602.
1990	0.00000	0.00000	0.00000	19255.
1991	0.00000	0.00000	0.00000	5865.

Activity Fractions
0.042858 0.042858 0.087647

LDT CAT 4 2

1957	0.00000	0.00000	0.00000	195770.
1958	0.00000	0.00000	0.00000	195770.
1959	0.00000	0.00000	0.00000	195770.
1960	0.00000	0.00000	0.00000	195770.
1961	0.00000	0.00000	0.00000	195770.
1962	0.00000	0.00000	0.00000	195770.
1963	0.00000	0.00000	0.00000	195770.
1964	0.00000	0.00000	0.00000	195770.
1965	0.00000	0.00000	0.00000	195770.
1966	0.00000	0.00000	0.00000	195640.
1967	0.00000	0.00000	0.00000	192640.
1968	0.00000	0.00000	0.00000	188466.
1969	0.00000	0.00000	0.00000	184292.
1970	0.00000	0.00000	0.00000	180118.
1971	0.00000	0.00000	0.00000	175944.
1972	0.00000	0.00000	0.00000	171760.
1973	0.00000	0.00000	0.00000	167360.
1974	0.00000	0.00000	0.00000	162642.
1975	0.00276	0.00276	0.00554	157586.
1976	0.00791	0.00791	0.01483	152166.
1977	0.01697	0.01697	0.02968	146355.
1978	0.02252	0.02252	0.03674	140126.
1979	0.02831	0.02831	0.04308	133447.
1980	0.03783	0.03783	0.05370	126289.
1981	0.05098	0.05098	0.06751	118614.
1982	0.05984	0.05984	0.07393	110388.
1983	0.06894	0.06894	0.07945	101569.
1984	0.07743	0.07743	0.08323	92115.
1985	0.07833	0.07833	0.07855	81980.
1986	0.08012	0.08012	0.07495	71116.
1987	0.08356	0.08356	0.07291	59470.
1988	0.09867	0.09867	0.08032	46985.
1989	0.10616	0.10616	0.08061	33602.
1990	0.11572	0.11572	0.08197	19255.
1991	0.06393	0.06393	0.04300	5865.

Activity Fractions
0.934121 0.934121 0.885704

LDT DSL 4 3

1957	0.00000	0.00000	0.00000	200903.
1958	0.00000	0.00000	0.00000	200903.
1959	0.00000	0.00000	0.00000	200903.
1960	0.00000	0.00000	0.00000	200903.
1961	0.00000	0.00000	0.00000	200903.
1962	0.00000	0.00000	0.00000	200903.
1963	0.00000	0.00000	0.00000	200903.
1964	0.00000	0.00000	0.00000	200903.
1965	0.00000	0.00000	0.00000	200903.
1966	0.00000	0.00000	0.00000	200761.
1967	0.00000	0.00000	0.00000	197496.
1968	0.00000	0.00000	0.00000	192953.
1969	0.00000	0.00000	0.00000	188410.
1970	0.00000	0.00000	0.00000	183867.
1971	0.00000	0.00000	0.00000	179324.
1972	0.00000	0.00000	0.00000	174778.
1973	0.00000	0.00000	0.00000	170163.
1974	0.00000	0.00000	0.00000	165431.
1975	0.00000	0.00000	0.00000	160546.
1976	0.00514	0.00514	0.00855	155471.
1977	0.01079	0.01079	0.01711	150165.
1978	0.01411	0.01411	0.02117	144581.
1979	0.02961	0.02961	0.04183	138666.
1980	0.03948	0.03948	0.05214	132360.
1981	0.10031	0.10031	0.12308	125594.
1982	0.19895	0.19895	0.22531	118287.
1983	0.10012	0.10012	0.10430	110349.
1984	0.11450	0.11450	0.10927	101730.
1985	0.12035	0.12035	0.10312	92192.
1986	0.12766	0.12766	0.09839	81592.
1987	0.13896	0.13896	0.09572	69769.
1988	0.00000	0.00000	0.00000	56498.
1989	0.00000	0.00000	0.00000	41503.
1990	0.00000	0.00000	0.00000	24453.
1991	0.00000	0.00000	0.00000	7553.

Activity Fractions
0.023021 0.023021 0.026649

MDT NCAT 5 1

1957	0.00000	0.00000	0.00000	200140.
1958	0.00000	0.00000	0.00000	200140.
1959	0.00000	0.00000	0.00000	200140.
1960	0.00000	0.00000	0.00000	200140.
1961	0.00000	0.00000	0.00000	200140.
1962	0.00000	0.00000	0.00000	200140.
1963	0.00000	0.00000	0.00000	200140.
1964	0.00000	0.00000	0.00000	200140.
1965	0.00000	0.00000	0.00000	200140.
1966	0.00000	0.00000	0.00000	200014.
1967	0.05446	0.05446	0.06485	197113.
1968	0.05446	0.05446	0.06485	193077.
1969	0.05446	0.05446	0.06485	189041.
1970	0.05446	0.05446	0.06485	185005.
1971	0.05329	0.05329	0.06485	180980.
1972	0.05085	0.05085	0.06485	177183.
1973	0.06416	0.06416	0.07535	173255.
1974	0.08100	0.08100	0.08762	168990.
1975	0.10261	0.10261	0.10223	164359.
1976	0.12729	0.12729	0.11682	159332.
1977	0.15549	0.15549	0.13143	153874.
1978	0.02251	0.02251	0.01752	147948.
1979	0.02884	0.02884	0.02068	141514.
1980	0.03715	0.03715	0.02453	134528.
1981	0.03500	0.03500	0.02129	126943.
1982	0.02398	0.02398	0.01343	118708.
1983	0.00000	0.00000	0.00000	109767.
1984	0.00000	0.00000	0.00000	100060.
1985	0.00000	0.00000	0.00000	89520.
1986	0.00000	0.00000	0.00000	78078.
1987	0.00000	0.00000	0.00000	65654.
1988	0.00000	0.00000	0.00000	52165.
1989	0.00000	0.00000	0.00000	37519.
1990	0.00000	0.00000	0.00000	21619.
1991	0.00000	0.00000	0.00000	6603.

