Mexico City Vehicle Activity Study

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Nicole Davis, James Lents, Nick Nikkila, Mauricio Osses

ndavis@issrc.org or jlents@issrc.org
International Sustainable Systems Research
21573 Ambushers St. Diamond Bar, CA 91765

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EXECUTIVE SUMMARY

Mexico City, Mexico was visited from January 25, 2004 to February 5, 2004 to collect and analyze data related to on-road transportation. The study effort was designed to support estimates of the air pollution impacts of on-road transportation in Mexico City that will be used in the development of air quality management plans for the region. It is also hoped that the collected data can be extrapolated to other Mexican cities to support environmental improvement efforts in these cities as well. The data collection effort was a partnership between Mexico local and regional governments, universities, and non-government officials, staff from International Sustainable Systems Research Center, and the Hewlett Foundation. In all, about thirty persons participated in data collection activities over an approximate two week period.

The study collected three types of information on vehicles operating on Mexico City streets: technology distribution, driving patterns, and start patterns. Each area is summarized below.

Vehicle Technology Distribution

Objective:
To develop a representative distribution of vehicle types, sizes, and ages of the operating fleet in the Mexico City area on various roadway types.

Methodology:
The technology distribution of vehicles was developed using a combination of two approaches. Vehicles were video taped on a variety of streets and the video tapes were reviewed to count the numbers of the various types of vehicles plying Mexico City streets. Simultaneous with this data collection process, recent I/M records were surveyed to determine specific technology types within each vehicle class operating in Mexico City.

Results:
The observed vehicle class distribution for the city, weighting various roadways and portions of the city, indicate passenger vehicles and taxis make up approximately 90% of the on-road activity. There is some variation in the activity distribution by vehicle class for the various roadways. The largest deviation was seen in the residential areas, where there are virtually no truck and bus traffic. There is significant variation in the temporal and spatial distribution within the city, ranging from 62% passenger vehicles in Central City and up to 98% passenger vehicles in the North West portion of the city.

In addition to observing the vehicle classes, an analysis of recent I/M data was conducted to determine the emissions control technology and engine type of the passenger fleet. Approximately 30% of the passenger vehicles have no catalysts, while only 10% of the taxi fleet has no catalyst. The majority of passenger vehicles on the road are gasoline multipoint fuel injected vehicles with three way catalysts. This fleet data collected compares relatively well with other estimates of the fleet composition in the Mexico City.

Vehicle Driving Patterns

Objectives:
To collect second-by-second information on the speed and acceleration profiles of the main types of vehicles operating in Mexico City on a representative set of roadways throughout the day.

Methodology:
The driving patterns for the various classes of vehicles were measured using Global Positioning Satellite (GPS) technology. This technology allows for the second by second measurements of vehicle speeds and altitude. GPS units were carried on nine selected routes. Data was collected from 07:00 to 19:00 to provide driving pattern information for differing times of the day.

Results:
Driving pattern data was successfully collected over 6 days from a number of passenger vehicles, taxis, buses and delivery trucks. In general, congestion lowers the average velocity during the daytime hours by 30 to 60 percent of free flow velocities. It is interesting that the fastest and lowest velocities occur on the highways, the highest speeds during the very early morning hours and lowest velocities in the middle of the day, when average speeds are even lower than on residential roadways. (This trend has been observed in other areas). Delivery trucks maintain a relatively low average velocity throughout the day due to the idle time during deliveries. Buses and taxis have similar average speeds to passenger vehicles traveling on arterial and residential roadways. Bus velocities do not have a large variation in average velocity with changes in congestion, as seen for the taxi, trucks and the passenger fleet. Taxis and passenger vehicles operating on the highway during the middle of the day and evening exhibit the highest occurrences of hard accelerations, due to congestion and high target velocities.

Vehicle Start Patterns

Objective:
To collect a representative sample of the number, time of day, and soak period from passenger vehicles operating in Mexico City.

Methodology:
The vehicle engine start patterns were collected using equipment that senses vehicle system voltage denoted VOCE units. VOCE data can be used to determine when vehicles start, how long they operate, and how long they sit idle between starts. This information is essential to establish vehicle start emissions. The VOCE units were placed in passenger vehicles and left there for a period of a week.

Results:
Over 340 days of start patterns from 80 different vehicles were collected over the study period. The results show that on average, a typical passenger car is started 5.6 times per day. Approximately 30% of the starts occur between 6 am and 9 am, and another 30% occur between 3 pm and 6 pm. In the early morning hours, over half of the starts occur after having soaked over 12 hours. These long soaks leave the engine cold, which results in increased starting emissions.

Conclusions

The three types of data collected in this study have been used to compile a comprehensive analysis of the make-up and behavior of the current on-road mobile fleet in Mexico City. This data is pertinent for correctly estimating current mobile source emissions and projecting the impact of proposed control strategies and growth scenarios, because the vehicle type, speed profiles, and the number and type of starts have a large impact on the mobile source emissions inventory.

Overall, the results of this study have shown that driving in Mexico City is similar to other developing urban areas with some subtle but important differences. Mexico City has the lowest daytime average velocity and specific power of these urban areas as well. Most of this is attributed to many hours of heavy congestion throughout the day.

In general, Mexico City's fleet looks the most similar to Los Angeles than all the other urban areas studied to date (Almaty, Nairobi, Pune, Santiago, and Lima). Mexico City has the highest percentage (excluding Los Angeles) of three way catalyst equipped vehicles when compared with these other passenger fleets, and the highest fraction of travel by passenger vehicles and taxis within the on-road fleet. The average age of the passenger fleet and average mileage accumulation varies widely from city to city in the countries studied to date, but Mexico City falls in the middle of this range for both variables.

The data collected in this study was formatted to allow vehicle emissions estimates using the International Vehicle Emissions Model (http://www.issrc.org/ive or www.gssr.net/ive). The IVE model was developed with USEPA funding to make emissions estimates under different technology and driving situations as found in various countries, and has been used extensively in several developing countries. Although up-to date vehicle activity and fleet information was collected in this study, no emissions measurements were performed. All emission estimates conducted in this paper use the IVE model's default emission rates. An emissions study is currently planned for the fall of 2004 that will supplement current emissions values in the IVE to create Mexico City specific emissions inventory.

A preliminary emissions analysis using the IVE model indicate that on the order of 15 metric tons of PM, 410 tons of NOx, 375 tons of VOC, and 3,900 tons of CO are emitted from on-road motor vehicles each day in Mexico City. By viewing the contribution of various vehicle types to the inventory, it was determined that to reduce PM (and toxic) emissions in Mexico City, buses and trucks must be controlled. To reduce NOx, buses, trucks, and passenger vehicles must be further controlled. Mexico City currently has the second highest emission rate for PM and NOx on a per vehicle mile basis from the urban areas in Los Angeles, Nairobi, Santiago, Pune and Mexico City, largely due to the lack of control technology on the trucks and buses and the fuel quality. It must be noted again that the emissions analysis is subject to the appropriateness of the emission rates used in the IVE model.

Several recommendations for additional study include using the tools outlined in this report to develop a strategy for improving future air quality, determine the appropriateness of the collected data to suburban areas outside of Mexico City or other urban areas within Mexico, and improve the emission factors for in-use vehicles. An improved estimate of current overall vehicular travel (VKT) and future growth rates is also recommended.

I. INTRODUCTION

The vehicle activity study was conducted in Mexico City, Mexico, from January 25, 2004 to February 5, 2004. During this time, in cooperation with local universities and government officials, three types of information were collected. Subsequently, this data was processed and analyzed and put into a format to be used in the IVE model. The data, collection process, comparisons with other areas studied, and emissions results from the IVE modeled are reported in this paper. The data collected has three purposes:

- To estimate the technology distribution of vehicles operating on Mexico City streets.
- To measure driving patterns for the various classes of vehicles operating on Mexico City streets.
- To estimate the times and numbers of vehicle engine starts for the various classes of vehicles operating on Mexico City streets.

The technology distribution of vehicles was developed using a combination of two approaches. Vehicles were video taped on a variety of streets and the video tapes were reviewed to count the numbers of the various types of vehicles plying Mexico's streets. Simultaneous with this data collection process, local officials provided inspection maintenance records to identify specific technology information about vehicles operating in Mexico City.

The driving patterns for the various classes of vehicles were measured using Global Positioning Satellite (GPS) technology. This technology allows for the second by second measurements of vehicle speeds. GPS units were carried on a variety of vehicles on a variety of street types throughout the metropolitan area. Data was collected from 07:00 to 19:00 to provide driving pattern information for differing times of the day.

The vehicle engine start patterns were collected using equipment that senses vehicle system voltage denoted VOCE units. VOCE data can be used to determine when vehicles start, how long they operate, and how long they sit idle between starts. This information is essential to establish vehicle start emissions.

The data collected in this study was formatted to allow vehicle emissions estimates using the International Vehicle Emissions Model (www.gssr.net/ive). This model was developed with USEPA funding to make emissions estimates under different technology and driving situations as found in various countries. Each process and results are described in the next sections.

II. VEHICLE TECHNOLOGY DISTRIBUTION

II.A. BACKGROUND AND OBJECTIVES

The most critical element of on-road transportation emissions analysis is the nature of the vehicle technologies that operate on the street or in the region of interest. Differing vehicle technologies can produce considerably different rates of emissions. Vehicles operating on the same roads can produce emissions that are 300 times different from one another. The fractions of various types of vehicles in a local fleet and the fractions of these various types of vehicles actually operating on the roadways are not necessarily the same. This difference occurs because some classes of vehicles are operated considerably more than other classes vehicles. For example, a class of vehicles that operates twice as much as another class will produce an on-road fraction that is twice as great even if there are equal numbers of vehicles in the static fleet.

The fraction of interest for estimating on-road emissions is the fraction of driving contributed by the various vehicle technologies since this will correspond to the about of air emissions that are produced. Thus, the most accurate estimate of vehicular contribution to air emissions is made by determining the fractions of the various vehicle technology classes actually operating on city streets rather than the distribution of vehicles registered in the region of interest.

The objective of this portion of the study is to develop a representative distribution of vehicle types, sizes, and ages of the operating fleet in the Mexico City area on various roadway types through a passenger survey. The goal of the survey was to identify the specific engine technologies, drive train, control technologies, air conditioning, total use, and model years of the vehicles surveyed.

II.B. METHODOLOGY

To determine the fractions of the various vehicle technology classes operating on city streets, video cameras were set up along the sides of the road and traffic movement taped. Figure II-1 illustrates this process on an arterial street in Mexico City.

Figure II-1. Video Taping Roadways in Mexico

The completed videotapes were analyzed in slow motion to insure the most accurate counts of vehicles.

It is not possible using the video taping process to determine the exact nature of the vehicle technologies observed. The video taping allowed the determination of the fraction of travel from trucks, buses, passenger vehicles, 2-wheelers, 3-wheelers, and such operating on the roadways in the region. To understand the specific technologies of local vehicles, inspection/maintenance records were reviewed. This specifies the engine technology, model year, control equipment, and fuel type. Typically, for more accurate data, parked vehicle surveys are conducted to estimate the more specific natures of the general vehicle classifications determined from the video tape studies. Figure II-2 illustrates a parking lot survey process in Nairobi, Kenya. For Mexico City, parking lot surveys were not conducted at the request of the local government.

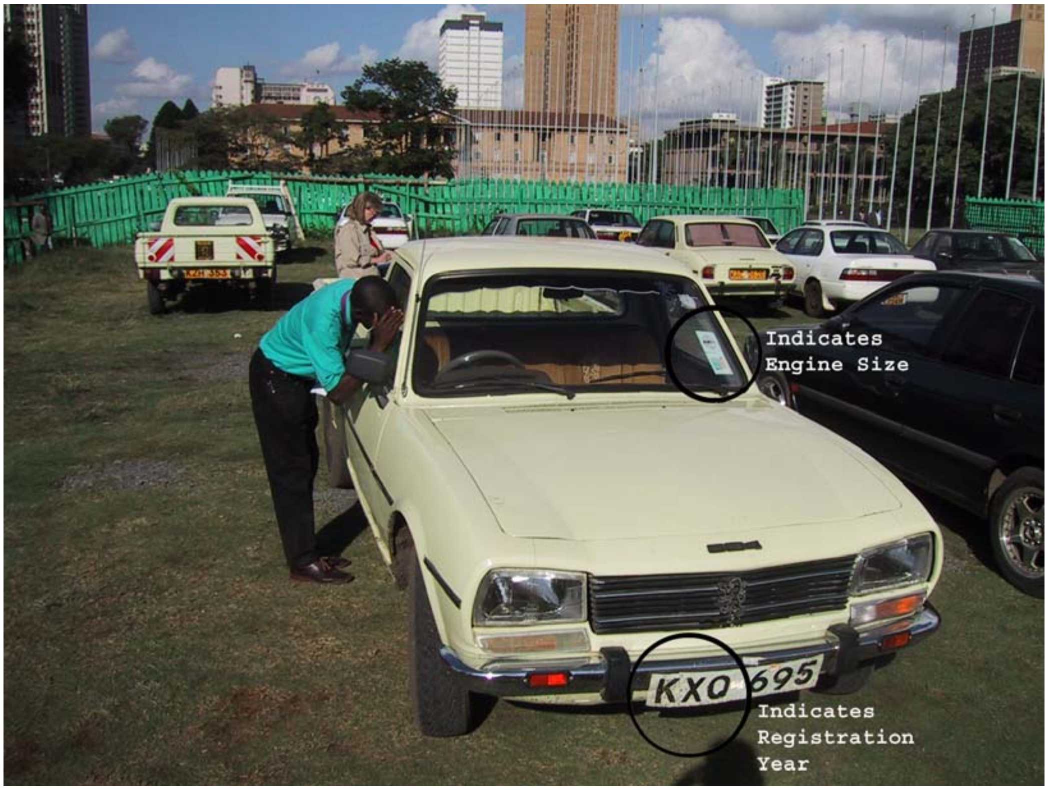

Figure II-2: Parking Lot Survey in Nairobi, Kenya

In order to insure that the most representative data is collected, video collection was carried out from 07:00 in the morning to 19:00 in the evening over 6 days in 3 representative sections of the urban area. Surveys were carried out on a residential street, an arterial roadway, and a highway in each area surveyed. For the commercial area, Distrito Central, there were no residential roadways and therefore two arterial roadways and one highway was surveyed. Table II.1 indicates the locations in Mexico City where video surveys were completed. These locations were suggested by the Mexico City officials as representative of the general metropolitan area. They also represent the locations were driving patterns were measured.

Table II-1 Video Locations Surveyed in Mexico City, Mexico

Street Type	Location	Date and Hour of Surveys
Highway-A1	Highway in Distrito Central (Comercial)	Th 1/29 – 6 am, 9 am, 12 pm Fri 1/30 – 1 pm, 4 pm, 7 pm Sat 1/31 – 9 am, 11 am Mon 2/2 – 3 pm, 6 pm Tue 2/3 – 7 am. 10 am Wed 2/4 – 2 pm, 5 pm
Highway-B1	Highway in Zona Satelite (Ingreso Superior)	
Highway-C1	Highway in Delegacion Estapalapa (Ingreso Inferior)	
Arterial-A2	Arterial in Distrito Central (Comercial)	Th 1/29 – 7 am, 10 am Fri 1/30 – 2 pm, 5 pm Sat 1/31 –6 am, 9 am, 12 pm Mon 2/2 –1 pm, 4 pm, 7 pm Tue 2/3 – 8 am, 11 am Wed 2/4 – 3 pm, 6 pm
Arterial-B2	Arterial in Zona Satelite (Ingreso Superior)	
Arterial-C2	Arterial in Delegacion Estapalapa (Ingreso Inferior)	
Arterial-A3	2nd Arterial section in Distrito Central (Comercial)	Th 1/29 – 8 am, 11 am Fri 1/30 –3 pm, 6 pm Sat 1/31 – 7 am, 10 am Mon 2/2 – 2 pm, 5 pm Tue 2/3 – 6 am, 9 am, 12 pm Wed 2/4 – 1 pm, 4 pm, 7 pm
Residential-B3	Residential section in Segundo Arterial	
Residential-C3	Residential section in Delegacion Estapalapa (Ingreso Inferior)	

Two cameras were placed along roads as described in Figure II-1. The cameras were operated for 20 minutes during the hour of interest. The cameras were then moved to the next location of interest and again operated for 20 minutes. The 20 minute operation times were selected to yield a significant amount of data and to allow for disassembly movement to a new location and reassembly in order to collect data in the next hour. The actual 20 minutes surveyed in any hour was random depending upon the time it took to move the cameras from one location and get them set up in a second location. The schedules followed are shown in the preceding Table II-1. The video tapes were reviewed in slow motion and stop action as needed to yield accurate analysis of the roadway vehicle distributions. This is a key advantage of using video tape instead of direct human observation. The categorization of the video data into fleet files falls within seven vehicle class groups (buses and trucks are grouped together). The groups are typically defined by the engine size and vehicle function (Table II-2).

Table II-2Vehicle Class Categorization Examples

Vehicle Class	Vehicle Description	Vehicle Example
Passenger Vehicle – Light	Vehicle with a 1.5 Liter or smaller engine Typically weighs less than 5000 pounds.	
Passenger Vehicle - Medium	Vehicle with btwn 1.5 and 3 Liter engine. Typically weighs less than 5500 and 6600 pounds.	 
Passenger Vehicle - Large	Vehicles with > 3 Liter engine. Typically weighs between 6600 and 9000 pounds and carries less than 8 passengers	 
Small Truck	Trucks between 9000 and 14,000 pounds.	
Medium Truck	Trucks between 14,000 – 33,000 pounds. Trucks usually have a single rear axle.	

Large Truck	Trucks >33,000 pounds. Usually has a double rear axle and may have more than one trailer	
Small Bus	Buses less than 14,000 pounds. Usually carry between 8 and 19 passengers	
Medium Bus	Buses between 14,000 and 33,000 pounds. Usually carry between 20 and 45 passengers	
Large Bus	Buses > 33,000 pounds. Usually carry more than 45 passengers.	
Others	Bicycles, off – road vehicles, animals, etc.	

II.C. SURVEY RESULTS

II.C.1. Fleet Composition

As can be seen in

Table II-3 the distribution of vehicles varies with street type and time of day. Thus, for highly time and street specific analysis, care must be taken to construct a proper technology distribution for the time and street of interest. For this analysis, overall average technology distributions are developed for the general metropolitan area.

Table II-3 Results of Analysis of Mexico City Videotapes

Road Type	Area	Time	Vehicles/hr	Passenger Cars	Taxi	Small Truck	Med Truck	Large Truck	Small Bus	Med Bus	Large Bus	2-w
Arterial	Central City	7:00	4787	70%	20%	3%	2%	1%	2%	0%	1%	1%
Arterial	Central City	10:00	4756	65%	21%	5%	2%	2%	3%	0%	1%	2%
Arterial	Central City	14:00	4435	67%	19%	3%	3%	1%	4%	0%	1%	3%
Arterial	Central City	17:00	3195	63%	21%	4%	3%	2%	4%	0%	1%	2%
Arterial	North West	6:00	270	82%	3%	9%	1%	0%	2%	0%	0%	2%
Arterial	North West	9:00	876	91%	3%	4%	2%	0%	0%	0%	0%	0%
Arterial	North West	12:00	1637	95%	2%	1%	1%	0%	0%	0%	0%	1%
Arterial	North West	13:00	1431	97%	1%	1%	0%	0%	0%	0%	0%	0%
Arterial	North West	16:00	1427	93%	3%	1%	1%	0%	0%	0%	0%	1%
Arterial	North West	19:00	2097	98%	2%	0%	0%	0%	0%	0%	0%	0%
Arterial	South	8:00	2098	66%	12%	3%	3%	1%	12%	1%	2%	0%
Arterial	South	11:00	1554	62%	17%	5%	3%	0%	9%	1%	2%	1%
Arterial	South	15:00	1933	59%	20%	4%	1%	0%	12%	1%	2%	1%
Arterial	South	18:00	1664	58%	22%	3%	1%	0%	12%	1%	1%	2%
Arterial	Central City	8:00	3546	78%	16%	2%	1%	0%	1%	0%	2%	1%
Arterial	Central City	11:00	3975	76%	16%	2%	1%	0%	2%	0%	3%	1%
Arterial	Central City	15:00	3237	76%	13%	2%	1%	0%	3%	0%	3%	2%
Arterial	Central City	18:00	2643	78%	12%	2%	1%	0%	2%	0%	4%	2%
Highway	Central City	6:00	3684	64%	25%	3%	2%	1%	4%	0%	0%	0%
Highway	Central City	9:00	4195	62%	28%	3%	1%	0%	3%	0%	0%	2%
Highway	Central City	12:00	4373	66%	25%	2%	2%	0%	3%	0%	1%	1%
Highway	Central City	13:00	4765	69%	23%	2%	1%	0%	3%	0%	1%	1%
Highway	Central City	16:00	4473	72%	20%	3%	1%	0%	3%	0%	1%	1%
Highway	Central City	19:00	3054	83%	9%	1%	0%	0%	3%	1%	1%	1%
Highway	North West	8:00	5039	84%	1%	4%	2%	1%	5%	1%	2%	0%
Highway	North West	11:00	7710	87%	2%	3%	1%	1%	3%	1%	0%	1%
Highway	North West	15:00	7971	87%	1%	3%	1%	1%	4%	2%	0%	1%
Highway	North West	18:00	7916	90%	0%	2%	1%	1%	4%	1%	1%	0%
Highway	South	7:00	3840	72%	18%	3%	1%	1%	3%	0%	2%	1%
Highway	South	10:00	3682	69%	16%	4%	3%	3%	3%	1%	2%	0%
Highway	South	14:00	3189	72%	16%	3%	2%	2%	3%	0%	2%	1%
Highway	South	17:00	3130	70%	13%	10%	2%	1%	2%	0%	1%	1%
Residential	North West	7:00	18	83%	0%	17%	0%	0%	0%	0%	0%	0%
Residential	North West	10:00	36	92%	0%	8%	0%	0%	0%	0%	0%	0%
Residential	North West	14:00	129	95%	0%	2%	2%	0%	0%	0%	0%	0%
Residential	North West	17:00	98	97%	0%	0%	0%	0%	0%	0%	0%	3%
Residential	South	12:00	302	51%	30%	14%	1%	0%	1%	0%	0%	3%
Residential	South	13:00	435	63%	28%	4%	1%	1%	1%	0%	0%	1%
Residential	South	16:00	375	55%	37%	5%	2%	0%	1%	0%	0%	0%
Overall Arterial			2272	79%	11%	3%	1%	0%	3%	0%	1%	1%
Overall Highway			5300	77%	11%	3%	1%	1%	3%	1%	1%	1%
Overall Residential			170	80%	11%	7%	1%	0%	0%	0%	0%	1%
Overall			1760	79%	11%	4%	1%	0%	2%	0%	1%	1%

The overall averages shown in the last row of

Table II-3 are weighted averages based on the vehicle counts on the various types of streets and the observed technology distributions. It was estimated based on a map of the area that 0.6% of the roadway length is freeways, 10.9% is arterials, and 88.5% is residential. Based on the average flow observed in the video and the lengths of the various road types in Mexico City, 58% of the vehicle kilometers traveled (VKT) or activity occurs on arterial roadways, 7% on highways, and 35% on residential streets.

Figure II-3 shows a comparison of the fraction of all on-road activity that is conducted by passenger vehicles and taxis from various metropolitan regions around the world. Since Pune has the most two and three wheeled vehicles and buses, they have the least fraction of travel by passenger vehicles. Los Angeles, which averages greater than 1 passenger vehicle per person, has the greatest fraction of activity by passenger vehicles. Mexico City is approaching Los Angeles with almost 90% of all on-road travel from light duty gasoline vehicles.

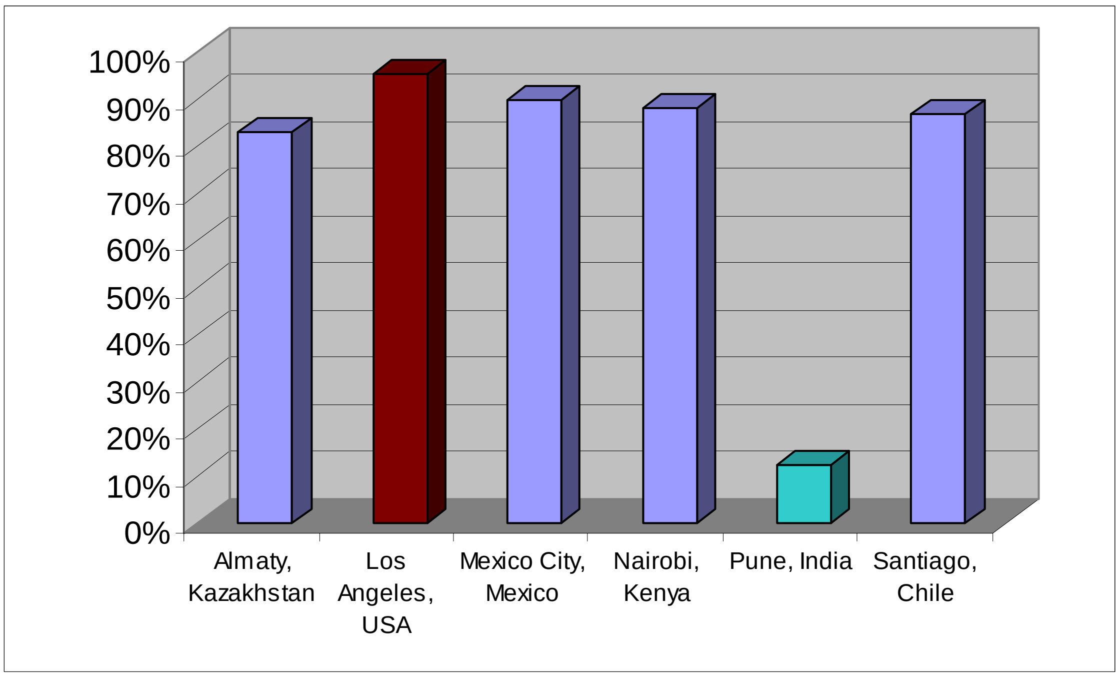

Figure II-3 Comparison of On-road Activity from Passenger Vehicles and Taxis around the World

II.C.2. Passenger Vehicle and Taxi Technology Distribution

The parking lot survey was not conducted in Mexico City. Instead, I/M data submitted from the GDF and the State of Mexico was used to identify the specific engine technologies, drive train, control technologies, air conditioning, total use, and model years of the vehicles surveyed. Over 64,000 passenger vehicle records and 1300 taxi records were used to develop the technology distribution of these categories. The team's observation and local experts provided the technology distribution of the local truck and bus fleet. Table II-4 indicates some of the general characteristics observed in the local fleet.

