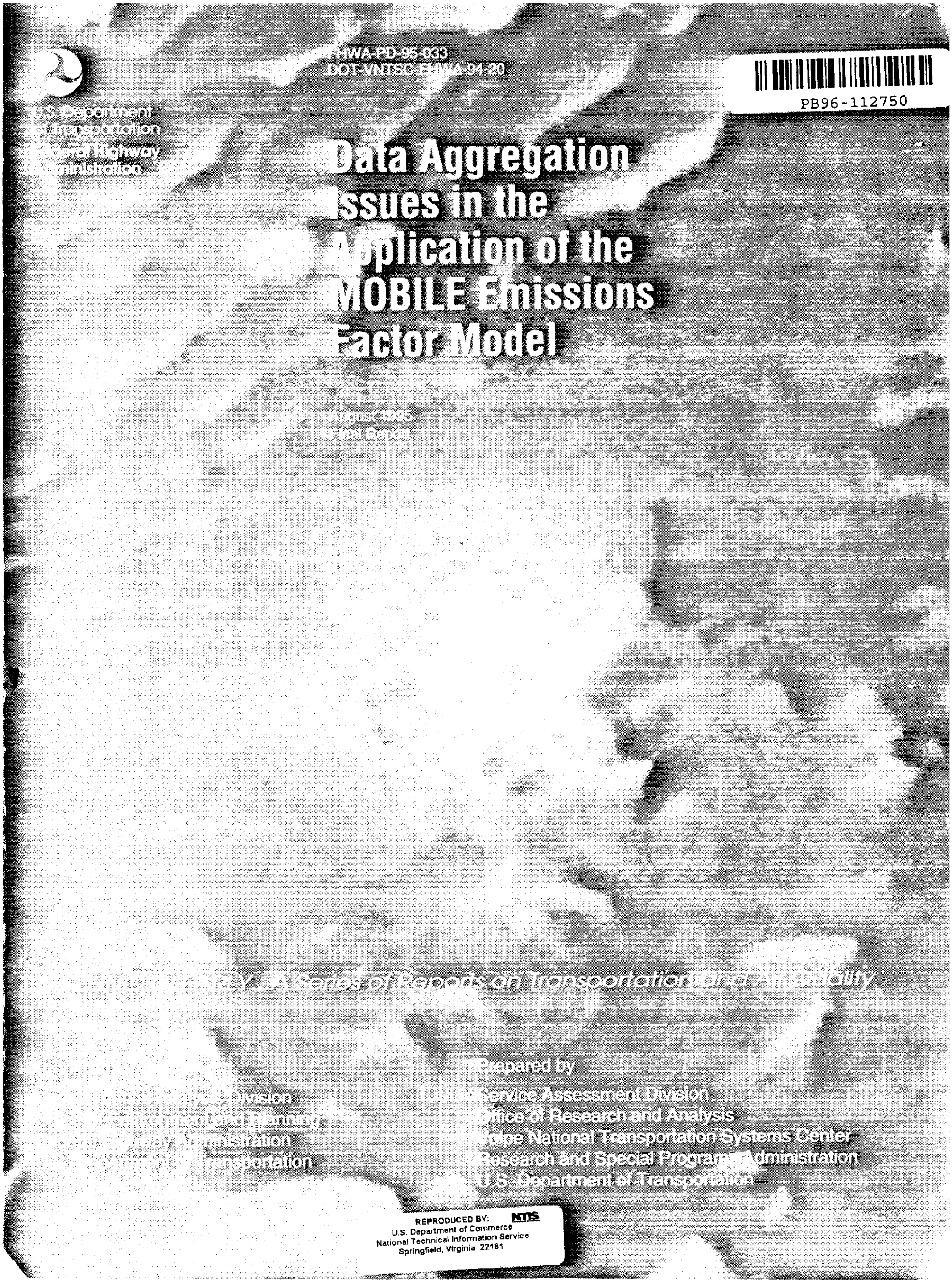

U.S. Department of Transportation
Federal Highway Administration

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Data Aggregation Issues in the Application of the MOBILE Emissions Factor Model

August 1995
Final Report

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U.S. Department of Transportation

Prepared by

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The appropriate level of spatial and temporal data aggregation for highway vehicle emissions analyses is one of several important analytical questions that has received considerable interest following passage of the Clean Air Act Amendments (CAAA) of 1990. Should vehicular emissions be calculated on a link, traffic and analysis zone, grid cell, functional class, corridor, subarea, or areawide basis? Further, should these same vehicular emissions be estimated on an hourly, peak period, or daily basis? A number of motivating factors that are contributing to this interest are discussed. The primary purpose of this report is to examine the effects on vehicular emissions that result from using different levels of spatial and temporal data disaggregation of actual travel data from three representative urban areas. The work also contributes to three important additional objectives that are of widespread current interest: the effects on total estimated vehicular emissions of using successive versions of the MOBILE model; an assessment of the Clean Air Act's mandated Federal policies in reducing future year emissions; and specific MOBILE input variables that should be modified in developing a spatially and temporally disaggregated emissions estimate.

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Prepared for

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Prepared by

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2 = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2 = 0.09 square meter (m$_2$)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (1)
1 pint (pt) = 0.47 liter (1)
1 quart (qt) = 0.96 liter (1)
1 gallon (gal) = 3.8 liters (1)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yeards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliters (ml) = 0.03 fluid ounce (fl oz)
1 liter (1) = 2.1 pints (pt)
1 liter (1) = 1.06 quarts (qt)
1 liter (1) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5) y + 32] °C = x °F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES 0 1 2 3 4 5 6 7 8 9 10
CENTIMETERS 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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EXECUTIVE SUMMARY

The Environmental Protection Agency's MOBILE emissions factor model has been applied using transportation data from three representative and geographically diverse urban areas to develop estimates of total urban area motor vehicle emissions under a variety of analysis conditions. The results contribute to an improved understanding of how the MOBILE model can be effectively and efficiently applied by metropolitan planning organizations and State Departments of Transportation. Estimates of mobile source emissions must be developed for a wide variety of transportation and air quality purposes. Both an improved understanding and guidelines for the application of the MOBILE model would be useful to those agencies and individuals having responsibilities for the development of mobile source emission estimates. The following is a summary of the principal findings resulting from the analyses that have been conducted:

1. The estimation of on-highway vehicular emissions is no longer as simple as multiplying an area-wide estimate of vehicle miles of travel by a simple per mile emissions factor. The challenges of conducting accurate mobile source emissions analyses have increased significantly during recent years, corresponding with the development of an improved understanding of the multiple sources and causes of vehicular emissions. Important factors to be incorporated into an analysis include vehicle operating conditions, the number and timing of trips, temperature, fuel properties, and vehicle fleet characteristics.

2. The capabilities of the MOBILE emissions factor model have been changed over the years in many important ways. These include the inclusion of more sources of vehicular emissions, and the more detailed representation of these emissions. At the same time, improvements in the understanding of vehicle emissions data continue to be made and new releases of the MOBILE model, or its equivalent, are almost a certainty. The most recent release, MOBILE5a, produces measurably higher estimates of emissions under equivalent analysis assumptions than previous versions. In conducting transportation emission analyses, it is important that the results from one version of the MOBILE model not be compared with the results of other releases.

3. In using the MOBILE model to generate vehicular emission rates, the model's input parameters should be adapted to reflect local conditions. In addition to vehicle operating speed, these include operating mode fractions, temperature, and vehicle fleet characteristics. Capturing differences in these data by geographic sector, highway functional class, and time of day also is important and can result in significant differences in the magnitude of estimated mobile source emissions. The practice of adopting national default analysis assumptions should be avoided. Similarly, the

adoption of a single region-wide set of MOBILE input parameters is not recommended.

4. The Federally mandated motor vehicle emissions control program, together with the other Clean Air Act mobile source control strategies that may be required in a particular urban area, will produce significant reductions in future year emissions but may not be sufficient by themselves to achieve the target emission reductions required by the 1990 amendments to the Clean Air Act. This is especially the case in those regions of the country experiencing high rates of growth in travel. In addition, NO_X emissions are not reduced nearly as much as either CO or VOC emissions by these Federal measures. This will be an important consideration in those areas of the country where the formation of ozone is controlled more by NO_X than by VOC emissions.

5. The development of a spatially and temporally distributed estimate of mobile source emissions is required to support use of a photochemical oxidant model. Such models utilize input that is defined on both a grid and hourly basis. The development of such estimates, though, is not a natural output of today's standard urban transportation planning models, and considerable effort may be involved to produce accurate information at this level of detail. To make this effort as efficient as possible, it is recommended that time periods, roadway types, and other analysis conditions be grouped into segments of relative equivalency but without resorting to the use of a single MOBILE input file.

6. In developing emission inventories and conducting other mobile source emission analyses, it may not always be useful to develop a full spatially and temporally disaggregated estimate of mobile source emissions unless the accuracy of the vehicle speed estimates are verified and spatial and temporal differences in other MOBILE model input parameters are developed as well. Using data from the three urban areas examined in this analysis, only relatively small differences in the results are obtained between link-based or similarly detailed analyses and analyses that are based only on a simpler disaggregation of highway functional classes and time periods. It may be more important to develop accurate estimates of vehicle operating speed, especially for those portions of the roadway system that may be operating on those portions of the MOBILE model speed correction curves where vehicular emissions increase in a markedly nonlinear manner with changes in vehicle speed. It also is desirable to capture geographic and temporal differences in other MOBILE model input parameters. Accomplishing both of the above tasks is important in developing an accurate estimate of mobile source emissions.

7. Different emission "inventories" or estimates may be developed for different analysis purposes including establishment of a SIP inventory, evaluation of alternative mobile source control strategies, and for photochemical oxidant modeling. Care should be taken to document underlying assumptions and in comparing estimates of emissions that have been developed for different purposes within the same nonattainment area.

1. INTRODUCTION

1.1 BACKGROUND

The appropriate level of spatial and temporal data aggregation for highway vehicle emissions analyses is one of several important analytical questions that has received considerable interest following passage of the Clean Air Act Amendments (CAAA) of 1990. Should vehicular emissions be calculated on a link, traffic analysis zone, grid cell, functional class, corridor, subarea, or areawide basis? Further, should these same vehicular emissions be estimated on an hourly, peak period, or daily basis?

A number of motivating factors are contributing to this interest:

- Nonattainment areas that are classified as "serious" or higher under the new Clean Air Act are required to use photochemical oxidant models. These models, such as the Urban Airshed Model (UAM), require emission inventories to be specified by both hour of the day and geographic grid cell.

- The scope and content of the section 176(c) conformity provisions are significantly expanded under the Clean Air Act Amendments of 1990. Under these expanded provisions, the total nonattainment area emissions expected to result from implementing transportation plans, programs, and projects must be equal to or less than these projected in the corresponding mobile source emission reduction schedules contained in the State Implementation Plan (SIP). For ozone nonattainment areas, this implies consistency with the volatile organic compound (VOC) and the NO_X emission inventories for on-road mobile sources. This concept of a regional "emissions budget" creates a much stronger analytical basis for the conformity determination than existed in the past.

  Section 51.452 of the Final Conformity Rule (40 CFR Part 51, subpart T) requires that a network-based travel demand model be used in serious, severe, and extreme ozone nonattainment areas and serious carbon monoxide nonattainment areas. The rule specifies attributes that the transportation demand modeling process should possess and states that the choice of models, analytical methods, and associated assumptions should be topics for interagency consultation. While the rule further states that separate "peak and off-peak travel demand and travel times must be provided," specific procedures for any geographic, functional classification, or additional temporal disaggregation of the emissions analysis that may be desirable are not specified. The emphasis, instead, is on the use of "acceptable professional practice" and methods that are "reasonable for purposes of emission estimation." Additional guidance for the application of network-based travel demand models in conformity analyses, could thus be helpful to metropolitan planning organizations and State departments of transportation in developing procedures for the aggregation of vehicles miles of travel (VMT) and vehicular operating speeds, and for converting from an average annual daily traffic (AADT) situation to conditions that are more representative of the summer ozone season.

- Emissions increase disproportionately at speeds below approximately 20 mph, conditions which may be reflective of peak period congested traffic flow in urban areas. Yet these low speeds may be averaged out of an analysis if either long time periods or large geographic areas are used as the basis for estimating VMT and speed.

- There is increasing evidence that mobile source emissions have been significantly underestimated in the past. This is necessitating a re-examination of all methodologies used in estimating mobile source emissions. Problems may exist in the emissions models themselves, in the structure of the transportation models, in the interface between transportation and emission models, or a number of different factors may be contributing to this underestimation. For example, the MOBILE model emission rates are based on a concept of a representative trip, from origin to destination. Questions have been raised regarding the appropriateness of interfacing the MOBILE model with a network travel demand model. Specifically, how should a trip-based emissions model such as MOBILE be used to estimate link-level emissions where there may be relatively few changes in vehicle operating speed over the length of any one individual link?

- The Environmental Protection Agency (EPA) has continued to refine and expand the variables included in its MOBILE emissions factor model, with MOBILE5a being the current release. As the understanding of both the formation of vehicular emissions and photochemical modeling has improved, MOBILE output has increasingly been disaggregated by individual components of exhaust and evaporative emissions, as well as by different groupings of reactive hydrocarbons. In addition, increased attention has been devoted to isolating trip end emissions, including cold and hot start and hot soak emissions. It is important that transportation and emissions models be linked using a compatible, consistent set of variables. California's EMFAC/BURDEN mobile source emissions estimation procedures already include this capability. In addition, a number of urban areas have adapted the MOBILE model to produce trip end emissions. Traffic assignment programs are beginning to be modified so as to track trips in addition to VMT; and EPA is considering the option of explicitly outputting trip end emissions as part of a future modification of the MOBILE model.

1.2 OBJECTIVE

The transportation portion of a regional emissions inventory traditionally has been calculated on a highly aggregate basis, often using only single areawide estimates of VMT and travel speed and the corresponding MOBILE-generated emissions factor. Although agreement exists that increased data disaggregation is desirable, there is less certainty about how much detail is justified. Two factors, in particular, complicate the situation. First, many transportation and air quality agencies are operating under serious personnel and financial resource constraints. More detailed analyses require correspondingly higher levels of personnel time and cost. What are the specific benefits of these higher expenditures? Second, is the same level of data disaggregation required in all emission analyses? Could policy evaluations be performed at one level of analysis, with the much less frequent photochemical oxidant modeling being performed with more detailed hourly and gridded data?