Activity Fractions
0.076053 0.076053 0.174734

MDT CAT 5 2

1957	0.00000	0.00000	0.00000	200140.
1958	0.00000	0.00000	0.00000	200140.
1959	0.00000	0.00000	0.00000	200140.
1960	0.00000	0.00000	0.00000	200140.
1961	0.00000	0.00000	0.00000	200140.
1962	0.00000	0.00000	0.00000	200140.
1963	0.00000	0.00000	0.00000	200140.
1964	0.00000	0.00000	0.00000	200140.
1965	0.00000	0.00000	0.00000	200140.
1966	0.00000	0.00000	0.00000	200014.
1967	0.00000	0.00000	0.00000	197113.
1968	0.00000	0.00000	0.00000	193077.
1969	0.00000	0.00000	0.00000	189041.
1970	0.00000	0.00000	0.00000	185005.
1971	0.00000	0.00000	0.00000	180980.
1972	0.00000	0.00000	0.00000	177183.
1973	0.00000	0.00000	0.00000	173255.
1974	0.00000	0.00000	0.00000	168990.
1975	0.00000	0.00000	0.00000	164359.
1976	0.00000	0.00000	0.00000	159332.
1977	0.00000	0.00000	0.00000	153874.
1978	0.01359	0.01359	0.02721	147948.
1979	0.01741	0.01741	0.03210	141514.
1980	0.02242	0.02242	0.03809	134528.
1981	0.02913	0.02913	0.04558	126943.
1982	0.03751	0.03751	0.05405	118708.
1983	0.04799	0.04799	0.06369	109767.
1984	0.05767	0.05767	0.07050	100060.
1985	0.06865	0.06865	0.07730	89520.
1986	0.08109	0.08109	0.08410	78078.
1987	0.09646	0.09646	0.09214	65654.
1988	0.11739	0.11739	0.10327	52165.
1989	0.14500	0.14500	0.11749	37519.
1990	0.17930	0.17930	0.13382	21619.
1991	0.08640	0.08640	0.06066	6603.

Activity Fractions
0.923947 0.923947 0.825266

HDT1 DSL 6 3

1957	0.00000	0.00000	0.00000	914155.
1958	0.00000	0.00000	0.00000	914155.
1959	0.00000	0.00000	0.00000	914155.
1960	0.00000	0.00000	0.00000	914155.
1961	0.00000	0.00000	0.00000	914155.
1962	0.00000	0.00000	0.00000	914155.
1963	0.00000	0.00000	0.00000	914155.
1964	0.00000	0.00000	0.00000	914155.
1965	0.00000	0.00000	0.00000	914155.
1966	0.00000	0.00000	0.00000	911422.
1967	0.00330	0.00330	0.00621	892137.
1968	0.00143	0.00143	0.00256	869047.
1969	0.00430	0.00430	0.00730	844733.
1970	0.00113	0.00113	0.00183	819194.
1971	0.00827	0.00827	0.01278	792430.
1972	0.00691	0.00691	0.01022	764441.
1973	0.01416	0.01416	0.02008	735227.
1974	0.00121	0.00121	0.00164	704788.
1975	0.00836	0.00836	0.01095	673125.
1976	0.01749	0.01749	0.02208	640237.
1977	0.02293	0.02293	0.02792	606124.
1978	0.04391	0.04391	0.05165	570786.
1979	0.09449	0.09449	0.10750	534223.
1980	0.02372	0.02372	0.02610	496425.
1981	0.03920	0.03920	0.04180	457345.
1982	0.02186	0.02186	0.02263	417097.
1983	0.05919	0.05919	0.05950	375635.
1984	0.03064	0.03064	0.02993	332948.
1985	0.19080	0.19080	0.18124	289037.
1986	0.10858	0.10858	0.10038	243901.
1987	0.04460	0.04460	0.04015	197540.
1988	0.08424	0.08424	0.07392	149954.
1989	0.03199	0.03199	0.02738	101143.
1990	0.09901	0.09901	0.08268	51107.
1991	0.03827	0.03827	0.03158	12815.

