Sensitivity Testing of MOBILE6, the U.S. Environmental Protection Agency's Most Recent Edition of Its Emissions Estimator for Gasoline and Diesel Powered Roadway Vehicles

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ABSTRACT

The Assessment and Standards Division (ASD) of the U.S. Environmental Protection Agency's (USEPA) Office Transportation and Air Quality (OTAQ) has recently completed an update of its emission model, MOBILE6. This model estimates emissions of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) from roadway use of gasoline and diesel fueled automobiles and trucks. MOBILE6 is used by local and state governments to determine their compliance with the Clean Air Act. Hence, the emissions results can have large impacts on transportation planning and budgeting.

MOBILE6 has the option for allowing the user to enter local data in lieu of default national data for several parameters. And, of course, resources are required to determine this local data. So, a prior knowledge of the relative importance of the different input parameters on the MOBILE6 results can be an important factor in determining whether local data should be collected. This report presents a systematic study of the relative importance of the different MOBILE6 input parameters.

INTRODUCTION

Recently, the Assessments and Standards Division of the USEPA has released its latest version, MOBILE6, of a computerized model which facilitates the determination of HC, CO, and NOx inventories from mobile sources for a given locale. MOBILE6 is a significant revision of the previous version, MOBILE5, both in the style and the type of user inputs. These inputs include a set of default data which is based on average U.S. national data collected and/or compiled by the USEPA which produce default emission results. However, these national input data will differ from specific localities and regions of the country. Hence, the resulting MOBILE6 default emissions will not necessarily be representative of the mobile source emissions of a specific locale.

Efficient use of MOBILE6 will depend on the user's familiarity with the many different MOBILE6 input parameters and the USEPA's usage guidance, the location specific mobile source statistics (e.g., vehicle registrations, vehicle usage in terms of mileage, roadway types, fuel types, inspection and maintenance programs, etc.), and which of the input parameters make significant impacts on the MOBILE6 emissions results. So, in an effort to expedite the use of MOBILE6 and its inputs, a systematic study has been done which will allow users to compare the relative importance the individual parameters have on emissions results. Because of the number of individual inputs and the many dimensional aspects of many of the individual inputs (except for temperature and humidity) the emissions results were not studied as a function of the input parameter interdependencies.

Results are listed in terms of percentage increase or decrease in the input with the ensuing percentage increase or decrease in the emissions for light duty vehicles (LDGV) and fleet wide vehicles (All Vehicles or emissions of all 28 MOBILE6 vehicle types weighted by vehicle mileage) relative to the MOBILE6 national default inputs and their emissions results. (For a complete description of the

MOBILE6 vehicle classifications see the *User's Guide to MOBILE6.0 Mobile Source Emission Factor Model*, USEPA Report #EPA420-R-02-001.) Also, for some inputs the emissions in grams/mile are displayed as a function of the specific input parameter or the percent change in the input parameter relative to the default value. Calendar years from1975 through at least 2020 in increments of 5 to 20 years were considered for each input studied. In this report a summary of the light duty gas vehicle (LDGV) results for all inputs is given. Additionally, a subset of input parameters were found to have at least a 20% effect on emissions when the input parameters was varied by 20% from the default values. Details of the analysis methodology and the results for this subset of relatively important parameters are presented below. A systematic report which will include all results will be covered in a forthcoming EPA report.

METHODS

MOBILE6 inputs have a variety of formats and requirements. They could consist of single numbers, sets of numbers, or simply the input command acting as an "on/off" switch. Hence, there was no single standard method of changing the inputs to get understandable and useful information from the resulting changes in the emissions. However, once a method of changing the inputs was decided upon, the results were quantified in terms of a percentage change in the input relative to the MOBILE6 default values versus a percentage change in the emissions relative to the emissions calculated from the default input values.

Figure 1. To determine how differences in the 24 hour temperature cycle effect emissions, four cycles were considered. The cycles had minimum and maximum temperatures which differed by 34°F, 24°F, 14°F, and 0°F (or a constant temperature) over the entire day.

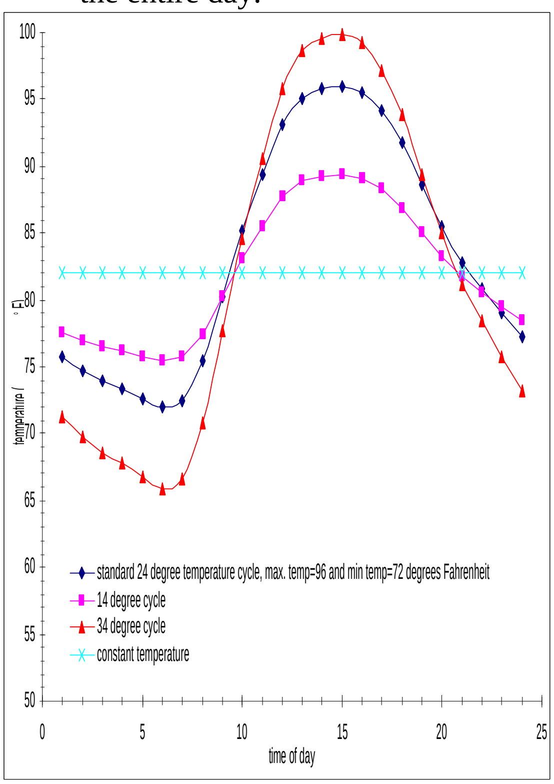
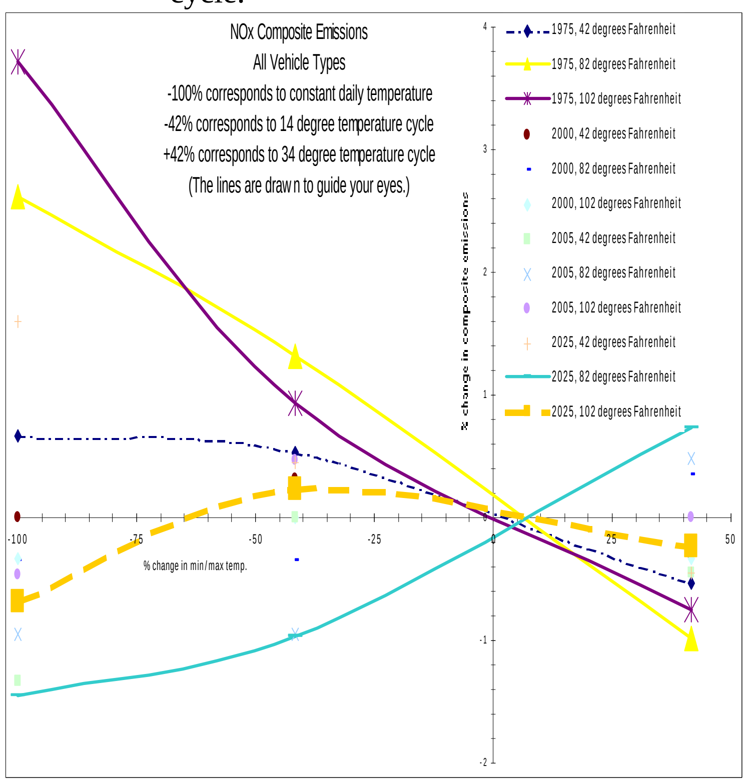


Figure 2. This figure shows the relationship between All vehicles NOx emissions and changes in the hourly temperature cycles depicted Figure 1. It shows that NOx emissions are not highly dependent upon the shape of the temperature cycle.