Table II-4 General Characteristics of the Surveyed Passenger Car and Taxi Fleet

Passenger Vehicles	**Fraction of Passenger Vehicles**	**Taxis**	**Fraction of Taxi Vehicles**
Gasoline, 4-stroke, Carburetor, No Catalyst	26.40%	Gasoline, 4-stroke, Carburetor, No Catalyst	10.22%
Gasoline, 4-stroke, Single Point Fuel Injection, No Catalyst	1.99%	Gasoline, 4-stroke, Carburetor, 3-Way Catalyst	0.31%
Gasoline, 4-stroke, Single Point Fuel Injection, 3-way Catalyst	4.27%	Gasoline, 4-stroke, Single Point Fuel Injection, 3-way Catalyst	0.00%
Gasoline, 4-stroke, Multipoint Fuel Injection, No Catalyst	0.44%	Gasoline, 4-stroke, Multipoint Fuel Injection, No Catalyst	0.00%
Gasoline, 4-stroke, Multipoint Fuel Injection, 3-Way Catalyst	63.59%	Gasoline, 4-stroke, Multipoint Fuel Injection, 3-Way Catalyst	89.47%

The engine size of the Mexico City vehicle fleet was generally midsize. Table II-5 and Table II-6, using again the I/M database supplied by the GDF and the State of Mexico, list the engine size and use distribution of the passenger vehicle and 2-wheel vehicle fleets respectively. Most passenger vehicles have less than 80,000 kilometers and are mid-size. The vast majority of taxis are mid-size and have a variety of miles on them.

Table II-5 Size and Use Characteristics of the Surveyed Passenger Car Fleet

Vehicle Engine Size	Low Use (<80 K km)	Medium Use (80-161 K km)	High Use (>161 K km)
Small (<1.5 liter)	5.2%	1.1%	0.4%
Medium (1.5 – 3.0 liter)	52.6%	10.7%	4.3%
Large (>3.0 liter)	20.0%	4.1%	1.6%

Table II-6 Size and Use Characteristics of the Taxi Fleet

Vehicle Engine Size	Low Use (<80 K km)	Medium Use (80-161 K km)	High Use (>161 K km)
Small (<1.5 liter)	2.0%	1.1%	2.5%
Medium (1.5 – 3.0 liter)	33.9%	19.0%	41.4%
Large (>3.0 liter)	0.1%	0.0%	0.1%

Figure II-4 shows a comparison of the fraction of catalyst equipped vehicles from around the world. Mexico City has the highest percentage of three way catalyst equipped vehicles when compared with the current passenger fleets of Almaty, Nairobi, Pune, Santiago, and Lima.

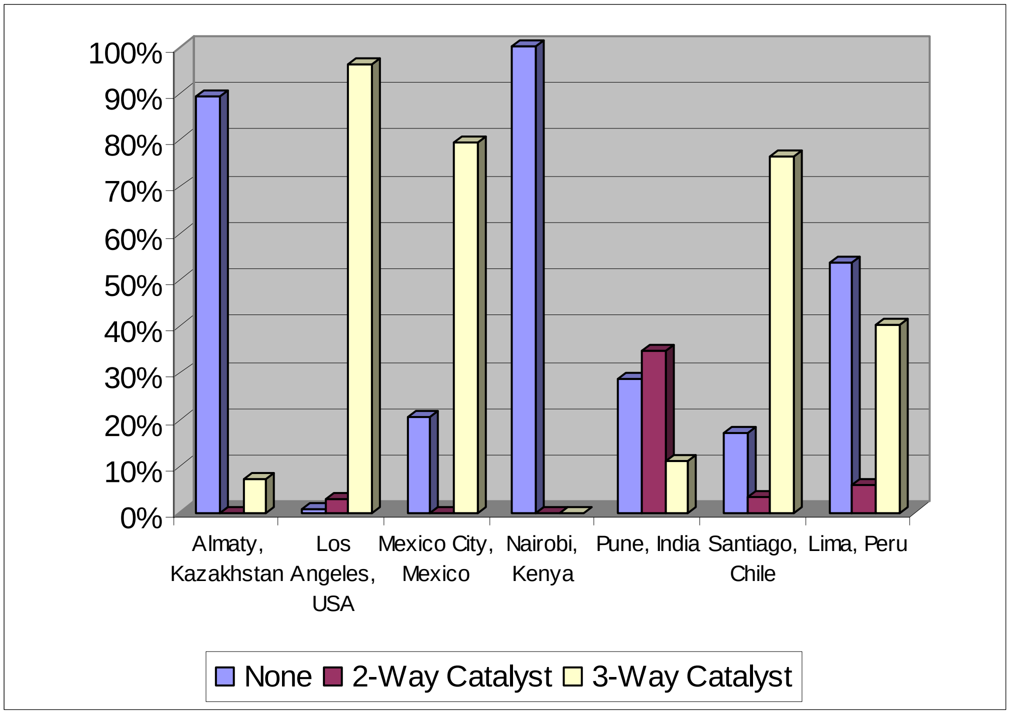

Figure II-4 Comparison of Emissions Control Technology on Passenger Vehicles around the World

Information in Table II-4 must be combined with information in Table II-5 and Table II-6 along with the video collected data in

Table II-3 to produce the passenger vehicle and taxi fleet information for estimating emissions.

The model year can also be helpful to further differentiate among the multipoint fuel injection vehicles and the improved technologies in taxis. Figure II-5 illustrates the model year distribution for active passenger vehicles in Mexico City, as observed from over 64,000 record of recent I/M data. This data is weighted by the average travel per vehicle. The average travel per vehicle was calculated from the odometer reading in the I/M database and the vehicle use by age calculated in Figure II-9. A simple straight averaging method was not used. Instead, an empirical equation was developed for current use by vehicle age from the odometer data. For example, a 5 year old vehicle with an odometer reading of 83,000 would not have a current use 83000/5=16,600, instead based on the formula in Figure II-9, it would have a current use of 13,000 kilometers per year. Then, the active fleet distribution is calculated. For example, if there are 10 1980 vehicles that drive 100 miles each this year (based on the formula) and 5 1990 vehicles that drive 1000 miles this year, the active fraction of 1980 vehicles would be 10*100/(10*100+5*1000) = 0.17 and the active fraction of the 1990 vehicles would be 5*1000/(10*100+5*1000) = 0.83. This methodology gives the model year and age distribution of the fleet as seen on the road, not the static fleet. The calculated average age of passenger vehicles on the road using this method is 6.1 years.

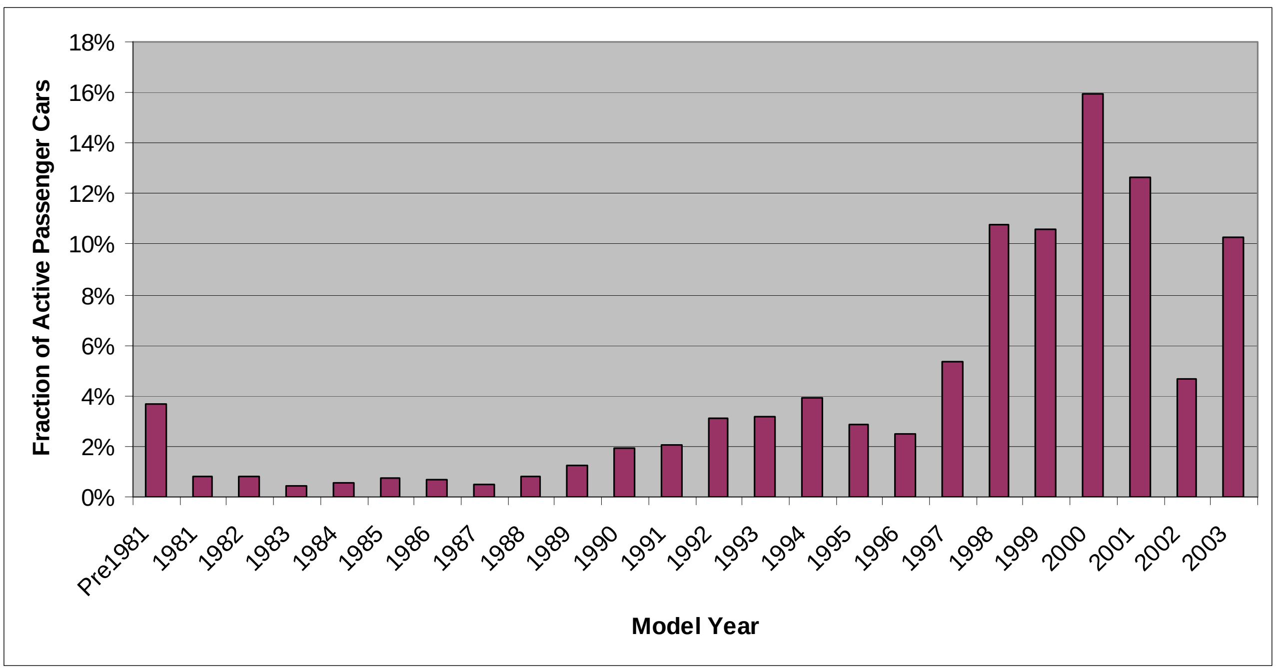

Figure II-5 Model Year Distribution in the Active Mexico City Passenger Vehicle Fleet

Figure II-6 is the same distribution as seen in Figure II-5 compared with the 2000 MCMA emissions inventory. Two important distinctions limit the usefulness of the comparison: The MCMA data is four years older than the data collected in this survey, and the data in this study uses an empirically calculated VKT per year as a function of vehicle age. The first distinction limits the comparison of young vehicles in the fleet. The second distinction may be why the MCMA data shows a higher percentage of older vehicles. In reality, we typically see a much smaller fraction of travel from older vehicles even though their registration data may not reflect smaller numbers.

Because the most current I/M data was used and was corrected for the average use per vehicle per age, the data collected in this study will be used in the fleet makeup.

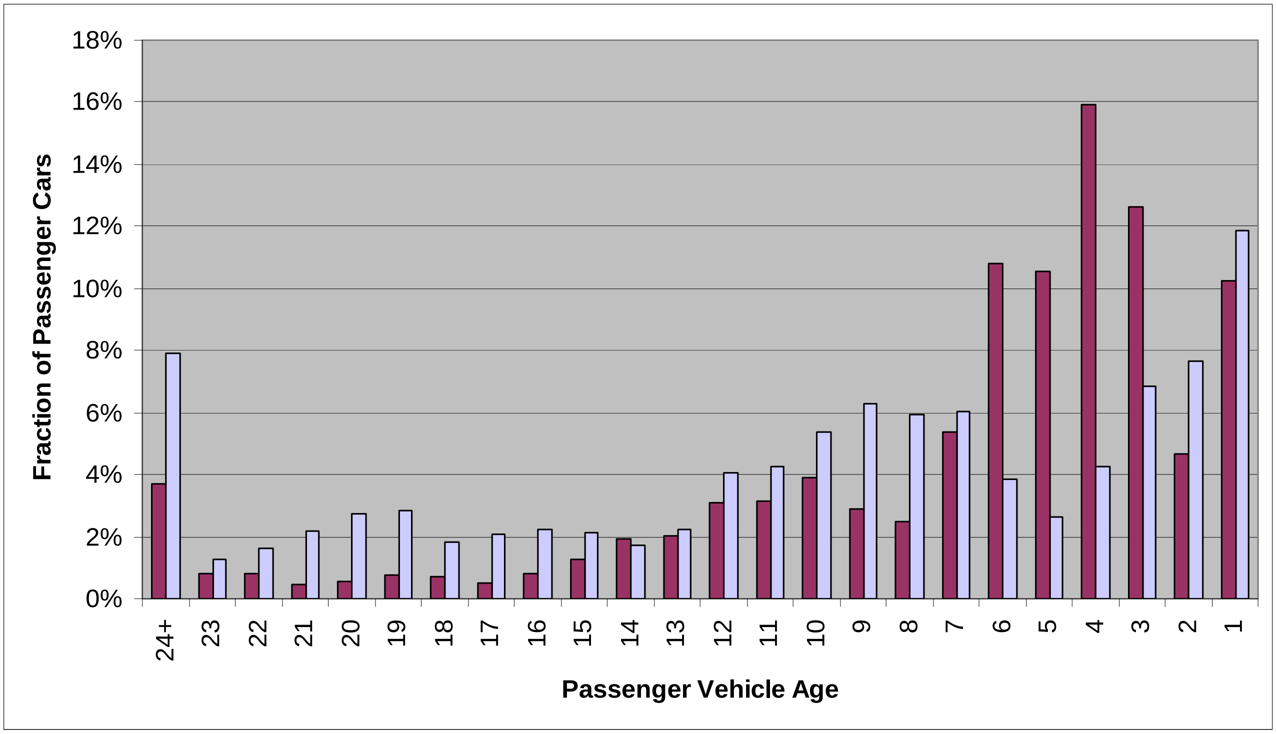

Figure II-6 Comparison of Observed Age Distribution of On-road Passenger Fleet with the 2000 MCMA Inventory

Figure II-7 illustrates the model year distribution for active taxis in Mexico City. In contrast to private passenger vehicles, the taxi fleet is slightly newer with and average age of 5.5 years, and contains virtually no vehicles older than 13 years. This may partly explain why there are more advanced technology taxis than passenger vehicles.

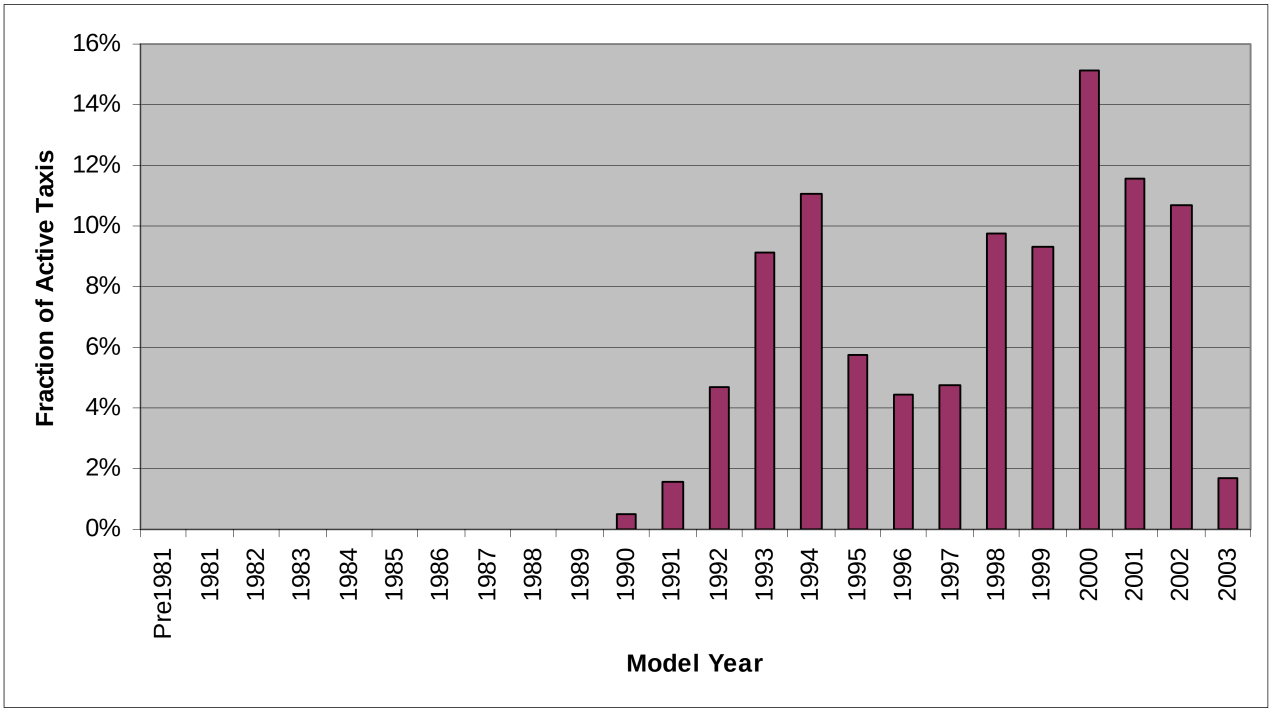

Figure II-7 Model Year Distribution in the Mexico City Taxi Fleet

Figure II-8 shows a comparison of the average age of the passenger fleet from several cities studied to date. Mexico City falls within the middle of the cities surveyed. It is interesting to note that the average age of the passenger fleet is younger in Mexico City than it is in Los Angeles.

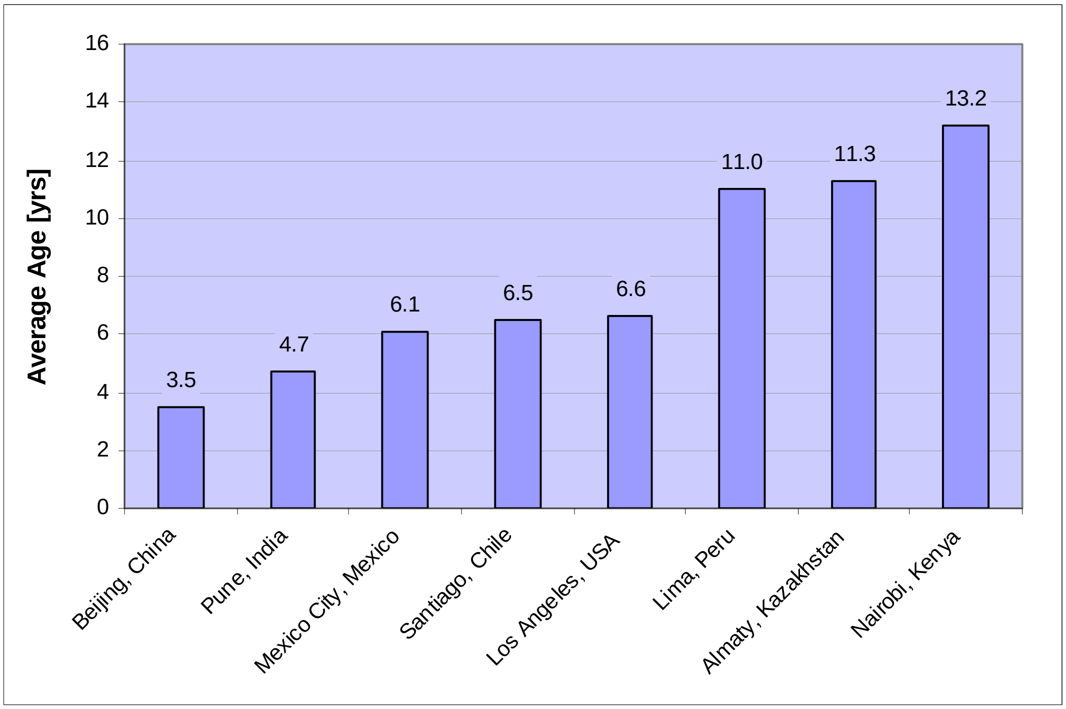

Figure II-8Average age of the Passenger Fleet around the World

II.C.3. Bus and Truck Technology Distribution

Data on buses operating in Mexico City were provided for this analysis. Table II-7 presents the characteristics of the microbus and large bus and truck fleet for this area. The diesel fuel used by the larger buses and trucks contains 500ppm sulfur. Sixty four percent of all bus travel is conducted by microbuses. The remainder of the travel is conducted by larger buses.

Table II-7 General Characteristics of the Surveyed Truck and Bus Fleet

MicroBus	Fraction of MicroBuses	Trucks and Large Buses	Fraction of Large Buses
Gasoline, 4-stroke, Carburetor, No Catalyst	45.91%	Diesel, Pre-Chamber Injection, No Catalyst	23%
Gasoline, 4-stroke, Carburetor, 3-Way Catalyst	0.00%	Diesel, Direct Injection, Improved Emission Control	77%
Gasoline, 4-stroke, Multipoint Fuel Injection, No Catalyst	24.44%		
Gasoline, 4-stroke, Multipoint Fuel Injection, 3-Way Catalyst	2.44%		
Natural Gas, 4-stroke, Carburetor, No Catalyst	0.8995%		
Liquid Propane, Carburetor, No Catalyst	26.2626%		
Liquid Propane, Carburetor, 3-Way Catalyst	0.0527%		

II.C.4. Vehicle Use

Odometer data was obtained from I/M reports. Some approximation of the use of individual vehicles can be made and this can be extrapolated to make approximations of total vehicle use for Mexico City.

Figure II-9 shows the passenger vehicle use taken from vehicle odometers. The figure also includes a second order least square fit to the data. As is typical for the United States and all other countries studied so far, vehicle use decreases with vehicle age. A new passenger car in Mexico will be driven about 20,000 km per year, and the average about 12,000 kilometers per year. Using the age distribution illustrated in previous Figure II-5, the average passenger car age in Mexico City is approximately 6 years. This translates to an average daily driving of 32 kilometers of driving per day over the year. The scatter in the data for the high use years is due to the small numbers of vehicles observed with higher ages and the fact that the odometers themselves become unreliable. The equation shown in Figure III-6 will produce unreasonable results if extrapolated beyond 20 years due to the uncertainty in the odometer readings for vehicles older than 12 years. It may be more appropriate to replace the second order term in the vehicle use equation with a value that is similar in a relative sense to those measured in other countries.

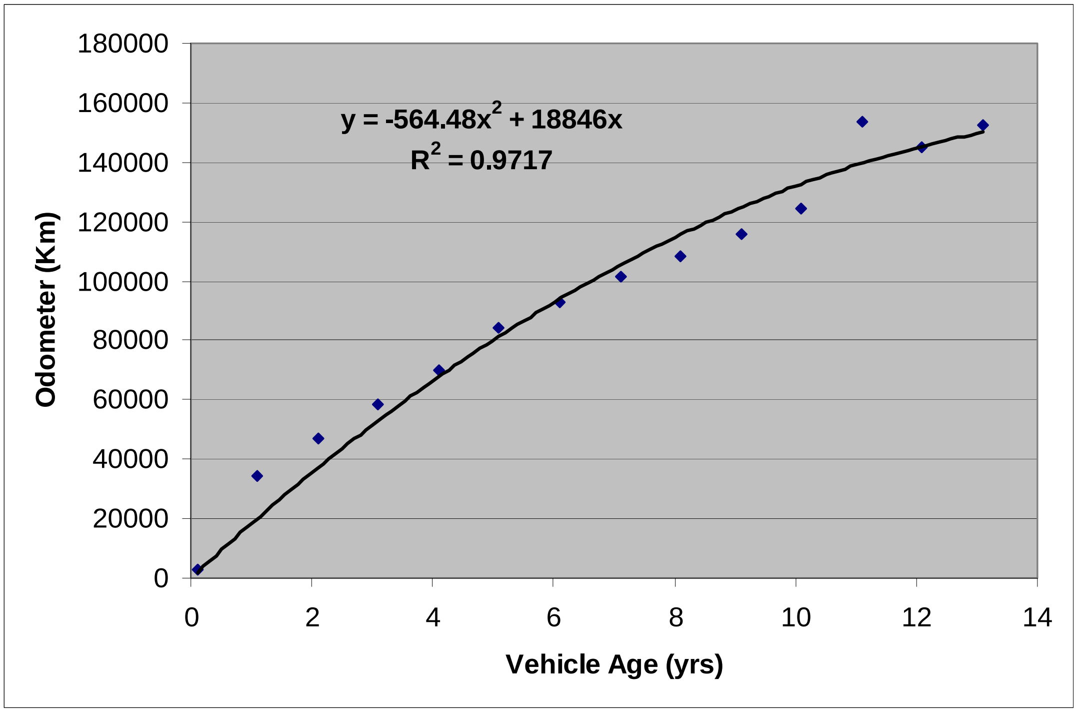

Figure II-9 Passenger Vehicle Use During the First Thirteen Years of Age

Figure II-10 presents Taxi vehicle use over the first 2 and then 14 years of vehicle life.