Activity Fractions
1.000000 1.000000 1.000000

HDT2 NCAT 7 1

1957	0.00000	0.00000	0.00000	204592.
1958	0.00000	0.00000	0.00000	204592.
1959	0.00000	0.00000	0.00000	204592.
1960	0.00000	0.00000	0.00000	204592.
1961	0.00000	0.00000	0.00000	204592.
1962	0.00000	0.00000	0.00000	204592.
1963	0.00000	0.00000	0.00000	204592.
1964	0.00000	0.00000	0.00000	204592.
1965	0.00000	0.00000	0.00000	204592.
1966	0.00000	0.00000	0.00000	204118.
1967	0.01124	0.01124	0.02480	200803.
1968	0.01124	0.01124	0.02480	197014.
1969	0.01124	0.01124	0.02480	193225.
1970	0.01124	0.01124	0.02480	189436.
1971	0.01124	0.01124	0.02480	185647.
1972	0.01172	0.01172	0.02480	181817.
1973	0.01509	0.01509	0.02940	177698.
1974	0.01805	0.01805	0.03237	173224.
1975	0.02140	0.02140	0.03534	168365.
1976	0.02520	0.02520	0.03831	163087.
1977	0.02949	0.02949	0.04128	157354.
1978	0.03434	0.03434	0.04425	151128.
1979	0.04180	0.04180	0.04959	144365.
1980	0.05125	0.05125	0.05598	137020.
1981	0.06201	0.06201	0.06236	129042.
1982	0.07424	0.07424	0.06875	120378.
1983	0.08813	0.08813	0.07513	110967.
1984	0.10386	0.10386	0.08152	100745.
1985	0.12164	0.12164	0.08790	89643.
1986	0.14171	0.14171	0.09429	77584.
1987	0.01802	0.01802	0.01104	64487.
1988	0.02102	0.02102	0.01186	50262.
1989	0.02485	0.02485	0.01290	34812.
1990	0.02989	0.02989	0.01429	18031.
1991	0.01009	0.01009	0.00463	4553.

Activity Fractions
0.543347 0.543347 0.693103

HDT2 CAT 7 2

1957	0.00000	0.00000	0.00000	204592.
1958	0.00000	0.00000	0.00000	204592.
1959	0.00000	0.00000	0.00000	204592.
1960	0.00000	0.00000	0.00000	204592.
1961	0.00000	0.00000	0.00000	204592.
1962	0.00000	0.00000	0.00000	204592.
1963	0.00000	0.00000	0.00000	204592.
1964	0.00000	0.00000	0.00000	204592.
1965	0.00000	0.00000	0.00000	204592.
1966	0.00000	0.00000	0.00000	204118.
1967	0.00000	0.00000	0.00000	200803.
1968	0.00000	0.00000	0.00000	197014.
1969	0.00000	0.00000	0.00000	193225.
1970	0.00000	0.00000	0.00000	189436.
1971	0.00000	0.00000	0.00000	185647.
1972	0.00000	0.00000	0.00000	181817.
1973	0.00000	0.00000	0.00000	177698.
1974	0.00000	0.00000	0.00000	173224.
1975	0.00000	0.00000	0.00000	168365.
1976	0.00000	0.00000	0.00000	163087.
1977	0.00000	0.00000	0.00000	157354.
1978	0.00000	0.00000	0.00000	151128.
1979	0.00000	0.00000	0.00000	144365.
1980	0.00000	0.00000	0.00000	137020.
1981	0.00000	0.00000	0.00000	129042.
1982	0.00000	0.00000	0.00000	120378.
1983	0.00000	0.00000	0.00000	110967.
1984	0.00000	0.00000	0.00000	100745.
1985	0.00000	0.00000	0.00000	89643.
1986	0.00000	0.00000	0.00000	77584.
1987	0.17352	0.17352	0.20176	64487.
1988	0.20240	0.20240	0.21668	50262.
1989	0.23922	0.23922	0.23579	34812.
1990	0.28777	0.28777	0.26115	18031.
1991	0.09709	0.09709	0.08462	4553.

Activity Fractions
0.456653 0.456653 0.306897

HDT3 DSL 8 3

1957	0.00000	0.00000	0.00000	641611.
1958	0.00000	0.00000	0.00000	641611.
1959	0.00000	0.00000	0.00000	641611.
1960	0.00000	0.00000	0.00000	641611.
1961	0.00000	0.00000	0.00000	641611.
1962	0.00000	0.00000	0.00000	641611.
1963	0.00000	0.00000	0.00000	641611.
1964	0.00000	0.00000	0.00000	641611.
1965	0.00000	0.00000	0.00000	641611.
1966	0.00000	0.00000	0.00000	640300.
1967	0.00450	0.00450	0.01466	631120.
1968	0.00450	0.00450	0.01466	620629.
1969	0.00457	0.00457	0.01487	610138.
1970	0.00495	0.00495	0.01611	599646.
1971	0.00548	0.00548	0.01785	589155.
1972	0.00631	0.00631	0.01960	578536.
1973	0.00754	0.00754	0.02133	567008.
1974	0.00895	0.00895	0.02308	554354.
1975	0.01057	0.01057	0.02482	540463.
1976	0.01243	0.01243	0.02657	525213.
1977	0.01454	0.01454	0.02832	508469.
1978	0.01706	0.01706	0.03026	490083.
1979	0.02096	0.02096	0.03386	469893.
1980	0.02686	0.02686	0.03950	447719.
1981	0.03372	0.03372	0.04513	423365.
1982	0.04167	0.04167	0.05078	396612.
1983	0.05088	0.05088	0.05642	367222.
1984	0.06149	0.06149	0.06207	334926.
1985	0.07146	0.07146	0.06565	299446.
1986	0.07976	0.07976	0.06668	260458.
1987	0.08942	0.08942	0.06802	217608.
1988	0.10230	0.10230	0.07079	170510.
1989	0.12224	0.12224	0.07694	118735.
1990	0.15053	0.15053	0.08617	61812.
1991	0.04730	0.04730	0.02585	15630.