The primary purpose of the work reported on herein has been to examine the effects on vehicular emissions that results from using different levels of spatial and temporal data disaggregation of actual travel data from three representative urban areas. As hypothesized, would estimated emissions increase with increasing levels of data disaggregation? Averaging vehicle speeds over moderately long time periods may yield results that are on the relatively flat portion of the emissions rate vs. vehicle speed curve. In this case, emissions produced under congested low speed operations can be entirely lost if not explicitly accounted for in the summation process. Given the non-linear relationship between emissions and vehicle speed, especially at the low end of the speed curve, these high emissions may be systematically omitted by the averaging process and, therefore, result in underestimating total vehicular emissions. The work also contributes to three important additional objectives that are of widespread current interest.

- What are the effects on total estimated vehicular emissions of using successive versions of the MOBILE model?

- How important are the Clean Air Act's mandated Federal policies in reducing future year emissions?

- What specific MOBILE input variables should be modified in developing a spatially and temporally disaggregated emissions estimate, especially with respect to cold/hot start operating mode, temperature, and vehicle fleet mix?

1.3 APPROACH

Three large representative metropolitan areas were selected as sources of data for the analyses. The areas vary by population size, volume of travel, growth rate and nonattainment status (table 1):

- An eastern urban area in serious nonattainment of the ozone standard and moderate nonattainment of the carbon monoxide standard;

- A western urban area in moderate nonattainment of the carbon monoxide standard; and

- A southern urban area in severe nonattainment of the ozone standard.

Table 1. Characteristics of Urban Areas Analyzed

Urban Area	Population (1990)	Non-Attainment Status		Daily Vehicle Miles of Travel (VMT)		Average Annual Growth Rate
		Ozone	Carbon Monoxide	Base Year	VMT Per Capita	
Eastern	4,300,000	Serious	Low Moderate	77,400,000	18.0	1.9%
Western	1,850,000	Transitional	High Moderate	32,300,000	17.5	6.4%
Southern	3,300,000	Severe	Attainment	92,900,000	28.1	2.3%

Travel network volume and speed data were used for each of these areas as provided by local agencies, without any post-processing adjustment for geographic network coverage, vehicle speed, or off-network roads. VMT and speed data were examined on a functional class and areawide basis, and where possible, also on a link basis. In addition, these data were grouped on both a major time period and daily basis. Priority was given to using data generated by urban area metropolitan planning organizations (MPOs) or State Departments of Transportation (DOTs) so as to duplicate as closely as possible the same analysis procedures as would typically be performed in actual practice.

The distributions of VMT by functional roadway classification and daily time period are summarized for each urban area in tables 2 and 3 respectively, with complete tabular summaries of the travel data contained in the appendix of this report. As indicated in table 4, the eastern area, in addition to having link level data, contained four functional roadway classifications and five time periods. The western urban area utilized eight functional classifications, three time periods, and five geographic subareas. The southern urban area tabulated data according to six functional classifications, four time periods, and three geographic subareas.

Emission estimates were developed for both a current base line condition and the year 2010 using MOBILE model datasets also provided by each of the urban areas. Carbon monoxide emissions were analyzed for winter conditions; hydrocarbon and NO_X emissions were analyzed for summer conditions. Traffic volumes and vehicle operating speed, however, were not adjusted by time of year. Clean Air Act policies included in all future year analyses included Tier I vehicle emission standards, the cold temperature carbon monoxide standard, and the new evaporative test procedure. Other CAA policies included in the future year analyses varied by nonattainment status and current SIP decision making. These include enhanced vehicle inspection/maintenance, reformulated fuel, oxygenated fuel, reduced Reid Vapor Pressure (RVP), and Stage II refueling controls. In addition to discretionary SIP measures, the following four required Clean Air Act policies were not accounted for in the analyses: Clean Fueled Fleets, California LEV Opt-In, Employee Commute Option Programs, and Transportation Control Measures to Offset VMT Growth. SIP planning had not progressed sufficiently far in these urban areas at the time the analyses were performed to permit definitive measures to be defined in the input data.

It also is important to note differences in the MOBILE input datasets provided. The eastern and western urban areas used a single dataset, while the southern urban area defined separate MOBILE datasets for each of the four daily time periods examined. The use of multiple datasets allowed adjustments by time of day to be made in ambient temperature and vehicle cold/hot start operating mode data. The MOBILE model, while providing national defaults, allows extensive adaptation of input parameters to reflect local analysis conditions. For example, there is considerable variation in the age of the vehicle fleet among individual states, with states in warm and dry climates having older vehicle fleets than states in colder climates that experience extensive snow and repeated cycles of freezing and thawing. Adjusting the vehicle age distribution can have an important effect on estimated total emissions. Similarly, changes in RVP have a significant impact on hydrocarbon emissions. In conducting a highway vehicle emissions analysis using the MOBILE model, the full range of potential input parameters should be adapted to reflect local conditions. Spatially and temporally disaggregating VMT and vehicle speed data

Table 2. Distribution of Vehicle Miles of Travel by Roadway Functional Classification

	Urban Area					
Functional Classification	Eastern		Western		Southern	
Freeways and Express Highways	42%		41%		44%	
Major Arterials	29	} 44%	36	} 44%	16	} 41%
Minor Arterials	15		8		25	
Collectors	–		15		6	} 15%
Local Roads	14		–		9	
Total	100%		100%		100%	

Table 3. Distribution of Vehicle Miles of Travel by Time Period

	Urban Area					
Time Period	Eastern		Western		Southern	
AM Peak	20%		13%		18%	
PM Peak	26		26		25	
Mid Day	28	} 54%	–		38	} 57%
Off Peak	26		61		19	
Total	100%		100%		100%	

Table 4. Classification of Highway Network Data by Urban Area

	Urban Area		
	Eastern	Western	Southern
Highway Functional Classes	4	8	6
Time Periods	5	3	4
Geographic Subareas	1	5	3

will not eliminate errors in the estimated emissions if temperature, operating mode, RVP, vehicle fleet, inspection/maintenance, and other data are also not accurately known and properly coded.

1.4 RELATED MOBILE MODEL WORK

This work was undertaken as part of a broader analysis of the MOBILE emissions factor model conducted for the Federal Highway Administration of the U.S. Department of Transportation. The overall objectives of the larger project have been to 1) develop an improved understanding of the MOBILE model on the part of transportation agencies, and 2) to assess the effects of recent changes in the MOBILE model on the estimated emissions of transportation plans, programs, and projects.

The application of MOBILE to three representative urban areas represents a "macro" analysis using actual urban area data. The emphasis is on assessing the impact on total estimated urban area emissions rather than on isolating the effects of individual MOBILE input variables. To compare the effects of different evolutionary versions of the MOBILE model, analyses were conducted using MOBILE4 and MOBILE4.1 as well as MOBILE5/5a.

Work reported on separately has concentrated on identifying, documenting, and evaluating the effects of individual changes incorporated by the Environmental Protection Agency (EPA) in MOBILE4, MOBILE4.1, and MOBILE5.[1] Sensitivity analyses were conducted for each of the major MOBILE input data variables using national default assumptions. The purpose was to determine the relative importance of these individual changes on the outcome of transportation analyses. Compared to the representative urban area analyses reported here, these single variable results are more "micro" in nature. They have the important advantage of isolating the effects of individual variables, but do not necessarily capture the effects of simultaneous changes in multiple variables such as typically would occur within the data for an actual urban area. The results presented in this report use particular combinations and values of MOBILE input parameters that reflect conditions within particular urban areas.

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[1] *Evaluation of MOBILE Vehicle Emissions Model*, FHWA-PD-94-038, December 1994.

A second objective of this related work has been to identify important areas of uncertainty in the MOBILE model. The representativeness of the current "LA4" driving cycle used as the basis for the vehicle emissions certification Federal Test Procedure (FTP) was given particular emphasis. For example, questions have been raised regarding the appropriateness of utilizing aggregate FTP emissions rates in a transportation analysis where emissions estimates are being developed on either a link or functional class basis, conditions where individual facilities or classes of facilities may have very different operating characteristics than those represented in the current FTP. In addition, how would potential changes in the current FTP potentially impact both the manner in which mobile source emissions estimates are developed and the overall magnitude of these estimates?

The results of these two related analyses of MOBILE model applications should be helpful to both transportation and air quality personnel in developing an improved understanding of the interface between transportation and emissions modeling. It is especially important that personnel of metropolitan planning organizations and State Departments of Transportation develop a sound understanding of the methodologies and variables utilized in emissions modeling if the analytical requirements of the Clean Air Act are to be accomplished in an efficient and productive manner. These two related efforts have been designed to help accomplish this overall goal.

2. FINDINGS

The estimates of MOBILE emissions for the three representative urban areas have been examined from the perspective of four principal questions:

1. What is the impact of using MOBILE5a to estimate areawide mobile source emissions relative to the use of MOBILE4 and MOBILE4.1?
2. How much are the Clean Air Act's required mobile source control strategies likely to reduce future year emissions, compared to the emissions that would otherwise result from projected growth in population, employment, and travel?
3. What are the effects of changing MOBILE input variables other than vehicle speed in developing emission inventories?
4. What are the effects on estimated total areawide emissions of introducing additional levels of spatial and temporal data disaggregation?

Each of these questions is addressed in the following sections. For each question, the analysis results are first presented in graphical form and then the implications of these findings are discussed.

2.1 DIFFERENCES BY MOBILE MODEL

Base year emission inventories in 1990 were initially developed using MOBILE4.1. MOBILE5 was released in December 1992, updated to MOBILE5a in March 1993, and is now the standard for all future emission analyses. Comparisons of the estimated base year emissions calculated by MOBILE4, MOBILE4.1, and MOBILE5 for each of the three urban areas are displayed in figures 1, 2, and 3.[2]

For hydrocarbons, estimated emissions are roughly equivalent for MOBILE4 and MOBILE4.1 for the western and southern urban areas. MOBILE5, however, results in significantly higher estimated emissions in each of the three cases; 24 percent for the western urban area, 15 percent for the southern urban area, and 23 percent for the eastern urban area.[3] For carbon monoxide emissions, MOBILE5 again produces higher estimated emissions for the same analysis conditions than either MOBILE4 or MOBILE4.1. For the western urban area, MOBILE5 carbon monoxide emissions are 29 percent higher than those estimated with MOBILE4.1. The difference is

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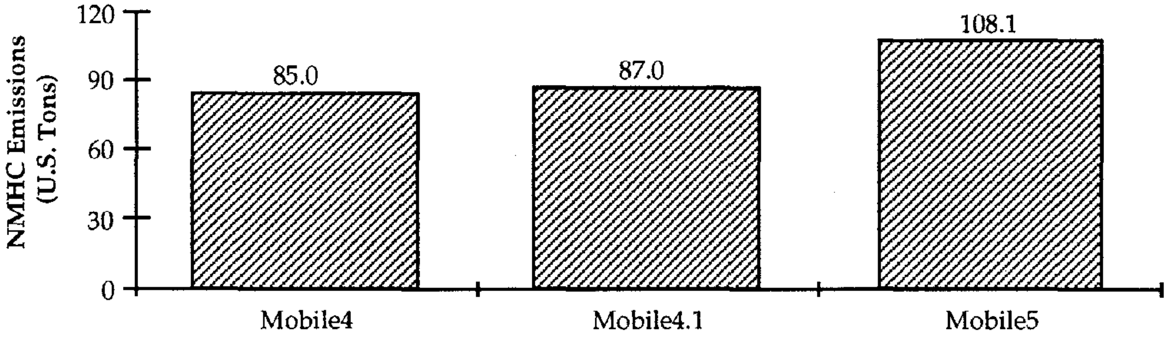
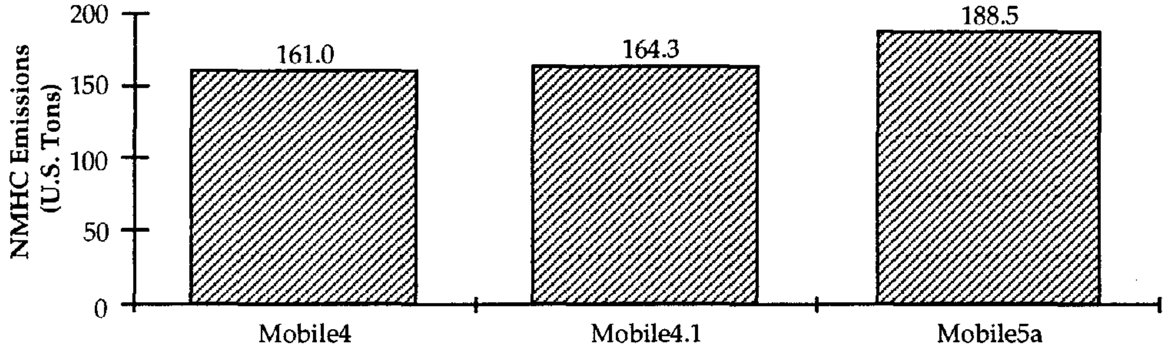
[2] These comparisons are presented only for base year conditions since new Clean Air Act control strategies are not incorporated in MOBILE4 and MOBILE4.1. EPA has stated that these models do not produce valid results for future year analysis conditions. The displayed results were developed using the most disaggregate classification of data that were available for each urban area.

[3] As figure 1 indicates, the western and southern urban areas estimated emissions of nonmethane hydrocarbons (NMHC) using successive versions of the MOBILE model. In the eastern urban area, however, the estimates of hydrocarbon emissions produced by MOBILE4 and 4.1 refer to volatile organic compounds (VOC), while those estimated using MOBILE5 refer to NMHC. Because these two measures of hydrocarbon emissions (NMHC and VOC) include slightly different chemical compounds, the estimated inventories are not strictly comparable.