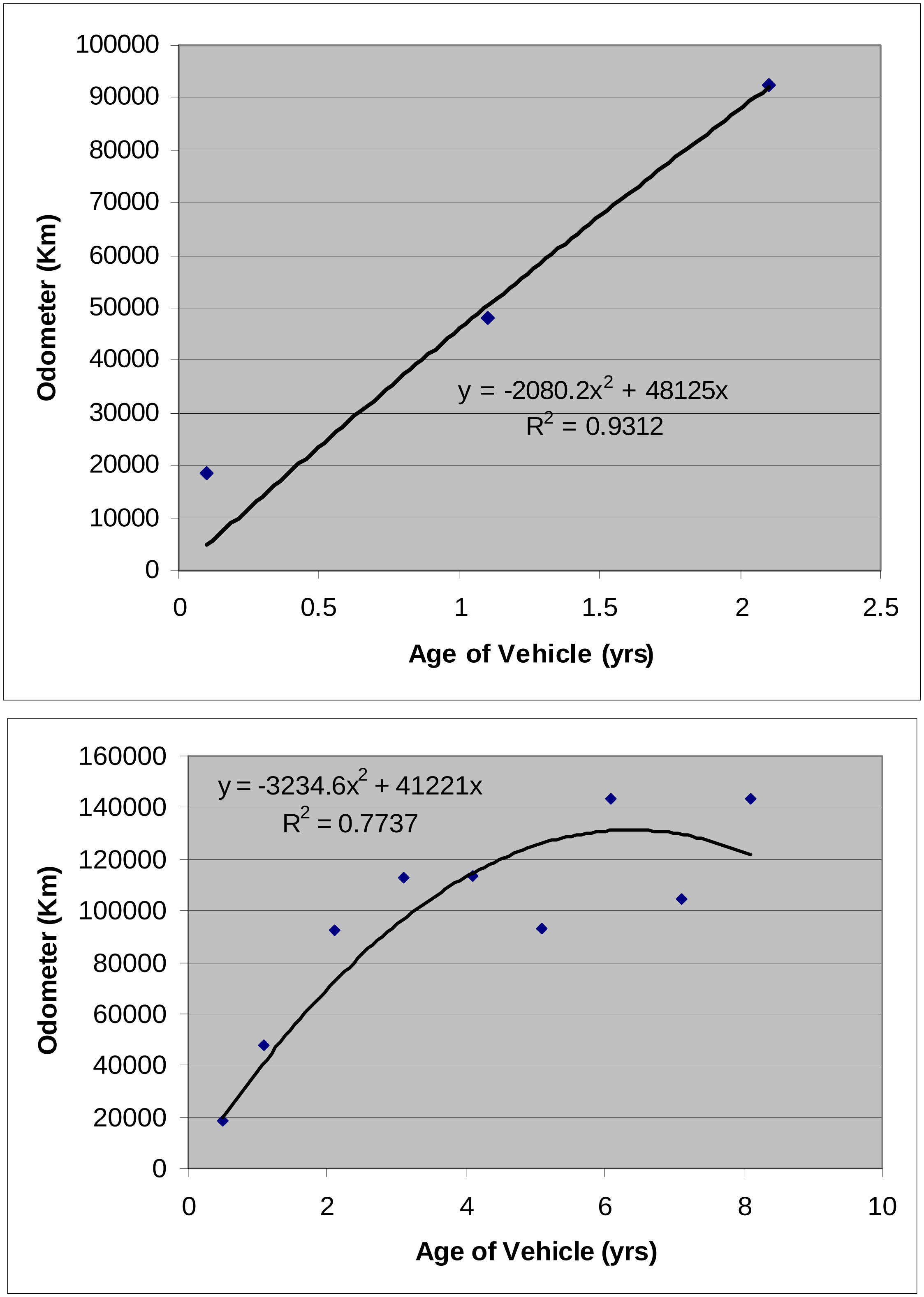

Figure II-10 Taxi Use During the First Two and Eight Years of Age

It is noteworthy that a new taxi is operated about 43,000 kilometers per year. This compares to about 20,000 kilometers per year from a new passenger vehicles. Using the age distribution illustrated in previous Figure II-6, the average age of taxis operating in Mexico City is 5.5 years. This is similar to the passenger car average age. This translates to an average daily use of 90 kilometers per day. The equation in Figure II-10 will produce unreasonable results if extrapolated beyond 8 years. This, as is the case for passenger vehicles, is due to the fact that on older vehicles the odometer may have turned over, been disconnected, or failed making vehicle use readings for older vehicles less reliable. The MCMA 2000 inventory reports taxi drivers average 200 km per day. It is unknown where the discrepancy arises.

The current travel in Mexico City is estimated to be approximately 150,000,000 kilometers per day as estimated from two separate sources [1,3]. This estimate is used in the IVE analysis to project emissions for the MCMA. Table II-8 below provides the estimated total driving based on measurements made in this study. For comparison purposes, the fleet distribution as reported in the MCMA 2000 inventory is shown as well. The two estimates compare relatively well, except for the taxi and truck breakdown. This discrepancy could be due to the lower mileage per day used in this study for taxis and trucks, the fact that the MCMA distribution may be a registration distribution instead of an observed activity distribution, or a combination of the two.

Table II-8 Observed Travel Distribution by Vehicle Type in the Mexico City Metropolitan Area

Vehicle Category	Equivalent MCMA Categories	Description of Category	Fraction of Observed Travel, 2004	MCMA 2000 Fraction
Passenger Vehicles	Autos particulares	Vehicles, SUVs, and Trucks that weight less than 9000 pounds	79%	77%
Taxi			11%	4%
Trucks	Trucks greater than 9000 pounds	Trucks greater than 9000 pounds	5%	14%
Small Bus/Combis			2%	2%
Large Bus			1%	1%
Motorcycles			2%	3%
Total			100%	100%

The values shown in Table II-8 should only be treated as approximations, but they should be in the ballpark of the true total driving occurring in the MCMA in 2003.

A final issue of interest is to compare Mexico City driving with other areas. Figure II-11 illustrates the total driving per vehicle for the countries studied to date. As can be seen, passenger cars are driven the most in the United States and the least in Pune, India. Mexico City has the second lowest mileage accumulation for passenger vehicles of the areas studied to date.

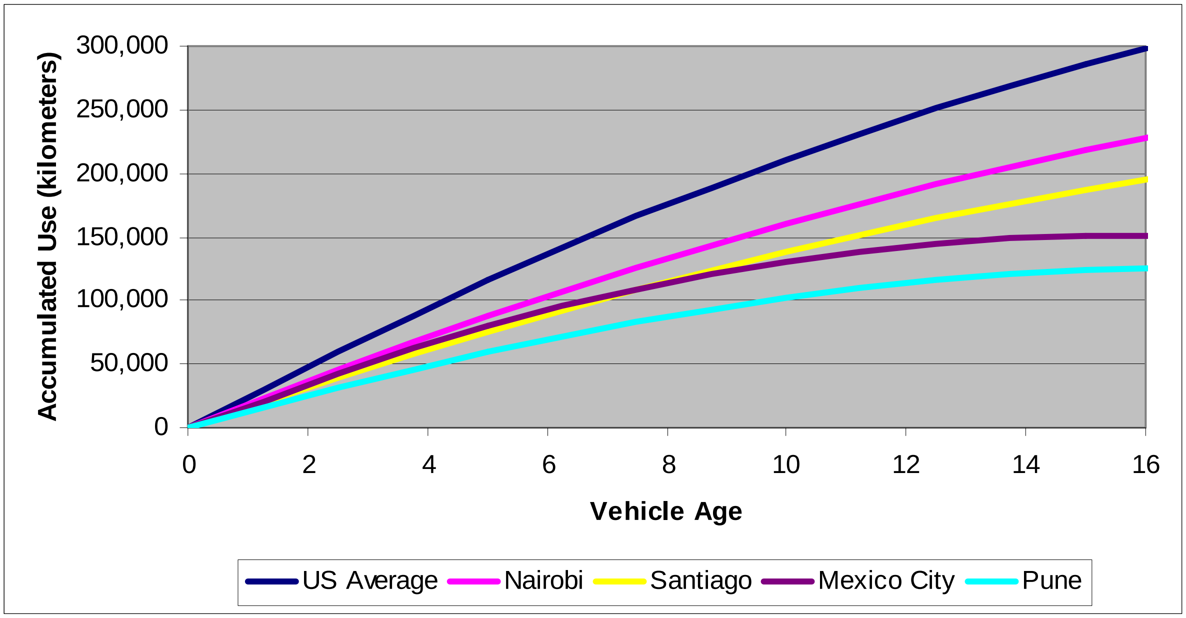

Figure II-11 Comparison of Passenger Vehicle Use in Different Countries

III. VEHICLE DRIVING PATTERNS

III.A. BACKGROUND AND OBJECTIVES

The main objective of this section is to collect second-by-second information on the speed and acceleration of the main types of vehicles operating in Mexico City on a representative set of roadways throughout the day.

III.B. METHODOLOGY

Vehicle driving patterns were measured using GPS technology as described in Appendix A. This technology allows the measurement each second of vehicle location, speed, and altitude. The altitude reading is the least certain of the data collected by a GPS unit, but it is still useful for estimating road grade. Figure III-1 illustrates the location data collected from one of the study days in Mexico City. A student was asked to get on buses with the computerized GPS equipment and ride the buses for about 7 hours.

Figure III-2 presents an example of speeds as measured by the GPS unit for about 90 seconds around 11:30.

Figure III-1 Map of Mexico City where Driving Traces were Performed.

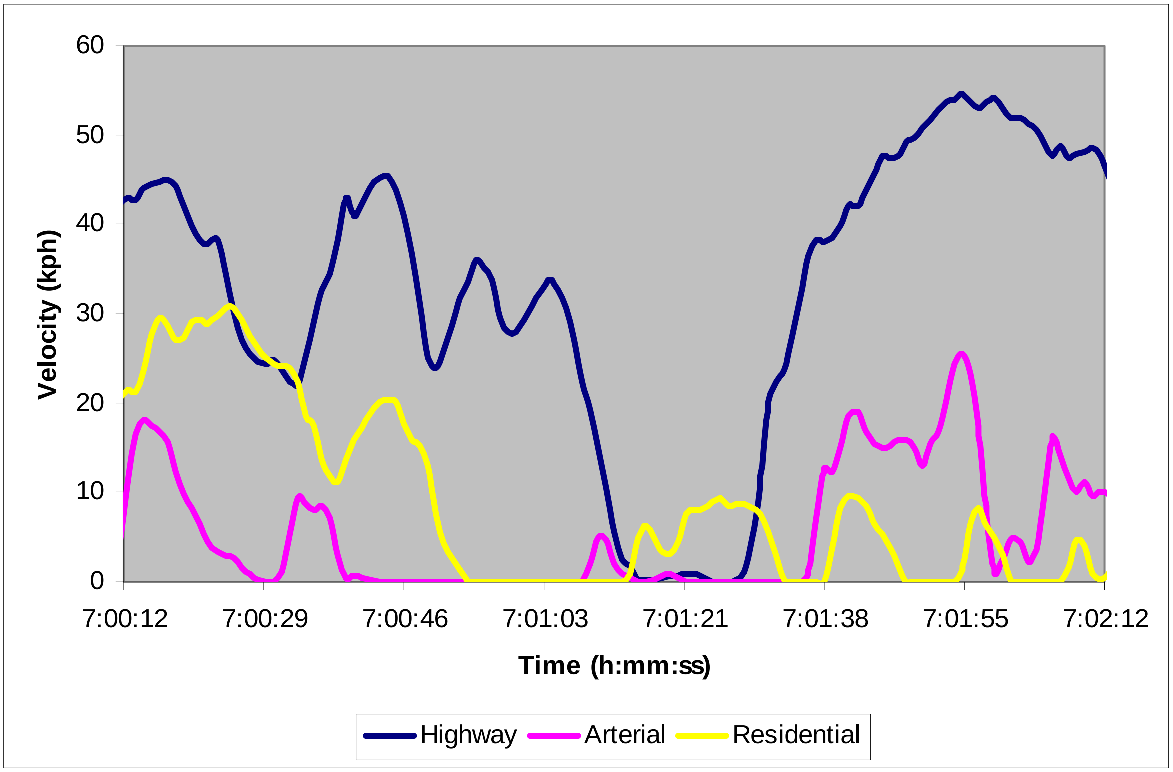

Figure III-2 Example of Residential, Arterial, and Highway Driving at 07:30 in Mexico City

Figure III-3 presents an example of altitude recorded while driving on an arterial over a 10 minute drive. As noted earlier, the altitude measurement is the least accurate of the GPS determinations.

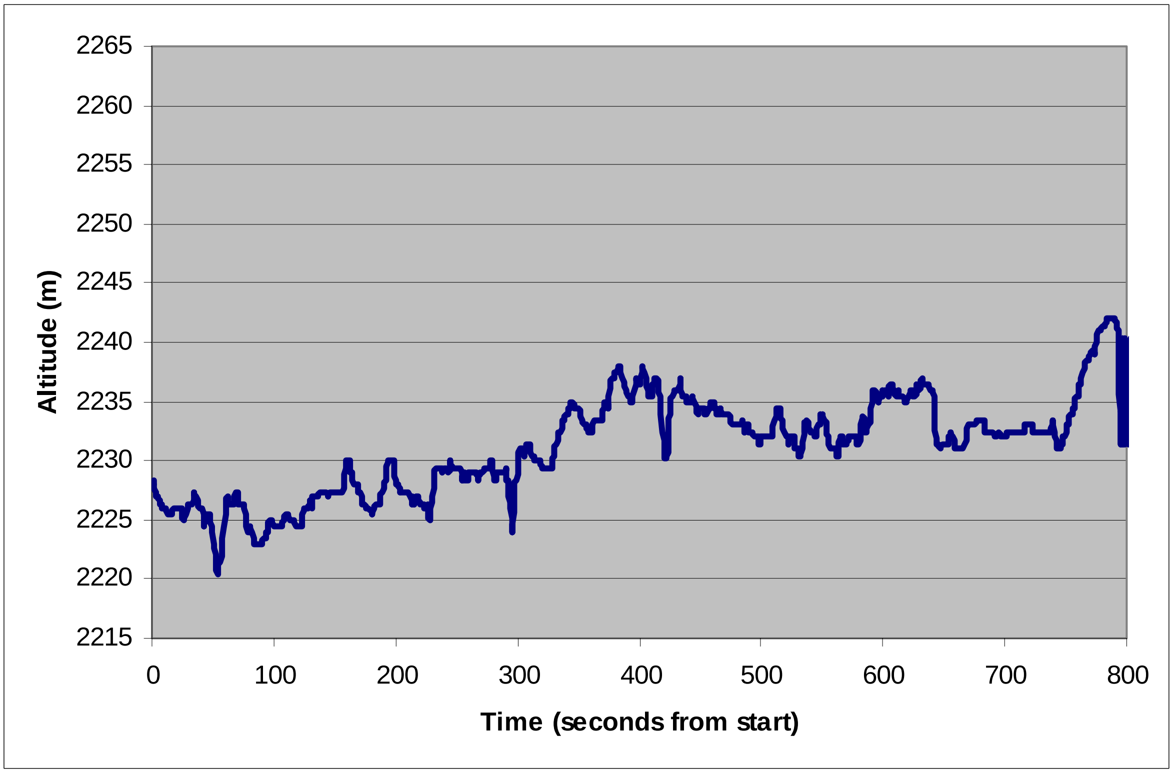

Figure III-3 Example of Altitude Recorded by GPS over a 13 Minute Drive

In using this data to estimate road grade, care must be taken to look at multiple adjacent sample points to make the most appropriate estimate of road grade.

A new method of estimating emissions variation due to driving behavior has been developed by UCR and is used in the IVE model. A similar method is also being developed and used in the next generation of emissions models by the US EPA. This method uses vehicle specific power binning and another factor to correct emissions.

The method developed for the IVE model uses a calculation of the power demand on the engine per unit vehicle mass to correct for the driving pattern impact on vehicle emissions. This power factor is called vehicle specific power (VSP). The VSP is the best, although imperfect, indicator of vehicle emissions relative the vehicles base emission rate. Equation III.1 presents the VSP equation used in the IVE model.

$$VSP = 0.132*S + 0.000302*S^2 + 1.1*S*dS/dt + 9.81*Atan(Sin(Grade)) \qquad III.1$$

Where,

S = vehicle speed in km/second.
dS/dt = vehicle acceleration km/second/second.
Grade = grade of road grade radians.

About 65% of the variance in a vehicle's running emissions can be accounted for using VSP. To further improve the emissions correction for vehicle driving, a factor denoted vehicle stress was developed. Vehicle stress (STR) uses an estimate of vehicle RPM combined with the average of the power exerted by the vehicle in the 15 seconds before the event of interest. This is an implied RPM value and does not change from vehicle to vehicle or from location to location. These VSP and stress correlations have been developed and validated on a broad database of second by second emissions measurements from non-catalyst, catalyst, and advanced technology vehicles, pickups, and heavy duty trucks both operating on the dynamometer and on the road. Equation III.2 indicates the calculation for STR.

$$STR=RPM + 0.08*PreaveragePower \qquad III.2$$

Where,

RPM = the estimated engine RPM/1000 (an algorithm was developed by driving many different vehicles and measuring RPM compared to vehicle speed and acceleration. The minimum RPM allowed is 900.

PreaveragePower = the average of VSP the 15 seconds before the time of interest. The 0.08 coefficient was developed from a statistical analysis of emissions and speed data from about 500 vehicles to give the best correction factor when combined with VSP.

Ultimately the GPS data for each vehicle type studied is broken into one of 20 VSP bins and one of 3 STR Bins. Thus, each point along the driving route can be allocated to one of 60 driving bins. A given driving trace can be evaluated to indicate the fraction of driving that occurs in each driving bin. These fractions are used to develop a correction factor for a given driving situation.

III.C. RESULTS

III.C.1. Passenger Cars

Data on passenger car driving was collected in three parts of Mexico City (see Table II.1) over six days. Due to limited data, the driving data collected was allocated into 2 hour groups instead of 1 hour groups. Table III-1 indicates the average speed for each type of road studied for each 2-hour group.

Table III-1 Average Passenger Car Speeds on Mexico City Roads (km/hr)

Time	Highway	Arterial	Residential Street
5:30	51.82	24.58	20.54
7:30	51.82	14.63	20.53
9:30	32.27	13.99	21.63
11:30	32.95	15.71	21.72
13:30	15.07	11.69	11.90
15:30	3.35	18.36	13.96
17:30	14.94	18.66	15.46
19:30	40.86	23.89	11.96

Speed is not a good indicator of vehicle power demand. Vehicle acceleration consumes considerable energy and is not indicated by average vehicle speed. Table III-2 to Table III-4 below provide the power bin distribution for the driving on Mexico City Highways, Arterials, and Residential streets respectively averaged over all hours. For use in the IVE model, the power bin distributions can also be used in the two hour groupings indicated in Table III-1 to make hourly estimates of emissions from passenger vehicles.

It should be noted that Power Bins 1-11 represent the case of negative power (i.e. the vehicle is slowing down or going down a hill or some combination of each). Power Bin 12 represents the zero or very low power situation such as waiting at a signal light. Power Bins 13 and above represent the situation where the vehicle is using positive power (i.e. driving at a constant speed, accelerating, going up a hill or some combination of all three.

Table III-2 Distribution of Driving into IVE Power Bins for Passenger Cars Operating on Highways Averaged Over All Hours (average speed: 25 km/hour)

Stress Group	Power Bins									
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.06%	0.01%	0.04%	0.08%	0.18%	0.23%	0.45%	0.93%	1.73%	3.17%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	7.27%	49.59%	14.45%	10.15%	5.79%	2.40%	0.39%	0.09%	0.03%	0.04%
Med	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.02%	0.01%	0.03%	0.03%	0.08%	0.80%	1.19%	0.47%	0.15%	0.11%
High	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table III-3 Distribution of Driving into IVE Power Bins for Passenger Cars Operating on Arterials Averaged Over All Hours (average speed: 16 km/hour)

Stress Group	Power Bins									
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.01%	0.00%	0.01%	0.01%	0.05%	0.09%	0.09%	0.18%	0.73%	2.22%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	7.51%	57.73%	18.41%	8.66%	2.81%	0.90%	0.12%	0.04%	0.01%	0.09%
Med	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.01%	0.01%	0.00%	0.01%	0.00%	0.06%	0.15%	0.03%	0.01%	0.03%
High	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table III-4 Distribution of Driving into IVE Power Bins for Passenger Cars Operating on Residential Streets Averaged Over All Hours (average speed: 19 km/hour)

Stress Group	Power Bins									
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.03%	0.01%	0.02%	0.01%	0.02%	0.09%	0.10%	0.25%	0.77%	2.24%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	7.85%	53.23%	20.74%	9.44%	3.55%	0.80%	0.25%	0.06%	0.02%	0.10%
Med	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.10%	0.13%	0.06%	0.02%	0.09%
High	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

It is clear looking at Table III-2 through Table III-4 that the times in the zero power bin, 12, (stopping and idling) increases from the highway to arterial driving. It is also noteworthy that the high stress, high power demand driving only shows up on residential streets likely due to fast accelerations from stops on less crowded streets.

III.C.2. Taxis

Several taxis were equipped with the GPS units and allowed to drive their normal daily routes. The vehicles were not restricted to specific streets. They were simply asked to operate their vehicles as they normally would, picking up passengers and dropping them off over the Mexico City Metropolitan area. Table III-5 shows the average speeds recorded for the taxis.

Table III-5 Average Taxi Speeds on Mexico City Roads

Time	Overall
5:30	34.75
7:30	25.16
9:30	20.48
11:30	15.89
13:30	14.08
15:30	11.34
17:30	16.57
19:30	22.57

The taxi speeds are, as expected, similar to a combination of highway and arterial driving from passenger vehicles. Similar congestion patterns are observed in the taxi driving patterns as the passenger vehicles in terms of steadily increasing congestion and lowering average velocities throughout the day, with the minimum speed occurring between 13:30 and 15:30.

Table III-6 presents the power-binned data for the taxis averaged over all hours.

Table III-6 Distribution of Driving into IVE Power Bins for Taxis Averaged Over All Hours (average speed: 17.41 km/hour)

Stress Group	Power Bins									
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.04%	0.02%	0.03%	0.05%	0.09%	0.19%	0.33%	0.60%	1.17%	2.30%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	5.37%	61.48%	11.47%	8.11%	4.80%	1.77%	0.25%	0.06%	0.02%	0.04%
Med	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.01%	0.02%	0.04%	0.07%	0.14%	0.54%	0.55%	0.19%	0.07%	0.12%
High	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%

III.C.3. Buses

Table III-7 indicates average Bus vehicle speeds in Mexico City. The maximum speed is in the early morning and late afternoon. There are some lowered velocities during the middle of the day, however, not as drastic an effect as for the passenger vehicles and taxis. Table III-8 indicates the power bin distributions for a bus averaged over all hours.

Table III-7 Average Bus Speeds on Mexico City Roads

Time	Overall
05:30	20.09
07:30	15.10
09:30	16.01
11:30	15.63
13:30	13.83
15:30	19.28
17:30	20.09
19:30	20.09

Table III-8 Distribution of Driving into IVE Power Bins Buses Averaged Over All Hours (average speed: 16.7 km/hour)

Stress Group	Power Bins									
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.02%	0.01%	0.01%	0.02%	0.04%	0.09%	0.19%	0.39%	0.95%	2.11%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	5.18%	59.23%	17.79%	8.72%	3.32%	0.79%	0.16%	0.07%	0.03%	0.05%
Med	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.02%	0.01%	0.02%	0.04%	0.16%	0.16%	0.08%	0.05%	0.16%
High	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.13%

III.C.4. Trucks

Table III-9 indicates average truck vehicle speeds in Mexico City. The maximum speed is in the early morning and evening. During the day the average velocity is significantly lower.

Table III-9 Average Truck Speeds on Mexico City Roads

Time	Overall
05:30	21.24
07:30	21.24
09:30	12.61
11:30	7.83
13:30	15.35
15:30	9.46
17:30	10.87
19:30	21.24

Table III-10 shows the power bin distributions for trucks averaged over all hours. A large fraction of the truck driving pattern is spent idling. This idling is attributed to the deliveries the truck drivers make while the vehicle is running. The daytime deliveries, in conjunction with daytime congestion, explain why the average velocity is so much lower during business hours and lower than buses traveling at the same time.

Table III-10 Distribution of Driving into IVE Power Bins Trucks Averaged Over All Hours (average speed: 12.75 km/hour)

Stress Group	Power Bins									
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.05%	0.17%	0.44%	1.31%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	4.29%	69.14%	17.92%	5.67%	0.89%	0.05%	0.01%	0.00%	0.00%	0.00%
Med	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
High	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

III.C.5. Summary of Driving Pattern Results

Figure III-4 compares driving speeds by hour for the four types of vehicles studied. In general, congestion lowers the average velocity during the daytime hours by 30 to 60 percent of free flow velocities. It was assumed that the early morning and late evening velocities were similar to the late evening and 6 AM data because no data was collected between 10 pm and 5 AM. Overall, various road types and vehicle types have similar average velocities. It is interesting that the fastest and lowest velocities occur on the highways, the highest speeds during the very early morning hours and lowest velocities in the middle of the day, when average speeds are even lower than on residential roadways. Delivery trucks maintain a relatively low average velocity throughout the day due to the idle time during deliveries. Buses and taxis have similar average speeds to passenger vehicles traveling on arterial and residential roadways.