Activity Fractions
1.000000 1.000000 1.000000

MCY NCAT 9 1

1957	0.00000	0.00000	0.00000	39656.
1958	0.00000	0.00000	0.00000	39656.
1959	0.00000	0.00000	0.00000	39656.
1960	0.00000	0.00000	0.00000	39656.
1961	0.00000	0.00000	0.00000	39656.
1962	0.00000	0.00000	0.00000	39656.
1963	0.00000	0.00000	0.00000	39656.
1964	0.00000	0.00000	0.00000	39656.
1965	0.00000	0.00000	0.00000	39656.
1966	0.00000	0.00000	0.00000	39656.
1967	0.00000	0.00000	0.00000	39656.
1968	0.00000	0.00000	0.00000	39656.
1969	0.00000	0.00000	0.00000	39656.
1970	0.00000	0.00000	0.00000	39656.
1971	0.00000	0.00000	0.00000	39656.
1972	0.00000	0.00000	0.00000	39656.
1973	0.00000	0.00000	0.00000	39656.
1974	0.00000	0.00000	0.00000	39656.
1975	0.00000	0.00000	0.00000	39656.
1976	0.00000	0.00000	0.00000	39656.
1977	0.00000	0.00000	0.00000	39485.
1978	0.00198	0.00198	0.00538	38288.
1979	0.00396	0.00396	0.01075	36920.
1980	0.00661	0.00661	0.01613	35513.
1981	0.01061	0.01061	0.02151	33835.
1982	0.01861	0.01861	0.03226	31846.
1983	0.02841	0.02841	0.04301	29546.
1984	0.04000	0.04000	0.05376	26935.
1985	0.05339	0.05339	0.06452	24014.
1986	0.09799	0.09799	0.10753	20782.
1987	0.12836	0.12836	0.12903	17239.
1988	0.15073	0.15073	0.13978	13386.
1989	0.17492	0.17492	0.15054	9222.
1990	0.18752	0.18752	0.15054	4747.
1991	0.09691	0.09691	0.07527	1197.

Activity Fractions
1.000000 1.000000 1.000000

Fleetmix data for Analysis 1, Telecommuters on TC days

cat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.03722	0.05761	0.04000	59.
1978	0.01073	0.01235	0.02000	17.
1979	0.00000	0.00000	0.00000	0.
1980	0.00505	0.00823	0.02000	8.
1981	0.05174	0.05350	0.08000	82.
1982	0.12744	0.11523	0.04000	202.
1983	0.02839	0.05761	0.04000	45.
1984	0.00631	0.00412	0.02000	10.
1985	0.05678	0.10288	0.12000	90.
1986	0.22839	0.14815	0.16000	362.
1987	0.17224	0.13169	0.12000	273.
1988	0.06498	0.11111	0.12000	103.
1989	0.08454	0.11523	0.10000	134.
1990	0.03155	0.00823	0.02000	50.
1991	0.09464	0.07407	0.10000	150.

Totals for technology group

vmtfrac	tripfrac	pop
0.99373	0.99184	0.98039

noncat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	1.00000	1.00000	1.00000	10.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.00627	0.00816	0.01961

cat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.08639	0.35484	0.16667	33.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.17277	0.22581	0.16667	66.
1985	0.27749	0.09677	0.33333	106.
1986	0.00000	0.00000	0.00000	0.
1987	0.38743	0.16129	0.16667	148.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.07592	0.16129	0.16667	29.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.79418	0.91176	0.75000

noncat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.04712	0.06452	0.16667	18.
1974	0.21204	0.03226	0.16667	81.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.20582	0.08824	0.25000

Fleetmix data for Analysis 1, Telecommuters on NTC days

cat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00161	0.00131	0.01205	18.
1977	0.02557	0.04308	0.02410	286.
1978	0.01439	0.01044	0.01205	161.
1979	0.02181	0.01436	0.03614	244.
1980	0.03379	0.01436	0.01205	378.
1981	0.08599	0.08486	0.07229	962.
1982	0.00420	0.01828	0.02410	47.
1983	0.00349	0.01958	0.03614	39.
1984	0.04684	0.04308	0.03614	524.
1985	0.15911	0.14752	0.14458	1780.
1986	0.15625	0.16710	0.13253	1748.
1987	0.11147	0.10705	0.10843	1247.
1988	0.12729	0.13969	0.10843	1424.
1989	0.07929	0.09922	0.10843	887.
1990	0.07098	0.05352	0.07229	794.
1991	0.05792	0.03655	0.06024	648.

Totals for technology group

vmtfrac	tripfrac	pop
0.97194	0.98079	0.97647

noncat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.43963	0.40000	0.50000	142.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.56037	0.60000	0.50000	181.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.02806	0.01921	0.02353

cat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00814	0.00654	0.00000	13.
1982	0.00000	0.00000	0.00000	0.
1983	0.13212	0.22222	0.08333	211.
1984	0.14778	0.24183	0.16667	236.
1985	0.01002	0.05882	0.08333	16.
1986	0.01252	0.03922	0.08333	20.
1987	0.28929	0.10458	0.16667	462.
1988	0.19537	0.07190	0.08333	312.
1989	0.03068	0.06536	0.08333	49.
1990	0.17408	0.18954	0.25000	278.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.86185	0.91617	0.85714

noncat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.09142	0.06536	0.08333	146.
1973	0.00000	0.00000	0.00000	0.
1974	0.06888	0.02614	0.08333	110.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.13815	0.08383	0.14286

Fleetmix data for Analysis 1, Control Group

cat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.04037	0.03853	0.02703	175.
1978	0.04521	0.06239	0.05405	196.
1979	0.08558	0.12110	0.05405	371.
1980	0.08166	0.05688	0.05405	354.
1981	0.01499	0.02752	0.05405	65.
1982	0.05582	0.06239	0.05405	242.
1983	0.04175	0.05872	0.02703	181.
1984	0.02745	0.03119	0.08108	119.
1985	0.14002	0.15780	0.21622	607.
1986	0.06621	0.09725	0.08108	287.
1987	0.06344	0.09174	0.10811	275.
1988	0.15087	0.04954	0.08108	654.
1989	0.06344	0.07706	0.05405	275.
1990	0.12318	0.06789	0.05405	534.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.99131	0.98198	0.94872

noncat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.52632	0.90000	0.50000	20.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.47368	0.10000	0.50000	18.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.00869	0.01802	0.05128

cat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.16162	0.09677	0.14286	96.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.02357	0.09677	0.14286	14.
1983	0.00000	0.00000	0.00000	0.
1984	0.42929	0.51613	0.28571	255.
1985	0.00000	0.00000	0.00000	0.
1986	0.29293	0.21505	0.28571	174.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.09259	0.07527	0.14286	55.