A. Western Urban Area



B. Southern Urban Area



C. Eastern Urban Area

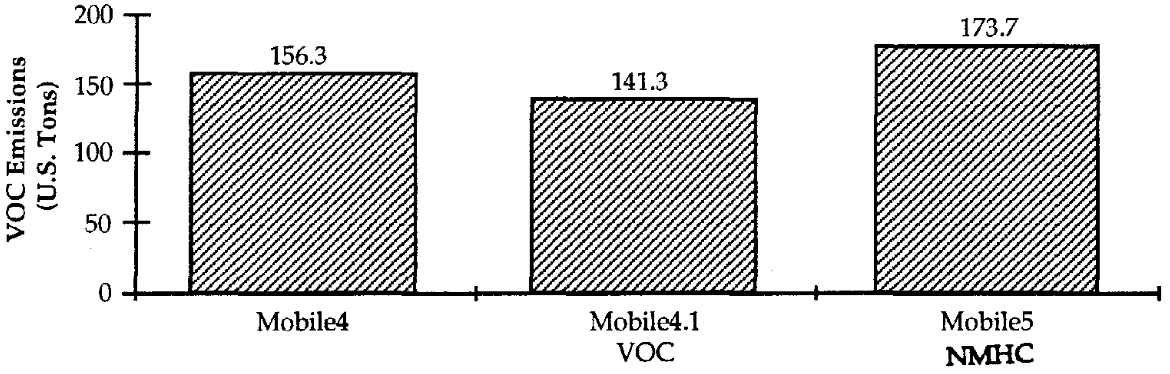
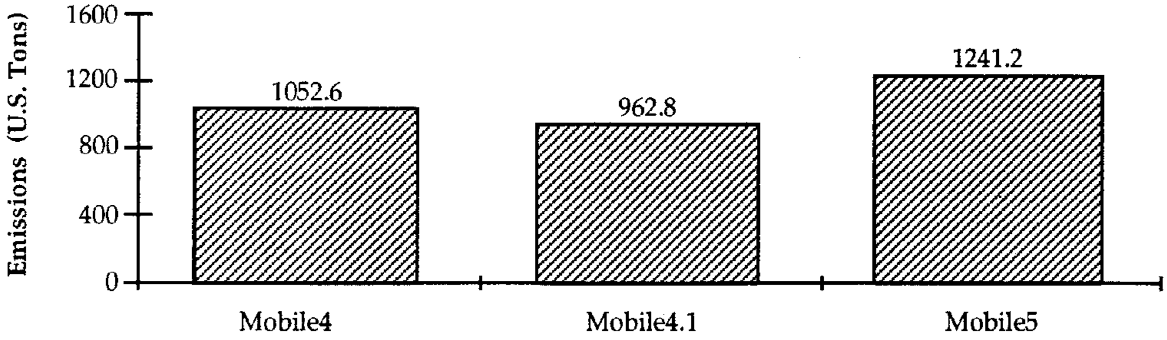
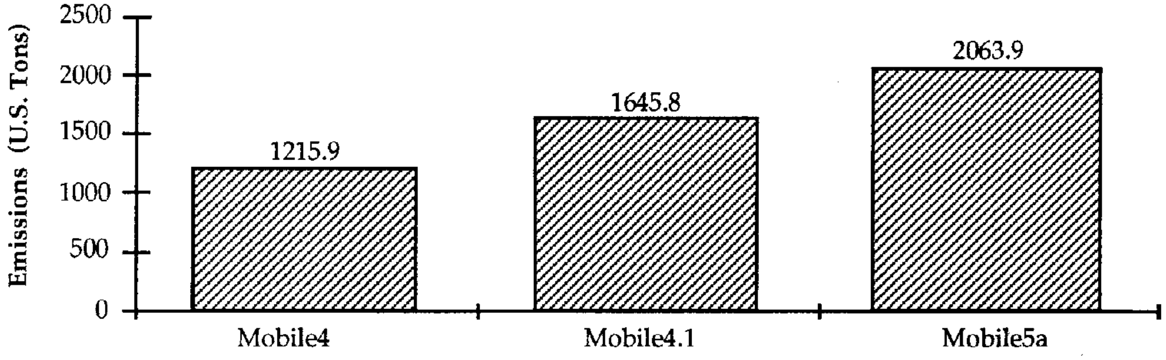


Figure 1. Comparison of MOBILE Model Base Year Emission Estimates: Hydrocarbons

A. Western Urban Area



B. Southern Urban Area



C. Eastern Urban Area

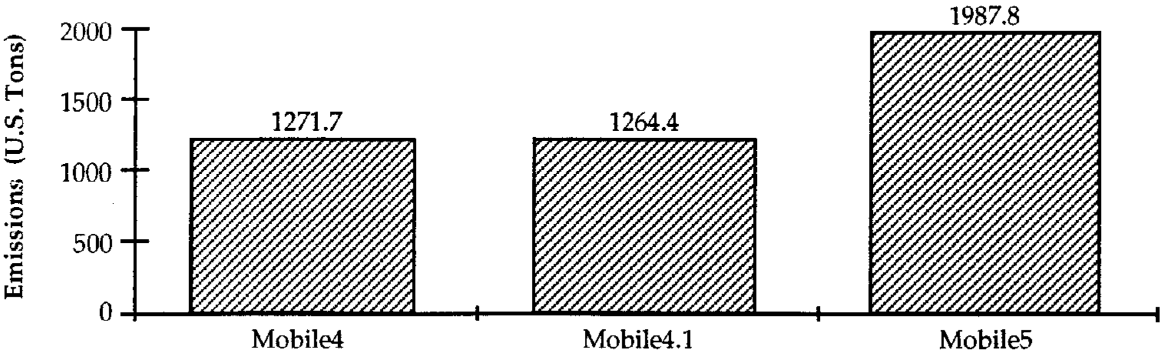
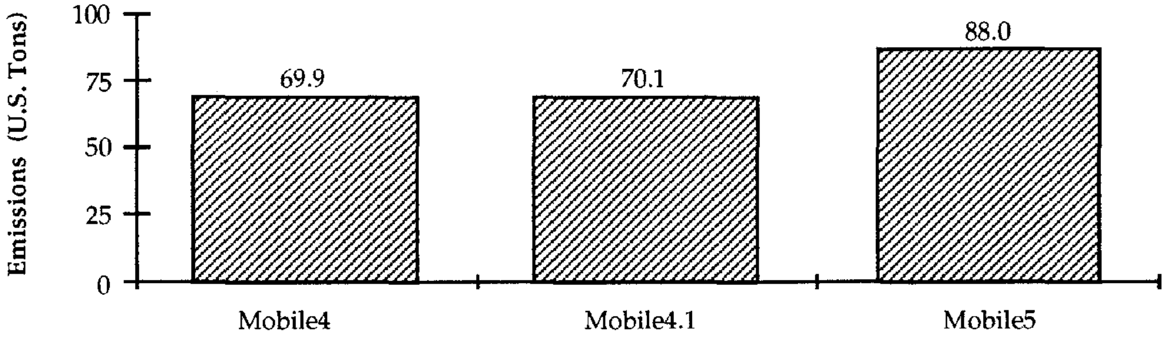
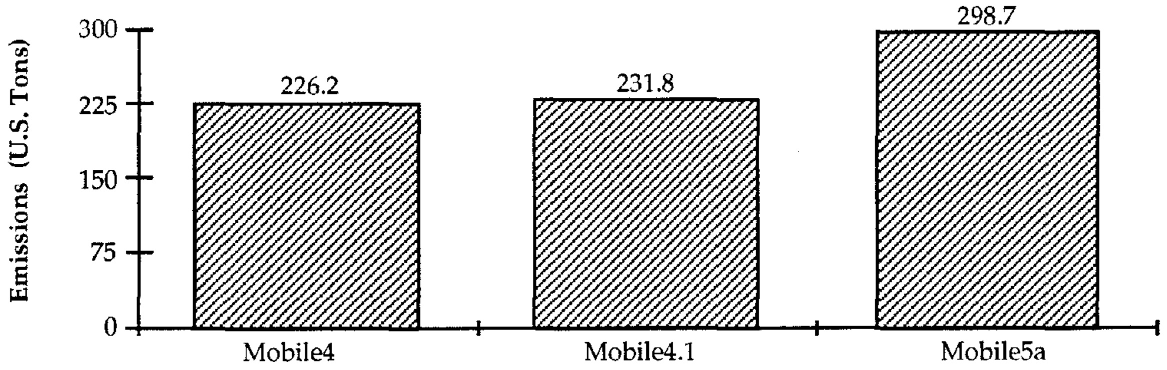


Figure 2. Comparison of MOBILE Model Base Year Emission Estimates: CO

A. Western Urban Area



B. Southern Urban Area



C. Eastern Urban Area

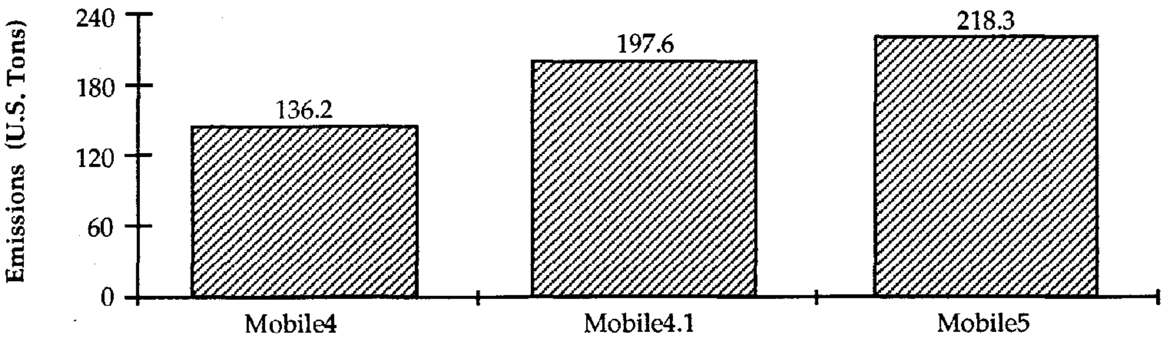


Figure 3. Comparison of MOBILE Model Base Year Emission Estimates: NO_x

25 percent for the southern urban area, and 57 percent for the eastern urban area. The relationship between MOBILE4.1 and MOBILE4, however, is not consistent. Estimated areawide carbon monoxide emissions for the western urban area are lower with MOBILE4.1 than with MOBILE4, while for the southern urban area, MOBILE4.1 produced higher estimated carbon monoxide emissions than MOBILE4. For the eastern urban area, MOBILE4 and MOBILE4.1 produced essentially identical estimates of carbon monoxide emissions.

For NO_X emissions, the pattern is similar to that observed for hydrocarbons. MOBILE5 NO_X emissions are 11 percent higher than MOBILE4.1 for the eastern urban area; 25 percent higher for the western urban area; and 29 percent higher for the southern urban area.

A detailed discussion of the differences between the MOBILE4, MOBILE4.1, and MOBILE5 emission factor models appears in the parallel technical report for this project.[4] Although numerous revisions have been made by EPA in each successive version of the MOBILE model, the primary reason for the consistently higher emission estimates produced by MOBILE5 is an increase in the base emission rate curves, especially for accumulated vehicle mileages that are in excess of 50,000 miles. As urban areas have transitioned from MOBILE4 to MOBILE5a, this change in the MOBILE model has resulted in increased base and future year emission inventories, and a need to decrease mobile source emissions by a larger amount than originally was anticipated. Both the higher emission estimates produced by MOBILE5 and the uncertainty created by the prospect of continued changes in the MOBILE model may make it more difficult than it otherwise would be for urban areas to demonstrate consistency with future year emission reduction targets. In the development of plans, programs, and projects by a metropolitan planning organization or State Department of Transportation, the emission estimates from one version of the MOBILE model should not be compared with the results from another version of the model; care should be taken to always use the same version.

2.2 EFFECTS OF THE CLEAN AIR ACT

Future year emissions are projected to be lower than current year emissions, at least on a per vehicle basis, because of the progressively cleaner vehicle fleet. There has been considerable interest, though, in whether the increased emissions associated with anticipated growth in population, employment, and personal travel will be of sufficient magnitude so as to offset the effects of a cleaner vehicle fleet. Section 182(d)(1)(A) of the new Clean Air Act specifically states that ozone nonattainment areas that are classified as severe or above are required to offset the emissions that result from growth in travel. In addition, under section 182(b)(1)(D) emission reductions resulting from the Federal Motor Vehicle Emission Control Program are not creditable toward the required 15 percent emission reductions.