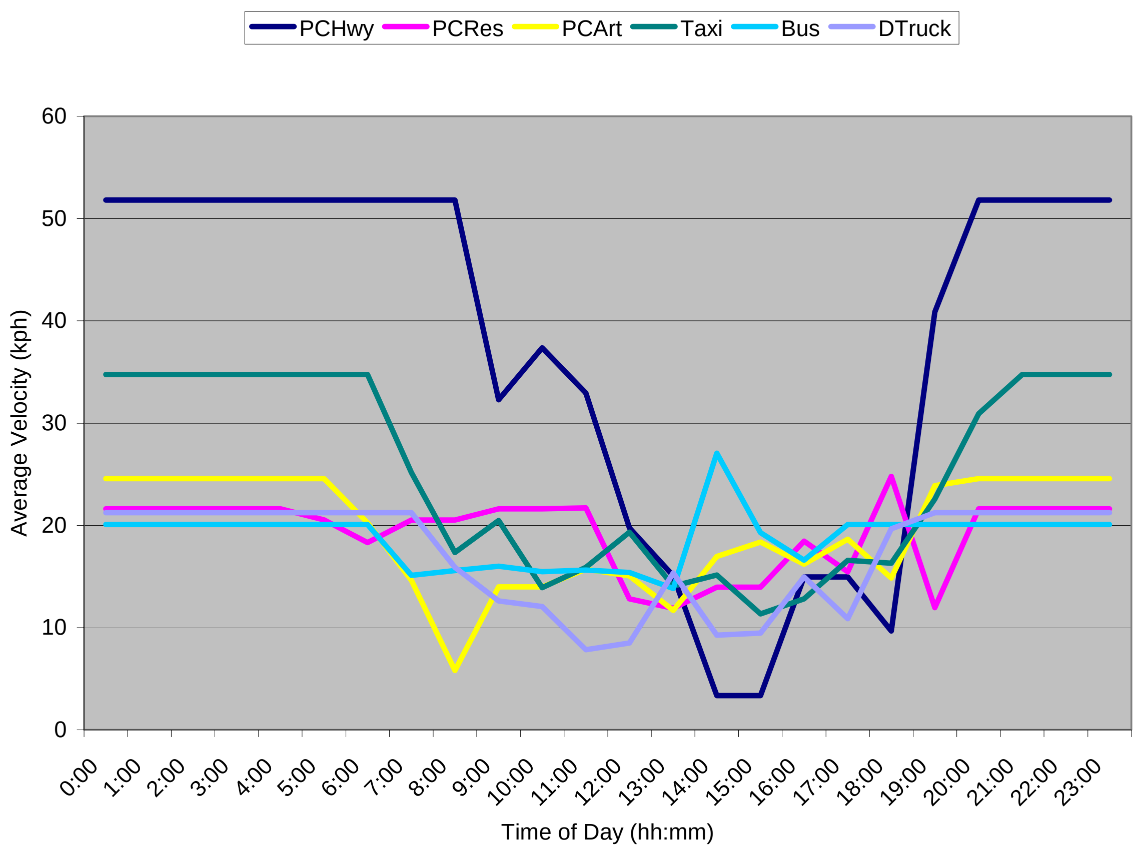

Figure III-4 Average Speeds for All Road Types and Vehicle Classes in Mexico City

Data sets using the binned data and average speeds are used in the IVE model to correct emission estimates for local driving patterns. Figure III-5 shows the distribution into driving bins for four of the main classes of driving at 05:30. The delivery trucks have the highest fraction of near idle operation and passenger vehicles on the highway have the lowest. The passenger vehicle highway and taxis have some moderate stress driving due to the harder accelerations and higher velocities in free flow conditions.

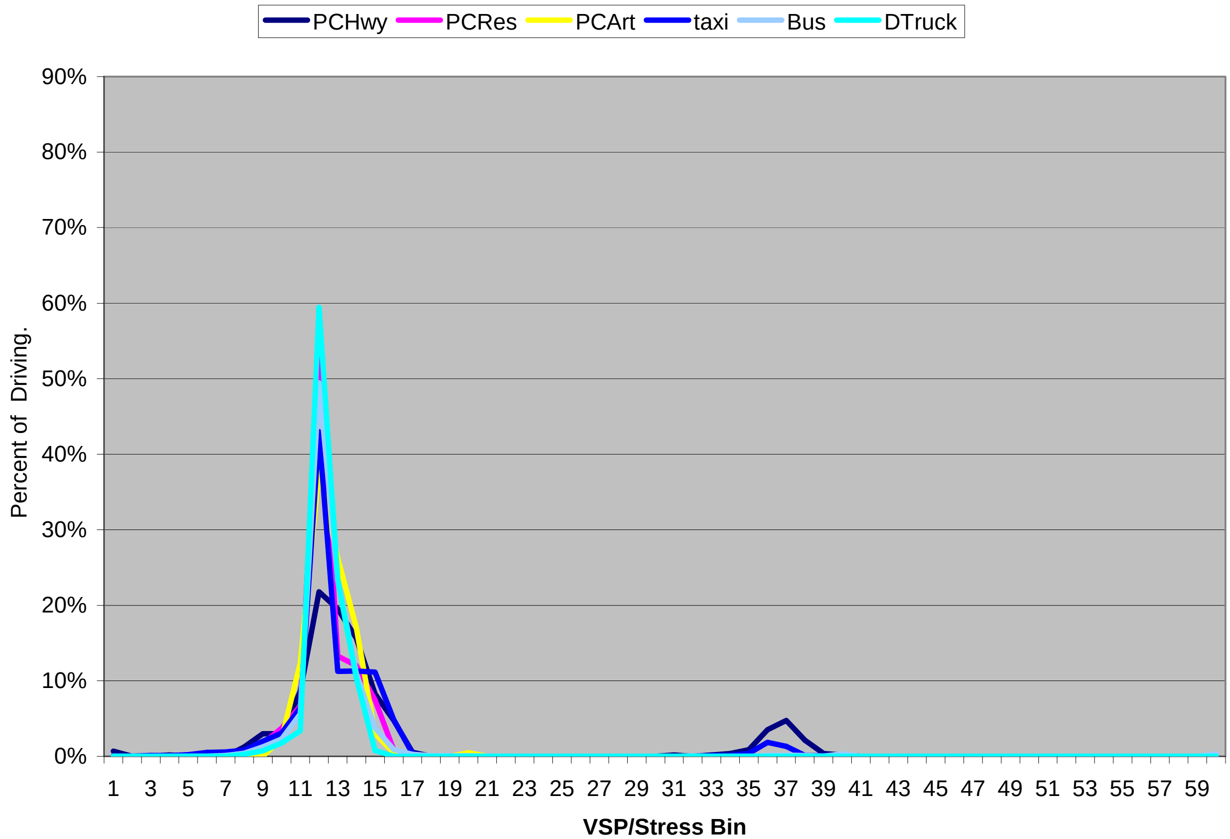

Figure III-5 Comparison of Driving Patterns for Four Major Vehicle Classes for 05:30

Figure III-6 represents driving at 09:30. In this case, the highway passenger vehicles and taxi driving look very similar and contain some higher power driving (bins above 20) which is caused by hard accelerations. The highway driving contains the lowest percentage of idle and low stress driving. All driving patterns are significantly different and contain more idle time than the early morning driving patterns.

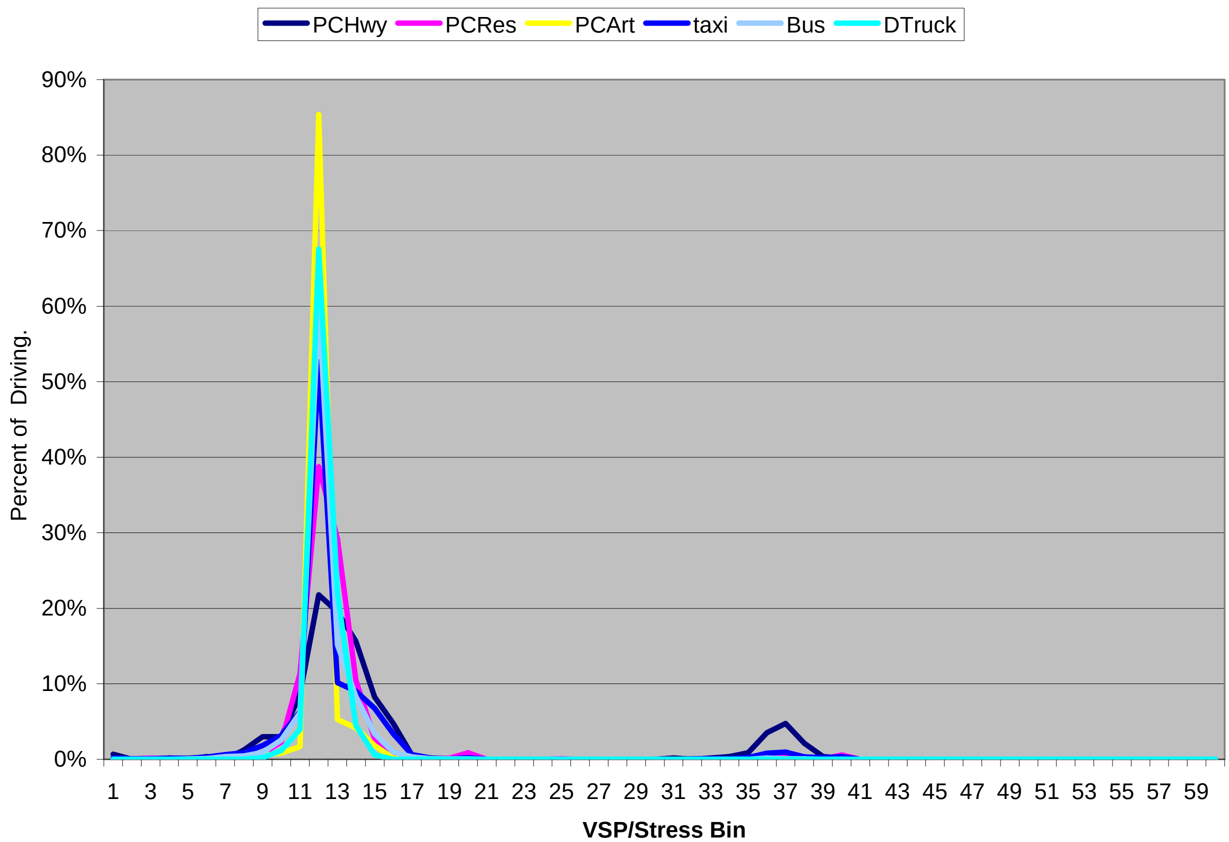

Figure III-6 Comparison of Driving Patterns for Four Major Vehicle Classes for 09:30

Figure III-7 represents the 12:30 time frame. This hour of the day represents the most uniform driving among the various vehicle classes. Very little high stress driving is seen here. Both the 09:30 and the 12:30 driving contain much larger proportions of low stress and idle driving.

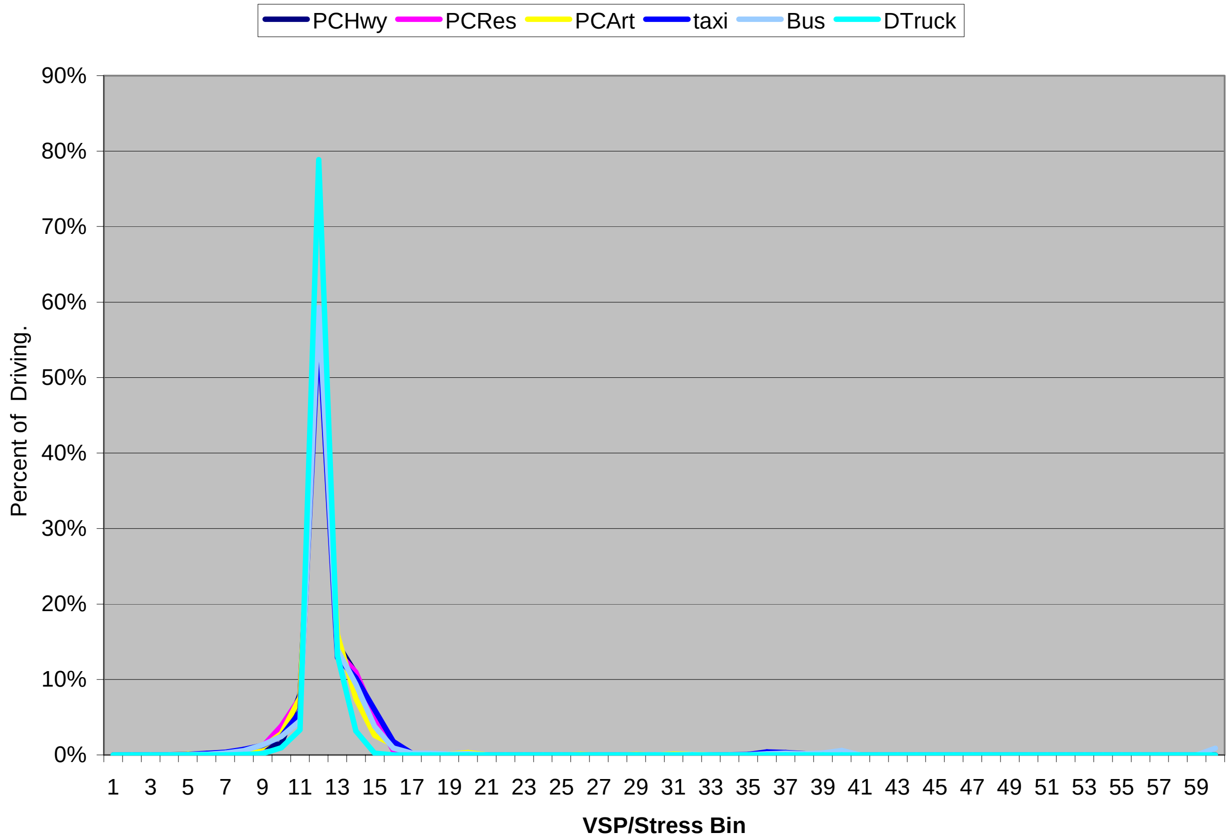

Figure III-7 Comparison of Driving Patterns for Four Major Vehicle Classes for 12:30

Figure III-8 shows the average daytime velocity on freeways for several areas worldwide. Los Angeles has the highest average velocity of 62 kilometers per hour and Mexico City has the lowest of 20 km/hr. The average freeway velocity is determined not only by the local speed limits, but the amount of daytime congestion due to high flow rates, non-vehicular objects (i.e. people, horses), and adherence to the lane dividers and other traffic laws, as well as road conditions. Figure III-9 shows a similar comparison using vehicle specific power instead of speed. Vehicle speed and specific power are loosely related so a similar trend is not unusual.

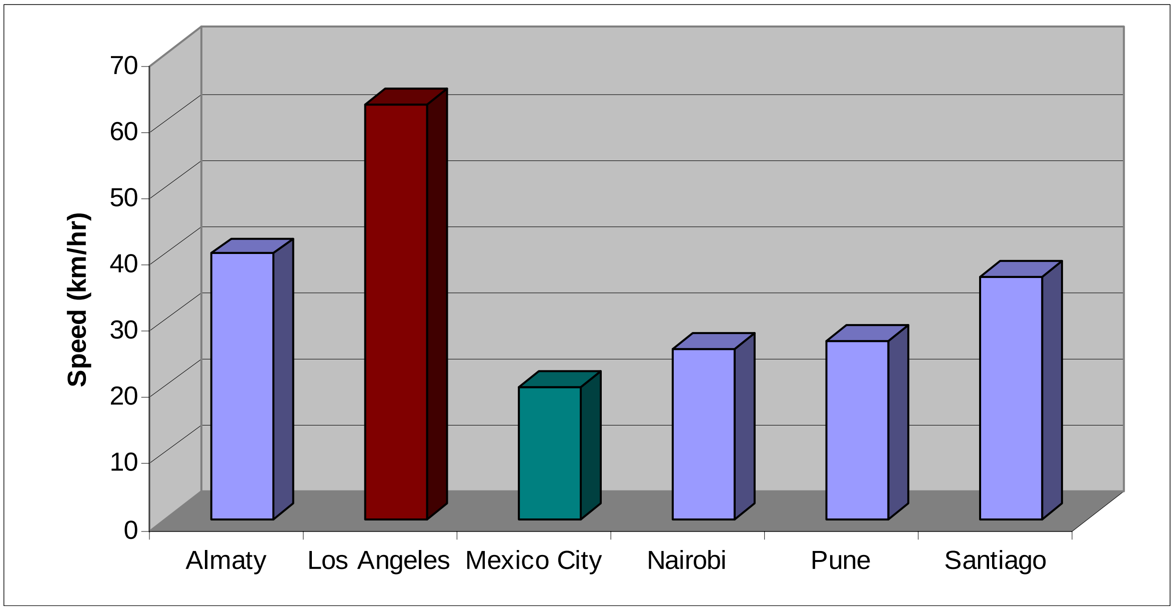

Figure III-8 Average Measured Velocity from Several Urban Areas Worldwide

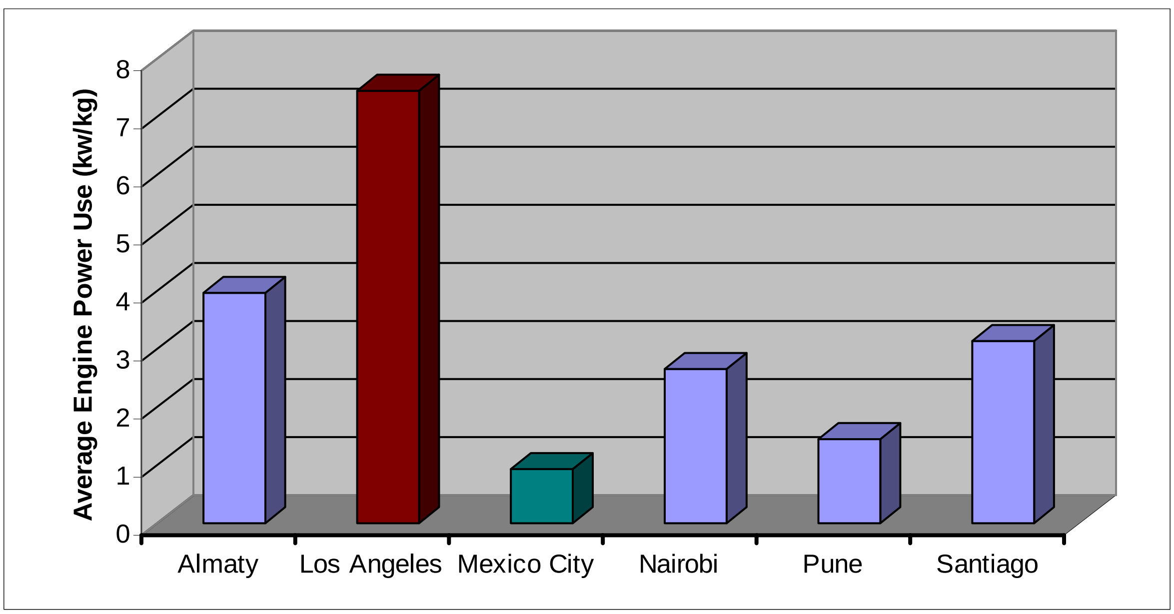

Figure III-9 Average Measured Vehicle Specific Power from Several Urban Areas Worldwide

IV. VEHICLE START PATTERNS

IV.A. BACKGROUND AND OBJECTIVES

Between 10% and 30% of vehicle emissions come from vehicle starts in the United States. This is a significant amount of emissions. Thus, it is important to understand vehicle start patterns in an urban area to fully evaluate vehicle emissions. To measure start patterns, a small device that plugs into the cigarette lighter or otherwise hooks into a vehicles electrical system has been developed. The voltage fluctuations in the electrical system can be used to estimate when a vehicle engine is on and off. This process is described in Appendix A.

The main objective of this section is to collect a representative sample of the number, time of day, and soak period from passenger vehicles operating in Mexico City.

IV.B. METHODOLOGY

The vehicle engine start patterns were collected using equipment that senses vehicle system voltage denoted VOCE units. VOCE data can be used to determine when vehicles start, how long they operate, and how long they sit idle between starts. This information is essential to establish vehicle start emissions. The VOCE units were placed in passenger vehicles and left there for a week.

IV.C. RESULTS

Table IV-1 indicates the measured start and soak patterns for passenger vehicles in Mexico City. Data was successfully collected from about 80 passenger vehicles over about 4 days for each vehicle. This provides about 340 vehicle days of data. While this amount of information is significant, it was felt that hour by hour data would include too few events and would thus not be meaningful. Thus, the data was lumped into 3 hour groups.

Table IV-1 Passenger Vehicle Start and Soak Patterns for Mexico City

Soak Time (hrs)	Overall PC	PC 06:00-08:59	PC 09:00-11:59	PC 12:00-14:59	PC 15:00-17:59	PC 18:00-20:59	PC 21:00-23:59	PC 00:00-2:59	PC 03:00-05:59
0.25	28%	31.7%	28.3%	31.9%	28.0%	29.2%	19.3%	10.9%	20.2%
0.5	9%	7.7%	12.2%	10.5%	9.1%	9.8%	12.4%	2.7%	4.9%
1	12%	9.9%	11.0%	10.0%	11.6%	18.7%	6.9%	10.9%	7.1%
2	11%	7.9%	17.6%	13.4%	11.4%	15.4%	10.3%	5.5%	2.9%
3	6%	3.4%	8.3%	6.4%	6.3%	7.9%	13.2%	2.7%	1.3%
4	3%	1.0%	3.2%	9.1%	3.0%	1.9%	13.8%	0.0%	0.7%
6	4%	1.3%	4.6%	7.5%	5.0%	4.2%	9.5%	9.8%	0.7%
8	3%	0.6%	2.6%	3.2%	3.0%	1.8%	2.7%	2.7%	6.0%
12	13%	19.2%	3.0%	3.1%	10.4%	8.3%	5.6%	35.5%	34.0%
18	11%	17.3%	9.2%	4.9%	12.3%	2.8%	6.3%	19.1%	22.1%
Events	1909	412	221	263	410	327	61	30	184
Fraction		22%	12%	14%	21%	17%	3%	2%	10%

Overall, Mexico City passenger vehicles were started 5.6 times per day. This is typical of what is observed in other urban areas that have been studied. Starts per day vary from 6-8 for passenger vehicles in the urban areas studied to date.[1] As expected, most starts occur in the 06:00 to 09:00 time frame. The second highest number of starts is in the 15:00- 18:00 time frame, and the third in the 18:00 – 21:00 time frame. The highest fraction of starts after an 8 or more hour weight occurs in the early morning to morning time frame as would be expected. These long soak times leave the engine cold and result in much greater start emissions.

[1] Studies to date have been conducted in Los Angeles, USA; Santiago, Chile; Nairobi, Kenya; and Pune, India.

V. IVE APPLICATION AND EMISSIONS RESULTS

The total daily driving in the Mexico City Metropolitan Area is on the order of 150,000,000 kilometers based on the information provided to us [1,3]. The fraction of driving per hour is estimated using traffic counts shown in

Table II-3 and averaged according to the fraction of driving on each type of street (section II.C.1). Based on the observed number of vehicles on the road types and the total length of each type of road in Mexico City, it was estimated that 58% of all driving in Mexico City occurs on arterial roadways, 7% on highways, and 35% on residential streets.

The results of the temporal activity distribution in Mexico City are shown in Table V-1. Since there was no data collected between 0:00 and 06:00 and between 19:00 and 0:00 these values were estimated using fractions observed in other urban areas. In the case of vehicle starts, Table V-1 was weighted by the fraction of passenger vehicles. Only the number of total kilometers traveled was used in the emission estimate, not the number of vehicles.

Table V-1 Estimated Fraction and VMT and Starts By Hour in Mexico City Metropolitan Area

Time of Day	Estimated Driving Fractions in Each Hour	Total Estimated Driving by Hour (kilometers)	Fraction of Starts in Each Hour	Total Estimated Starts by Hour
0:00	1.0%	1,496,112	0.5%	136,235
1:00	1.0%	1,496,112	0.5%	136,235
2:00	1.0%	1,496,112	0.5%	136,235
3:00	1.0%	1,496,112	3.2%	840,674
4:00	1.0%	1,496,112	3.2%	840,674
5:00	2.0%	2,992,224	3.2%	840,674
6:00	10.0%	14,961,120	7.2%	1,883,287
7:00	10.0%	14,961,120	7.2%	1,883,287
8:00	5.0%	7,480,560	7.2%	1,883,287
9:00	6.0%	8,976,672	3.9%	1,010,908
10:00	6.0%	8,976,672	3.9%	1,010,908
11:00	6.0%	8,976,672	3.9%	1,010,908
12:00	6.0%	8,976,672	4.6%	1,204,098
13:00	6.0%	8,976,672	4.6%	1,204,098
14:00	6.0%	8,976,672	4.6%	1,204,098
15:00	6.0%	8,976,672	7.2%	1,875,280
16:00	6.0%	8,976,672	7.2%	1,875,280
17:00	6.0%	8,976,672	7.2%	1,875,280
18:00	6.0%	8,976,672	5.7%	1,496,488
19:00	4.0%	5,984,448	5.7%	1,496,488
20:00	1.0%	1,496,112	5.7%	1,496,488
21:00	1.0%	1,496,112	1.1%	280,351
22:00	1.0%	1,496,112	1.1%	280,351
23:00	1.0%	1,496,112	1.1%	280,351
	Total	149,745,000		26,205,375

(data in red was estimated from data collected in other urban areas since these times were not observed in Mexico City)

The calculations shown above are for illustrative purposes only. They are approximations and more extensive measurements should be completed in Mexico City to improve the estimate of total daily driving in the MCMA and hourly driving outside of the hours measured in this study.

Figure V-1 shows the modeling results using the data developed or estimated from this study for Carbon Monoxide. The top line reflects start and running emissions added together.