As mentioned above, many of the MOBILE6 inputs consist of a set of numbers. And determining how to make changes to the input so that the resulting changes in emissions can be quantified and useful to potential users of MOBILE6 varied from input to input. For example, the hourly temperature values or daily minimum and maximum temperature inputs determine a daily temperature cycle which is based on 24 standard temperature increments/ decrements from the National Weather Service. MOBILE6 uses these 24 values with the MIN/MAX TEMP input command to construct a daily temperature cycle (scaled according to the user supplied minimum and maximum temperatures) with the minimum and maximum temperatures occurring between 6am and 7am and 3pm and 4pm, respectively. The temperature inputs can thus vary the average daily temperature, the 24°F temperature cycle, and the individual hourly temperatures. All of these input variations have different effects on the emissions results. As a result, each of these variations were analyzed independently to determine their individual effects on the emissions. Figures 1 and 2 illustrate emissions changes with variations in the daily temperature cycle (a 34°F daily temperature rise and fall, a 24°F daily temperature rise and fall, a 14°F daily temperature rise and fall, and a constant temperature for each hour of the day). Similarly, methods were determined for each MOBILE6 input which would make possible a practical quantification of the changes in MOBILE6 emissions output due to changes in input.

RESULTS

In the Appendix Table 1 lists those inputs which have the most effect on all vehicle emissions. They have at least a 1-to-1 emissions-to-input percentage rate response and lead to an emissions increase of at least 20%. This report will focus on these results. (The results of Table 1 can be generalized to the LDGV category.) Table 2 in the Appendix contains a full summary of the LDGV sensitivity results. It lists the MOBILE6 input considered, an abbreviated description of how its values were changed relative to the default values and percent change in emissions result for each of the three pollutants, non-methane hydrocarbons (NMHC) [volatile organic compounds(VOC) for the Average Speed command], carbon monoxide(CO), and oxides of nitrogen(NOx). (The complete results for other vehicle types will not be presented here.) Results in these tables were derived from the standard MOBILE6 descriptive output.

In this communication the results in Tables 1 will be discussed. Both the methodology to change the inputs and the impacts these changes had on emissions for the three MOBILE6 pollutant types, HC, CO, and NOx, will be described. (As mentioned above, except for the results of the Average Speed command the hydrocarbon emissions are all in terms of non-methane hydrocarbons or NMHC. The Average Speed command results were in terms of hydrocarbon volatile organic compounds or VOC.) As previously mentioned, a thorough discussion of the overall results contained in Table 1 and 2 will be in a forthcoming EPA report.

HC Emissions

Hydrocarbon emissions are effected most by the age distribution of the fleet (Registration Distribution command; see Figures 3, 4, and 5), low vehicle speeds (Average Speed and Speed VMT commands; see Figures 6 through 9), and high average daily temperatures (Min/Max temperature or Hourly Temperature commands; see Figures 10 and 11).

The age distributions were changed by increasing the fraction of vehicles with ages greater than 13 years old and subtracting the same fraction from the vehicles which are younger than 13 years old. Each vehicle age had an equal fraction added or subtracted. Figure 3 displays the MOBILE6 default values and the values used to induce changes in the emission results. Figures 4 and 5 show the relationship between vehicle age and hydrocarbon emissions. They show the impact of the main MOBILE6 assumption, i.e., the emission rates deteriorate with vehicle age or mileage. The all or fleet wide vehicles have at least a 1-to-1 emissions-to-input percentage rate response for changes in the emissions due to changes in vehicle age. The LDGV numbers mirror this vehicle age and NMHC emissions relationship.

Figure 3. The MOBILE6 default vehicle registration fractions were shifted from newer to older vehicles in increments of 5%. The age thirteen vehicle fractions were unchanged. Although all vehicle registration fractions were changed this figure illustrates the light duty gas vehicle fractions.

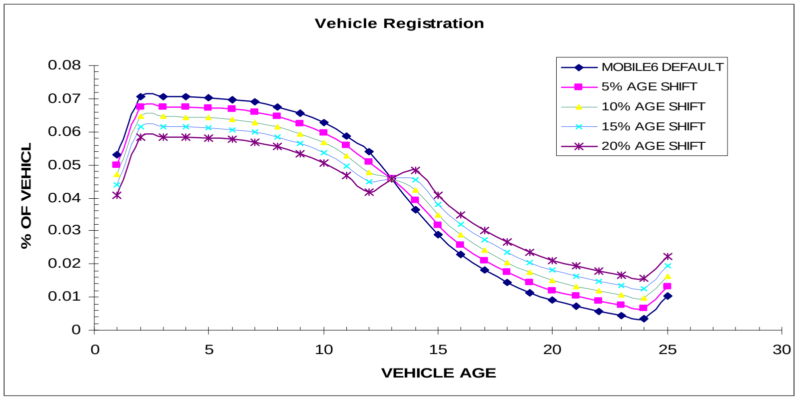
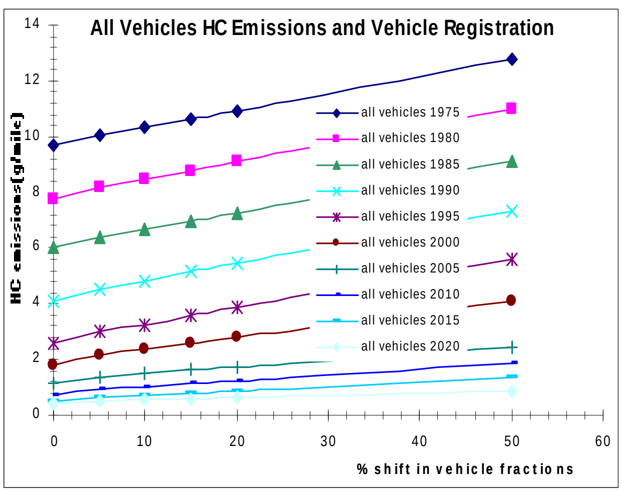
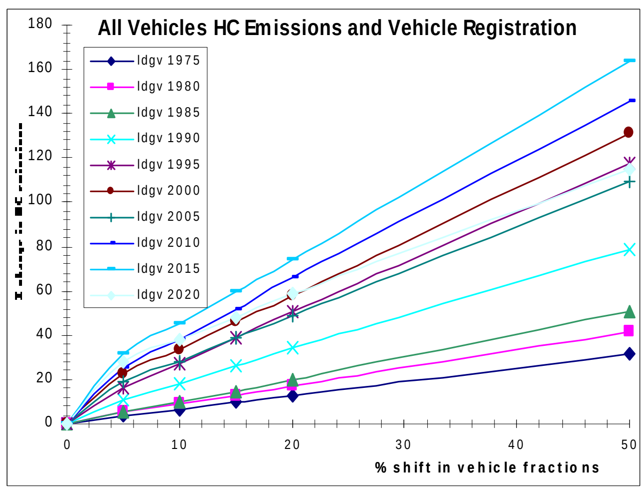


Figure 4. All vehicle hydrocarbon emissions as function of the percent change in all vehicle registration fractions from newer to older vehicles.