Comparisons of estimated future and base year emissions, by pollutant, for each of the three urban areas are presented in figures 4, 5, and 6. The right bar in each figure isolates the emission impact of the following three Clean Air Act policies:

- Tier I tailpipe exhaust emission standards;

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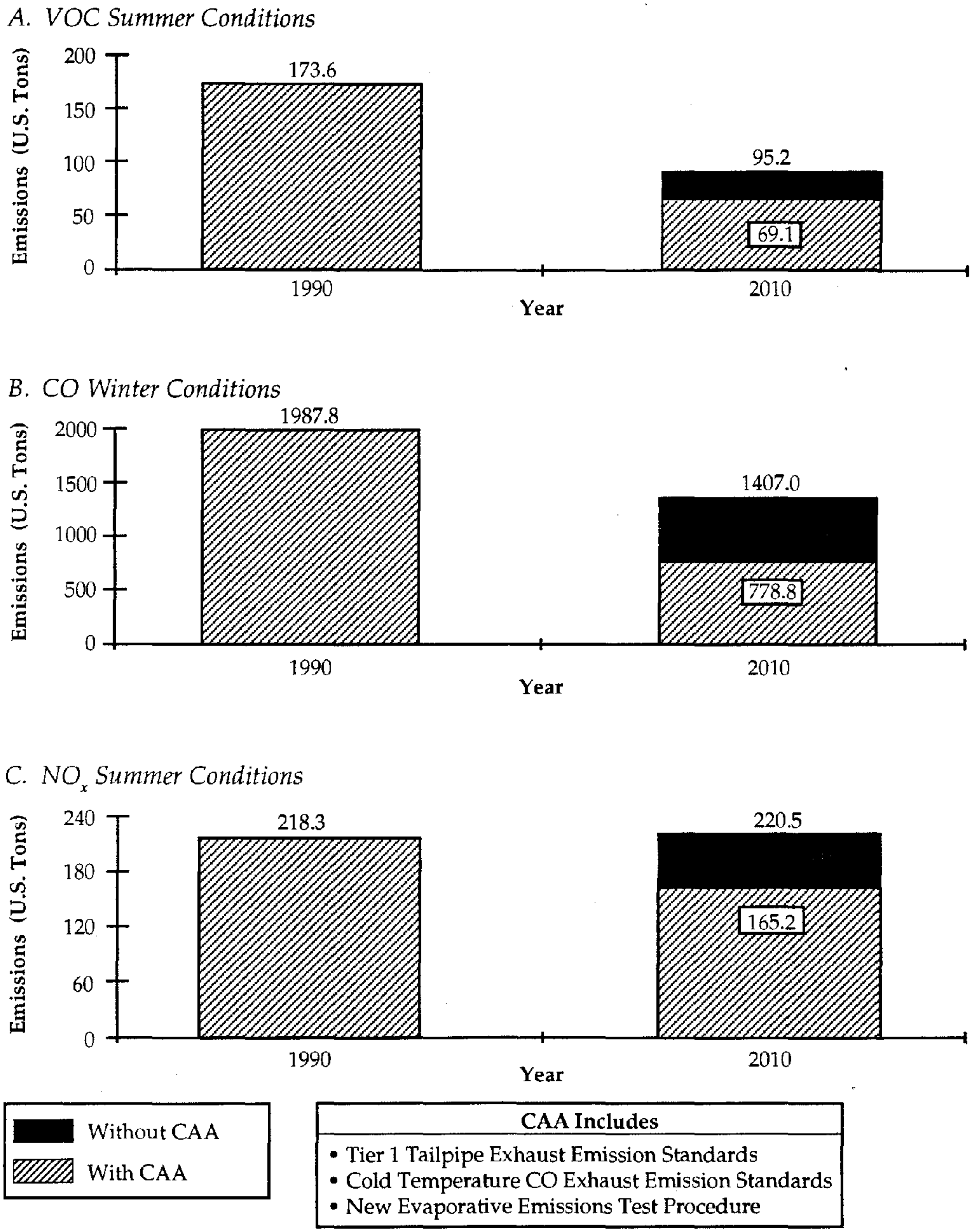
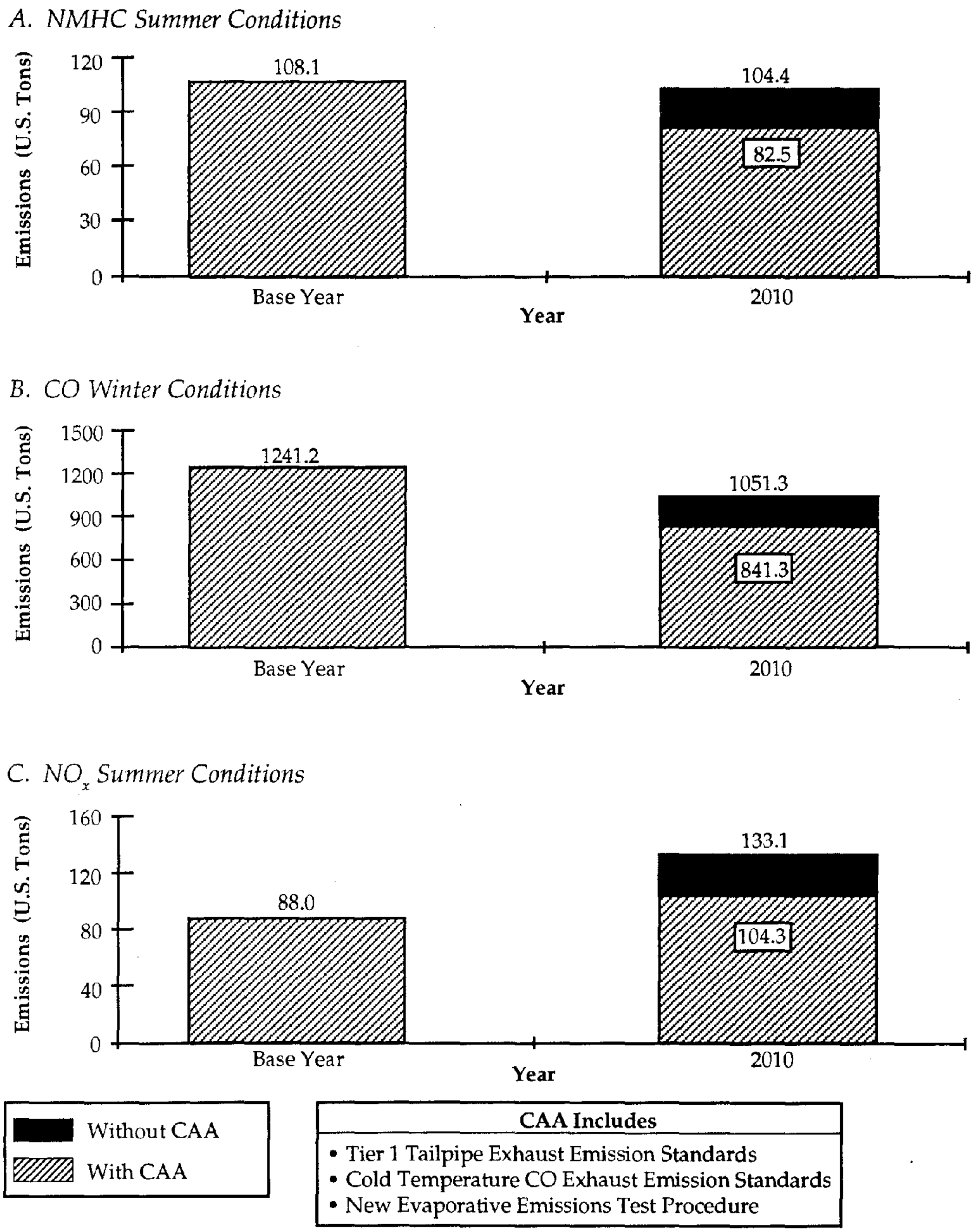
[4] *Evaluation of MOBILE Vehicle Emissions Model*, FHWA-PD-94-038, December 1994.



CAA Includes

- Tier 1 Tailpipe Exhaust Emission Standards
- Cold Temperature CO Exhaust Emission Standards
- New Evaporative Emissions Test Procedure

Figure 4. Estimated Future Year MOBILE5a Emissions With and Without Federal Clean Air Act Measures
Eastern Urban Area


A. *NMHC Summer Conditions*

B. *CO Winter Conditions*

C. *NO_x Summer Conditions*

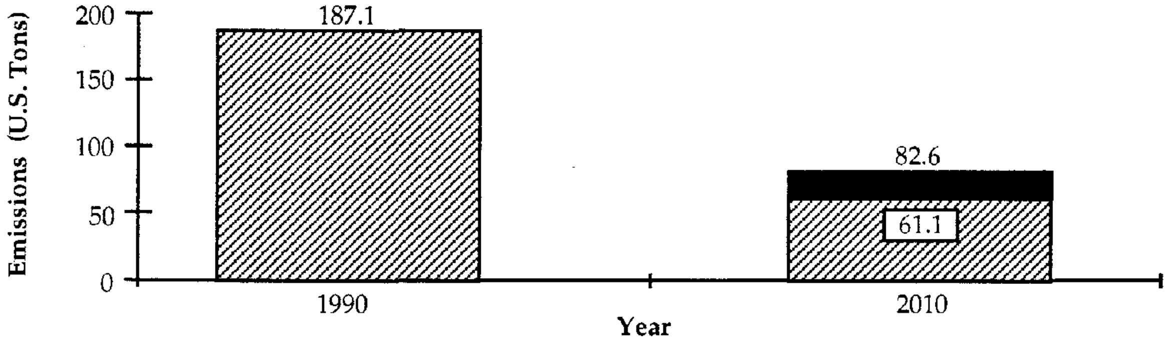
CAA Includes

- Tier 1 Tailpipe Exhaust Emission Standards
- Cold Temperature CO Exhaust Emission Standards
- New Evaporative Emissions Test Procedure

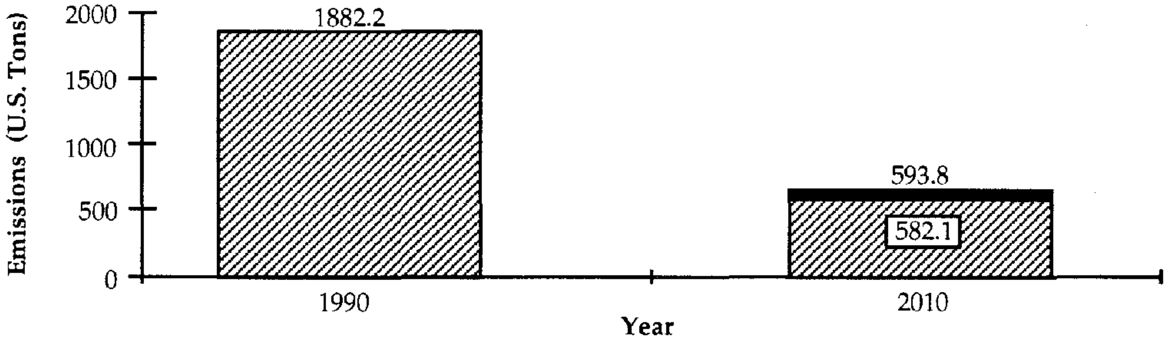
Figure 5. Estimated Future Year MOBILE5a Emissions With and Without Federal Clean Air Act Measures

Western Urban Area

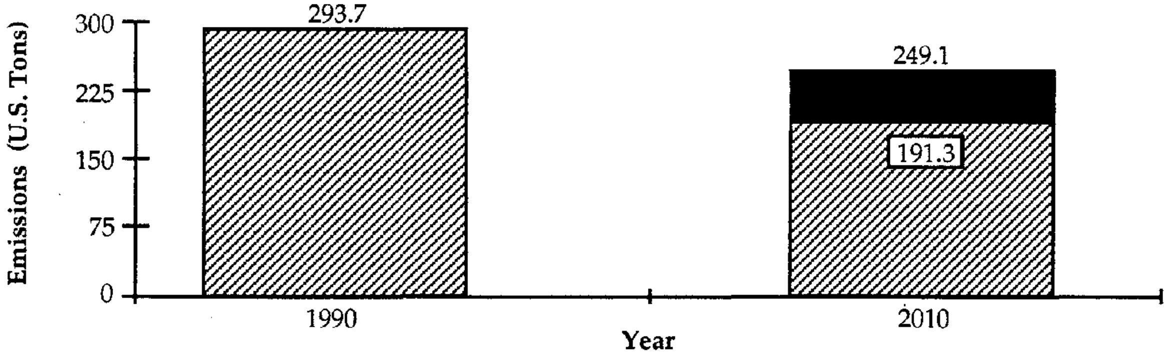
A. NMHC Summer Conditions



B. CO Winter Conditions



C. NO_x Summer Conditions



■ Without CAA
▨ With CAA

CAA Includes

- Tier 1 Tailpipe Exhaust Emission Standards
- Cold Temperature CO Exhaust Emission Standards
- New Evaporative Emissions Test Procedure

Figure 6. Estimated Future Year MOBILE5a Emissions With and Without Federal Clean Air Act Measures
Southern Urban Area

- Cold temperature carbon monoxide exhaust emission standards; and
- New evaporative emissions test procedure.

For each of the three pollutants examined, year 2010 estimated emissions are projected to be less than base year conditions when all CAA policies are included except for NO_X emissions in the western urban area. In the eastern urban area, year 2010 NO_X emissions are projected to decrease by 24 percent as a result of the Clean Air Act, but would increase slightly without implementation of the Federal Clean Air Act measures.

Future year VOC emissions are estimated to be 60 percent lower for the eastern urban area when considering the required policies of the Clean Air Act, but not including all discretionary measures that may be contained in the SIP. This corresponds to an average annual reduction of 3.0 percent. Eliminating the effects of the three CAA policies identified above would increase estimated future year VOC emissions from 69 to 95 tons, corresponding to a reduction of 45 percent from the current year estimate.

For the western urban area, hydrocarbon emissions are estimated to decrease from 108 tons per day to 82.5 tons per day with the Clean Air Act measures, but only to 104.4 tons per day when these measures are not considered. The projected decrease in carbon monoxide emissions is larger, 32 percent with the Clean Air Act measures, and 15 percent without the Clean Air Act measures. The increase in NO_X emissions and the smaller decreases in hydrocarbon and carbon monoxide emissions occurring in the western urban area compared to the other two urban areas reflect the considerably higher growth rate assumed for the western area. The emissions increases resulting from the growth in travel offset more of the emission decrease from a cleaner vehicle fleet in the western than in either the eastern or southern urban areas.

Estimated reductions in areawide emissions for the southern urban area are 67 and 69 percent respectively for nonmethane hydrocarbons (NMHC) and carbon monoxide. This corresponds to a 3.35 percent average annual reduction over this 20-year period. Because of the high ambient temperatures, the new cold temperature carbon monoxide standard has no impact in this particular urban area, although it affects winter carbon monoxide emissions in both the eastern and western urban areas.

NO_X emissions are not reduced as significantly in any of the three urban areas as are carbon monoxide and hydrocarbon emissions, and are projected to increase by 51 percent for the western urban area when the mandated Clean Air Act measures are not considered. This would be a problem for those areas where ozone formation is NO_X controlled and it is, therefore, more important to reduce NO_X than hydrocarbon emissions. For the southern urban area, year 2010 NO_X emissions are estimated to be reduced by 35 percent relative to 1990 base line conditions compared to the 67 percent reductions achieved for NMHC.

2.3 PARTIAL VERSUS FULL ADAPTATION OF MOBILE INPUT DATA

An important analytical question concerns the degree to which MOBILE input data should be modified in developing an emissions inventory. In addition to varying vehicle operating speed, candidate variables include temperature, cold/hot start operating mode, and vehicle fleet mix. In some large urban areas, there also may be geographic differences in the particular control policies that need to be represented within MOBILE. Modifying multiple MOBILE variables, however, significantly complicates the analysis, with special care having to be taken for temporally allocating diurnal emissions.