Totals for technology group

vmtfrac	tripfrac	pop
1.00000	1.00000	1.00000

noncat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	1.00000	1.00000	1.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.00000	0.00000	0.00000

Fleetmix data for Analysis 2, Telecommuting Days

cat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.04643	0.06178	0.05357	78.
1978	0.01012	0.01158	0.01786	17.
1979	0.00000	0.00000	0.00000	0.
1980	0.00476	0.00772	0.01786	8.
1981	0.04881	0.05019	0.07143	82.
1982	0.10833	0.10811	0.03571	182.
1983	0.02679	0.05405	0.03571	45.
1984	0.03631	0.02317	0.03571	61.
1985	0.05357	0.09653	0.10714	90.
1986	0.25119	0.15444	0.17857	422.
1987	0.15952	0.13514	0.12500	268.
1988	0.06131	0.10425	0.10714	103.
1989	0.06786	0.10811	0.08929	114.
1990	0.03571	0.01544	0.03571	60.
1991	0.08929	0.06950	0.08929	150.

Totals for technology group

vmtfrac	tripfrac	pop
0.99408	0.99234	0.98246

noncat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	1.00000	1.00000	1.00000	10.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.00592	0.00766	0.01754

cat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.03947	0.28205	0.12500	18.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.14474	0.17949	0.12500	66.
1985	0.23246	0.07692	0.25000	106.
1986	0.00000	0.00000	0.00000	0.
1987	0.32456	0.12821	0.12500	148.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.16009	0.28205	0.25000	73.
1991	0.09868	0.05128	0.12500	45.

Totals for technology group

vmtfrac	tripfrac	pop
0.63510	0.79592	0.72727

noncat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.35746	0.17949	0.12500	163.
1973	0.03947	0.05128	0.12500	18.
1974	0.17763	0.02564	0.12500	81.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.36490	0.20408	0.27273

Fleetmix data for Analysis 2, Non-Telecommuting Days

cat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00112	0.00053	0.00606	26.
1977	0.02280	0.03702	0.02424	527.
1978	0.01700	0.02221	0.01818	393.
1979	0.03318	0.04865	0.03636	767.
1980	0.04010	0.03966	0.03636	927.
1981	0.04896	0.04336	0.05455	1132.
1982	0.02418	0.03067	0.03030	559.
1983	0.01345	0.02644	0.03030	311.
1984	0.07877	0.10206	0.08485	1821.
1985	0.14585	0.12163	0.14545	3372.
1986	0.15468	0.14437	0.13939	3576.
1987	0.10147	0.09149	0.10303	2346.
1988	0.10818	0.09307	0.08485	2501.
1989	0.07111	0.08726	0.08485	1644.
1990	0.08413	0.07774	0.07879	1945.
1991	0.05502	0.03384	0.04242	1272.

Totals for technology group

vmtfrac	tripfrac	pop
0.97396	0.97575	0.96491

noncat-equipped light duty auto

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.45469	0.29787	0.33333	281.
1966	0.00000	0.00000	0.00000	0.
1967	0.03236	0.19149	0.16667	20.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.19094	0.29787	0.16667	118.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.02913	0.02128	0.16667	18.
1974	0.29288	0.19149	0.16667	181.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.02604	0.02425	0.03509

cat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.02941	0.04545	0.03571	90.
1967	0.00000	0.00000	0.00000	0.
1968	0.00000	0.00000	0.00000	0.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.00000	0.00000	0.00000	0.
1973	0.00000	0.00000	0.00000	0.
1974	0.00000	0.00000	0.00000	0.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.03137	0.02727	0.03571	96.
1978	0.01471	0.03333	0.03571	45.
1979	0.00000	0.00000	0.00000	0.
1980	0.02059	0.02424	0.03571	63.
1981	0.00425	0.00303	0.00000	13.
1982	0.05294	0.05455	0.07143	162.
1983	0.06895	0.10303	0.03571	211.
1984	0.17418	0.25758	0.14286	533.
1985	0.00523	0.02727	0.03571	16.
1986	0.06895	0.07879	0.10714	211.
1987	0.15098	0.04848	0.07143	462.
1988	0.10196	0.03333	0.03571	312.
1989	0.04085	0.04242	0.07143	125.
1990	0.15327	0.16970	0.17857	469.
1991	0.08235	0.05152	0.10714	252.