Figure 5. The same as Figure 4 except the percent differences in emissions are given as a function of the percent change in all vehicle registration fractions.





Next in importance for hydrocarbons is the emissions dependence on vehicle speed. This relationship is due to both an activity factor, i.e., the fraction of vehicles driving at a particular speed on a particular type of roadway during a particular hour of the day, and a functional vehicle emissions-vehicle speed relationship determined from data analysis (see Brzezinski, Hart, and Enns, in *Final Facility Specific Speed Correction Factors*, EPA Report #EPA420-R-01-0602001, Nov. 2001). Both of the above factors come into play when considering the difference between default emissions and those emissions resulting from using the Average Speed and Speed VMT commands.

Input of vehicle speeds using the Average Speed command has relatively large effects on emissions. Figures 6 and 7 show the LDGV and all vehicle hydrocarbon volatile organic compound (VOC) emissions dependence on speed using the Average Speed command for area wide roadway types at speeds ranging from 10 to 35 mph. There are results for five calendar years, i.e., 1975, 1995, 2000, 2005, and 2025. The Average Speed command (and the Speed VMT command) set(s) the fraction of vehicles which are operating at a given speed on the different MOBILE6 roadway types.

Figure 6. Light duty gas vehicle hydrocarbon volatile organic compound (VOC) emissions as a function of Area Wide speed supplied in the Average Speed command.

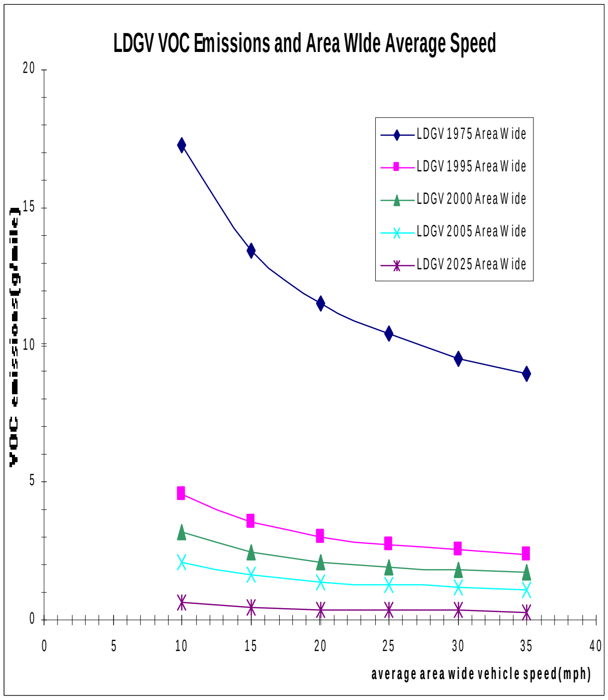
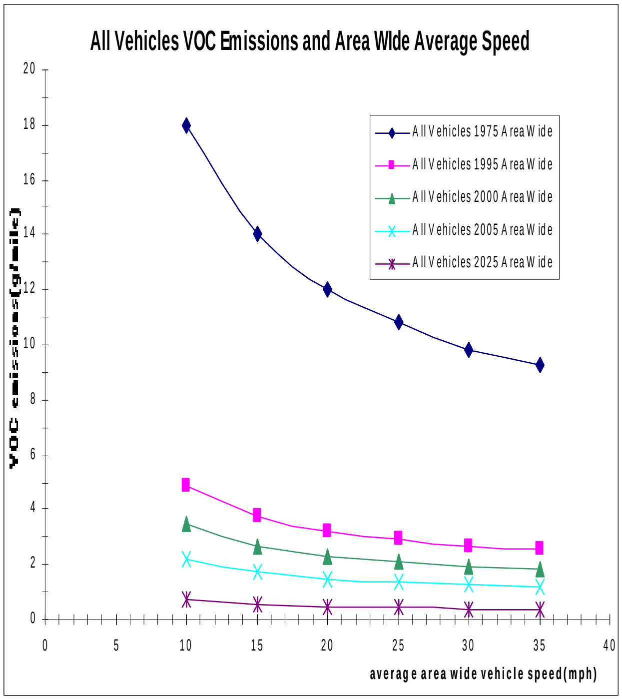


Figure 7. All vehicle hydrocarbon volatile organic compound (VOC) emissions as a function of Area Wide speed supplied in the Average Speed command.



The emissions results from Figures 6 and 7 above can be used to establish how the VOC emissions differ from emissions calculated using the default speed data. MOBILE6 default results are based on an average speed distribution rather than a single average speed. The average speed on these default distributions, including all roadway types is 27.6mph (see e.g., *Development of Methodology for Estimating VMT Weighting by Facility Type*, EPA Report #EPA420-R-01-009, April 2001). Figures 8 tand 9 display the percent changes in VOC emissions relative to default MOBILE6 results as a function of vehicle speeds via the Average Speed command. These figures display results for VOC from all vehicles using the Average Speed command for Area Wide Roadways and Freeways. For area wide roadways the speeds vary from 10mph to 35mph and for Freeways the speeds vary from 10mph to 70mph.

One last input parameter that has substantial effects on hydrocarbon emissions when changed from default values is the average daily temperature. As mentioned above (e.g., Figure 1) each hour of the day has a unique temperature value and is determined by the Min/Max Temp or the Hourly Temperature commands and the 24 hourly temperature differences. By shifting the maximum and minimum daily temperatures to higher or lower temperatures the average daily temperature can also be changed. The all vehicles hydrocarbon emissions dependence on the average daily temperature is displayed in Figure10. Percent differences in all vehicle emissions due to changes in temperature as a function of the percent difference in average daily temperature relative to a base value of 82°F with a temperature range of 70.6°F to 94.6°F are displayed in Figure 11. Each figure has results for calendar years of 1975, 1995, 2000, 2005, and 2025.

Figure 8. All vehicle VOC emissions as a function of area wide speed supplied in the Average Speed command. (The LDGV results are similar.)

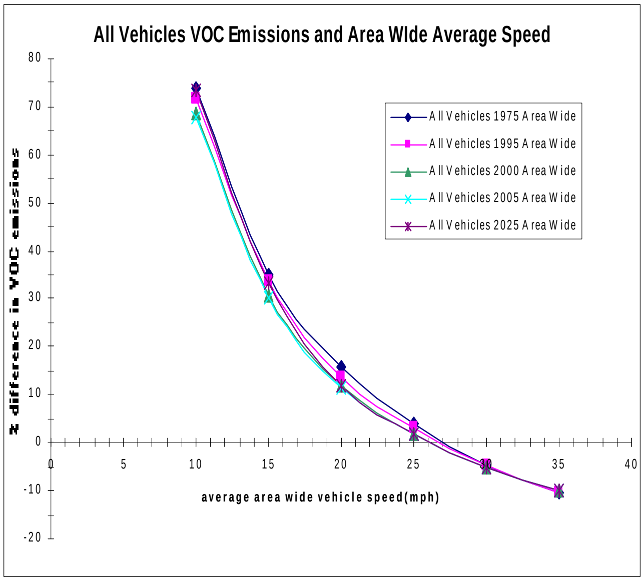


Figure 9. All vehicle percent differences in VOC emissions as a function of Freeway speed supplied in the Average Speed command (The LDGV results are similar.)