Only a single MOBILE dataset was utilized in developing the emission estimates for the eastern and western urban areas. Consistent with normal practice for those regions, only vehicle operating speed was modified in developing the different estimates of total areawide emissions. Multiple MOBILE datasets were available for the southern urban area, in which operating mode fractions changed by time of day. In addition, an ambient temperature was input separately for each of the four possible time periods rather than using the internally calculated MOBILE value.

Per mile emission hydrocarbon and NO_X rates for the southern urban area are displayed in figure 7 representing three separate vehicle speeds and five separate time periods. In order to compare equivalent emissions, the diurnal component of evaporative emissions is not included as part of the displayed emission rates. A 24-hour average emission rate is displayed as the right most bar, with the bars to the left representing the following four temporal subperiods: AM peak (7:00 to 9:00 AM), PM peak (4:00 to 6:00 PM), off-peak (6:00 PM to 7:00 AM), and midday (9:00 AM to 4:00 PM).

Hydrocarbon emission rates, as expected, are higher for 22 mph and progressively decrease for speeds of 35 and 55 mph. The pattern for NO_X emission rates, however, is different, but consistent with the changes incorporated by EPA in MOBILE5. NO_X emissions are only slightly higher at 35 mph than for 22 mph, but increase by almost 40 percent at 55 mph.

The PM peak period rates for hydrocarbon emissions are higher at each speed than those for the AM peak period because of the higher ambient temperature. This change more than offsets the lower cold start operating fraction which exists during the PM peak. The midday emission rates utilize a higher ambient temperature than the PM peak, but reflect the lowest cold start fraction of any of the defined time periods.

As discussed in section 2.4, there is more variation in the emissions estimated for the southern urban area when travel data are disaggregated than is the case for either the eastern or western urban area. This leads to the conclusion that it may be as useful to capture differences in temporal, spatial, link, or functional class emission rates that are caused by differences in temperature, operating mode, and vehicle mix as well as those that result only from vehicle operating speed.[5] It

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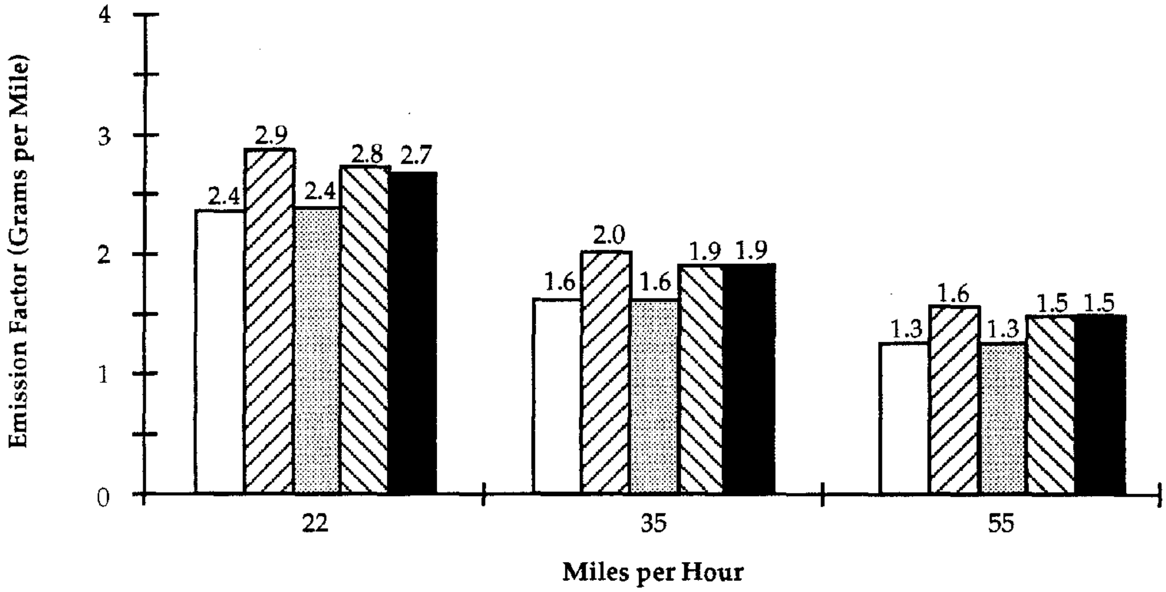
[5] It also may be useful to capture differences in emission rates that are caused by different acceleration/deceleration characteristics of the traffic stream. While these effects are the subject of current research being conducted by both the U.S. Environmental Protection Agency and the California Air Resources Board, only the standard FTP driving cycle is now modeled by the MOBILE and EMFAC emission factor programs.

A. VOC 1990 Summer Conditions



B. NO_x 1990 Summer Conditions

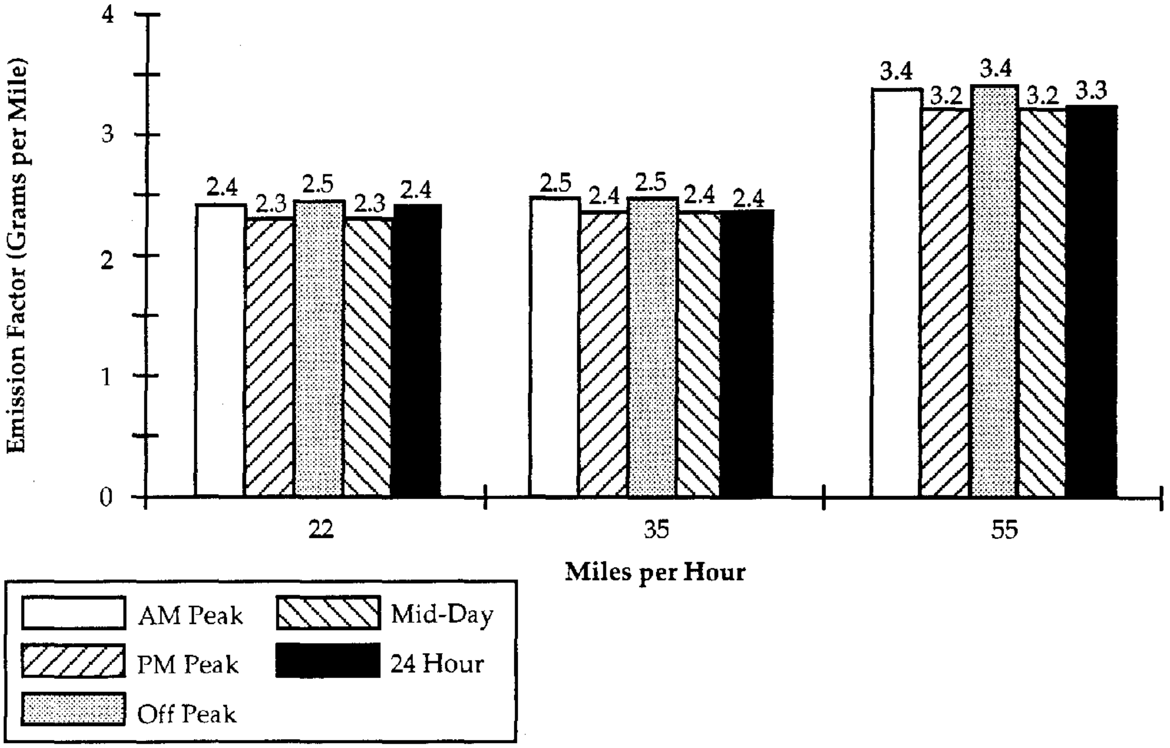


Figure 7. MOBILE5a Vehicle Emission Rates as a Function of Time of Day

Southern Urban Area

is now normal practice to vary vehicle operating speed primarily in developing emission inventories, even if these inventories are developed on an hourly or other disaggregate basis. Consistent with EPA guidelines for the development of spatially or temporally distributed emission inventories,[6] the accuracy of these inventories, can be increased if other MOBILE input variables are changed as well.

2.4 DATA DISAGGREGATION

Base and future year estimates of areawide emissions were developed at different levels of roadway and time period disaggregation based on available information. Base year MOBILE5 estimated total areawide emissions are displayed for each of the three urban areas in figures 8, 9, and 10. The left bar in each case represents the most disaggregate analysis. For the eastern area, this is a link level analysis corresponding to five analysis time periods. For the western urban area, the left bar represents five geographic subareas, eight functional classes, and three time periods. For the southern urban area, this corresponds to six functional classes and four time periods.

The right-most bar in each figure represents the highest level of data aggregation use of single areawide and daily estimates of VMT and vehicle speed. The center bars represent interim levels of data aggregation, as indicated in each figure.

For VOC in the eastern urban area, there is only a 3-ton difference in the results between the most and least disaggregate levels of analysis. The differences are somewhat larger for NO_X and carbon monoxide, with an increase in NO_X from 205 to 235 tons, or 12.7 percent, for the eastern urban area. For carbon monoxide, the difference is 261 tons, or 12 percent.

For the western urban area, a similar patterns exists but with smaller differences. Hydrocarbon emissions differ by only .6 tons between the areawide analysis and when the analysis is disaggregated by functional class, time period, and geographic sector. Carbon monoxide emissions differ by 2.4 percent and NO_X emissions differ by 7.3 percent.

For the southern urban area, the differences are larger than in the corresponding eastern and western cases. This is a result of using different MOBILE input datasets for each time period, in addition to taking into account differences in vehicle operating speed. Hydrocarbon emissions increase from 176 tons in the areawide analysis to 189 tons in the most disaggregate analysis, a difference of 6.5 percent. This difference is 23 percent for carbon monoxide and 16 percent for NO_X.

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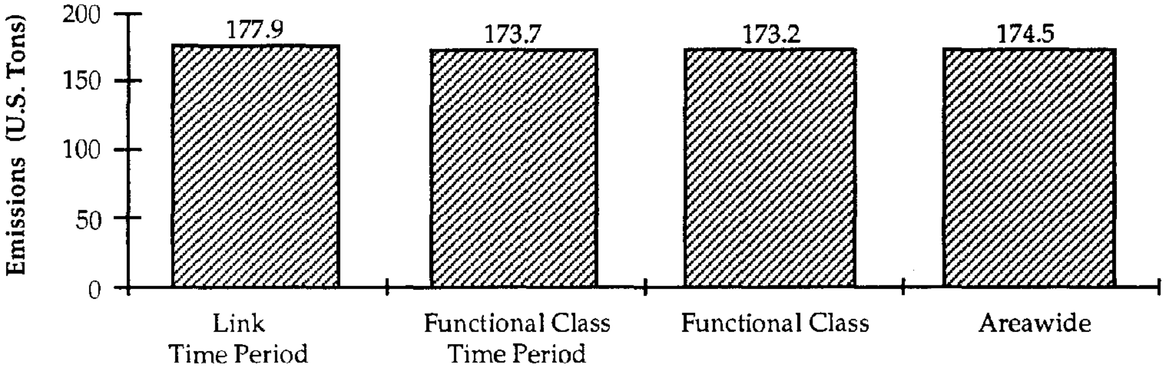
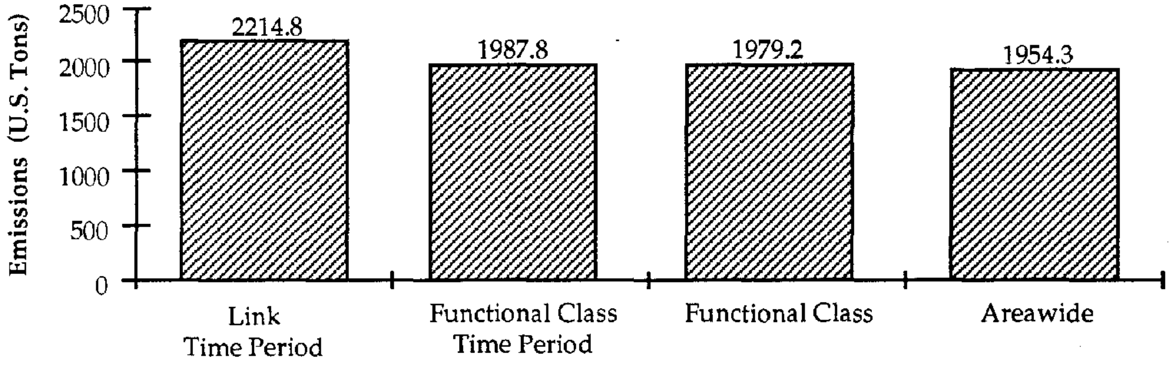
[6] U.S. Environmental Protection Agency, *Guidelines for the Preparation of Emission Inventories; Volume IV, Mobile Sources,* 1992.