Totals for technology group

vmtfrac	tripfrac	pop
0.87579	0.89674	0.90323

noncat-equipped light duty truck

year	vmtfrac	tripfrac	pop	vmt
1957	0.00000	0.00000	0.00000	0.
1958	0.00000	0.00000	0.00000	0.
1959	0.00000	0.00000	0.00000	0.
1960	0.00000	0.00000	0.00000	0.
1961	0.00000	0.00000	0.00000	0.
1962	0.00000	0.00000	0.00000	0.
1963	0.00000	0.00000	0.00000	0.
1964	0.00000	0.00000	0.00000	0.
1965	0.00000	0.00000	0.00000	0.
1966	0.00000	0.00000	0.00000	0.
1967	0.00000	0.00000	0.00000	0.
1968	0.05817	0.07273	0.03571	178.
1969	0.00000	0.00000	0.00000	0.
1970	0.00000	0.00000	0.00000	0.
1971	0.00000	0.00000	0.00000	0.
1972	0.04771	0.03030	0.03571	146.
1973	0.00000	0.00000	0.00000	0.
1974	0.03595	0.01212	0.03571	110.
1975	0.00000	0.00000	0.00000	0.
1976	0.00000	0.00000	0.00000	0.
1977	0.00000	0.00000	0.00000	0.
1978	0.00000	0.00000	0.00000	0.
1979	0.00000	0.00000	0.00000	0.
1980	0.00000	0.00000	0.00000	0.
1981	0.00000	0.00000	0.00000	0.
1982	0.00000	0.00000	0.00000	0.
1983	0.00000	0.00000	0.00000	0.
1984	0.00000	0.00000	0.00000	0.
1985	0.00000	0.00000	0.00000	0.
1986	0.00000	0.00000	0.00000	0.
1987	0.00000	0.00000	0.00000	0.
1988	0.00000	0.00000	0.00000	0.
1989	0.00000	0.00000	0.00000	0.
1990	0.00000	0.00000	0.00000	0.
1991	0.00000	0.00000	0.00000	0.

Totals for technology group

vmtfrac	tripfrac	pop
0.12421	0.10326	0.09677

APPENDIX 2

DATA TABULATIONS (FORTRAN OUTPUT)

The following table is for Analysis 1, Telecommuters on Non-TC days (population: lda=85, ldt=14)

Speed Distribution Table (percent VMT by mph and time of day)

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
12:00-6:00	.3083	.0000	.0000	2.0555	2.7749	2.3638	10.3803	18.0884	9.2497	14.2857	36.3823	4.1110	.0000
6:00-9:00	.0870	.5221	1.5662	3.1977	4.0679	4.9598	10.8549	18.5121	11.3117	20.5134	15.6406	2.7844	5.9822
9:00-12:00	.0000	3.3868	2.8520	11.2299	5.7041	13.7255	4.0998	17.1123	13.7255	13.1907	14.9733	.0000	.0000
12:00-3:00	1.0022	1.0022	2.7840	11.9154	6.5702	17.8174	5.9020	19.3764	13.3630	2.1158	.0000	7.7951	10.3563
3:00-6:00	.2246	1.3679	3.5933	6.5537	7.6562	8.7995	11.0657	15.1695	13.1891	13.6791	10.3716	5.2266	3.1033
6:00-12:00	.0000	.6964	6.4763	4.4568	12.1866	13.7883	3.3426	13.9972	16.2256	8.5655	11.9081	5.7103	2.6462

	Number of Cold starts		Cat fraction of cold starts		Number of Trips		
	Noncat	Cat	Noncat	Cat	Trucks	Cars	Total
12:00-6:00	1	35	100.0000	89.7436	11	29	40
6:00-9:00	8	207	80.0000	80.2326	38	230	268
9:00-12:00	0	36	.0000	65.4545	17	41	58
12:00-3:00	1	39	100.0000	53.4247	20	54	74
3:00-6:00	7	214	100.0000	64.0719	53	288	341
6:00-12:00	3	92	42.8571	57.5000	28	139	167
	----	----			----	----	-----
	20	623			167	781	948

	VMT			Percent VMT	
	Trucks	Cars	Total VMT	Trucks	Cars
12:00-6:00	43	425	468	9.1880	90.8120
6:00-9:00	635	4301	4936	12.8647	87.1353
9:00-12:00	136	513	649	20.9553	79.0447
12:00-3:00	228	479	707	32.2489	67.7511
3:00-6:00	533	3871	4404	12.1026	87.8974
6:00-12:00	278	1921	2199	12.6421	87.3579
	-----	----	----		
	1853	11510	13363		

The following table is for Analysis 1, Telecommuters on Telecommuting days (population: 1da=51, 1dt=8)

Speed Distribution Table (percent VMT by mph and time of day)

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
12:00-6:00	.0000	.0000	.0000	.0000	.0000	.0000	.0000	100.0000	.0000	.0000	.0000	.0000	.0000
6:00-9:00	.0000	.2924	5.2632	9.0643	13.1579	16.3743	14.9123	15.4971	17.8363	7.6023	.0000	.0000	.0000
9:00-12:00	1.6043	1.0695	10.6952	13.9037	11.2299	12.8342	13.3690	6.4171	.0000	2.1390	.0000	.0000	26.7380
12:00-3:00	.0000	1.3807	5.3254	14.5957	3.5503	9.8619	.0000	33.7278	6.1144	5.3254	6.7061	12.6233	.7890
3:00-6:00	.0000	2.3292	2.6398	11.6460	16.1491	4.3478	15.5280	27.0186	12.7329	2.7950	.0000	.0000	4.8137
6:00-12:00	2.6596	1.5957	3.4574	13.8298	8.5106	18.6170	2.9255	3.1915	34.8404	8.7766	.0000	.0000	1.5957

	Number of Cold starts		Cat fraction of cold starts		Number of Trips		
	Noncat	Cat	Noncat	Cat	Trucks	Cars	Total
12:00-6:00	0	1	.0000	100.0000	0	1	1
6:00-9:00	0	30	.0000	65.2174	4	42	46
9:00-12:00	0	22	.0000	61.1111	3	33	36
12:00-3:00	0	27	.0000	37.5000	2	70	72
3:00-6:00	0	47	.0000	60.2564	16	62	78
6:00-12:00	3	22	60.0000	53.6585	9	37	46
	----	----			----	----	-----
	3	149			34	245	279