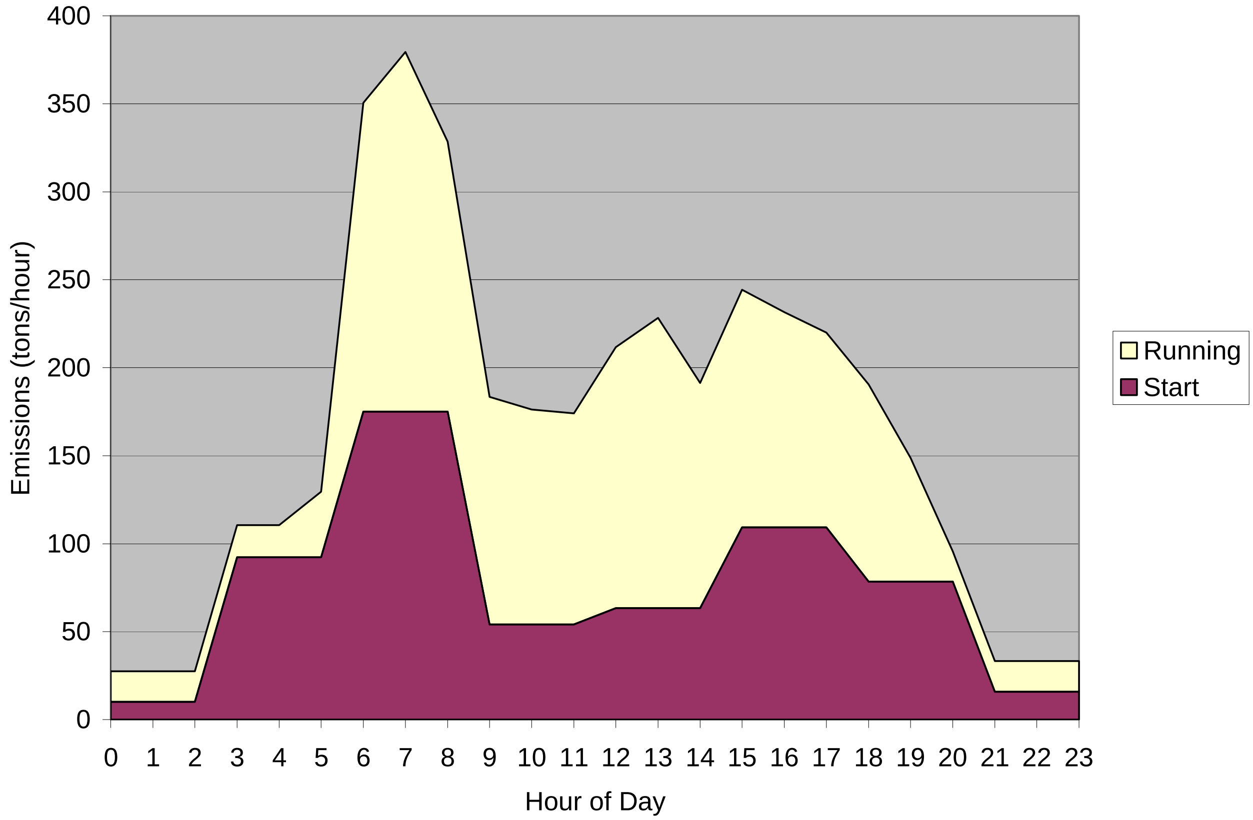

Figure V-1 Overall MCMA Carbon Monoxide Emissions

The peak CO emissions are occurring around 08:00 and 15:00. The minimum during the day occurs around 10:00. Off course, emissions are very low from 21:00 to 02:00. It is also valuable to note the importance of start emissions in Mexico City. Most of the time, they represent almost half of vehicle CO emissions. Overall, Figure V.1 reflects a total of 3900 metric tons of CO emitted per day into the air over Mexico City or an overall daily average emission rate of 26 grams/kilometer traveled including starting and running emissions.

Figure V-2 shows the modeling results using the data developed or estimated from this study for volatile organic compounds (VOC) including evaporative emissions. The top line reflects start, running, and evaporative emissions added together.

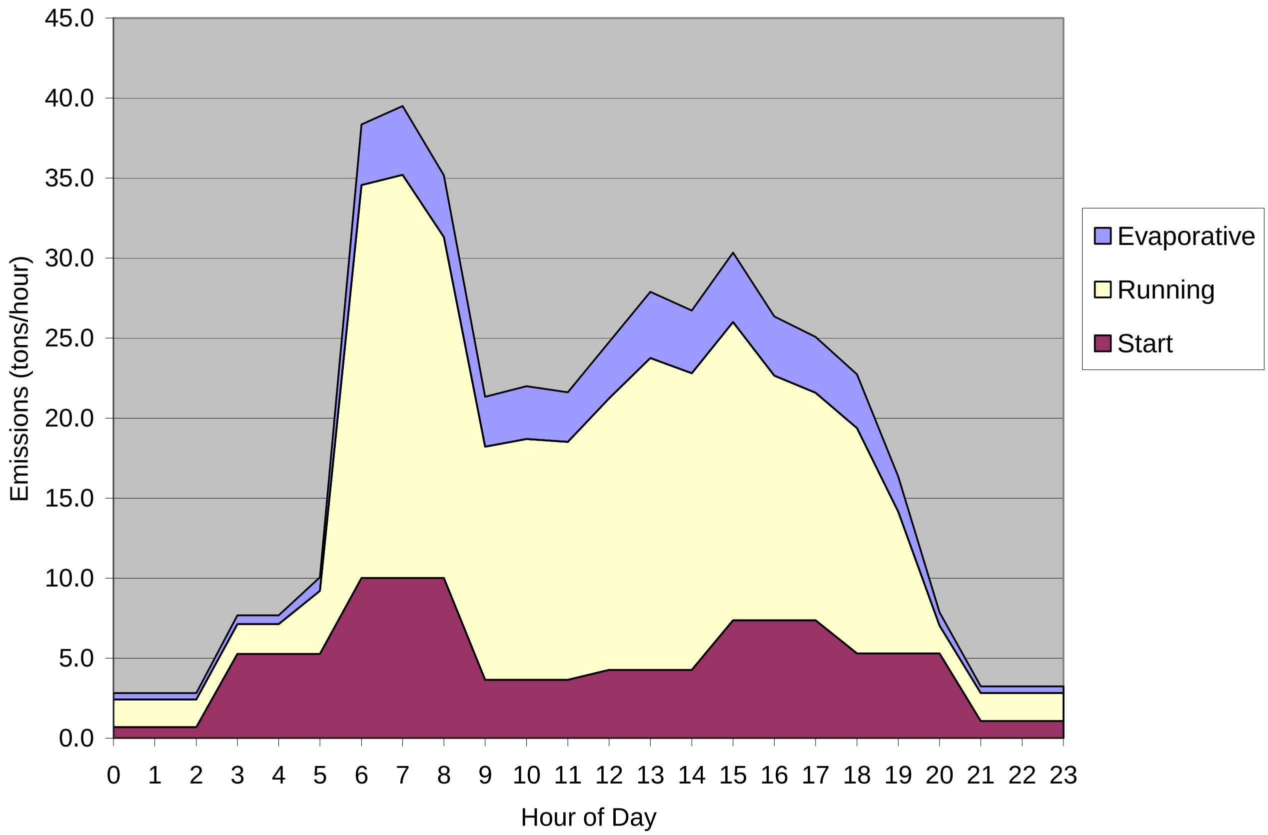

Figure V-2 Overall MCMA Volatile Organic Emissions

There are two VOC peak emissions, one occurring in the morning, which could facilitate ozone formation. Start emissions are not as great a percentage of emissions as is the case for CO, but they are still large. Evaporative emissions are somewhat important as well. Figure V-2 reflects a total of 374 metric tons per day of VOC emissions going into the air over the MCMA or an overall daily average emission rate of 3 grams/kilometer including starting, running, and evaporative emissions.

Figure V-3 shows the modeling results using the data developed or estimated from this study for Nitrogen Oxides (NOx). The top line reflects start and running emissions added together. Start emissions are much lower in this case although still large. As is the case for CO and VOC, there is a bimodal distribution of emissions with the largest peaks occurring in the morning and the afternoon. Figure V.3 reflects a total of 411 metric tons per day of NOx going into the air over the MCMA or an overall daily average emission rate of 3 grams/kilometer including starting and running emissions.

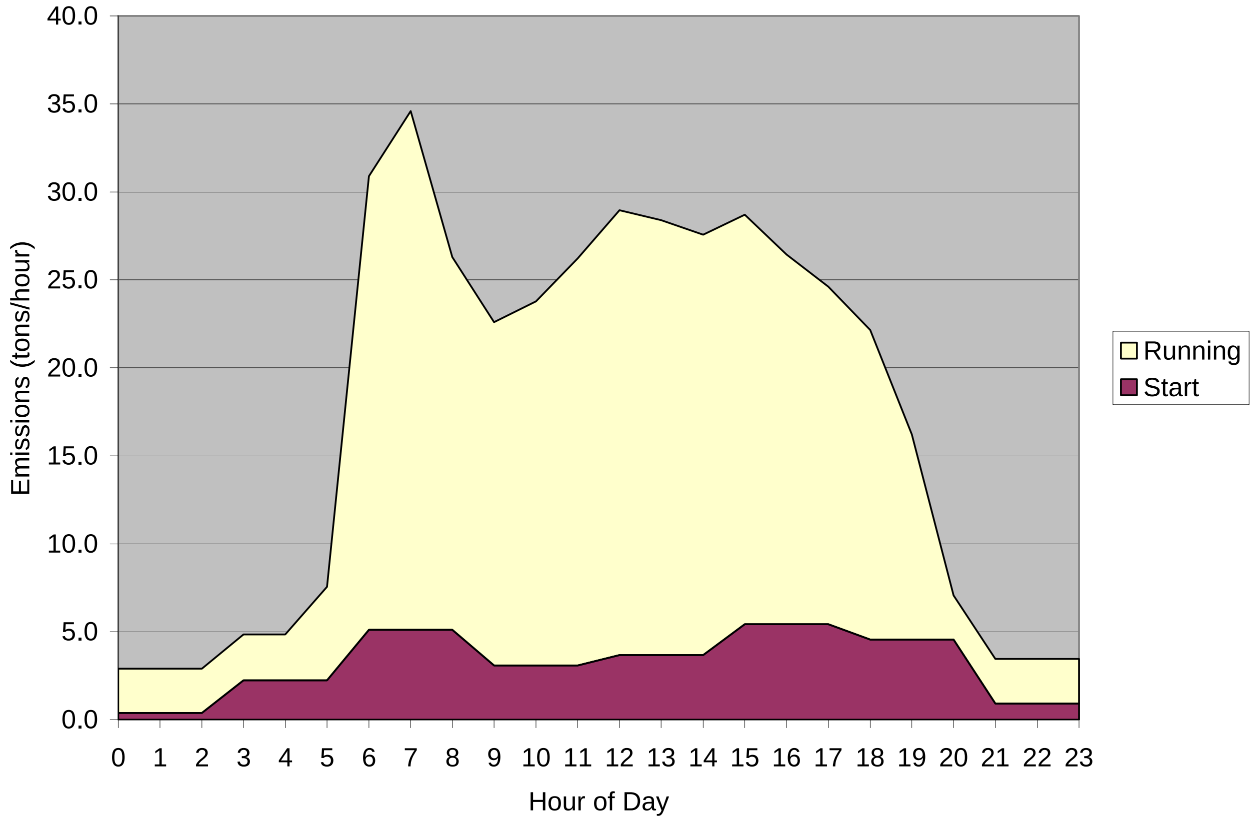

Figure V-3 Overall MCMA Nitrogen Oxide Emissions

Figure V-4 shows the modeling results using the data developed or estimated from this study for Particulate Matter (PM). The top line reflects start and running emissions added together. Start emissions are much lower in this case although still large. Figure V.4 reflects a total of 15 metric tons per day of PM going into the air over Mexico City or an overall daily average emission rate of 0.10 grams/kilometer including starting and running emissions.

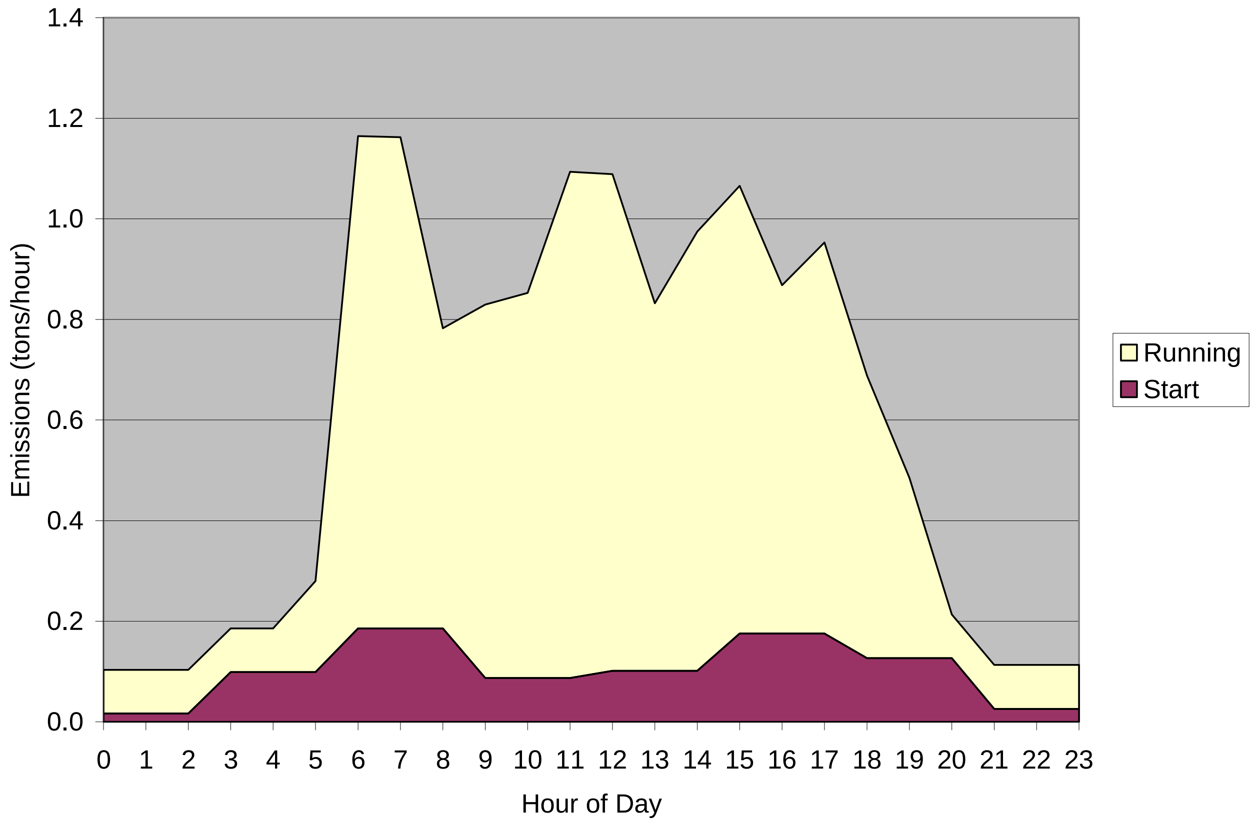

Figure V-4 Overall MCMA Particulate Matter Emissions

Figure V-1 through Figure V-4 were calculated based on a total daily driving of 150 million kilometers in the MCMA. The emission numbers will of course have to be modified if the total kilometers per day measured in the MCMA are greater than 150,000,000 kilometers.

To better understand the emissions created from the Mexico City vehicle fleet, it is useful to look at the contribution of each type of vehicle class. For Mexico City, the major vehicle categories include light duty passenger vehicles and trucks (LD), two wheeled vehicles (2w), taxis (taxis), buses (Bus), and trucks (Truck). The fraction of travel from each of these types of vehicles is shown in the last column of Figure V.5. The percent contribution each of these vehicle types to vehicular CO, VOC, NOx, and PM emissions is also shown in Figure V-5. These results indicate the majority of vehicular CO, VOC, and NOx are from passenger vehicles, similar to their percentage use. Both the 2 wheelers, buses and especially trucks have a disproportionate contribution to PM and to a lesser extent NOx emissions. This is due to the high NOx and PM emission rates of these types of vehicles.

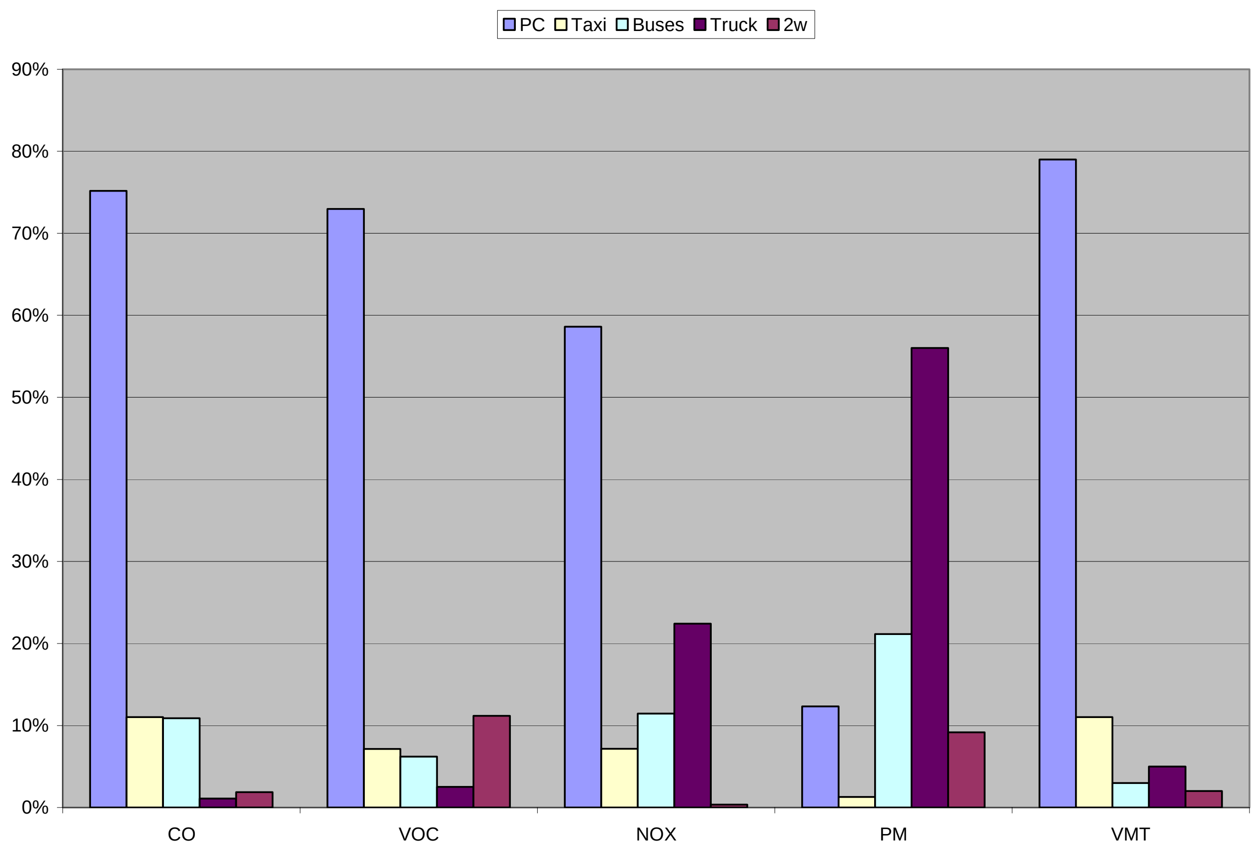

Figure V-5 Emission Contribution of Each Vehicle Type in the MCMA

Clearly, to reduce PM emissions in Mexico City, buses and trucks must be controlled. To reduce NOx, buses, trucks, and passenger vehicles must be further controlled.

To understand the importance of mobile sources to the inventory in relationship to other anthropogenic sources, the relative contribution to each pollutant to the inventory for the Mexico City Metropolitan Area (MCMA) estimated emissions for 2004 is shown in Figure V-6. The mobile sources are the top bar, estimated from the IVE data collected in this study. The other emissions were derived from the Air Quality in Mexico City report (1). This figure shows the importance of mobile sources to the inventory in this area. More than 80% of the CO and NOx is estimated to come from mobile sources. Approximately 23% of the SO2 and 30% of the PM10 are from mobile sources.

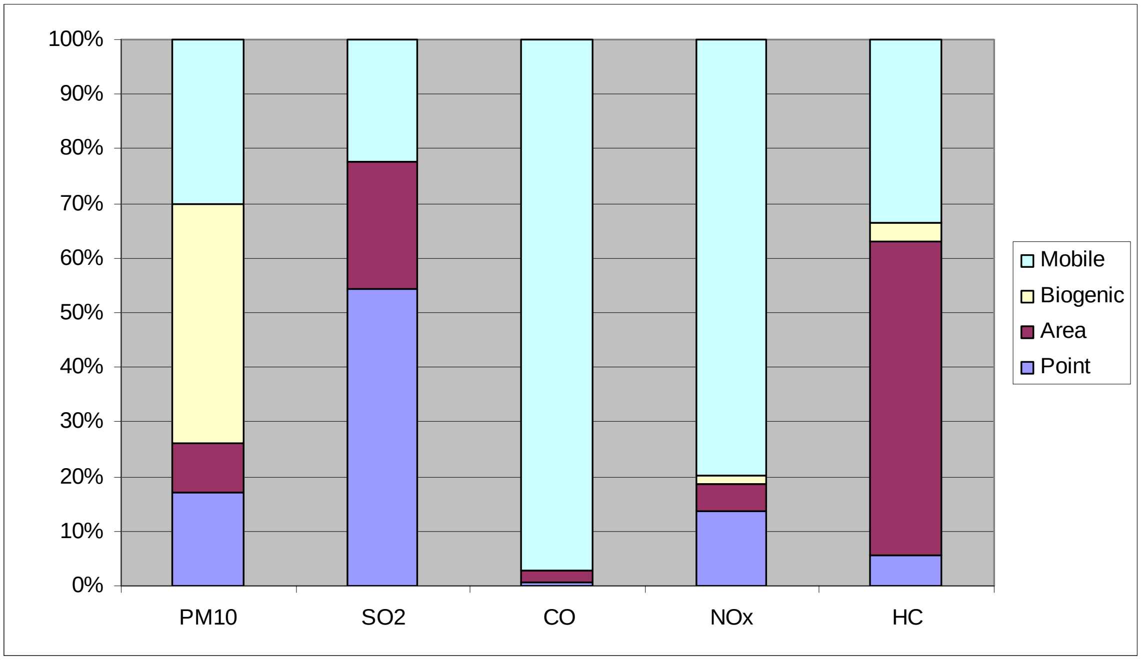

Figure V-6 Contribution of each source to the Base Case 2004 MCMA Inventory

Another calculation that is of interest is the overall per kilometer emissions of Mexico City vehicles compared to vehicle fleets in cities of other countries. Figure V-7 compares Mexico City with Los Angeles, Santiago, Nairobi, and Pune. These locations have a very different profile of vehicle fleet, fuel type, and driving patterns. It should be noted that the emissions shown in Figure V-7 and later in Figure V-8 and Figure V-9 include start and evaporative emissions that were prorated over the daily driving for all fleets shown.

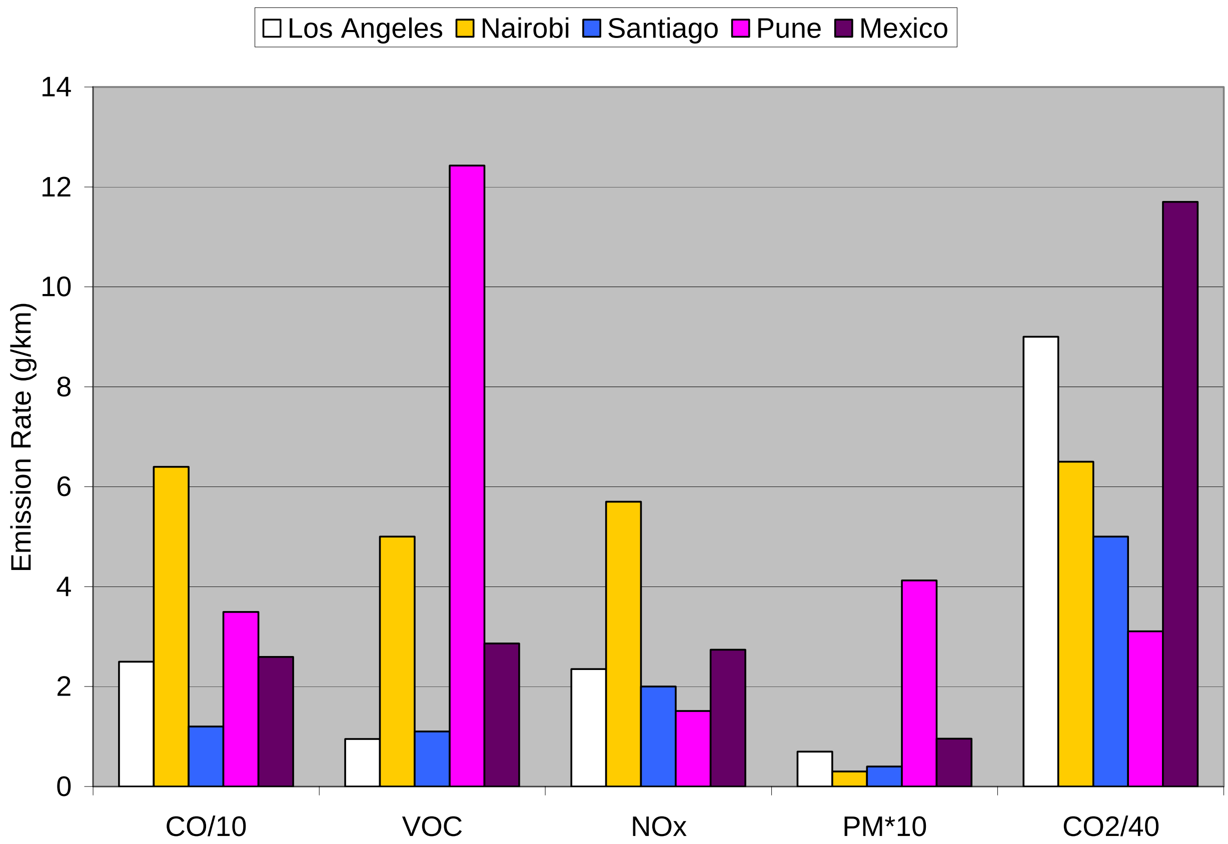

Figure V-7 Comparison of Daily Average Emission Rates in Countries Studied to Date

The Mexico City fleet has the second highest emissions of both NOx and PM, and the highest CO2 emissions. It is a moderate producer of CO and VOC. The high PM emissions, which are 40% higher than Los Angeles and 200-300% times higher than Nairobi and Santiago, are particularly troubling because they suggest a commensurate high emission rate of toxics. Figure V-6 and Figure V-7 illustrate the possibilities that if emission rates were lowered, significant emissions reductions could be achieved in the Mexico City area. Figure V-8 and Figure V-9 provide a view of a possible future emissions scenario in the MCMA with and without fuel improvements.