A. VOC Summer Conditions



B. CO Winter Conditions



C. NO_x Summer Conditions

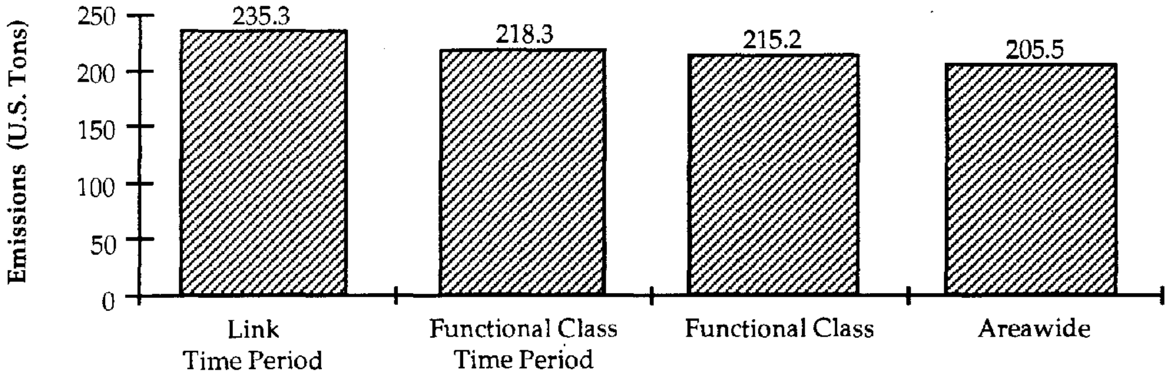
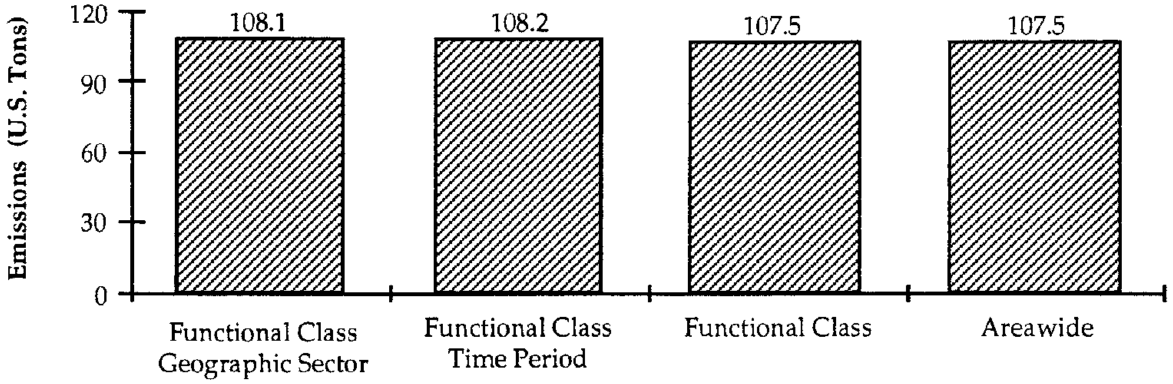
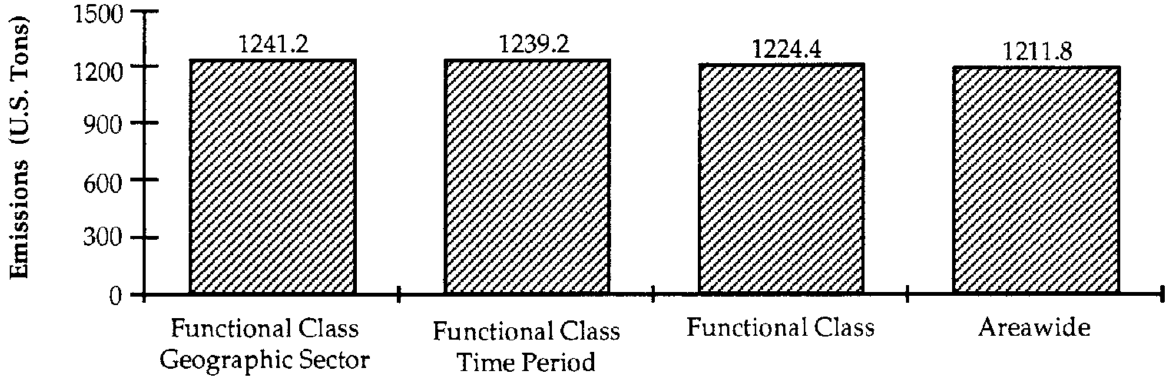


Figure 8. 1990 Base Year Emissions - MOBILE5a Eastern Urban Area

A. NMHC Summer Conditions



B. CO Winter Conditions



C. NO_x Summer Conditions

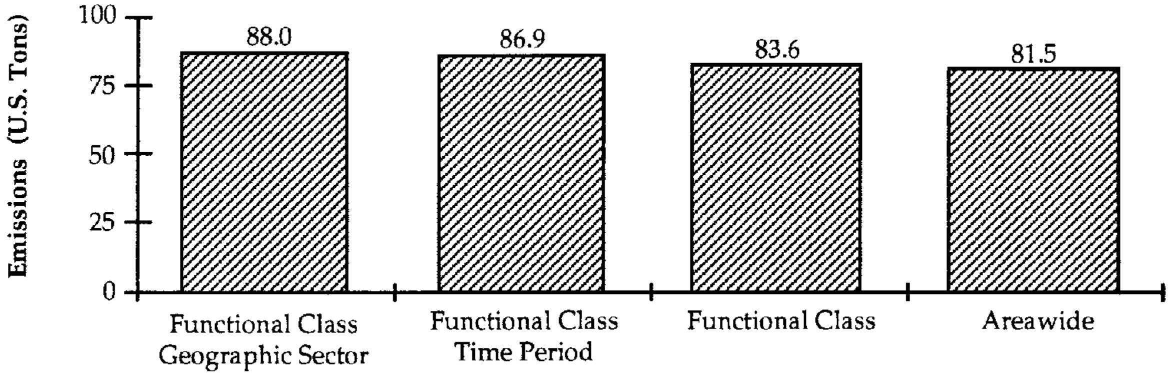
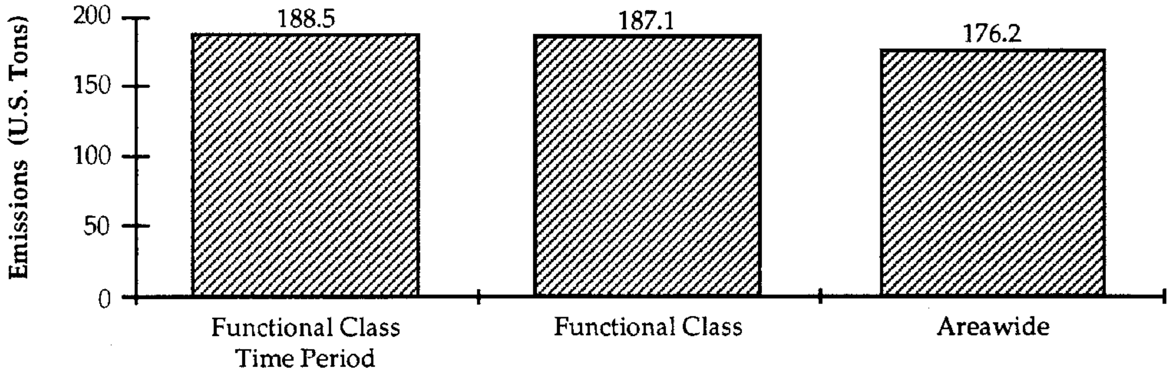
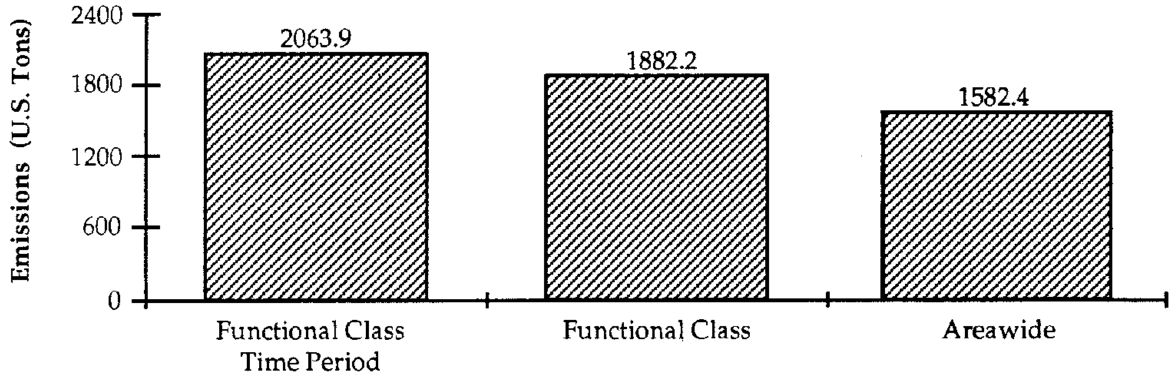


Figure 9. 1990 Base Year Emissions - MOBILE5a
Western Urban Area

A. NMHC Summer Conditions



B. CO Summer Conditions



C. NO_x Summer Conditions

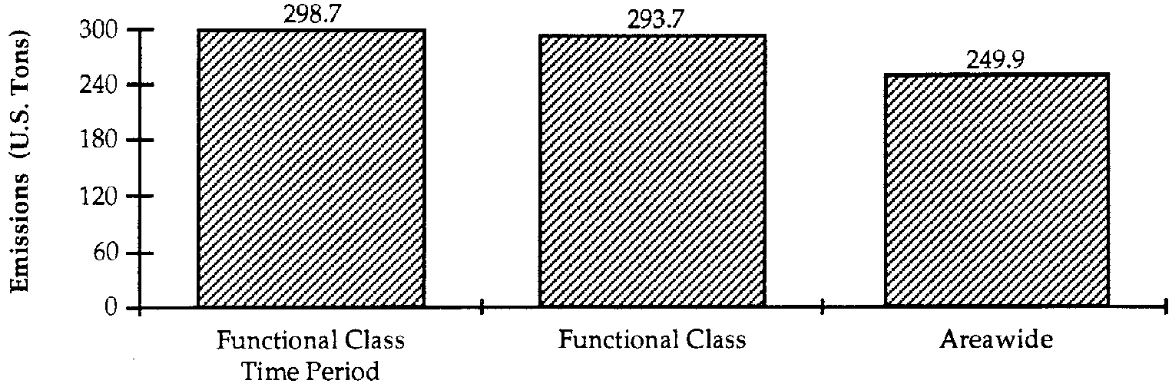


Figure 10. 1990 Base Year Emissions - MOBILE5a
Southern Urban Area

The year 2010 results for each of the three urban areas are illustrated in figures 11, 12, and 13 with the exception that equivalent future year disaggregate data were not available for the southern urban area. The pattern of the 2010 results is generally similar to that existing in the 1990 base year analyses. Small changes result for estimated VOC and carbon monoxide emissions, with the largest percentage differences for estimated NO_X emissions.

These same analyses also were compiled using MOBILE4 and MOBILE4.1, obtaining similar order of magnitude relative differences.

These results are in general agreement with the findings of similar analyses conducted by other organizations:

- A comparison of link-based and 5-km grid mobile source emission estimates for the Philadelphia area conducted by the Delaware Valley Regional Planning Commission (DVRPC), resulted in no difference in estimated hydrocarbon emissions. Carbon monoxide emissions differed by 0.4 percent when highways were classified by functional class and 0.7 percent without disaggregation by highway functional class.[7] Based on an examination of nine alternative scenarios, DVPRC concluded that, "None of the emission factor scenarios produced significant errors in emissions totals." Further, "These errors are insignificant for emissions reductions planning and are far less than the expected errors in the underlying emission factors or link-level VMT and speed estimates."

- The Metropolitan Washington Council of Governments has conducted emissions analyses using alternative levels of transportation data aggregation. In their 1991 conformity analysis, differences of under 1 percent in estimated hydrocarbon, carbon monoxide, and NO_X emissions were reported between "detailed" and "streamlined" analysis approaches with the more approximate methodology utilizing weighted averages.[8]

- Sierra Research, in work sponsored by the U.S. Environmental Protection Agency, examined the effects of alternative levels of data aggregation on both vehicle speed and emissions for the Washington, Phoenix, and Denver urban areas. Link-level results were compared with geographically segmented and network average conditions. For 1985 base year carbon monoxide emissions, the largest difference was in Denver where the network average result was 930 tons compared to 1,330 tons when vehicle speeds were estimated and summed on a link basis, a difference of

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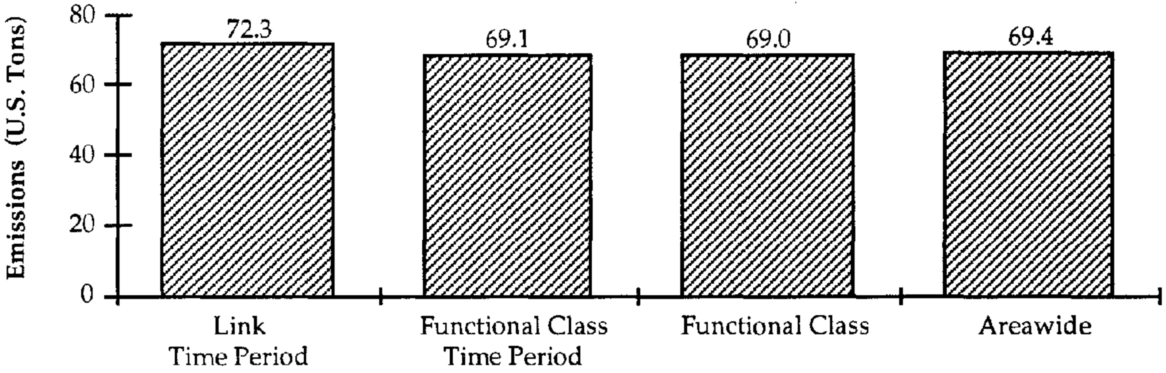
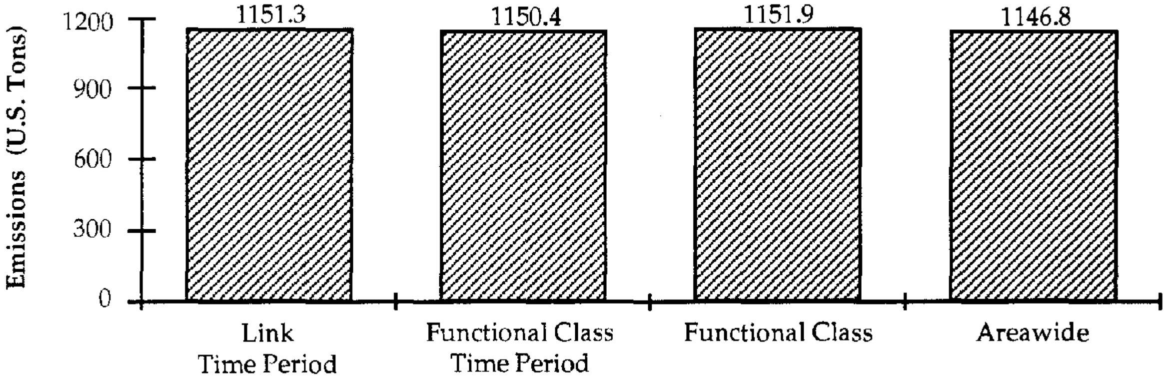
[7] Walker, W. Thomas, "Impact of Preaggregation of Highway Network Travel Data on Accuracy of MOBILE4-Based Emissions," Transportation Research Record No. 1366, *Air Quality, Environment, and Energy*, Transportation Research Board, Washington, D.C., 1992.