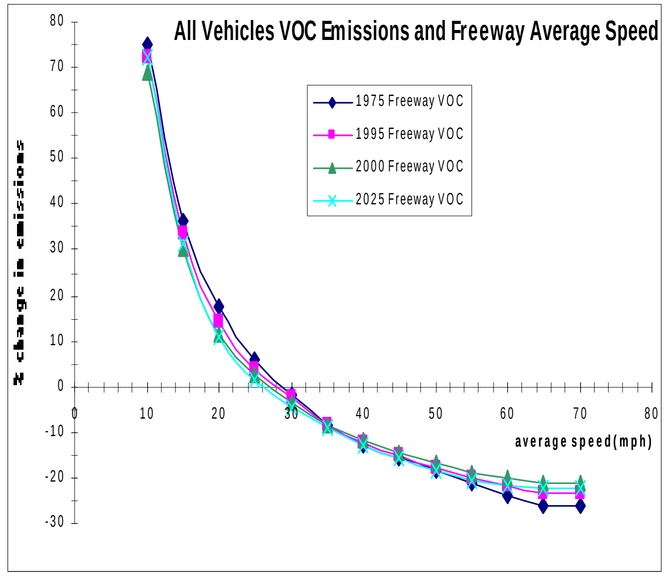


Figure 10. All vehicle NMHC emissions as a function of average daily temperature. The average daily temperatures were changed by shifting the 24°F temperature cycle (e.g., Figure 1) to higher or lower temperatures.

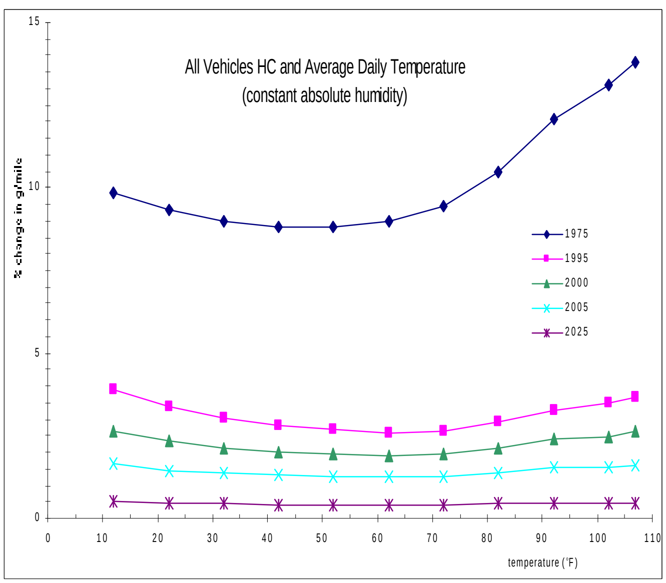
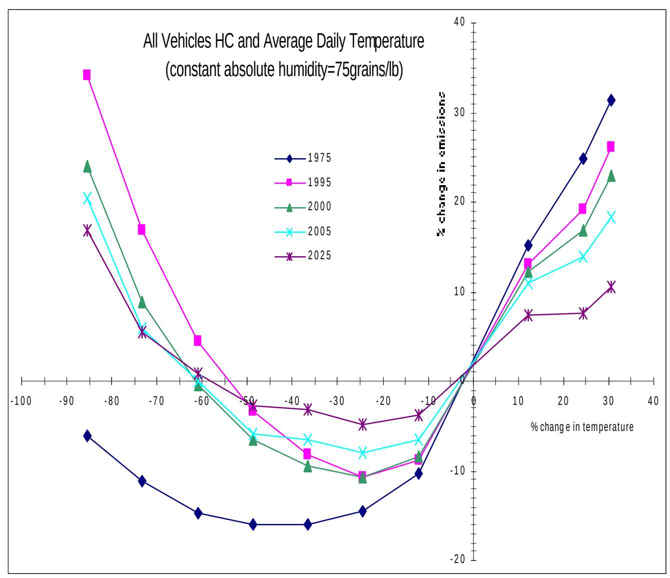


Figure 11. Percent changes in all vehicles NMHC emissions as function of the percent of change in average daily temperature from the default value of 82°F. (The LDGV results are similar.)



CO Emissions

Average daily temperatures below 50°F (Min/Max temperature or Hourly Temperature commands) have a very significant effect on carbon monoxide emissions (see Figures 12 and 13 below). Also, the age distribution of the fleet (Registration Distribution Command; see Figure 14), low vehicle speeds (Average Speed and Speed VMT commands), and annual vehicle mileage (Mileage Accumulation Rates command) have effects on emissions which are relatively large and can reach values greater than 20%.

As described above for hydrocarbon emissions the average daily temperature can be varied with the Min/Max Temp or the Hourly Temperature commands. The results of varying the average daily temperature on CO emissions are displayed in Figures 12 and 13 below. Figure 19 has the absolute humidity held constant at 75 grains/pound (the relative humidity will vary with temperature). Figure 20 has results with the relative humidity held constant at 49.5% (the absolute humidity will vary with temperature). The results are nearly identical and hence indicate that the humidity does not effect the emissions strongly when considering variations in the daily average temperature.

Absolute Humidity is new input parameter for MOBILE6 and only allows input of a single value of absolute humidity. However, as with the ambient temperature, this atmospheric physical quantity can vary from hour to hour during the day. Analysis of the temperature and humidity interdependency on MOBILE6 emissions results is less than 20% and outside of the scope of this discussion. This is true for all pollutants, hydrocarbons, carbon monoxide, and oxides of nitrogen. Part of the CO results have been illustrated and Figures 22 and 23 display a subset of the NOx analysis. The complete set of data for absolute humidity and temperature compiled will be available in a future EPA report

Figure 12. The relationship between the Change in emissions CO and average daily temperature when the absolute humidity is kept at a constant value of 75 grains/lb.

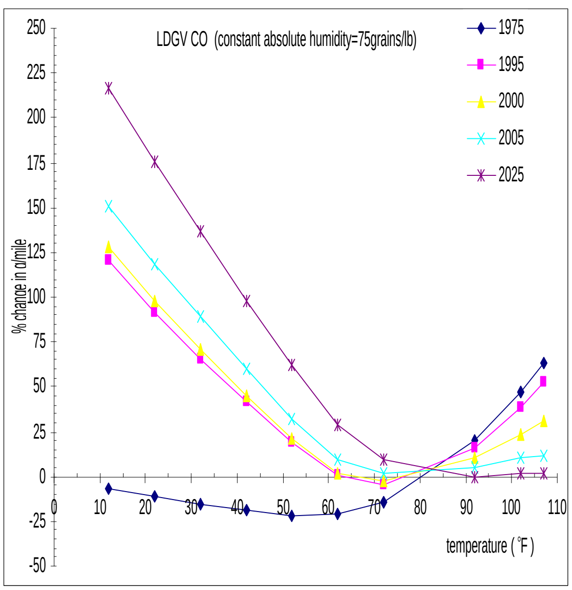


Figure 13. The relationship between the change in CO emissions and average daily temperature when the relative humidity is kept at aconstant value of 49.5%. a constant value of 49.5%.