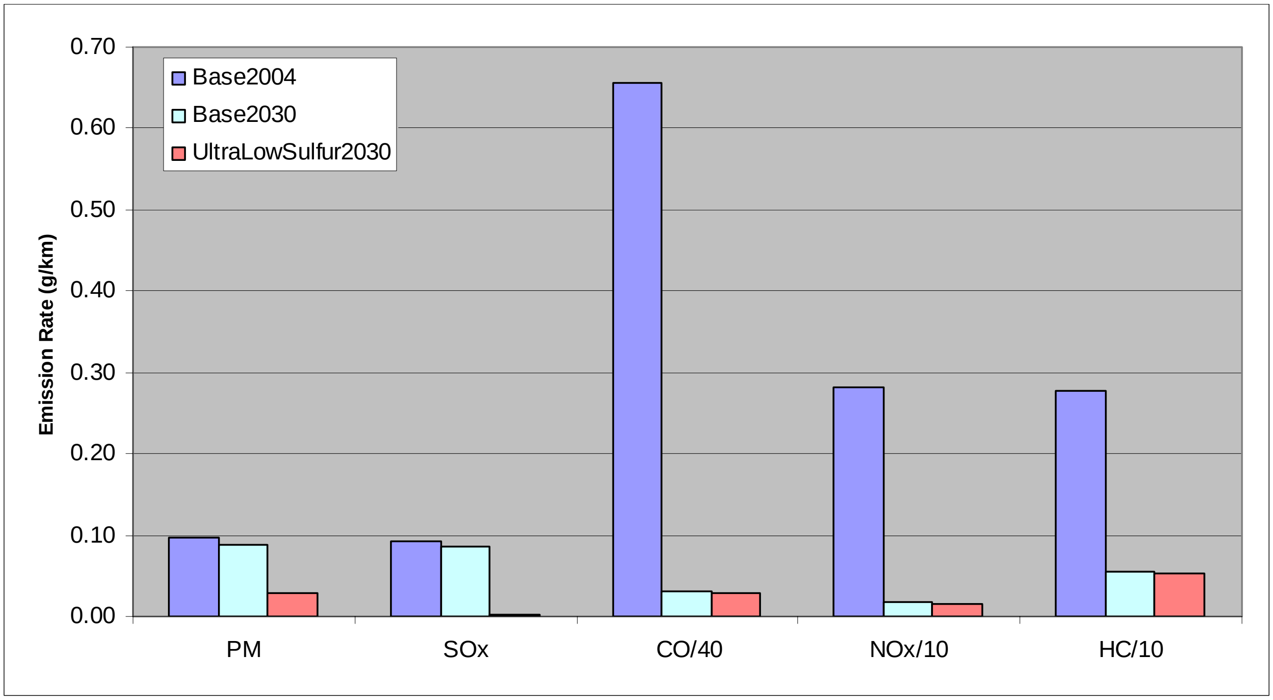

Figure V-8 Change in Emissions with an Improved Fleet in the MCMA

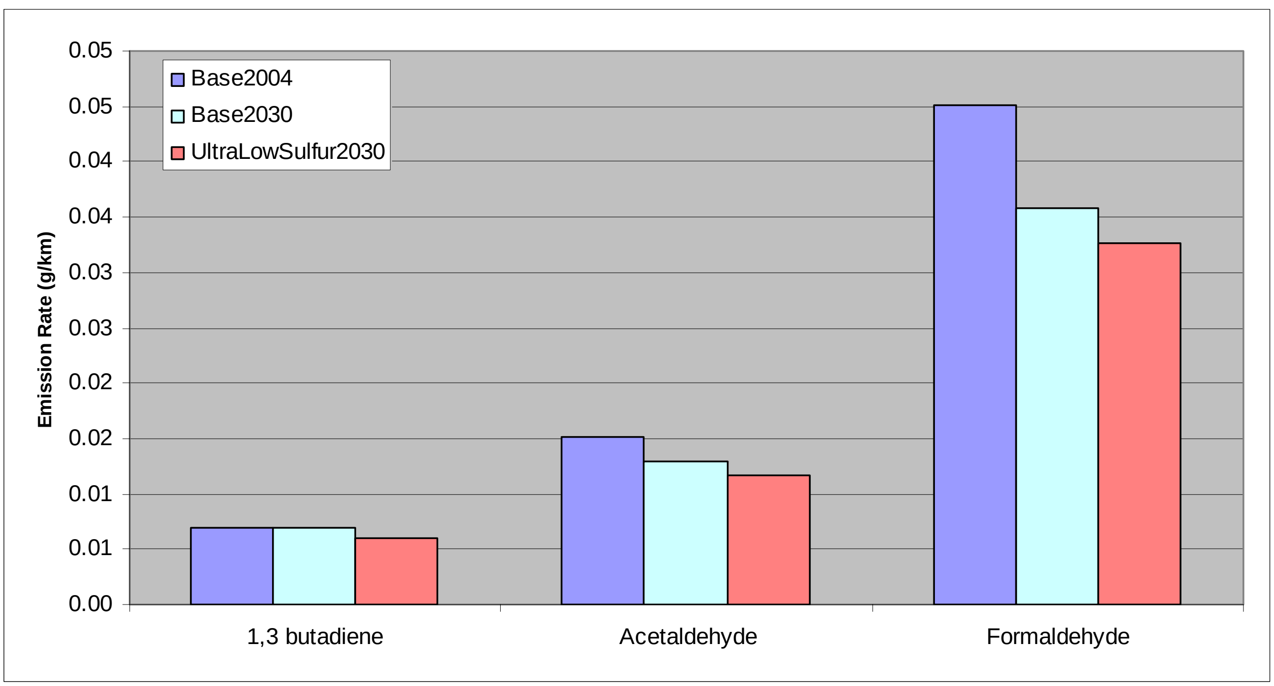

Figure V-9 Change in Toxic Emissions with an Improved Fleet and Fuel in the MCMA

To create Figure V-8 and Figure V-9, it was assumed that a future vehicle fleet would consist of all light and medium duty vehicles meeting Ultra Low Emission Vehicles (ULEV) and all diesel fueled vehicles would have PM and NOx controls. The ultra low sulfur fuel (15 ppm sulfur in gasoline and diesel) enables the controls to perform at their peak levels, further lowing emissions. This scenario is reflective of a fleet many years in the future, such as 2030. It is also assumed that driving in

Mexico City increases by 80% during the time the fleet is being improved. The result is emissions that are significantly lower for all pollutants, and emission rates that are significantly lower than present US values. The Figures above are only intended to illustrate that significant improvement in local emissions can take place using today's modern vehicle technologies and improved fuel quality even with considerable growth in driving in Mexico City. A more detailed analysis of the role technology and fuel improvements could play in the MCMA is included in a separate report[2].

In conclusion, this study has developed basic data to allow for improved estimates of emissions from the Mexico City fleet. Additional studies are needed to further improve emission estimates in Mexico, but significant planning activities can occur using the data in this report. Our recommendations are as follows:

1. Use the IVE model along with air quality measurements to map out a strategy for improved future air quality, and then seek to improve the air quality management process by further upgrading the Mexico City database.

2. Investigate the variations of the fleet, activity and fuel quality on areas beyond Mexico City if extrapolations are to be made to the entire metropolitan area.

3. Improve emission factors for in-use vehicles. More emission studies are needed to verify the operating emissions of passenger vehicles, buses and trucks in Mexico City to insure that the best emission factors are being used. This research is being planned for later in 2004.

4. Improve the estimate of total VMT for the entire Mexico City region to support overall emission estimates.

5. Directly measure toxic emissions from these vehicles to better quantify the toxic emission rates from these sources.

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2. “Mexico City Mobile Source Emissions Inventory Analysis” Nicole Davis, James Lents, March 15, 2004

3. “Inventario de Emisiones a la Atmosfera: ZonaMetropolitana del Valle de Mexico 2000” Sectretaria del Medio Ambiente, Gobierno del Distrito Federal Mexico, la Ciudad de la Esperanza

Appendix A

Data Collection Program Used in Mexico City

International Vehicle
Emissions Model

Field Data Collection Activities

Table of Contents

A.I. Introduction

This paper provides a description of the activities involved in a 2-week cooperative on-road vehicle study carried out in selected international urban areas. This International Vehicle Emissions (IVE) study is designed to efficiently collect important vehicle related data to support development of an accurate estimate of on-road vehicular emissions for the selected urban area.

Emissions from on-road vehicles vary considerably depending upon three factors: 1) vehicle type, 2) driving behavior, and 3) local geographic and climatic conditions. Vehicle type is defined by the engine air/fuel management technology and engine size, emissions control technology, fuel type, accumulated use and age of the vehicle. Driving behavior can be described by a measured velocity profile of the local driving, the number and distribution of vehicle starts and daily miles traveled. Local conditions that affect vehicle emissions include road grade, fuel quality, ambient temperature, ambient humidity, and altitude of operation. Data collection in this study will help to define vehicle types and driving behavior in the urban area by collecting four types of information as indicted in Table A.1.

Table A.1: Types of Data Collection in the IVE Study

Data Collection	Method of Data Collection	Described in Section
On-Road Driving Patterns	GPS Instrumented Passenger, Bus, 2-Wheeler, and 3-Wheeler Vehicles	III
Vehicle Technology Distribution	Digital Video Collection and Parking Lot Surveillance	IV, V
Vehicle Counts on Selected Streets	Digital Video Collection	IV
Vehicle start-up patterns	VOCE units placed in recruited vehicles	VI

The collected data will be formatted so that it is usable in the new International Vehicle Emission Model developed for estimating criteria, toxic, and global warming pollutants from on-road vehicles. The collected data may also be useable for other purposes by the local urban area.

Local temperatures, humidity, fuel quality, total vehicular counts, and total driving amounts are not determined as a part of this study. Locally collected data is typically relied upon for these parameters. It may be possible to make a very rough approximation of total vehicle driving from the collected data if the number of vehicles in the urban area is known, but this approximation is subject to considerable error. To make an accurate emission analysis, the total amount of driving in an urban area must be assessed. If key data outside of the scope of this study is not available, then steps should be considered to determine this important data. ISSRC will work with the urban area to suggest ways to make such assessments.

A.II. Collecting Representative Data

Before the specific study elements are described, it is important to consider the overall data collection process. The IVE study is carried out over a single 2-week study period. Given that there are limited equipment and study personnel, it is not possible to collect a complete data set over an entire urban area. Thus, the study must be designed to collect representative data that can be extrapolated to the full urban area. The IVE study process has been designed with this thought in mind.

On-road driving varies by the time of the day, by the day of the week, and by the location in an urban area. To account for this, during the IVE study, data is collected at different times of the day and in different locations within an urban area. This study is not designed to generally capture data on the weekend or very late at night. Thus, the study is primarily applicable to weekday driving and only limited weekend extrapolations and assumptions about traffic flow very late at night can be made. Conducting a weekend study will produce valuable information and should be considered for future research[2]. It should also be noted that the collected data could be improved in the future by replicating data collection activities to improve statistics, expanding the parts of the city studied, and expanding the times that are studied.

Selecting Parts of a City for Study

Three representative sections of the city are normally selected for the IVE study. The areas selected should represent the fleet makeup and the general driving taking place in the city. It is recommended that one of the study areas represent a generally lower income area of the city, one of the study areas represent a generally upper income area of the city, and one of the study areas represent a commercial area of the city. The sections representing the upper and lower income areas of the city for study should not be the absolute poorest or richest part of the city. It is better to select areas that are representative of the lower half of the income and the upper half of the income. Normally the urban center is selected as the best commercial area to study. **Due to their much greater knowledge of their own city, it is an important role of the local partners for an IVE study to play a primary role in the selection of the three appropriate parts of the urban area to study.** ISSRC is amenable to modifications in the recommended study areas due to unique situations that might occur in a particular urban area. For example, there may not be a large enough discernable upper or lower income area.

The following criteria should be used as guidelines for selecting adequate sites:

- ♦ **Selection of a low income, upper income, and commercial area with a variety of streets (i.e. residential, freeway, and arterial) in the area.**

- ♦ **Accessibility to a representative parking lot or on-street parking where up to 150 parked vehicles can be studied within 10 minutes walking of each site selected.**

[2] In Los Angeles, some of the worst air pollution levels now occur on the weekend. This is due to the modified driving patterns and fleet mix that occurs on weekends compared to weekdays.

Selecting Driving Routes for Study

Within each of the study areas, different types of streets must be analyzed to gather data representative of all of urban streets. Streets are often classified into three general groupings. The first group represents streets that are major urban connectors and can connect one urban area to another. These streets are typically characterized by the highest traveling speed in free-flow traffic with minimal stops from cross-flow traffic and are commonly referred to as **highways** or **freeways** in some cases. The second classification of streets represents streets that connect sections of an urban area. They may connect one section of an urban area with another or may provide an important connection within a section of the urban area. These streets are typically referred to as **arterials**. The third classification of streets represents the streets that take people to their homes or small commercial sections of an urban area, and are usually one- or two-lane roadways with a relatively lower average speed and frequent intersections. These streets are typically referred to as **residential** streets.

Due to time limitations, only nine street-sections can be effectively studied during the IVE project. The term "street-section" as used in this study can include parts of more than one street, but to simplify data analysis, the streets that are included within a single street-section should all be the same street classification. For example, residential streets should not be mixed with highways in a single street-section. It is important that the nine selected street sections represent each of the important street types in the urban area.

The following criteria should be used as guidelines for selecting suitable street- sections:

- ♦ **For each of the street-sections, accessibility to a safe and legal location for the camera team to be dropped where 2 cameras & tripods can be set up with a clear view of the nearby traffic (tripods are approximately 0.5 meters in diameter). This location should be within approximately 5 minutes of the driving route. Preferably, the cameras will capture a portion of the driving trace[3] being covered by the chase vehicles.**

- ♦ **Access to the different street types in a part of the city so that the chase vehicle can move from one street-section type to another within 10 minutes driving time. This insures that time loss in moving from the highway street-section to the residential street section to the arterial street section and back does not require too much lost driving time.**

- ♦ **A driving trace for each street segment must be defined so that the driver can complete it in 50 minutes or less under the worst traffic conditions that will be encountered during the study.**

In the upper and lower income sections of the city, it is recommended that a highway street-section, an arterial street-section, and a residential street-section be selected in each of the two areas. In the commercial area it is recommended that a highway section and two arterial sections be selected for study. As noted earlier, the defined street-sections do not have to be the same street, although they should be the same classification of street for a street-section grouping. Figure A.1 shows an example of three street-segments designed for an upper-income area in Los Angeles, California.

[3] A driving trace is the route followed by the chase vehicles as they drive along one of the selected street-sections.

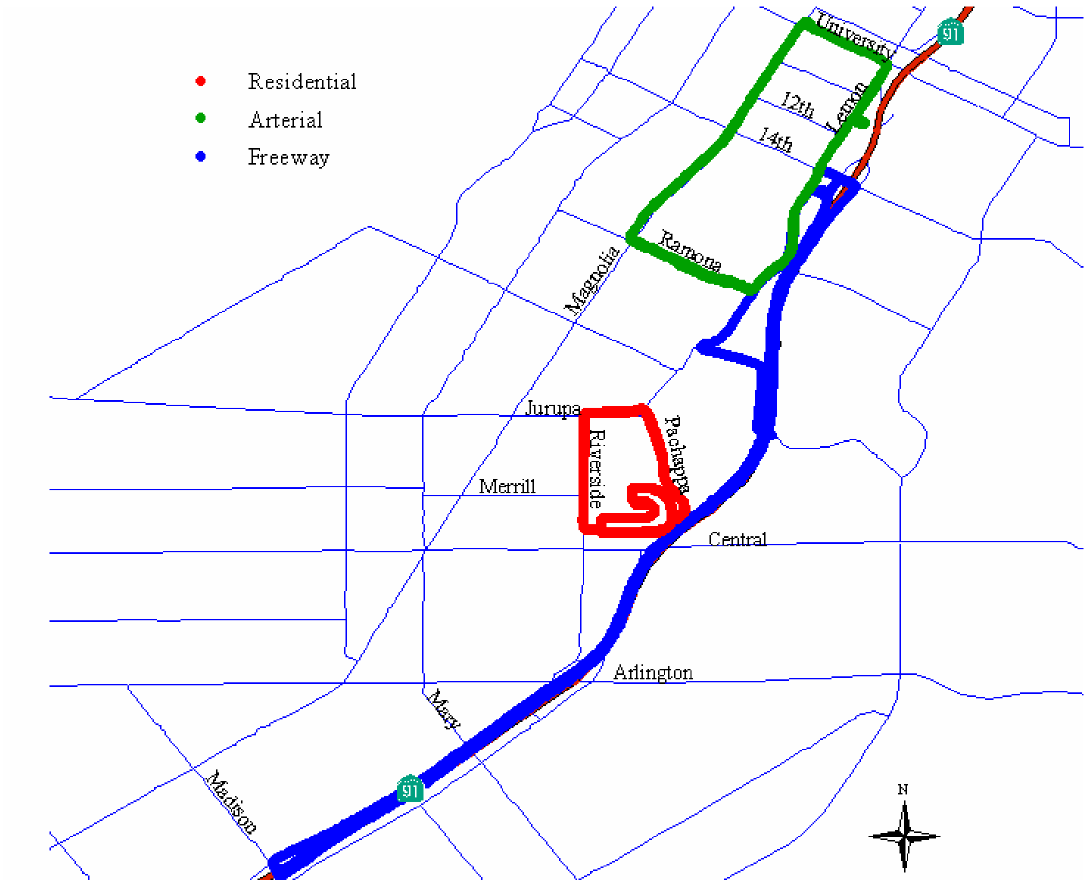

Figure A.1 Example of a Residential, Arterial, and Freeway Street-Segment Selected for a Single Study Area

Designing a set of interconnected arterials or residential streets that ultimately connect to one another to form a circular drive can provide an effective street-section for this study. This circular design is often not possible with highways and the driver may have to drive one way on a highway and then return on that same highway on the other side of the street. During less congested times, it is often possible that a driver can drive the designated street-section more than one time. This is not a problem and simply adds to the database during a time period. **As is the case with selecting general areas of the city to study, it is an important role of the local partners to select the nine streets to be studied.** ISSRC will review the nine selected street sections and make recommendations as necessary.

Times of Data Collection

It is also important to collect data at different times of the day to account for traffic congestion and resulting changing flow rates as the day progresses. Testing is carried out normally over a 6 day period for the collection of urban driving patterns and vehicle technology data. Since driving in difficult traffic situations and collecting on-road vehicle technologies are typically very tiring and dirty activities, data collection is held to about 7 hours each day. Since information is typically needed from 06:00 to 20:00 to understand the complete cycle of traffic flow, the driving times are set for 7 hours in the morning on one day of data collection and 7 hours in the evening the next day of data collection. Data collection is normally started at 06:00 and continues until shortly before 13:00 for the morning data collection and starts at 13:00 and goes to shortly before 20:00 for the afternoon data collection. If special circumstances exist in an area where data is desired at earlier or later times, this should be discussed in advance of the study period.

Collecting Other Related Data

Parking lot data is collected in the same parts of the city where on-road driving and technology data are collected. It is desirable to capture vehicle technologies that exist down to 1% of the fleet. To increase the probability of seeing the types of vehicles that exist at the 1% level and to improve the accuracy of vehicle use data, it is important to collect data on more than 800 randomly selected parked vehicles over the 6-day study period. Generally, it is attempted to collect data on 300 vehicles in each of the three selected sections of the urban area; however, vehicle availability in lower income sections often reduce the total collected data to 800-850 vehicles in the overall study.

In the case of the collection of start-up data, individuals are asked to carry small data collection devices in their vehicles. **It is important that the individuals selected for this portion of the study should be representative of the general driving population.** It would be best to study at least 300 persons, but lack of time and equipment does not allow this large of a study. As discussed later in this paper, it is more efficient to collect data over more days from fewer persons. In all, it is hoped that more than 100 persons will use the units for at least 3 days per person to provide 300 person-days of information.

A.III. On-Road Driving Pattern Collection Using GPS Technology

Collection of on-road driving pattern data will be conducted on the streets identified by local agencies as discussed in Section II. This data collection will be conducted using combined Global Positioning Satellite (CGPS) modules with microprocessors developed by CE-CERT and GSSR. The unit is placed on a vehicle that drives on predetermined street sections with the flow of traffic. The CGPS module collects information about the location, speed, and altitude on a second by second basis.

For areas with large passenger vehicle, bus, 2-wheeler, and/or 3-wheeler populations it is important to collect independent driving pattern data for all of these vehicles since they will likely operate differently. Eight CGPS modules will be provided for the study: three for passenger vehicles, one for a 2-wheeler, and two each for buses and 3-wheelers. An additional two units are brought as backup units. The collection procedure for each type of vehicle is described later in this section.

Figure A.2 shows a typical CGPS unit. They weigh about 5.5 kilograms each and can be strapped to the back of a 2-wheeler or placed on the seat of a passenger vehicle. An antenna is required. In the case of 2-wheelers, 3-wheelers, and buses some experimentation may be required to fina a suitable location for the antenna. The antenna is magnetic and will stick to the roof of automobiles easily. In the case of buses with fiberglass roofs, 2-wheelers, and 3-wheelers tape or other attachment means may be necessary. The antenna may be taped to the top of the CGPS box, the bus roof, or may be attached to the helmet of the 2-wheeler operator.

Figure A.2 CGPS Unit

Driving Pattern Collection for Passenger Vehicles and 2-wheelers

To collect general passenger vehicle driving patterns, the local partners for the study must arrange for three passenger vehicles and local drivers to drive for eight hours each day for 6 days. In addition, one CGPS unit will be dedicated to the collection of 2-wheeler data[4]. The local study

[4] The decision to collect data from 2-wheelers and 3-wheelers is dependent upon the size fraction of these types of vehicles in the fleet. In the case of studies in the United States and Chile it was determined that 2-wheelers and 3-wheelers were too small of a portion of the fleets to justify the collection of driving pattern data for these vehicles.

partners should identify up to six 2-wheelers and drivers to participate in this study[5]. Figure A.3 shows a passenger vehicle equipped with a GPS module as used in Santiago, Chile. The CGPS units do not require an operator or laptop computer. Thus, only the driver is necessary.

Figure A.3: GPS Instrumented Vehicle in Santiago, Chile

These drivers are asked to operate their vehicles on the nine designated street-sections (see Section II for a discussion of street-sections) over the course of the study. The purpose of the instrumented vehicle is to collect representative data concerning local passenger vehicle driving patterns. To accomplish this, the vehicle is operated on the selected street-sections in accordance with normal traffic at the time they operate. It is important that the drivers duplicate typical driving patterns for the study area. Each day, one of the instrumented vehicles is assigned to a different selected area of the city (see Section II for a discussion of the general test areas of the urban area). The vehicles will operate in their section of the urban area for two days before moving to the next selected area of the city. The first day they will operate their vehicles in the morning timeframe and the second day they will operate their vehicles in the afternoon timeframe. Each vehicle will operate on a selected street-section for 1 hour and then move to another of the selected street-section in a predetermined pattern. Since there are three street sections in an area, after the third section is reached, the driver will return to the first street section and repeat the process until the end of the 7-hour test period. Table III.1 shows the driving circuits for the three passenger vehicles and 2-wheeler. It is important that the drivers adhere strictly to the defined street-section order to insure that all times of the day are covered. The 3 parts of the urban area designated for study are denoted as Area A, Area B, and Area C. The 3 street-sections selected in each area are designated as street-section 1, 2, or 3. Thus the highway street-section in Area A is designated as Street-Section A.1 and similarly for the others.

[5] It should be okay to use as few as three 2-wheelers over the course of the study. It is important to get a cross section of 2-wheeler types that represent different engine sizes. The use of 6 2-wheelers will reduce driver fatigue during the course of the study. One 2-wheeler could operate each day through the 6-day study.