[8] Metropolitan Washington Council of Governments, *Conformity Determination for the Metropolitan Washington Region of COG/TPB Transportation Plans, Programs, and Projects With the Requirements of the 1990 Clean Air Act Amendments*, Washington, D.C., September 18, 1991.

A. VOC Summer Conditions



B. CO Winter Conditions



C. NO_x Summer Conditions

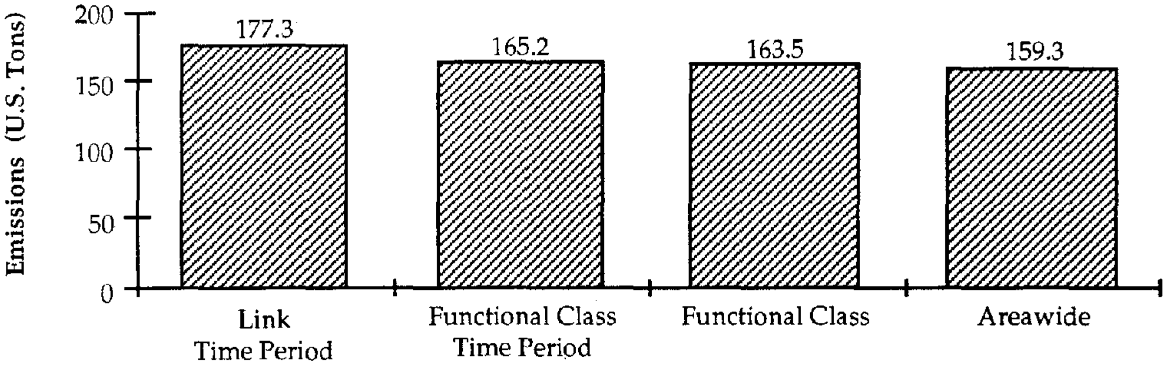
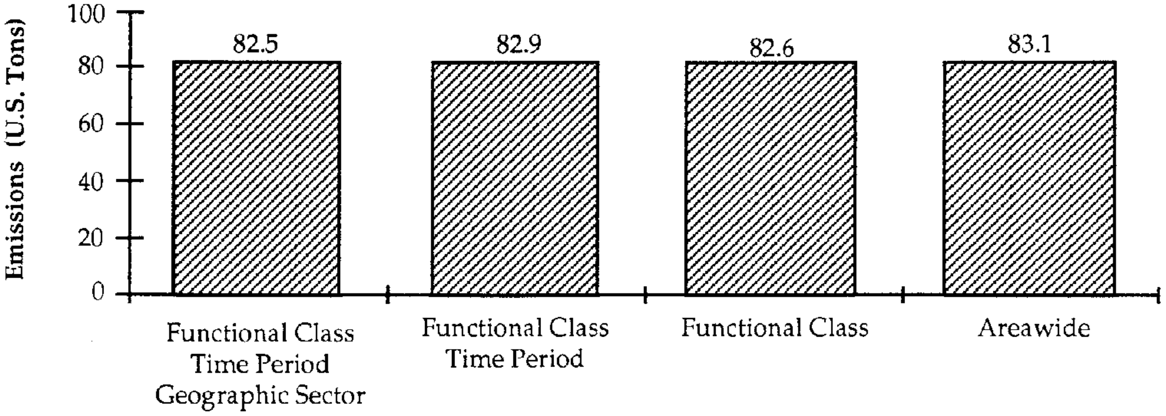
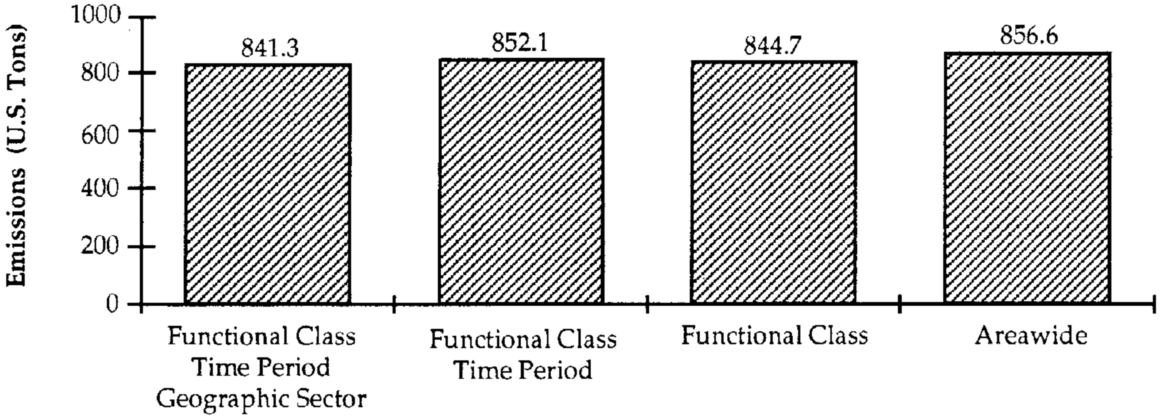


Figure 11. 2010 Future Year Emissions - MOBILE5a
Eastern Urban Area

A. NMHC Summer Conditions



B. CO Winter Conditions



C. NO_x Summer Conditions

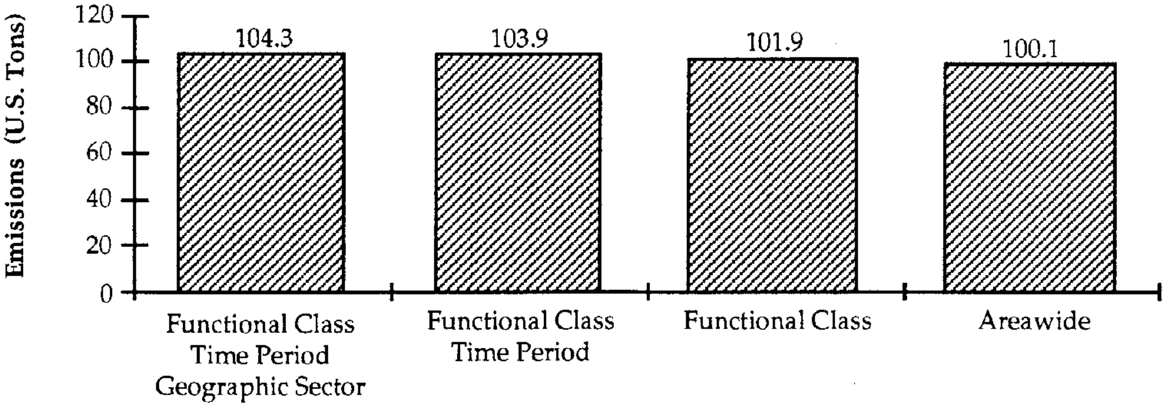
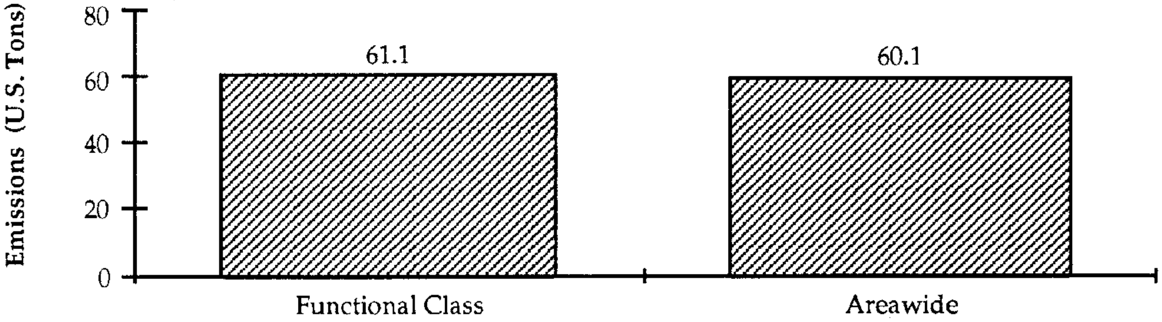
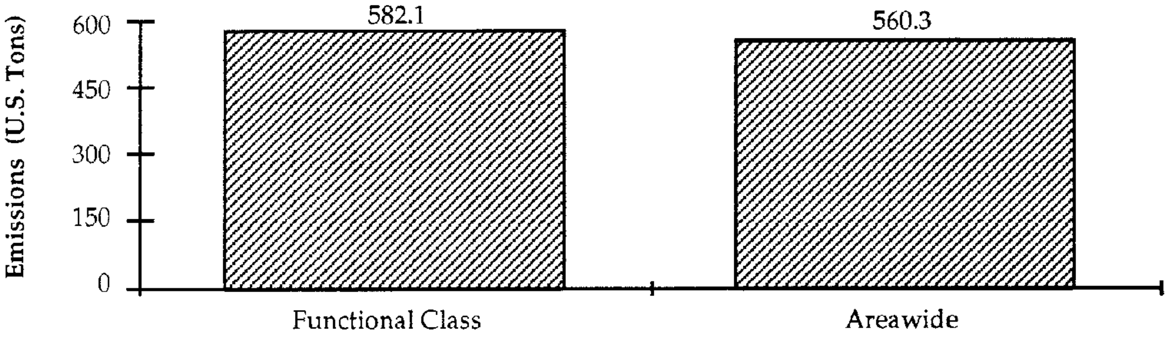


Figure 12. 2010 Future Year Emissions - MOBILE5a
Western Urban Area

A. NMHC Summer Conditions



B. CO Winter Conditions



C. NO_x Summer Conditions

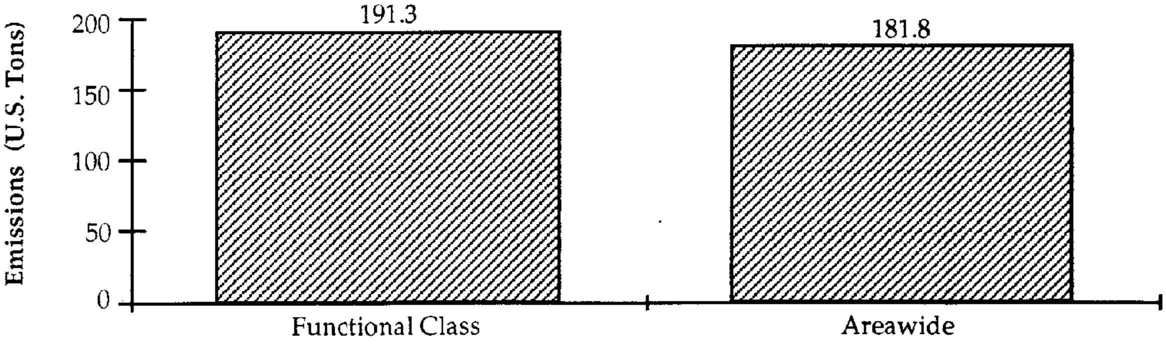


Figure 13. 2010 Future Year Emissions - MOBILE5a
Southern Urban Area

30 percent. The corresponding differences, however, were much smaller for the two other metropolitan areas examined, 5.4 percent for Washington and 11.8 percent for Phoenix.[9]

Five principal conclusions can be drawn from these results:

1. There are time periods and geographic areas in the data for each of the three urban areas where congestion is occurring and correspondingly low vehicle operating speeds exist. These conditions, though, are outweighed by the much larger proportion of traffic which is operating under mid-speed range conditions where there is much less variation in emission rates as a function of vehicle speed (figure 14). For example, AM and PM peak period speeds for CBD arterials are 11 and 15 mph in the western urban area, but this travel accounts for only .3 percent of daily VMT. The majority of estimated vehicle operating speeds are in the 20 to 50 mph range.

2. Full disaggregation of transportation data on a spatial and temporal basis may not always be useful in all urban areas and for all analyses. If congested travel conditions do not occur or occur for only very short periods of time, the added computational effort may add relatively little, by itself to the accuracy of the results. Where the objective of an analysis is simply to evaluate the relative potential of alternative actions, the added effort of a fully disaggregated analysis may add little benefit.

3. Doing a link-level analysis may not be helpful unless increased attention also is devoted to developing improved estimates of vehicle operating speed. In particular, it may be desirable to use a vehicle speed post-processor to ensure that vehicle speeds are not being over estimated, especially at the low end of the vehicle speed curve. Differences in estimated vehicle speeds by major time period may have a larger impact on the magnitude of estimated mobile source emissions than simply segmenting travel data on a geographic basis.

4. As displayed by the results for the southern urban area, it also is useful to capture variations in such MOBILE input data as temperature, operating mode, and vehicle fleet mix. The analyses for the eastern and western urban areas were performed by generating a one-dimensional vehicle speed table from MOBILE, holding all other variables constant. This approach, which is both efficient and widely practiced, may not be sufficient and may lead to underestimating mobile source emissions.

5. Calculating mobile source emissions on a geocoded link and hourly basis is essential to run the Urban Airshed Model or conduct a similar analysis of the formation of photochemical oxidants. For such purposes, it is necessary to both spatially and temporally allocate emissions if an accurate understanding of the patterns of ozone formation is to be developed. In such an analysis, hours of the day having roughly similar vehicle operating conditions can be grouped together for purposes of both

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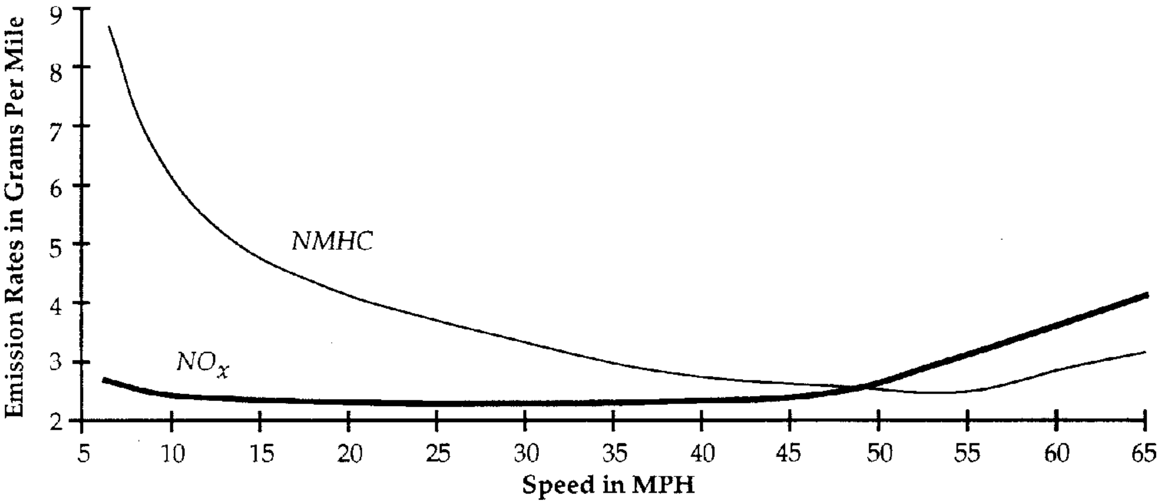
[9] Sierra Research, Inc., *Investigation of the Relationship Between VMT Growth and Vehicle Speed*, report prepared for the Office of Mobile Sources of the U.S. Environmental Protection Agency, Ann Arbor, Michigan, 1989.