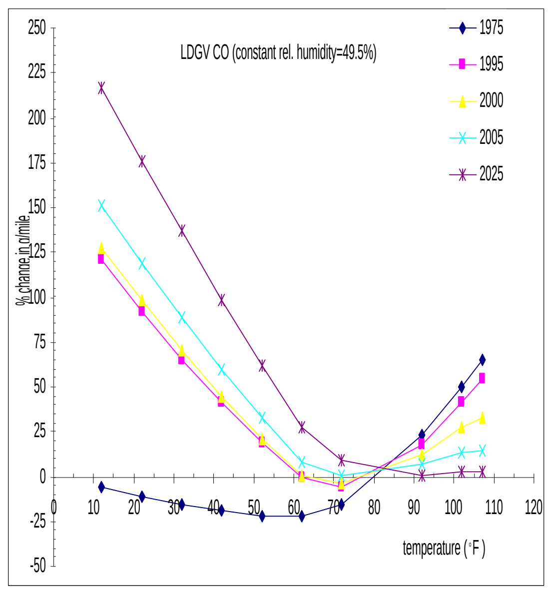
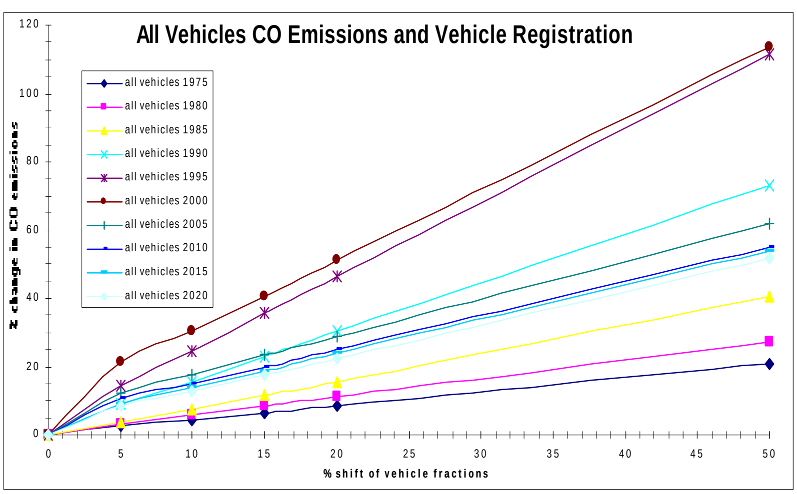


Figure 14. All vehicle CO emissions as a function of vehicle age.



As with HC emissions CO emissions are effected by changes in the distribution of vehicle ages for a given year. This reflects the deterioration of emissions with vehicle age which is the main assumption in MOBILE6 emissions calculations. Figure 14 displays the percent change in CO emissions versus the percent change in the vehicle age fractions for all vehicles. The light duty gas relationships are similar.

NOx Emissions

Lastly, emissions of oxides of nitrogen are most effected by the age distribution of the fleet (Registration Distribution command; see Figures 15 and 16), low vehicle speeds (Average Speed command; see Figures 17 through 21), and low average daily temperatures and exhibit a small temperature and humidity interdependence for temperatures above 40˚F (Min/Max Temperature command; see Figures 22 and 23).

As with HC and CO emissions, NOx emissions are effected by changes in the distribution of vehicle ages for a given year. And again this effect is mainly due to the deterioration of emissions with vehicle. Figures 15 and 16 illustrate the all vehicle NOx emissions dependence on the percent change in vehicle fractions.

Figure 15. All Vehicles NOx emissions as as a function of the increase in the percent of older vehicles

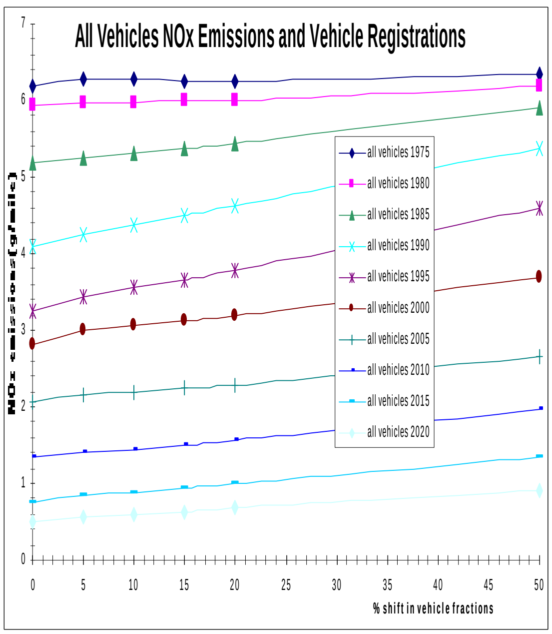
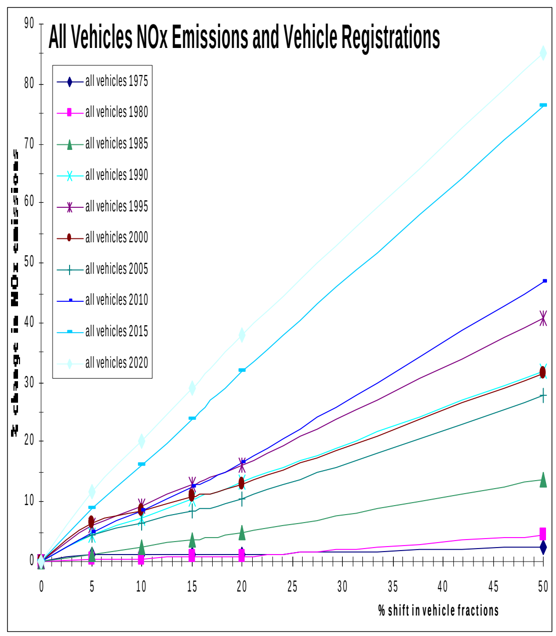


Figure 16. Percent changes in all vehicle NOx emissions as a function of an increase in the percent of older vehicles.



Figures 17, 18, and 19 show the NOx emissions dependence on light duty gas vehicle, heavy duty diesel vehicle, and all vehicles freeway speed using the Average Speed command for five calendar years, i.e., 1975, 1995, 2000, 2005, and 2025. In comparison with the results already seen for CO and HC emissions, the NOx emissions have a feature at speeds greater than 40mph which are due to diesel vehicles. That is, the diesel and all vehicles NOx emissions do not flatten out as vehicle speeds increase above 40mph. Rather, the NOx emissions increase with speeds above 40mph and this is due to diesel vehicles. This is only true for NOx emissions when using the Average Speed command on arterial and freeways because the Area Wide roadway option only allows for speed inputs below 40mph(see Figures 20 and 21). Without the heavy duty diesel emissions the NOx dependence on the speed using the Average Speed command would reflect the results found for hydrocarbon emissions.