	VMT			Percent VMT	
	Trucks	Cars	Total VMT	Trucks	Cars
12:00-6:00	0	20	20	.0000	100.0000
6:00-9:00	45	295	340	13.2353	86.7647
9:00-12:00	2	128	130	1.5385	98.4615
12:00-3:00	57	476	533	10.6942	89.3058
3:00-6:00	190	454	644	29.5031	70.4969
6:00-12:00	187	222	409	45.7213	54.2787
	-----	----	----		
	481	1595	2076		

The following table is for Analysis 1, Control Group (population: lda=39, ldt=7)

Speed Distribution Table (percent VMT by mph and time of day)

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
12:00-6:00	.0000	.0000	.0000	.0000	25.0000	75.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
6:00-9:00	.0000	.6051	3.0253	7.7558	12.9263	15.6766	13.6414	17.6568	6.1606	19.3069	2.0902	.9901	.1650
9:00-12:00	.3344	2.3411	6.6890	16.7224	11.7057	16.3880	1.0033	3.3445	33.4448	4.0134	.0000	.0000	4.0134
12:00-3:00	1.0959	3.5616	9.5890	9.0411	12.3288	15.6164	19.4521	22.7397	.0000	6.5753	.0000	.0000	.0000
3:00-6:00	.4233	1.6931	4.0212	8.2540	16.9841	11.2169	13.9153	11.9048	7.7778	16.3492	5.6085	.3704	1.4815
6:00-12:00	.3454	1.2090	3.9724	13.9896	23.6615	18.8256	9.3264	9.6718	15.5440	.0000	.0000	3.4542	.0000

	Number of Cold starts		Cat fraction of cold starts		Number of Trips		
	Noncat	Cat	Noncat	Cat	Trucks	Cars	Total
12:00-6:00	0	2	.0000	100.0000	2	0	2
6:00-9:00	2	142	66.6667	74.3456	23	171	194
9:00-12:00	1	41	100.0000	75.9259	16	39	55
12:00-3:00	1	33	33.3333	42.3077	15	66	81
3:00-6:00	1	144	50.0000	68.8995	31	180	211
6:00-12:00	1	55	100.0000	52.8846	6	99	105
	----	----			----	----	-----
	6	417			93	555	648

	VMT			Percent VMT	
	Trucks	Cars	Total VMT	Trucks	Cars
12:00-6:00	4	0	4	100.0000	.0000
6:00-9:00	223	1538	1761	12.6633	87.3367
9:00-12:00	33	250	283	11.6608	88.3392
12:00-3:00	102	274	376	27.1277	72.8723
3:00-6:00	211	1483	1694	12.4557	87.5443
6:00-12:00	21	828	849	2.4735	97.5265
	-----	----	----		
	594	4373	4967		

The following table is for Analysis 2, Telecommuting days (population: lda=57, ldt=11)

Speed Distribution Table (percent VMT by mph and time of day)

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
12:00-6:00	.0000	.0000	.0000	.0000	.0000	.0000	.0000	46.5116	.0000	.0000	53.4884	.0000	.0000
6:00-9:00	.0000	.1984	3.5714	7.7381	8.9286	15.0794	12.6984	14.0873	24.0079	6.1508	.0000	.0000	7.5397
9:00-12:00	1.2097	.8065	8.0645	10.4839	8.4677	9.6774	10.0806	4.8387	8.8710	1.6129	15.7258	.0000	20.1613
12:00-3:00	.0000	1.4085	5.4326	14.8893	3.6217	10.0604	.0000	17.1026	6.2374	14.6881	6.8410	18.9135	.8048
3:00-6:00	.0000	2.0270	2.2973	11.8919	16.3514	3.7838	18.3784	24.5946	11.0811	3.5135	.0000	1.8919	4.1892
6:00-12:00	2.6596	1.5957	3.4574	13.8298	8.5106	18.6170	2.9255	3.1915	34.8404	8.7766	.0000	.0000	1.5957

	Number of Cold starts		Cat fraction of cold starts		Number of Trips		
	Noncat	Cat	Noncat	Cat	Trucks	Cars	Total
12:00-6:00	0	2	.0000	100.0000	1	1	2
6:00-9:00	1	38	33.3333	67.8571	10	49	59
9:00-12:00	0	23	.0000	62.1622	5	33	38
12:00-3:00	0	28	.0000	38.3562	4	71	75
3:00-6:00	1	55	100.0000	61.7978	20	70	90
6:00-12:00	3	22	60.0000	53.6585	9	37	46
	----	----			----	----	-----
	5	168			49	261	310

	VMT			Percent VMT	
	Trucks	Cars	Total VMT	Trucks	Cars
12:00-6:00	23	20	43	53.4884	46.5116
6:00-9:00	145	357	502	28.8845	71.1155
9:00-12:00	63	128	191	32.9843	67.0157
12:00-3:00	93	384	477	19.4969	80.5031
3:00-6:00	207	579	786	26.3359	73.6641
6:00-12:00	187	222	409	45.7213	54.2787
	-----	----	----		
	718	1690	2408		

The following table is for Analysis 2, non-Telecommuting days (population: lda=171, ldt=31)

Speed Distribution Table (percent VMT by mph and time of day)