A. NMHC and NO_x Summer Conditions



B. CO Winter Conditions

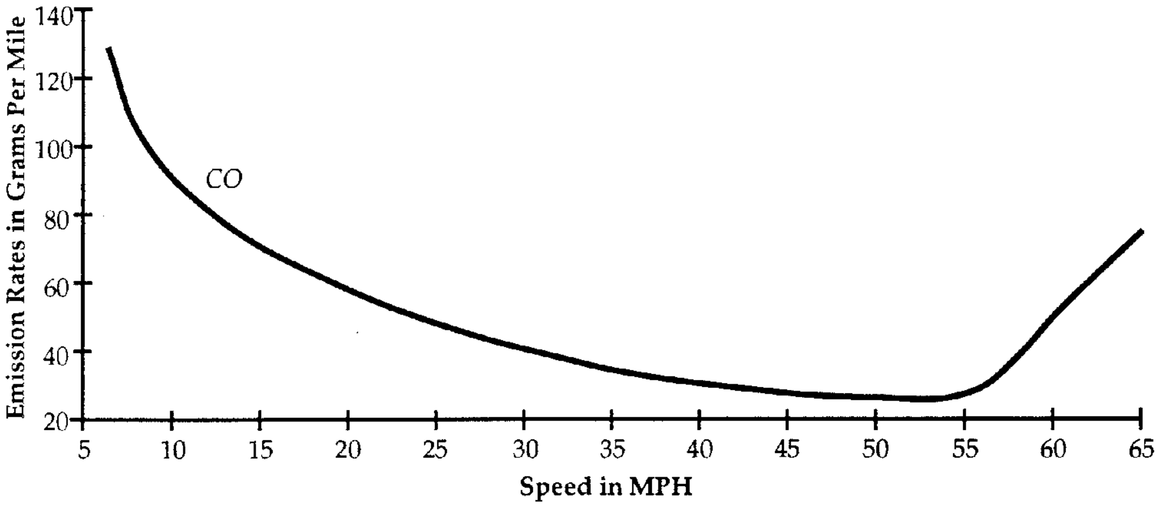


Figure 14. MOBILE5a Emission Rates as a Function of Vehicle Speed 1990 Base Year Conditions

Western Urban Area

estimating vehicle speed and defining MOBILE model input parameters. The level of geographic and temporal analysis detail needed to support an Urban Airshed Model, though, is not required to develop a SIP emission inventory, evaluate the effectiveness of alternative mobile source control measures, or support a determination of conformity.

Appendix

Tabular Summaries of Travel Data

Table A.1 Eastern Urban Area

Base and Future Year Vehicle Miles of Travel by Functional Class and Time Period

	1990						2010					
Functional Class	**Early**	**AM Peak**	**Midday**	**PM Peak**	**Late**	**Total**	**Early**	**AM Peak**	**Midday**	**PM Peak**	**Late**	**Total**
Local Street (a)	571,637	2,079,670	2,989,662	2,765,849	2,215,844	10,622,662	705,171	2,634,957	3,907,412	3,587,592	2,904,345	13,739,477
Minor Arterial	659,717	2,447,360	3,187,593	3,233,663	2,368,755	11,897,088	802,833	3,209,985	4,248,454	4,442,685	3,204,349	15,908,307
Major Arterial	1,237,209	4,482,964	5,993,735	5,828,360	4,639,877	22,182,145	1,570,395	6,116,424	8,347,349	8,300,166	6,525,233	30,859,568
Express Highway (b)	2,035,724	6,803,162	9,379,232	7,948,408	6,509,825	32,676,351	2,738,822	9,316,944	13,414,373	11,210,427	9,667,736	46,348,302
Total	4,504,288	15,813,156	21,550,222	19,776,280	15,734,300	77,378,246	5,817,222	21,278,310	29,917,588	27,540,871	22,301,663	106,855,654

Base and Future Year Average Vehicle Speed by Functional Class and Time Period

	1990						2010					
Functional Class	**Early**	**AM Peak**	**Midday**	**PM Peak**	**Late**	**Total**	**Early**	**AM Peak**	**Midday**	**PM Peak**	**Late**	**Total**
Local Street (a)	22.9	22.3	22.9	21.8	23.0	22.5	22.8	21.7	22.8	20.9	22.8	22.1
Minor Arterial	25.9	22.2	24.5	20.2	24.6	22.8	25.5	20.1	23.2	16.9	23.0	20.5
Major Arterial	36.5	32.5	34.7	30.1	34.2	32.9	36.2	29.4	32.5	25.3	30.9	29.5
Express Highway (b)	53.1	47.1	51.6	44.3	51.2	48.7	53.3	42.9	48.8	37.2	48.2	44.3
Total	36.7	32.5	35.0	29.9	34.6	33.1	37.0	30.1	33.8	25.9	32.9	30.6

(a) Includes centroid connectors
(b) Includes ramps

Table A.2 Western Urban Area – Base Year Data

CBD – Vehicle Miles of Travel and Average Vehicle Speed by Functional Class and Time Period

	VMT				Average Vehicle Speed			
	AM Peak	PM Peak	Off-Peak	Total	AM Peak	PM Peak	Off-Peak	Total
Highway	17.17	32.47	89.27	138.91	36.0	36.4	52.4	45.2
Major Regional	0.00	0.00	0.00	0.00	---	---	---	---
Major Arterial	17.16	35.64	75.78	128.58	10.7	15.1	20.4	16.7
Minor Arterial	14.83	29.12	62.64	106.59	6.4	11.2	16.4	12.2
Collector	3.25	5.24	9.09	17.58	6.8	10.2	15.2	11.1
Ramp	0.28	0.56	1.35	2.19	39.5	40.3	39.7	39.8
Frontage	0.00	0.00	0.00	0.00	---	---	---	---
Central Connector	3.48	8.07	19.11	30.66	20.7	20.3	19.9	20.1
Total	56.17	111.10	257.24	424.50	11.1	16.4	23.7	18.7

Fringe – Vehicle Miles of Travel and Average Vehicle Speed by Functional Class and Time Period

	VMT				Average Vehicle Speed			
	AM Peak	PM Peak	Off-Peak	Total	AM Peak	PM Peak	Off-Peak	Total
Highway	157.96	303.04	813.98	1274.98	37.0	37.3	52.4	45.7
Major Regional	2.62	5.55	14.50	22.67	19.4	16.9	33.1	25.2
Major Arterial	91.32	191.25	437.63	720.21	18.6	18.7	24.8	21.9
Minor Arterial	26.17	49.89	75.87	151.93	13.7	16.9	22.3	18.4
Collector	11.80	22.53	45.10	79.43	11.3	14.8	19.2	16.2
Ramp	10.06	19.67	53.38	83.11	17.2	18.5	32.4	25.2
Frontage	2.10	2.28	4.13	8.51	41.2	41.5	41.3	41.3
Central Connector	17.29	38.11	89.88	145.28	20.3	20.0	20.0	20.0
Total	319.32	632.33	1,534.47	2,486.12	23.2	24.2	33.6	29.0

Table A.2 Western Urban Area – Base Year Data (continued)

Urban – Vehicle Miles of Travel and Average Vehicle Speed by Functional Class and Time Period

	VMT				Average Vehicle Speed			
	AM Peak	PM Peak	Off-Peak	Total	AM Peak	PM Peak	Off-Peak	Total
Highway	389	745	2032	3,166.31	31.8	33.6	49.8	42.1
Major Regional	14	31	81	126.08	24.2	23.1	36.2	30.3
Major Arterial	512	994	2148	3,654.76	21.2	23.6	30.4	26.7
Minor Arterial	113	213	359	685.70	18.9	21.8	25.6	23.0
Collector	66	128	238	431.67	15.6	18.7	22.3	19.9
Ramp	28	50	146	224.26	9.4	15.4	16.8	15.0
Frontage	6	9	17	32.16	23.0	24.4	28.5	26.2
Central Connector	73	163	392	628.06	20.2	20.0	20.0	20.0
Total	1,200.86	2,333.61	5,414.54	8,949.01	22.2	24.8	32.3	28.4

Suburban – Vehicle Miles of Travel and Average Vehicle Speed by Functional Class and Time Period

	VMT				Average Vehicle Speed			
	AM Peak	PM Peak	Off-Peak	Total	AM Peak	PM Peak	Off-Peak	Total
Highway	603	1,166	3,007	4,776.62	41.2	43.2	53.5	48.8
Major Regional	49	89	218	357.12	22.8	30.7	38.3	33.2
Major Arterial	795	1,557	3,519	5,871.62	27.2	30.8	38.1	34.1
Minor Arterial	160	318	684	1,161.31	14.9	17.4	28.2	21.8
Collector	78	157	336	571.57	20.2	23.4	25.6	24.1
Ramp	34	68	174	276.35	11.2	14.7	29.6	20.4
Frontage	2	5	8	4.46	32.7	29.9	34.3	32.5
Central Connector	200	451	1,098	1,748.75	20.0	20.0	20.0	20.0
Total	1,921.53	3,811.58	9,044.68	14,777.79	26.1	28.7	35.8	32.2

Table A.2 Western Urban Area – Base Year Data (continued)

Rural – Vehicle Miles of Travel and Average Vehicle Speed by Functional Class and Time Period

	VMT				Average Vehicle Speed			
	AM Peak	PM Peak	Off-Peak	Total	AM Peak	PM Peak	Off-Peak	Total
Highway	336.01	651.49	1,812.46	2,799.96	49.8	51.4	55.0	53.5
Major Regional	69.97	136.93	338.74	545.64	48.5	48.8	49.1	49.0
Major Arterial	148.60	274.36	662.28	1,085.24	39.5	43.8	47.6	45.3
Minor Arterial	93.81	161.66	350.81	606.28	39.0	42.2	44.2	42.8
Collector	20.55	36.19	76.87	133.60	33.7	35.6	35.3	35.1
Ramp	5.88	10.38	22.57	38.83	27.7	32.6	38.7	34.9
Frontage	60.39	117.53	269.53	447.44	20.3	20.1	20.0	20.1
Central Connector	0.00	0.00	0.00	0.00	---	---	---	---
Total	735.20	1,388.54	3,533.25	5,656.99	40.5	42.4	45.3	43.9

All Areas – Vehicle Miles of Travel and Average Vehicle Speed by Functional Class and Time Period

	VMT				Average Vehicle Speed			
	AM Peak	PM Peak	Off-Peak	Total	AM Peak	PM Peak	Off-Peak	Total
Highway	1,503.62	2,898.11	7,755.05	12,156.77	39.2	40.9	52.7	47.4
Major Regional	136.31	262.68	652.51	1,051.50	31.5	35.6	42.7	39.0
Major Arterial	1,564.48	3,052.70	6,843.22	11,460.41	24.6	27.4	34.5	30.7
Minor Arterial	407.73	772.04	1,532.04	2,711.81	17.5	20.6	28.7	23.7
Collector	179.10	349.09	705.67	1,233.86	17.6	21.0	24.4	22.1
Ramp	77.95	148.93	397.86	624.74	11.5	16.1	23.6	19.0
Frontage	70.38	133.48	298.72	502.58	21.0	20.8	20.7	20.8
Central Connector	293.51	660.14	1,599.10	2,552.75	20.1	20.0	20.0	20.0
Total	4,233.08	8,277.16	19,784.17	32,294.41	25.7	28.3	35.7	31.9

Table A.3 Southern Urban Area – 1990 Base Year Conditions

Base Year Vehicle Miles of Travel by Functional Class and Time Period

	Time Period				
Facility Type	AM Peak	Midday	PM Peak	Off-Peak	Total
Freeways	7,307,979	15,374,149	10,362,345	7,925,905	40,970,377
Principal Arterials	2,548,433	5,459,137	3,665,175	2,660,836	14,333,581
Other Arterials	4,153,960	8,706,819	6,007,826	4,266,071	23,134,675
Major Collectors	744,323	1,626,918	1,103,825	892,117	4,367,183
Other Collectors	301,689	572,334	426,557	299,007	1,599,587
Locals	1,332,831	3,374,390	2,155,724	1,648,692	8,511,637
Totals	16,389,215	35,113,746	23,721,452	17,692,627	92,917,040

Base Year Average Vehicle Speed by Functional Class and Time Period

	Time Period				
Facility Type	AM Peak	Midday	PM Peak	Off-Peak	Total
Freeways	49.90	59.96	53.84	62.29	56.70
Principal Arterials	33.66	39.56	35.44	40.91	37.50
Other Arterials	29.45	34.25	31.01	35.67	32.65
Major Collectors	48.69	51.50	49.85	51.97	50.67
Other Collectors	24.98	26.51	25.60	28.37	26.28
Locals	22.54	22.23	22.45	22.67	22.42
Totals	36.45	41.14	37.99	42.91	39.71

Southern Urban Area – 2010 Forecast Year

Vehicle Miles of Travel and Average Vehicle Speed by Functional Class

Facility Type	VMT	Average Vehicle Speed
Freeways	68,829,242	51.13
Principal Arterials	14,099,462	35.81
Other Arterials	33,128,838	33.44
Major Collectors	7,096,318	46.59
Other Collectors	1,523,115	23.45
Locals	11,585,270	22.73
Totals	136,262,245	39.41