Finally, the last input parameter and emissions relationship considered in this report is that between NOx and average daily temperature. This is also not a straight forward relationship because of the NOx correction factor at higher temperatures and high humidity values. High values of humidity tend to decrease the formation of NOx which mainly occurs at high engine temperatures.

Figures 22 and 23 show the MOBILE6 LDGV NOx emissions as a function of temperature while holding the absolute humidity constant and holding the relative humidity constant, respectively. They show that the MOBILE6 NOx emissions sensitivity to varying ambient temperatures occurs at lower temperatures, i.e., below 20˚F. In the high ambient temperature region for the calendar years relevant to any current emissions calculations the interplay between humidity and temperature is relatively small. The emissions deviate from a default run at average daily temperature of 82˚F by at most 10% for a run with an average daily temperature of 107˚F.

Figure 17.

a. LDGV emissions as a function of freeway speed in the Average Speed command

b. HDDV NOx emissions as a function of freeway speed in the Average Speed command

c. All vehicles NOx emissions as a function of freeway speed in the Average Speed command

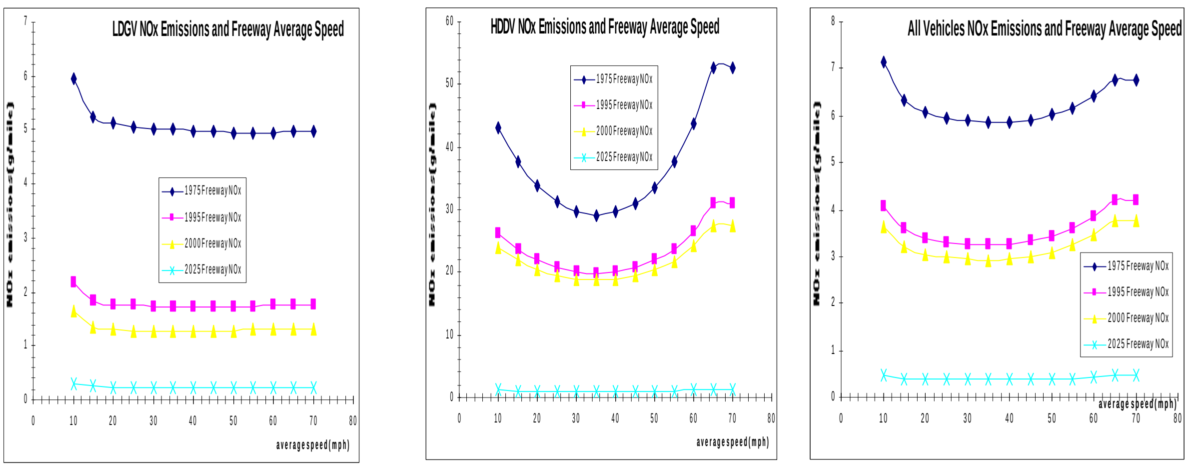


Figure 18. Percent change in light duty gas vehicle NOx emissions as a function of the speed on arterial roadways using the Average Speed command.

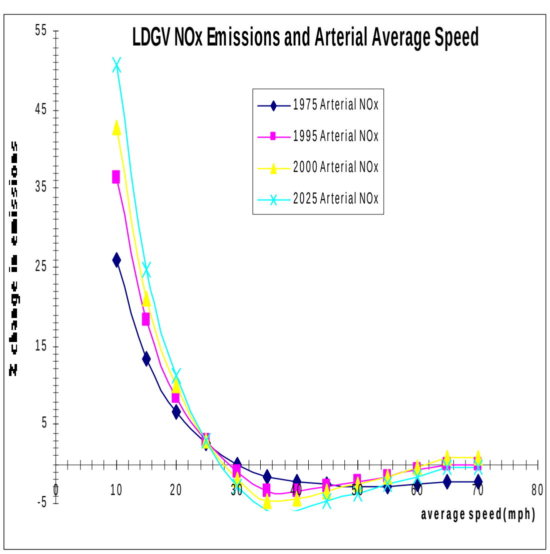


Figure 19. Percent change in all vehicle NOx emissions as a function of the speed on arterial roadways using the Average Speed command.

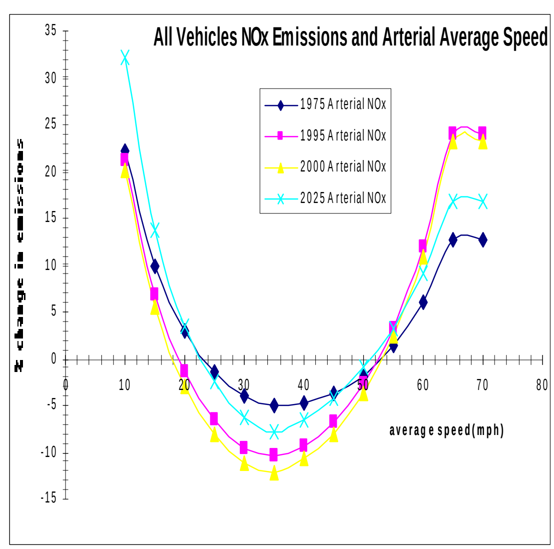


Figure 20. Percent change in light duty gas vehicle NOx emissions as a function of the speed on areawide roadways using the Average Speed command.

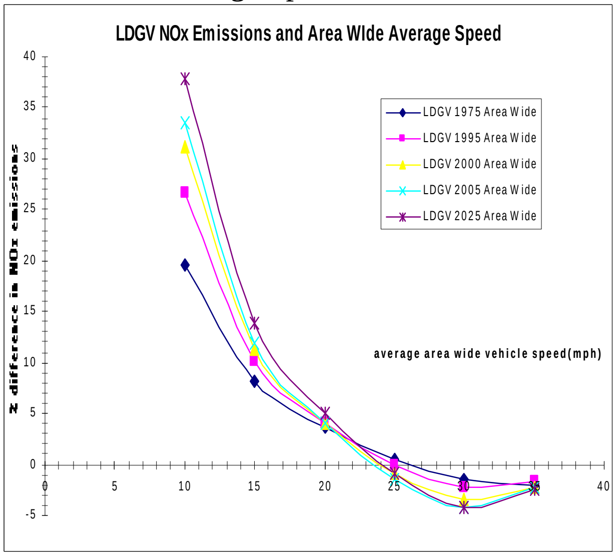


Figure 21. Percent change in all vehicle NOx emissions as a function of speed on areawide roadways using the Average Average Speed command.

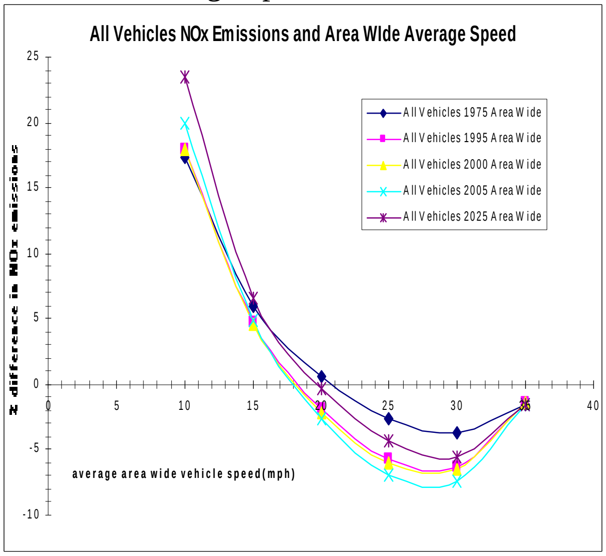


Figure 22. The relationship between the change in NOx emissions and average daily temperature when the absolute humidity is kept at a constant value of 75 grains/lb.