	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
12:00-6:00	.3743	.0000	.0000	2.5449	2.3204	4.7904	7.5599	13.1737	14.5210	16.8413	28.1437	9.7305	.0000
6:00-9:00	.0747	.5332	2.1542	4.6283	6.0467	8.3076	11.3149	24.7947	9.1714	17.1057	10.3125	2.5914	2.9647
9:00-12:00	.2983	2.4609	4.2506	10.3654	9.1723	11.9314	12.4534	11.7077	14.3177	13.5720	8.5757	.0000	.8949
12:00-3:00	.8004	1.5008	3.5018	9.1046	7.1036	13.6568	14.6573	23.3117	7.5038	4.8524	2.7014	6.6533	4.6523
3:00-6:00	.2846	1.6762	3.4894	6.8417	10.6156	9.5615	11.9545	19.0280	12.2075	13.6306	6.0405	2.7725	1.8975
6:00-12:00	.2438	1.1376	4.9296	8.0986	12.0531	11.2676	20.8830	10.5363	12.1614	6.8797	7.1777	3.1690	1.4626

	Number of Cold starts		Cat fraction of cold starts		Number of Trips		
	Noncat	Cat	Noncat	Cat	Trucks	Cars	Total
12:00-6:00	3	47	100.0000	88.6792	17	39	56
6:00-9:00	18	489	81.8182	76.1682	85	579	664
9:00-12:00	2	111	25.0000	71.1538	45	119	164
12:00-3:00	3	104	33.3333	48.8263	49	173	222
3:00-6:00	14	486	77.7778	65.0602	114	651	765
6:00-12:00	5	227	20.0000	55.3659	58	377	435
	----	----			----	----	-----
	45	1464			368	1938	2306

	VMT			Percent VMT	
	Trucks	Cars	Total VMT	Trucks	Cars
12:00-6:00	113	517	630	17.9365	82.0635
6:00-9:00	1085	8657	9742	11.1373	88.8627
9:00-12:00	267	1158	1425	18.7368	81.2632
12:00-3:00	458	1400	1858	24.6502	75.3498
3:00-6:00	1108	7465	8573	12.9243	87.0757
6:00-12:00	463	4540	5003	9.2544	90.7456
	-----	----	----		
	3494	23737	27231		

APPENDIX 3

SUMMER EMISSIONS OUTPUT

Table A.1 Analysis 1: Total Organic Gases (Summer)

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Running Exhaust	3.49	9.02	7.48
Cold Start Exhaust	6.61	13.39	17.94
Hot Start Exhaust	0.59	0.60	0.85
Diurnal Evaporation	0.38	0.25	0.24
Hot Soak Evaporation	2.48	4.03	6.85
Running Losses	4.17	7.46	7.36
Resting Losses	0.51	0.34	0.30
Total Organic Gas Emissions	18.22	35.10	41.03

Table A.2 Analysis 1: Reactive Organic Gases (Summer)

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Running Exhaust	3.07	7.96	6.45
Cold Start Exhaust	5.68	11.53	15.39
Hot Start Exhaust	0.51	0.51	0.73
Diurnal Evaporation	0.38	0.25	0.24
Hot Soak Evaporation	2.48	4.03	6.85
Running Losses	4.17	7.46	7.36
Resting Losses	0.51	0.34	0.30
Reactive Organic Gas Emissions	16.71	32.12	37.33

Table A.3 Analysis 1: Carbon Monoxide (Summer)

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Running Exhaust	35.94	87.03	63.45
Cold Start Exhaust	79.96	158.23	222.80
Hot Start Exhaust	9.05	9.27	13.39
Total Carbon Monoxide Emissions	124.95	254.50	299.61

Table A.4 Analysis 1: Oxides of Nitrogen (Summer)

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Running Exhaust	9.64	29.32	20.57
Cold Start Exhaust	3.91	6.99	9.21
Hot Start Exhaust	1.64	1.49	2.64
Total Oxides of Nitrogen Emissions	15.19	37.79	32.42

Table A.5 Analysis 1: Particulate Matter (Summer)

(in gm/person-day)	Telecommuters		Controls
	TC Days	Non-TC Days	
Exhaust	0.25	0.58	0.33
Tire-wear	3.83	10.42	6.64
Total Particulate Matter Emissions	4.08	11.00	6.97

Table A.6 Analysis 2: Total Organic Gases (Summer)

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	5.91	8.45
Cold Start Exhaust	7.35	14.47
Hot Start Exhaust	0.57	0.72
Diurnal Evaporation	0.38	0.24
Hot Soak Evaporation	2.95	5.02
Running Losses	4.62	7.78
Resting Losses	0.49	0.31
Total Organic Gas Emissions	22.31	36.99

Table A.7 Analysis 2: Reactive Organic Gases (Summer)

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	5.34	7.46
Cold Start Exhaust	6.36	12.48
Hot Start Exhaust	0.49	0.62
Diurnal Evaporation	0.38	0.24
Hot Soak Evaporation	2.95	5.02
Running Losses	4.62	7.78
Resting Losses	0.49	0.31
Reactive Organic Gas Emissions	20.64	33.91

Table A.8 Analysis 2: Carbon Monoxide (Summer)

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	62.04	75.76
Cold Start Exhaust	87.76	172.47
Hot Start Exhaust	8.98	10.87
Total Carbon Monoxide Emissions	158.85	259.10

Table A.9 Analysis 2: Oxides of Nitrogen (Summer)

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Running Exhaust	12.50	26.11
Cold Start Exhaust	4.20	7.69
Hot Start Exhaust	1.70	2.14
Total Oxides of Nitrogen Emissions	18.37	35.94

Table A.10 Analysis 2: Particulate Matter (Summer)

(in gm/person-day)	Telecommuting Days	Non-Telecommuting Days
Exhaust	0.27	0.53
Tire-wear	4.01	9.40
Total Particulate Matter Emissions	4.28	9.92