Table A.2: Passenger Vehicle and 2-Wheeler Driving Circuits

Start	End	Passenger Vehicle 1	Passenger Vehicle 2	Passenger Vehicle 3 & 2-wheeler
Day 1				
06:00	07:00	Street-Section A.1	Street-Section B.1	Street-Section C.1
07:00	08:00	Street-Section A.2	Street-Section B.2	Street-Section C.2
08:00	09:00	Street-Section A.3	Street-Section B.3	Street-Section C.3
09:00	10:00	Street-Section A.1	Street-Section B.1	Street-Section C.1
10:00	11:00	Street-Section A.2	Street-Section B.2	Street-Section C.2
11:00	12:00	Street-Section A.3	Street-Section B.3	Street-Section C.3
12:00	13:00	Street-Section A.1	Street-Section B.1	Street-Section C.1
Day 2				
13:00	14:00	Street-Section A.1	Street-Section B.1	Street-Section C.1
14:00	15:00	Street-Section A.2	Street-Section B.2	Street-Section C.2
15:00	16:00	Street-Section A.3	Street-Section B.3	Street-Section C.3
16:00	17:00	Street-Section A.1	Street-Section B.1	Street-Section C.1
17:00	18:00	Street-Section A.2	Street-Section B.2	Street-Section C.2
18:00	19:00	Street-Section A.3	Street-Section B.3	Street-Section C.3
19:00	20:00	Street-Section A.1	Street-Section B.1	Street-Section C.1
Day 3				
06:00	07:00	Street-Section B.2	Street-Section C.2	Street-Section A.2
07:00	08:00	Street-Section B.3	Street-Section C.3	Street-Section A.3
08:00	09:00	Street-Section B.1	Street-Section C.1	Street-Section A.1
09:00	10:00	Street-Section B.2	Street-Section C.2	Street-Section A.2
10:00	11:00	Street-Section B.3	Street-Section C.3	Street-Section A.3
11:00	12:00	Street-Section B.1	Street-Section C.1	Street-Section A.1
12:00	13:00	Street-Section B.2	Street-Section C.2	Street-Section A.2
Day 4				
13:00	14:00	Street-Section B.2	Street-Section C.2	Street-Section A.2
14:00	15:00	Street-Section B.3	Street-Section C.3	Street-Section A.3
15:00	16:00	Street-Section B.1	Street-Section C.1	Street-Section A.1
16:00	17:00	Street-Section B.2	Street-Section C.2	Street-Section A.2
17:00	18:00	Street-Section B.3	Street-Section C.3	Street-Section A.3
18:00	19:00	Street-Section B.1	Street-Section C.1	Street-Section A.1
19:00	20:00	Street-Section B.2	Street-Section C.2	Street-Section A.2
Day 5				
06:00	07:00	Street-Section C.3	Street-Section A.3	Street-Section B.3
07:00	08:00	Street-Section C.1	Street-Section A.1	Street-Section B.1
08:00	09:00	Street-Section C.2	Street-Section A.2	Street-Section B.2
09:00	10:00	Street-Section C.3	Street-Section A.3	Street-Section B.3
10:00	11:00	Street-Section C.1	Street-Section A.1	Street-Section B.1
11:00	12:00	Street-Section C.2	Street-Section A.2	Street-Section B.2
12:00	13:00	Street-Section C.3	Street-Section A.3	Street-Section B.3
Day 6				
13:00	14:00	Street-Section C.3	Street-Section A.3	Street-Section B.3
14:00	15:00	Street-Section C.1	Street-Section A.1	Street-Section B.1
15:00	16:00	Street-Section C.2	Street-Section A.2	Street-Section B.2
16:00	17:00	Street-Section C.3	Street-Section A.3	Street-Section B.3
17:00	18:00	Street-Section C.1	Street-Section A.1	Street-Section B.1
18:00	19:00	Street-Section C.2	Street-Section A.2	Street-Section B.2
19:00	20:00	Street-Section C.3	Street-Section A.3	Street-Section B.3

It is important that the passenger vehicle and 2-wheeler operators keep a record of the times when their driving should not be included in the analysis due to their taking a rest or leaving the study area. It is also important that the drivers note any unusual traffic conditions that would invalidate the data. Each driver is to be supplied with a writing tablet and pen in order to make records of unusual traffic situations. The CGPS unit will record information on where the driver operated the vehicle and how it was operated. Thus, data analysis will indicate if the proper driving routes were followed.

Measurement of Bus and 3-Wheeler Driving Patterns

In the case of 3-wheelers and buses, student participants will be asked to take passage on suitable buses and 3-wheeler vehicles operating on the street sections of interest. Four units are dedicated to this purpose. Two units will be used for 3-wheelers and two units will be used for buses[6].

Care should be taken to select likely bus routes and 3-wheeler routes to be used before the study begins in order to avoid lost time once ISSRC personnel reach the study area.

[6] The reserve CGPS units could also be used if the local partners are willing to provide additional 2-wheelers or students to collect bus and 3-wheeler data. Of course, if a CGPS unit fails the reserve units will have to be moved to replace the failed unit.

A.IV. On-Road Vehicle Technology Identification Using Digital Video Cameras

Two digital video cameras are set up on the roadside or above the road to capture images of the vehicles driving by. This data is later manually reviewed to determine the number, size and type of vehicle. It is important to set the cameras at an appropriate height in order to have a good view of traffic on one side of a roadway. Useful data can be captured with the cameras located at the roadside, but on busy roads it is best to have the cameras elevated 1 to 3 meters above the street level when possible. Figure IV.1 shows videotaping in Santiago, Chile on a residential street. In this case due to the low traffic volume and small street size, videotaping could be carried out at street level. Figure A.4 shows videotaping from an overpass of a freeway in Los Angeles, California. In this case due to the high traffic volume and the multiple lane roadways, data is best collected from directly above the street.

Data is collected on the same roads and at the same times when driving patterns are being collected. This allows driving speeds and patterns determined from the CGPS units (discussed earlier in this paper) to be correlated with traffic counts taken from the digital video cameras. Thus, selection of roadways, as discussed in Section II, should consider the video taping requirements as well.

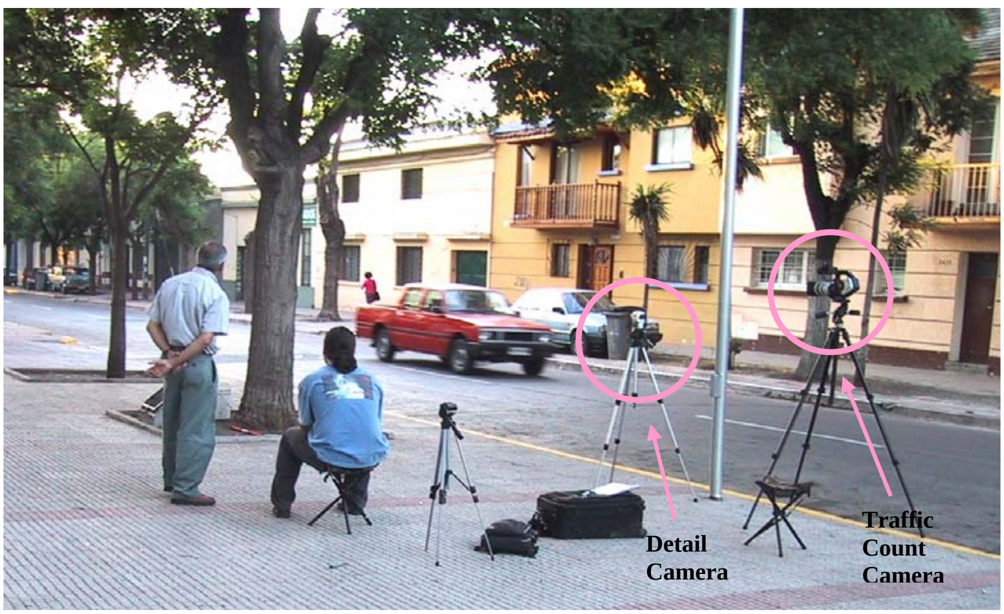

Figure A.4: Cameras collecting data on a residential roadway in Santiago, Chile

Camera Setup on the Overpass

Picture of the Freeway Below

Figure A.5: Camera collecting data from a freeway overpass in Los Angeles, California

The digital video cameras and the two operators usually travel with one of the instrumented vehicles to their desired location. Videotapes for analysis are collected for at least 20 minutes out of each hour and preferably for 40 minutes of each hour.

Local citizens passing the cameras often have questions and upon occasion, the police become concerned about the operation of the cameras. **It is important to provide a local person to explain the purpose of the data collection effort to avoid raising local concerns.** It should also be noted that working along side the street for up to 7 hours a day could expose the video taping crew to considerable dust and other pollutants. It is recommended that the camera operators have good quality dust masks for cases where the dust levels are high.

Each day about 3.5 hours of videotapes are collected. These videotapes are analyzed the following day by student workers and ISSRC staff to develop the needed data for establishing on-road fleet fractions. ISSRC will provide two videotape readers and laptop computers to support analysis of the data during the data collection process.

A.V. On-Road Vehicle Technology Identification Using Parked Vehicle Surveys

The on-road technology identification process using digital video cameras does not collect all of the information required to completely identify the vehicle. Therefore, it is important to supplement this data by visual inspection of parked vehicles using on-street and parking lot surveys. Figure V.1 shows data collection in a Nairobi parking lot. By use of an experienced mechanic recruited from the local area, model year distributions, odometer (distance traveled) data, air conditioning, engine air/fuel control, engine size, and emissions control technology can be estimated for the local fleet using this type of survey technique. Studies in Los Angeles indicate that the technology distributions found in parking lots and along the street closely mirror the on-road vehicle fleet.

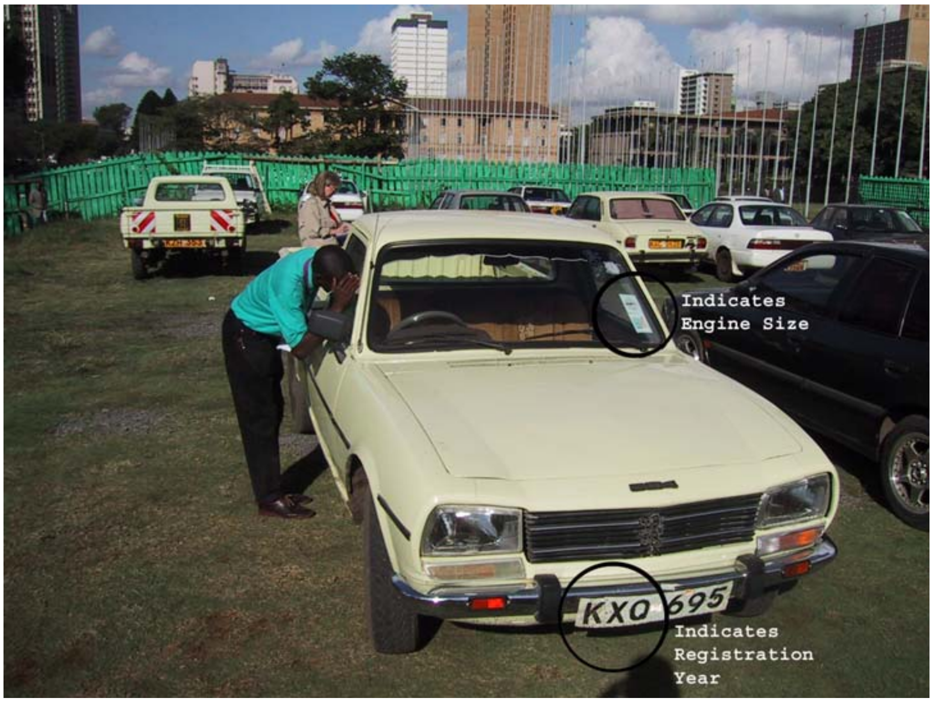

Figure A.6: Parking Lot Data Collection in Nairobi, Kenya

The determination of the needed data involves looking inside of parked vehicles. This process can alarm vehicle owners and the police upon occasion**. It is important that a local person participate in the parking lot survey that can explain the purpose of the study and resolve concerns of local law enforcement officials.**

Surveys are conducted in the same general areas where the vehicle driving patterns are collected. The parked vehicle survey team typically rides to their daily study area with the second instrumented vehicle (the first instrumented vehicle carries the on-road camera crew). The second instrumented vehicle leaves the parked vehicle survey team at a suitable location where sufficient numbers of parked vehicles can be found. This instrumented vehicle returns at the end of the study to pick up the surveyors.

As noted earlier it is desirable to collect data on more than 800 vehicles. Thus, the daily goal for the parking lot survey crew is 150 vehicles.

A.VI. Vehicle Start-Up Patterns by Monitoring Vehicle Voltage

As noted earlier, vehicles pollute more when they are first started compared to operations when they are fully warmed up. The colder the vehicle when started, the typically greater emissions. It is thus important to know how often vehicles are started in an urban area and how long a vehicle is off between starts to make an accurate estimate of start-up emissions. ISSRC will bring 56 Vehicle Occupancy Characteristics Enumerator (VOCE) units to measure the times that vehicles are started and how often. These VOCE units will also give us information on how long vehicles are typically operated at different hours of the day. Figure VI.1 shows one of the units in a typical application. It is normally plugged into the cigarette lighter in the vehicle and left there for up to a week at a time, collecting data all the while.

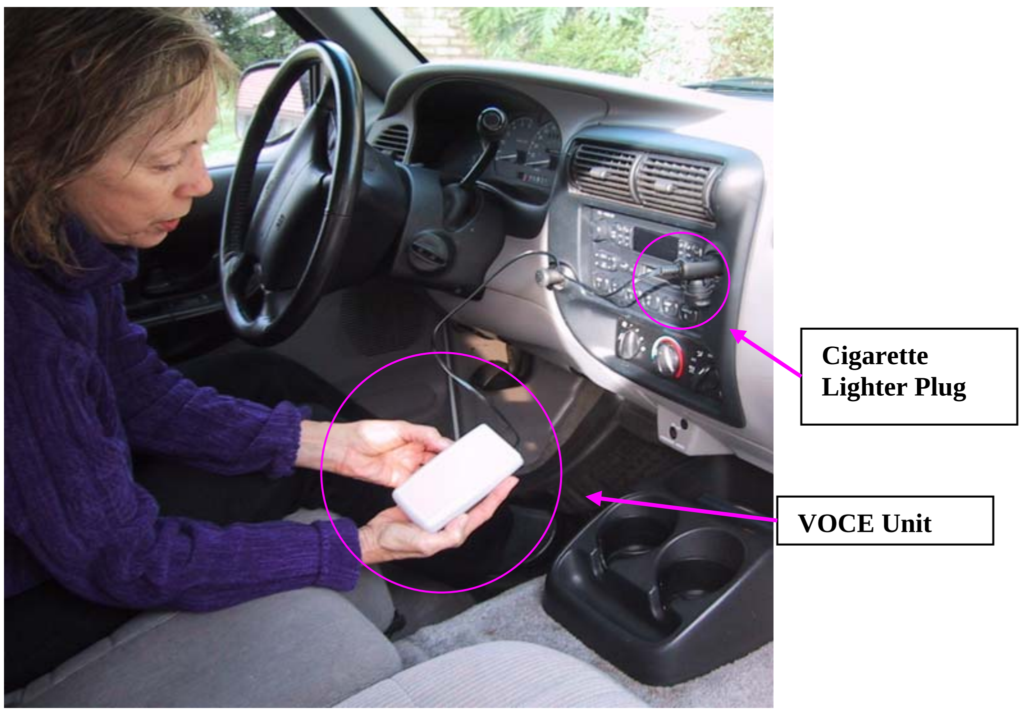

Figure A.7: VOCE Unit for Collecting Vehicle Start Information

The VOCE units operate by simply recording vehicle voltage on a second by second basis. The voltage rises when the vehicle is operated. Software has been developed to download and interpret data from the units. In cases where there are no cigarette lighters, clamps are available to directly clamp the VOCE units to the vehicle battery or other suitable location to capture system voltage.

During the study, 50 of the VOCE units will be distributed to local vehicle owners and attached to their vehicles for four days. The units are then retrieved, the data downloaded, and given back out to 50 different vehicle owners for another four days. **To complete this part of the study, 100 participants must be identified by the local partners to use the units by the time the ISSRC team reaches the location**. The VOCE units are distributed within the first 24 hours after arrival of the ISSRC team. At the end of 4 days, the units are retrieved, the data downloaded over night, and the units re-distributed the next day for another 4 days. This will give us 400 person days of information. In some cases when a weekend intervenes, the units are left for more than four days with the vehicle owners and weekend data is collected. The VOCE units are capable of operating and collecting data for more than a week if necessary. There will be 6 extra VOCE units that can be used to replace units if they become faulty.

In past studies, the vehicle owners have installed the units themselves since they normally only have to be plugged into the vehicles cigarette lighter and left there for the four days of data collection. In cases where the vehicle does not have a cigarette lighter, ISSRC personnel and local partners may have to help the vehicle owner to install the unit. **It is important that none of the VOCE units are lost because they are each hand built and can not be easily replaced.**

To complete this part of the operation, one local person is normally required to spend most of their time during the testing program to first identify 100 participants in advance and then to give out and retrieve the units. Vehicle owners often forget to bring the VOCE units back when they are supposed to or have a problem that keeps them from coming to work to return the units. Thus, while simple in concept, identification, deployment and retrieval of 50 units in the proper timeframe can be a complicated and tedious process. **Finally, in selecting vehicle owners to use the VOCE units it is import to select persons that represent a cross section of drivers in the urban area of interest**.

A.VII. Research Coordination and Local Support Needs

In order to properly carry out the data collection and processing outlined in this paper, both ISSRC and local support are needed. ISSRC will provide 2 persons to work on the project. It is requested that the local partners supply 17-23 persons. 7-14 of these people can be students. Table A.3 below outlines the needed ISSRC and local support requirements.

Table A.3: Study Support Requirements

ISSRC Support	Local Support - Staff	Local Support – Student
Prior to Start of the Test		
Obtain needed Visas, test and pack equipment, review streets selected by local partners.	Obtain permission to bring test equipment into the country. Identify 100 persons to participate in vehicle start pattern data collection. Identify road sections for vehicle technology and driving pattern measurement. Identify support staff including students, mechanics, motorcycle owners, and chase vehicles and drivers.	
On-Road Driving Patterns		
Researcher A: Provide training in use of GPS in chase car situations. Support data analysis as data is collected.	3 local drivers with vehicle to collect on-road passenger car driving patterns	1 student to support data analysis process.
Researcher A: Provide training in use of GPS on 2-Wheeler, 3-Wheeler, and Buses. Support data analysis as data is collected.	3-6 motorcycle operators for one or two days each (could be students).	3-4 students to ride in 3-Wheeler and Bus to collect driving pattern data.
On-Road Vehicle Technology Identification		
Researcher B: Setup and operate video camera and help determine best locations for videotaping.	1 person to help setup equipment and answer questions of local citizens and police.	
Researcher B: Support tape analysis and data entry as video data is collected.		2 students to review tapes and record technology information.
Parking Lot Technology Surveys		
Researcher B: Provide training on parking lot surveys. Support data analysis as data is collected.	1-2 expert vehicle mechanics to support identification of model year and engine technology	
Researcher A/B: Support data entry and analysis process.	1 person to answer questions and get permission to collect data in parking lots and on the street.	1 student to support entry of data into the computer and early analysis of data.
Vehicle Start Pattern Measurement		
Researcher A: Support distribution and retrieval of VOCE units and down loading data.	1-2 persons to identify 100 vehicle owners to use VOCE units in advance of start of study and to support distribution and retrieval of the VOCE units.	
Researcher A/B: Support data analysis.		
Total Personnel Requirements		
2 ISSRC personnel	10-15 persons to support field operations	7-8 students to support data review and entry.

As noted earlier, the typical daily schedule is from about 06:00 to 13:00 on 3 of the 6 data collection days and 13:00 to 20:00 on 3 of the 6 data collection days. The students involved in data analysis will be requested to work each day after fieldwork is conducted. A specific test schedule will be supplied for each location based on the dates of arrival of the ISSRC team members and intervening weekends.

Table A.4 below provides a checklist of equipment being brought into the country. **<u>The local partner must make arrangements with customs so that this equipment can be easily brought into and out of the country.</u>**

Table A.4: List of Equipment Brought Into and Out of the Country

Equipment	Use	Number
GPS Speed, Altitude, and Location Measurement Device	To measure traffic patterns of vehicles operating on urban streets.	10 units
VOCE Start-Up and Driving-Time monitor	To measure the typical times vehicles are started and operated in the urban area.	56 units
Portable Computer	To record data and carry out data analysis processes.	5 units
Portable Printer	To print out reports	1 unit
Video Camera	To record vehicle activity on selected streets.	2 units
Video Tape Reader	To read tapes and display pictures on computer screens.	2 units
Commercial GPS Device	To check operation of the main GPS testing units.	1 unit
Soldering Iron	To repair equipment as needed.	1 unit
Electrical Meter	To check and repair equipment as needed	1 unit
Commercial AA batteries	For use in the VOCE units	200 units

If you have questions about the study please contact:

James M. Lents
1-909-781-5742
jlents@issrc.org
or
Nicole Davis
1-909-781-5795
ndavis@issrc.org

Work Schedule for Pune India

March 2,2003	March 3, 2003	March 4, 2003	March 5, 2003	March 6, 2003	March 7, 2003	March 8, 2003
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
					Depart Los Angeles for Mumbai, India	Arrive Mumbai, India at 23:35 and spend the night in Mumbai.
March 9, 2003	**March 10, 2003**	**March 11, 2003**	**March 12, 2003**	**March 13, 2003**	**March 14, 2003**	**March 15, 2003**
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Picked up by van at 12:30 and transported from Mumbai to Pune	Meet with Pune study group at about 10:00 to discuss study and use of equipment. VOCE units distributed to first 50 participants.	1st day of on-road testing, video taping, and parking lot surveys.	2nd day of on-road testing, video taping, and parking lot surveys. Begin processing collected data.	3rd day of on-road testing, video taping, and parking lot surveys. Process collected data.	4th day of on-road testing, video taping, and parking lot surveys. Process collected data.	
March 16, 2003	**March 17, 2003**	**March 18, 2003**	**March 19, 2003**	**March 20, 2003**	**March 21, 2003**	**March 22, 2003**
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
	No field data collection or processing. First 50 VOCE Units collected. Data downloaded in the evening.	5th day of on-road testing, video taping, and parking lot surveys. VOCE Units distributed to 2nd 50 participants as early in day as possible. Process collected data.	6th day of on-road testing, video taping, and parking lot surveys. Process collected data.	Process collected data.	2nd 50 VOCE units collected and data downloaded. Meet at about 10:00 to review data collected and preliminary results of the study. Depart by van for airport in Mumbai at about 5PM.	Depart Mumbai at 01:05 Saturday morning.

Work Schedule for Almaty, Kazakhstan

March 30,2003	March 31, 2003	April 1, 2003	April 2, 2003	April 3, 2003	April 4, 2003	April 5, 2003
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Depart Los Angeles for Almaty, Kazakhstan	Arrive Almaty, Kazakhstan late evening.	Meet with Almaty study group at about 14:00 to discuss study and use of equipment. VOCE units distributed to first 50 participants	1st day of on-road testing, videotaping, and parking lot surveys.	2nd day of on-road testing, videotaping, and parking lot surveys. Begin processing collected data.	3rd day of on-road testing, videotaping, and parking lot surveys. Process collected data.	
April 6, 2003	**April 7, 2003**	**April 8, 2003**	**April 9, 2003**	**April 10, 2003**	**April 11, 2003**	**April 12, 2003**
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
	No field data collection or processing. First 50 VOCE Units collected. Data downloaded in the evening.	4th day of on-road testing, videotaping, and parking lot surveys. VOCE Units distributed to 2nd 50 participants as early in day as possible. Process collected data.	5th day of on-road testing, videotaping, and parking lot surveys. Process collected data.	6th day of on-road testing, videotaping, and parking lot surveys. Process collected data.	Process collected data. 2nd 50 VOCE Units collected in the afternoon and data downloaded.	Meet at about 14:00 to review data collected and preliminary results of the study.
April 13, 2003	**April 14, 2003**	**April 15, 2003**	**April 16, 2003**	**April 17, 2003**	**April 18, 2003**	**April 19, 2003**
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Depart from Almaty, Kazakhstan for Los Angeles in very early morning.						

Appendix B

Daily Log of the Data Collection Program Conducted in Mexico City

Day One - Sunday, January 25, 2004

Arrived on time at Mexico City airport and were met by Bernardo and his family who drove us to the San Marino hotel. Checked in using Jim's credit card.

Day Two – Monday, January 26, 2004

Bernardo picked us up at the hotel at 9 am and drove us to CENICA for a meeting with Hilda Martinez, Marco Balan, Antonio Mejia and students. Jim explained the four parts of the activity study. We learned prior to the start of the meeting that Hilda had intended to distribute the VOCE units that day and so Dan and I rode back to the hotel with Bernardo to pick them up. Hilda went to Costco to purchase batteries. During the discussion following Jim's description of the activity study, we learned that Thursday, February 5th, is a holiday (Mexican Constitution day), and that the passenger vehicle activity portion of the study had been scheduled for Thursday, Friday, and Saturday of the first week instead of Wednesday, Thursday, and Friday, as we had anticipated. I asked whether morning or afternoon would be the better time for the study on Saturday and was told the morning would be best. I described how we had learned that it was better for all to avoid an afternoon data collection period followed the next day by a morning data collection period. In this case, it appeared to be unavoidable for the first week. We then decided that on the second week we could start out with a morning period on Monday and then afternoons for Tuesday and Wednesday. Marco evidently intended that we would give him the CGPS units, the charging cords, and the download software, and they would collect the data, download it, and recharge the batteries. We indicated we wanted to see the data at the end of each day and preferred that either we do the downloading or someone else do it in our presence. It was agreed that the passenger car drivers would be paid $200 USD and be given an allowance of $50 USD for gasoline for the six days of the study. For the taxi drivers, we agreed to increase the payment from $10 to $15 so that they would bring the CGPS unit back at the end of each day, wait for the data to be downloaded, and return the unit to the person (?) who was coordinating the collection of data from the taxi cabs. It was decided that the CGPS units would be downloaded at the hotel and the units used for the passenger vehicles would be picked up and returned to the hotel each of the six days. Following the discussion, we put the batteries in the VOCE units and reset the clocks. We gave Hilda the 57 of the 59 (two were marked out of service) VOCE units and the paperwork. We split up into groups to discuss each of the parts of the activity study separately. I discussed the CGPS units with Marco, Antonio, and some students. Marco and Antonio indicated they needed the CGPS units the next day in order to start with their data collection. Antonio indicated he will have responsibility for the taxi and truck data collection. He then introduced me to Daniel Leon who apparently has coordinated the truck collection. I explained that we should anticipate equipment failures and, if it occurs, we will prioritize the data collection with the passenger vehicle data having the highest priority. Marco reported that in addition to microbuses, there are three types of buses that operate within the metropolitan area. Each would be expected to operate differently and have different engine characteristics than the other two. It was decided that we would collect data for one type for two, another type for two days, and the last type for the last two days. We discussed the opportunity to also collect bus data on routes that operate along portions of Eje Ocho and Insurgentes avenues. This will assist Mauricio Osses in the work that he is doing with the World Bank. Marco said he had too many students and intended to double and possibly triple up on the bus riders. We learned that there were no plans for anyone to accompany the drivers of the passenger vehicles. I suggested to Marco that it would be much better if three of the students are used to ride with the drivers in order to watch the CGPS units and keep notes on the start and stop times of each route as well as any other data worthy of note. Marco indicated that change would be made. At the conclusion of the meeting, we returned to the hotel. When removing the CGPS units from their pelican cases, I noticed that one of the locks was badly damaged and it appeared that the case (I believe it was case 2) had either experienced some kind of a fall or had somehow been hit by something. I plugged the CGPS units into the wall plugs via multi-outlet cords and we left at about 2 pm for a walk. We walked for over four hours and went through the old cathedral next to the national palace. We then walked to the Sheraton-Centro Historica and met with Mauricio Osses, Lee Schipper, Carl-Heinz Mume, Luis (?), and Adriana (?). We had supper with them at the Sunflower restaurant. Adriana gave us a ride back to the hotel. Upon returning to my room I discovered that the charger on unit 9 had shorted out (and stunk up my room). Several of the other chargers were much hotter than normal. Number 6 appeared to be dangerously hot so I unplugged it. At about 11:30 pm I unplugged the rest.