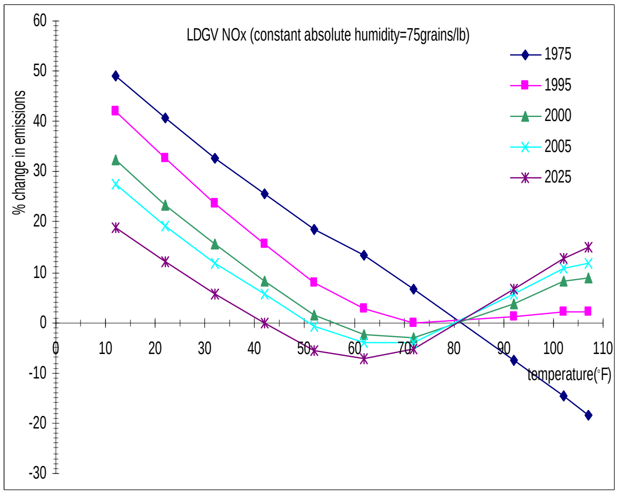
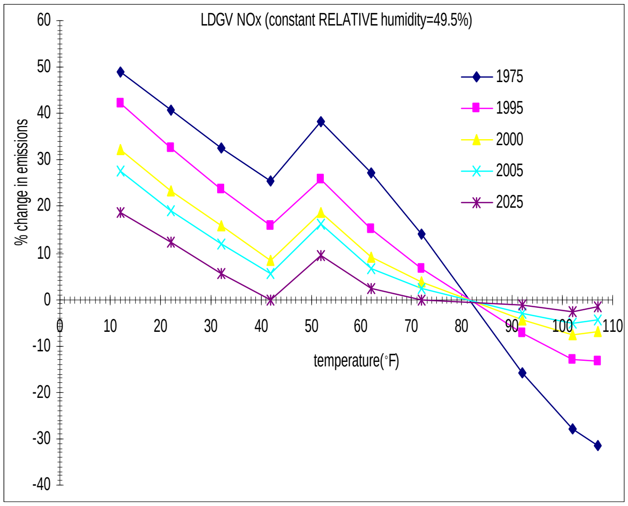


Figure 23.The relationship between the change in NOx emissions and average daily temperature when the relative humidity is kept at a constant value of 49.5%.



CONCLUSION

Three MOBILE6 input parameters, vehicle age or registration distribution, average daily temperature, and vehicle speed when changed via the Average Speed command, can have large effects (changes in emissions of 20% or more relative to the emissions calculated with default input values) on emissions results calculated by MOBILE6. All pollutant types, CO, HC, and NOx, have a high dependence on the vehicle registration distribution. This is mainly due to the basic assumption that vehicle emissions worsen as vehicles age. Next, CO emissions increase rapidly with temperature once the average daily temperature moves below 55°F. Hydrocarbon and oxides of nitrogen emissions also have relatively high emissions at very low temperatures, i.e., average daily temperatures below 20°F. Finally, the Average Speed command changes the default values of speed and the fractions of vehicles travelling on different

MOBILE6 roadways types which produces significant changes in emissions especially at speeds near 10mph.

The results presented here are only a subset of the complete MOBILE6 sensitivity analysis. They represent only those inputs which have at least a 1-to-1 emissions-to-input percentage rate response and lead to an emissions increase of at least 20%. Details and results of all inputs considered will be forthcoming in an EPA report.

APPENDIX

Table1. Summary of LDGV and All Vehicle results with input parameter induced emissions changes greater than 20%.

HC	CO	NOx
Average Speed Command - low speeds (15mph), Arterial roadways , Area Wide roadways and Freeways : 20% to 80% emissions increases	Min/Max Temperature Command - Average daily temperature (vary the average daily temperature from 12°F to 107°F by shifting the standard temperature cycle) emissions increases up to 200%(average daily temperature of 12°F) with temperature decreasing below 55°F; this variability increases with increasing calendar year	Registration distribution (decrease newer vehicle fractions and increase older vehicle fractions) 20% age shift to older vehicles can yield about 40% increase in emissions depending on the calendar year of evaluation
Registration distribution (decrease newer vehicle fractions and increase older vehicle fractions) 20% age shift to older vehicles can yield about a 50% increase in emissions depending on the calendar year of evaluation	Registration distribution (decrease newer vehicle fractions and increase older vehicle fractions) 20% age shift to older vehicles can yield about a 50% increase in emissions depending on the calendar year of evaluation	Average Speed Command - low speeds (10mph), Arterial roadways , Area Wide roadways and Freeways : 20% to 50% emissions increases
Min/Max Temperature Command - Average daily temperature (vary the average daily temperature from 12°F to 107°F by shifting the standard temperature cycle) emissions increases up to 25% for calendar years around 1995 (the variability lessens with increasing calendar years)	Average Speed Command - low speeds (10mph), Arterial roadways , Area Wide roadways and Freeways : 15% to 40% emissions increases	Min/Max Temperature Command - Average daily temperature (vary the average daily temperature from 12°F to 107°F by shifting the standard temperature cycle) emissions increases up to 20% to 50% at low average daily temperature (12°F); this variability decreases with increasing calendar year and increasing temperatures

Table 2. Summary of the LDGV results.

COMMAND	**Change in Input**	**Change in Hydrocarbon emissions**	**Change in CO emissions**	**Change in Oxides of Nitrogen emissions**
Air Conditioning	Emissions Differences with Air Conditioning Correction Applied and Not Applied	2%(1975) 2%(2005) 0%(2025)	16%(1975) 20%(2005) 5%(2050)	5%(1975) 10%(19995) 18%(2025)
Altitude	Emissions Differences Between High Altitude and Low Altitude	26%(1975) 4%(1995) <1%(2025)	41%(1975) 8%(1995) 0%(2005)	-31%(1975) -4%(1995) 0%(2005)