Day Three – Tuesday, January 27, 2004

I got up early and carried units 10, 8, and 7 around looking for a spot with an unobstructed view of the sky. Since the units could be mistaken for some sort of time bomb and the U.S. embassy was only a block away, I decided to return to the hotel and see if I could get permission to use their roof in order to acclimate the CGPS units. They were kind enough to let Jose-Luis take me up there. The three units were able to acquire seven satellites in approximately three minutes. Patti Camacho and (?) came and I gave them unit 10 to use in the taxi. Antonio came and gave Jim a book that contains information on the engine size and control equipment for each model of passenger vehicle. Jim indicated that he needed one month's data from the I/M databank. Antonio indicated he would get it and bring it to Jim tomorrow. I gave Antonio CGPS units 7 and 8 for the trucks. I showed both Patti and Antonio how to operate the units. Jim and Suzy took units 1,2,3, and 5 up to the roof of the hotel and acclimated them. Marco arrived and reported that now he does not have enough students and that some of them can only work in the morning and some of them only in the evening. It was agreed that we would get bus data for three mornings and three afternoons. Jim gave Marco units 1, 2, 3, and 5. Jim then demonstrated how the units acquire satellites for Antonio. I left with Bernardo, Hilda, and Antonio to buy a new 6 volt battery, battery charger, and micrometer. We took the items back to the hotel and I gave them to Jim and Dan. Then Bernardo, Hilda, Antonio, and I left again to look over the passenger vehicle routes that had been selected. For the commercial area, they had assumed that since we said we needed two arterial routes they could just drive one route for two out of every three hours. I told them that created an unwanted bias to the data. We drove around and Hilda selected a route that appeared to be acceptable. We then drove back to the hotel because Antonio had a time problem. Bernard, Hilda, and I then left to look at the routes in the upper income area. The arterial route was very similar to the highway route and they had not selected a residential route because they thought all that was needed was to drive around in a residential area. We changed the arterial route and selected a residential route. We then returned to the hotel because Hilda had a time problem. Bernard and I left to look over the routes in the lower income area and to select a residential route. We did not drive the entire highway and arterial routes but, in my opinion, they will be fine with the possible exception that the arterial route is overly long and it is possible that there may not be enough time to complete it. As with the upper income area, it was difficult to find a residential route, but we did eventually and then returned to the hotel. Jim and Dan had already made reparations to unit 6 and had begun to charge the battery.

During the Day, Dan, Jim, and Suzy had taken photos of various types of vehicles in order to prepare some training for the students that will be counting vehicles from the videos.

Day Four – Wednesday, January 28, 2004

Hilda Martinez arrived at 10 am. I showed her the streets for the residential route in the lower income area. I had prepared a route schedule for her, but learned that since it had been arranged for the police to be with Dan and the cameras on certain days at certain locations, we had to amend the schedule. The amendments consisted simply of changing the letter designation for two of the three routes. The central commercial area is now area A and the upper income area is now area B. Thus, car one, which will be driven by Bernardo, will be in the commercial area for the first two days. Then car one will be in the upper income area for the next two days, and, finally, in the lower income area for the final two days. After making the changes I gave Hilda a cd with the schedule on it. Hilda left to prepare the maps make copies of both maps and schedules for each of the cars. Later in the day, Antonio brought copies of I/M data on about 65,000 vehicles for Jim to use in his technology survey. Earlier I had asked Antonio if the GPS unit had been put in a taxi and, if so, when I could expect to receive the unit to download the data. He said he would check with Patti Camacho and call me back. I never received a call from either Antonio or Patti.

Day Five – Thursday, January 29, 2004

Took units 4, 6, and 9 out front of the hotel about 4:35 am. Units 4 and 6 were very quick to acquire satellites (less than 2 minutes). Unit 9 was considerably slower and took about 10 minutes to acquire. The driver of car three (Mauricio) arrived just before 5 am. By 5:10 everyone had arrived. Car one is driven by Bernardo. The student that is accompanying Bernardo is Bernice. Dan Shewmaker will work out of car one for the entire period. Patti Camacho is accompanying Dan for at least the first two days. CGPS unit 9 was assigned to car one. Bernardo's cell phone number is 0445591662085. I did not get the name of the driver of car two. The student's name is Eduardo. His telephone number is 0445514218713. I failed to record the number of the GPS unit given to Eduardo. It is either 4 or 6. The driver of car three is Mauricio. He is picking the student up on the way to his first route so I did not see the student. Neither Mauricio nor the student have a cell phone. As with car two, I failed to record the number of the CGPS unit I gave to Mauricio. It is either 4 or 6. Marco Balan explained to each of the drivers and students how to operate the CGPS units and the need to take notes. Prior to each car leaving, I placed the antenna on the roof and made sure each unit again acquired satellites. Everyone left by about 5:45. Hilda asked if we could pay for the meal of the person accompanying Dan each day. We agreed to do so. I called Dan through Patti's cell phone and asked him to pay for her lunch. Marco indicated that the students riding the buses would be at the hotel between 1 and 2 pm on the morning days and 8 to 9 pm on the evening days. Apparently the CGPS units from the trucks will not come back until 8 pm or so. I still do not know what is occurring with the taxis. I went to Office Max and purchased 5 more three prong to two prong adapters. The students will each need one if they are going to charge the CGPS units for the taxis, trucks, and buses. I am concerned about letting the students take the units home, but there does not seem to be another choice. Hilda called and said the driver from the upper income area would be returning by himself since he had dropped the student off on the return trip. I met him at the street since there was no place for him to park. I received unit 4 from him and downloaded the data as Car 2. Car 1 (unit 9), and Car 3 (unit 6) were also received and downloaded. The data looks reasonably good although the city center data (Car 1) has to be expanded in graph form just to see the different routes. Unit 10 came back and the student reported he had used it when riding buses. (I am surprised since I am thought I had given unit 10 to Patti Camacho for use in taxis – maybe she and Marco switched after I gave them their units) After unit 10 was downloaded, it was given back to the student so that he could give it to another student to ride more buses in the afternoon/evening. When that student returns it around 8 or 9 pm, I will download it and then give him back the unit along with a charging cable and instructions on how to charge the battery. Unit 1 came back and the student reported he had been riding microbuses. I showed him how to charge the battery, returned CGPS unit 1, and gave him a charging cable. He is going to ride more microbuses tomorrow afternoon. Jim returned from his meeting on the BRT and began training Antonio Mejia and Guadalupe (Lupita) Tzintzun (and me) on the IVE model. We then waited around for the units being used on the trucks, taxi, and the rest of the buses. At 5:30 pm Moises Diaz from Pepsi trucking company delivered CGPS units 7 and 8. He reported that unit 7 had not been working (the red light would not come on). We downloaded the data from unit 8 and stored it as truck1. From checking unit 7, it appears either the charger or the battery have failed. I will get replacements in the morning and try to get it operating again. Unit 8 was returned to Mr. Diaz along with the charging cord and instructions on how to charge the unit. Unit 5 was brought in by a student who said she had been riding buses. It was downloaded and the data designated and stored as Bus 2. The student was shown how to recharge the battery and was given back unit 5 along with a charging cable. Unit 10 came back a second time with bus data from the afternoon. It was downloaded and recorded as Bus3 and the unit was returned to the student along with the charging cable and instructions on how to charge the battery.

Unit 2 was brought in by a student who said he had been riding microbuses. It was downloaded and the data designated as microbus2. The student was shown how to recharge the battery and was given back unit 2 along with a charging cable. Unit 3 was brought up by (?Eduardo?) who said it had been used in a taxi cab. It was downloaded and designated as taxi1. Since he had already seen how to recharge the battery, he was given unit 3 and a charging cable. He left indicating that he would arrange for the unit to be used by another taxi tomorrow. I took the battery charger out of unit 7 and could see it had gotten hot enough to melt part of the case. Antonio is coming over around 9 am in the morning and we are going to go back to the electronics store and get another charger and battery.

Day 6 – Friday, January 30, 2004

Mauricio Osses called to say that he had obtained a room in the hotel and would be available to provide assistance if needed. Antonio called around 9:30 am from the lobby indicating that he had VOCE units for downloading and would be ready to go to the electronics store. Antonio and I purchased the battery and charger and then went to his office at the Mexico City air pollution control center and picked up some of the VOCE units. Fabiola from Antonio's office accompanied us back to the hotel and once we downloaded the VOCE data and replaced the batteries, she took seven units back. It may be that the new batteries were put in backwards in unit 66 because the batteries overheated and the unit began to stink. I removed the batteries and later took the unit apart to find that the circuit board had been damaged. Since this was one of the original seven units that Fabiola had brought with her, we downloaded one of the two units that Hilda brought and after replacing the batteries, we gave it to Fabiola who then took the units back to her office to distribute. Jim left with Hilda to download VOCE units at the Mexico state office. The three CGPS units were provided to cars 1, 2, and 3 for their afternoon data collection. One young lady, Roselia, was present during the late morning to read the video tapes. Jim trained her using the photos of vehicles he and Dan and Suzy had taken earlier. She was joined at around two pm by two other young ladies, Carmen Mendoza and Salome Medrano. She trained them on how to differentiate between the various sizes and types of vehicles. Rosalia left in the late afternoon. I repaired CGPS unit 7 with the new battery and charger. It will be given to the Pepsi truck representative when he brings unit 8 to be downloaded this evening. In that way, we should be able to collect truck data from two trucks on Saturday, Jan 31st. Looking over Marco's list, it looks like we have 6 students working on the project from UNAM. Marco told me that the buses riding is costing more than expected and, overall, will probably be in the area of 1200 pesos over the six days of the study. Last night, Jose Antonio paid 150 pesos to the taxi driver. We need to reimburse him. Starting tonight, the taxi drivers should come up to my room with the CGPS unit and we will pay them each night. Before leaving, Marco asked if I would give VOCE unit 20 to Rudolfo when he comes with the VOCE units from INE. He said Hilda had given him the unit and asked him to give it to Rudolfo. He did not know if the unit had already been downloaded or not. I hooked it up to the VOCE download program and it had data on it (although it may have all been 0's, I did not have time to watch the download). I then replaced the batteries in the unit. A student brought in CGPS unit 10 and said he had been riding buses that morning. I downloaded the data and returned the unit to the student who is going to ride buses again this afternoon. Rodrigo brought in three more VOC units (8, 13, & 24). I downloaded them, replaced the batteries and gave them back to him. He is going to reassign them tonight and we will get them back next Friday morning. Jim determined that VOCE unit 7 did not have valid data. It looks like about 10% of the VOCE units do not have data. It is possible the person using the VOCE units did not push them all the way into the cigarette lighter. The units appear to be working correctly but, only recorded 0's every minute. Jim is working to make the needed corrections to some of the VOCE units that showed minor anomalies. The following CGPS units came in and were downloaded and filed as follows:

Unit 5 – Bus2, Unit 6 – Car1, Unit 4 – Car2, Unit 9 – Car3, Unit 10 (second time today) – Microbus1, Unit 1 – Microbus2, Unit 2 – Microbus3, Unit 3 – Taxi1, Unit 8 – Truck1.

Unit 7, which has been repaired, was given to the Pepsi representative along with Unit 8. A different person will be returning the two units tomorrow. Jim provided his VOCE data file that includes the corrections he has made as of the moment. It will be included in the day two compilation cd as "JimLentsMexVOCE." It occurs to me that I failed to pay or ask Jim to pay the fellow that is handling the taxi data. I expect we now owe him 300 pesos. We are told that today is also payday for a lot of people. So, the traffic may be even greater than normal. Later, in talking with Eduardo, I was told that people are generally paid every two weeks so, it sounds like payday Fridays occur about 50% of the time.

Day 7 – Saturday, January 31, 2004

At 4:35 am, took CGPS units 9,6, & 4 to the street in front of the hotel. 9 acquired very quickly, 4 almost as quick, and 6 took about 4 minutes. Met with Marco and Hilda. I told Marco I had again failed to pay the taxi cost. Apparently the taxi drivers are somehow related to the person that is coordinating with them and the CGPS unit so, they have been patient and think maybe the plan is to pay them at the end of the week. I think we need to pay them up to date today. I asked that Marco tell the coordinator to speak to me when he brings the CGPS unit back today since I am very busy about that time trying to download the CGPS data so the people can leave. Marco noted that the drivers have been consuming a lot of gas and may not have enough gas to finish the day's routes. He says they are driving about 225 to 250 kilometers per day. I gave him 300 pesos which he divided up between the drivers of car two and car three. Dan indicated that yesterday he had given Bernardo 200 pesos to cover the cost of lunch for the people in the car. I told him to let Jim and/or Suzy know so they could keep track of the costs. I mentioned to Hilda that we had found we could rent a van and were assuming that Bernardo would drive it on Sunday so we could visit the pyramids and Xochilmilco. She talked to Bernardo and said that he also works at the university and would lose money if he took the time off on Sunday. He says he would lose 620 pesos. I returned to my room and at 6:15 am Bernice knocked on my door. She said the light on CGPS number 6 would not come on. I pushed the on button and the light came on. She was dismayed and said that she had been trying every since they reached the city center. I then turned the unit off and when I tried to turn it on, the light did not come on. So, I shut it off again and when I turned it on the light came on. So, I advised her to just turn it of and on until the light comes on when she returns to the city center. It may be that the switch is loose. I will try to look at it this afternoon. Later, I met Jim, Suzy, and Mauricio for breakfast about 8:45 am. Jim said he had continued working with the VOCE data and had determined that of the data that had been downloaded from 56 units (Antonio's boss, Sergio, will keep the 57th until next Friday), 6 did not contain viable data. So, in the first round, we received usable VOCE data from 50 vehicles. Rosalia arrived so I took her up to my room so she could begin to work on the vehicle counts. A short time later, two members of the state police arrived indicating that they were here for a meeting with Hilda Martinez that was supposed to take place at 6:30 am. After some confusion, we guessed that this was in regard to having a policeman along with Dan while he is up North in the "Zona Satellite." As we were going up to my room to call Hilda, Carmen and Salome arrived to work on the videos with Rosalia. I could not reach Hilda but, was able to reach Bernardo and he apparently told the policeman where Dan is located with the camera. The policeman left indicating that someone would be with Dan this morning and again on Monday. I asked Mauricio to call Bernardo and tell him we would pay him 200 pesos and buy his meals if wanted to drive a rental van to take us to the pyramids & Xochimilco. Bernardo indicated he wouldn't be able to do it. Mauricio later determined that we can travel to the pyramids by bus without a lot of difficulty. Jim and Dan created a digitized map of the Mexico City metro area by taking a digital photo of a map and then sizing it so that it matched with some GPS readings in different parts of the city. He showed me how to impose the routes upon the map so we can get a better idea of where the travel occurred. I created additional daily folders that contain this information. The young lady with unit 5 came in and said she could not get the unit to acquire satellites. I took it up on the roof of the hotel and concluded the antenna was malfunctioning. After replacing the antenna, I gave the unit back to her. Since it was almost noon at that time, it was too late for her to then go out and collect data. So, no data for unit 5 will be available for Jan 31st. Most of the other units arrived early in the afternoon and were downloaded without problem. We decided to go across the street to eat some lunch and I left a note on the door and at the reception desk so anyone coming in with GPS units could locate us. Just as we were served out food, two gentlemen from Pepsi trucking arrived with units 7 and 8. I downloaded the data and returned the units to them. After eating a late lunch, we returned to wait for the rest of the CGPS units to come in. When the taxi driver arrived, I paid him 150 pesos. Rodrigo was the last to arrive at about 7 or 8 pm. He said he had started recording data at 1 pm and the light had been blinking until around 4:45. He could not get it to acquire satellites after that. He mentioned that he had run out of the 50 pesos that Marco had given him. Mauricio gave him 100 pesos more. Unfortunately, the only data that was on the unit was from the previous day. We downloaded the data twice and could find no data for the 31st. I asked him to let me keep the unit (unit 2) and I will try to determine the problem so that he can pick the unit up Monday morning. Thus, for Jan 31st we will only have 9 sets of data. Two sets from unit 10 (one in the morning and one in the afternoon), and one set each from units 1, 3,4,6,7,8, and 9. There won't be data sets from either units 2 or 5 for this day.

Day 8 – Sunday, February 01, 2004

There won't be any data collection today so we are planning on catching a bus out to the pyramids and maybe look at a museum or two here in the city after we return. We need to fix unit 2 and give some thought to how/where we are going to get data on the engines and technologies in the bus and truck fleets.

Day 9 – February 02, 2004

Got to thinking about unit 2 and why it did not contain any data for the 31st when Rodrigo said the light had been blinking for over four hours. It bothered me that a number of the units were not dumping the previous days data. I got to looking at the procedures and do not believe I have been setting the flash position to the new beginning after the downloads. There were a two or three units on which I had tried to dump the previous data on Saturday and Sunday and I am now concerned that my actions may have resulted in unit 2 not collecting data. Even more, that other units might not collect data today. I also found Paul's earlier note to Jim and now have the instructions on how to reset the speed filter to 0.0. I then downloaded the data again from unit 2 and reset the flash position to the new beginning as well as reset the speed filter to 0. For some reason, after resetting the flash position, it showed the ending setting as 538. I manually reset it to 8000. I reset the speed filter and reset the flash position to the new beginning for units 4, 6, and 9. I would like to go through the same process for the buses, trucks and taxi CGPS units, but don't have access to them until they come in today with the day's collected data. It may be that one or more of them will have no data recorded just like unit two yesterday. Rodrigo came in and picked up unit 2 and left to ride some buses. Jim provided me with the set of data from the 50 VOCE units that he found to have good data out of the 56 units that came in after the first data collection period during week one. I made a cd for day three with all the data collected to date including Jim's good VOCE data. Rosalia came about 10:30 and started working on the video tape counts. I called Hilda at 10:45 and she said she would be here in 20 minutes. I mentioned to her that it would be better if we could have access to the other CGPS units before the students began riding buses or the taxi started collecting data. I expect the trucks have left with their CGPS units fairly early this morning so we will just have to wait to see what, if any, data they collect. Gerardo returned unit 10 that he had been using in the morning on suburban buses. I downloaded it and reset the flash position. I queried the speed filter and it showed as 0.0 so, it may have been reset earlier in my clumsy attempts. However, I can't honestly say whether I did it on Saturday after they brought the unit in or not. When the unit used in the taxi was brought in, I noticed while downloading that the speed filter was set at 0.0. In fact, all of the units except 1, 7, & 8 were already set at 0.0 when I downloaded their data. I reset the speed filter for units 1, 7, and 8 to 0.0 so the data for Feb 3 and 4 will be the only days in which these three units will operate at that speed filter setting. Rodrigo returned with unit 2 and said that there was a long while when the unit was not acquiring satellites. When we downloaded his data, the eastern (north-south) leg of his route did not appear. It is curious that this leg occurs close to the airport. It may be that with the current global security situation, there is some method being used to block GPS signals near the airport. Unit 2 was given back to Rodrigo and he is going to ride bus routes tomorrow that are to the Northwest of the city center. So, we will see if there are any gaps in his data then. The previous work I did on applying the data to the metropolitan map contained errors since I apparently didn't understand the way to impose the data on the maps as well as I thought I did. At the time the compilation cd's were made for Day Four, I had corrected days one and two. I think day four is okay and will check day three tomorrow. Because the maps are actually photos that are very data intensive, it takes two cd's to store the data now.

Day 10 – Tuesday, February 03, 2004

At 4:35 am, when I unplugged units 4, 6, and 9 from charging, I noticed that Mauricio had not connected the internal cables on unit 6 when he plugged them in. So, as a result, unit 6 did not receive a charge. For that reason, I assigned unit 6 to the team that is operating in the city center area that is the closest to our hotel. If it runs out of power, there is a possibility that we could get a hold of one of the bus units and get the city center team back out collecting data as soon as possible. Unit 4 would not acquire satellites. I used our last spare antenna and the unit immediately acquired satellites. Unit 9 was assigned to car 1 for the southern (low income) area. Unit 6 was assigned to the northern (high income) area. I gave 100 pesos each to the drivers Mauricio and Bernardo and 50 pesos to Berenice for her brother. I told Dan that if he or the policemen with him felt the situation was unsafe, they should pack up and the residential area immediately. I told Marco Balan that we would like to get 30 minutes of driving data each hour that they will be driving the residential route in the low-income area. Hilda is going to call a couple of times during the day to check on the team in the low-income area. There will be two policemen assigned with Dan today and tomorrow. Marco told me that Antonio Mejia will not be able to be with us today or tomorrow. Marco apparently got this information from Sergio, Antonio's boss. Rosalia arrived around 10 am to read the videos. Heard that Car 1 was not able to connect with the policeman who was to accompany Dan in the low-income area. As a result, they did not get CGPS data or video for the 0600-0700 hour and 0900-1000 hour residential routes. They did eventually make contact and the policeman accompanied Dan for the rest of the morning. It is the same policeman that accompanied Dan in the commercial area the first two days. I paid 40 pesos to Jose Antonio, 20 pesos to Valeria, and 40 pesos to Gerardo for bus fares. The CGPS data for bus 1 and bus 2 was downloaded as well as cars 1, 2, and 3 and microbus1. Jim and I went to Office Depot and purchased cd labels and cases as well as envelopes for the students' pay. Around 7 pm a taxi driver called from downstairs. He had an amazing amount of data on unit 3 (over 43000 entries). I paid him 150 pesos. A little after 7 pm Salome and Carmen left. The ladies had finished all of the video tapes for February 2nd and 1 of the two video tapes for February 3rd.

Day 11 – Wednesday, February 04, 2004

Rosalia arrived around 10 a.m. and started on the one tape that was left from yesterday. Hilda and I sent an email to Carmen and Salome telling them that they shouldn't come in the afternoon since

Rosalia would have the one tape finished before they arrived. Jim and I went to the money exchange and got the pesos to pay off the students and other workers. Jim and Suzy put the correct amount in envelopes with the individual's name on them accompanied by a receipt for them to sign. Gerardo arrived with the morning bus data on unit 10. I downloaded the data as bus1 and set it aside to give to Jose Antonio for his microbus data collection in the afternoon. I gave Gerardo his envelope and he signed the receipt. He seemed to be pleased with the amount provided to him. Jose Antonio arrived and I gave him the CGPS unit. Dan, Bernardo, and Eduardo left in car 1 at about 11:50 a.m. to reach the low income area. Car 2 and Car 3 left between 12 and 12:30. I gave Bernardo 200 pesos and Juventino 200 pesos. Mauricio said he only needed 100. Hilda and Marco arrived. Marco and I went over the amounts of money that have been paid to the bus riders for bus fare and to the drivers of cars 1, 2, and 3 for gasoline. Our records seemed to jive. Hilda and Marco took off in Marco's pickup to get a book from Antonio Mejia. They had a small fender bender that ended up taking an hour of their time. They returned without having gone to Antonio's office. Hilda later went by herself and brought the book to Jim. The policeman never arrived to meet up with Dan. As a result, they did all of the routes except the last one which was scheduled for the residential area. The students arrived, data was downloaded and checked. Unit two (Rodrigo) had gaps in the data again. Odd, since it appeared to have perfect data yesterday. Wonder is Rodrigo is experimenting with the placement of the antenna since yesterday he said he had placed in on the floor of the microbus and it still worked. He seems to think the metal bus acts as a big antenna. Paid the students. Paid the taxi driver.

Day 12 – Thursday, February 5, 2004

Carmen and Salome arrived around 9 am to count vehicles from the videos taken yesterday. Rosalia arrived around 10 am. We paid them and then left to visit the anthropological museum asking them to close and lock the door to my room when they finished and left. The vehicle count sheets were on my table along with the two videos when we returned. Received a call from Victor Hugo Paramo. He will come to the hotel tomorrow at 5 pm to have a coffee and say hello. When downloading Hilda's VOCE unit it was discovered that there may be a programming problem either in Warren's downloading software or Jim's evaluation software. Where ever the problem is (and it could be a combination of both places), it results in a time difference in some of the data. VOCE units began to arrive and Jim, Mauricio and I started to download them. The following units were observed to have problems during downloading: 40-all zeros, 22-weird data, 9-weird data, 3-weird data, 4-weird data and all zeros. Unit 25 did not have any data. Unit 68 was damaged when the user attempted to wind the cord up after unplugging it and broke off the attachment that plugs into the cigarette lighter. Gave Hilda units 1, 2, 5, 6, and 7. She is going to put them in taxi's for a week and then send them to us once she gets to New Orleans on Feb 28th. Having trouble getting three of the units back from the State of Mexico. Received the three units just as Victor Hugo Paramo arrived. Mauricio downloaded them while Jim and I went down to see Victor Hugo.