Average Speed (Arterial roadways)	min.	10mph	(VOC) 68%(1975) 83%(2025)	39%(1975) 18%(2000) 30%(2025)	26%(1975) 51%(2025)
		30mph		-6%(1975) -12%(2025)	-2%(1975) -6%(2025)
	max.	70mph	(VOC) -24%(2000) -29%(2025)	0%(1975) 21%(2000) 15%(2025)	-2%(1975) 0%(2025)
Average Speed (Area Wide roadways)	min.	10mph	(VOC) 73%(1975) 68%(2000) 81%(2025)	35%(1975) 14%(2000) 26%(2025)	19%(2025) 38%(2025)
	max.	35mph	(VOC) -12%	-3%(1975) 1%(2005) 0%(2025)	-3%
Average Speed (Freeways)	min.	10mph	(VOC) 74%(1975) 68%(2000) 81%(2025)	40%(1975) 28%(2025)	17%(1975) 32%(2025)
		35mph		-8%	-1%(1975) -5%(2025)
	max.	70mph	(VOC) -27%(1975) -22%(2000) -27%(2025)	0%(1975) 17%(2000) 13%(2025)	-2%(1975) 1%(2000) 0%(2025)
Facility VMT (Add and subtract fraction of vehicles to/from freeways and arterials: New_freeway + new_ramp=(old_freeway + old_ramp) + x*old_arterial New ramp= 0.08*(new_ramp + new_freeway) new_freeway=(0.92/0.08) * new_ramp New_arterial=(1-x)*old_arterial	min.	subtract 40% from arterials	(NMHC) -1%(1975) 0%(2000)	2%(1975) 4%(2000) 3%(2020)	1%(1975) 5%(2000) 2%(2020)
	max.	add 40% to arterials	(NMHC) 1%(1975) 0%(2007)	-1%(1975) -4%(2005) -3%(2020)	-1%(1975) -5%(2000) -2%(2020)
Fuel Program/Sulfur Content (calendar years 2000 and later; for default conventional eastern program reduce sulfur content by 10%, 20%, and 30%)	min.	-10%	(NMHC) -0.5% (2000) to 0%(2025)	-1.6%(2000) to -0.6%(2025)	-0.7%(2000) to 0%(2025)
	max.	-30%	(NMHC) -1.5%(2000) to -0.5%(2025)	-4.7%(2000) to -2%(2025)	-2.2%(2000) to -3.7%(2025)
Absolute Humidity [Use high and low humidity values from August morning and afternoon average relative humidities from Atlanta and Tuscon (National Weather Service data).]	min.	-28% (54grains/lb)	(NMHC) <-1% ldgv total:<0.5%	ldgv running -1.9%(2000) to -0.6%(2025)	ldgv running 5%(2025) to 6%(1975)
	max.	100% (149grains/lb)	(NMHC) ldgv running:4% ldgv total:<0.5%	ldgv running 2.3%(2025) to 8.4%(2000)	ldgv running -14%(1975) to -10%(2025)
Mileage Accumulation(increase and decrease mileage accumulation relative to the MOBILE6 defaults)	min.	20% decrease	(NMHC) 3%(1980) 5%(2005) 1%(2015) -2%(2020)	-2.5%(1985) to -11%(2020)	0%(1990) to -24%(2020)
	max.	20% increase	(NMHC) 1%(1990) -2%(2000) -3%(2005) 2%(2020)	1%(1990) to 22%(2020)	1%(1980) to 9%(2020)
Oxygenated Fuels (ether concentration from 1% to 2.7%; market share variations from 5% to 50%)	min.	5% mkt, 1%ether, 0% alcohol	(NMHC) 0%(2005&2020)	Approximatley 0% (all years)	0%
	max.	50% mkt, 0%ether, 2.7% alcohol	(NMHC) -2% (2000) to -2%(2020)	-5%(2000) to -3%(2020)	0%
Oxygenated Fuels (alcohol concentration from 0.7% to 3.5%; market share variations from 5% to 50%)	min.	50% mkt, 0%ether, 0.7% alcohol	(NMHC) 1% (2000) to 2%(2020)	0.3%(2000) to 2%(2020)	0%
	max.	50% mkt, 0%ether, 3.5% alcohol	(NMHC) Approximatley 0% (all years)	-5%(2000) to -2.5%(2020)	0%

Registration Distribution(decrease newer vehicle fractions and increase older vehicle fractions)	min.	5% age shift	(NMHC) 4%(1985) to 25%(2015)	2%(1980) to 16%(2000)	0%(1985) to 14%(2020)
	max.	20% age shift	(NMHC) 12%(1975) to 80%(2015)	7%(1975) 52%(1995) 24%(2020)	-1%(1980) to 50%(2020)
Speed VMT (Arterial; -3% - null low speed vehicle fractions 9% - equal vehicle fractions for all speeds 14% - increase low speed vehicle fraction by 10% 21% - increase low speed vehicle fraction by 20% 29% - increase low speed vehicle fraction by 30%)	min.	-3% (free-flow/ all day non-rush hour speeds)	(NMHC) -3%(all years)	3% (all years)	-1% to 0% (all years)
	max.	29%(congested traffic flow,i.e., 30% more vehicles at the lower speeds)	(NMHC) 32%(1985) to 44%(2050)	-2%(2005) to +3%(1975)	5%(1975) to 8%(2050)
Speed VMT (Freeway; reduce fraction of vehicles from high speeds to lower speeds)	min.	-50% (equal distribution of speeds)	(NMHC) +13%(1975) to 5%(2050)	3%(1975) to -2%(2005)	-1.1%(2050) to -0.5%(1985)
	max.	10%(most vehicles at the higher speeds)	(NMHC)- 3.5%(1975) to - 1%(2010)	< 0% and >-2%	+1.6%(1985) to 2%(2050)
Starts Per Day(change the number of starts per day from -50% to +50% in increments of 10% for each vehicle type)	min.	-50%	(NMHC) -17%(2025) to -12%(1975)	-15%(1975) to -11%(2025)	-13%(1975) to -7%(2025)
	max.	50%	(NMHC) 17%(2025) to 12%(1975)	11%(2025) to 15%(1975)	13%(1975) to 7%(2025)
Start Distribution	compare emissions with default hourly start fractions to a constant fraction of starts for each hour of the day		(NMHC) 4.5%(1975) to 0.4%(2025)	3%(1975) to 0%(2025)	3%(1975) to 1%(2025)
Sulfur Content (calendar years 1999 and earlier)	min. (300ppm)	0%	(NMHC) 0% (1975) to -0.5%(1999)	0%(1975) to -1%(1999)	0%(1975) to -1%(1999)
	max. (30ppm)	-90%	(NMHC) 0% (1975) to -3.5% (1999)	0%(1975) to -1%(1999)	0%(1975) to -7%(1999)
Average Daily Temperature (standard temperature cycle and vary average daily temperature 12 F to 107 F)	min.	12 F	(NMHC) 10%(2025) 37%(1995) -13%(1975)	-6%(1975) to 216%(2025)	49%(1975) to 19%(2025)
	max.	107 F	(NMHC) 0%(2025) 24%(1995) -34%(1975)	63%(1975) to 2%(2025)	-19%(1975) to 15%(2025)
Temperature Cycles (keep average daily temperature a constant and vary the standard temperature cycle)	min.	constant temperature (-100%)	(NMHC) -3%(1975,102 F) -2%(1975,42 F) 14%(2025,102 F) -1%(2025,42 F) -8%(2005,82 F)	-11%(1975,102 F) -2%(1975,42 F) -0.5%(2025, 102 F) 5%(2025,42 F) 5%(2005,42 F)	5%(1975,102 F) 1%(1975,42 F) -1.4%(2025,102 F) 1%(2025,42 F) -8%(2025,75 F)
	max.	34 F temperature range (+42%)	(NMHC) 3%(1975,102 F) 2%(1975,42 F) 3%(2025,102 F) 2%(2025,42 F) 6%(2005,82 F)	4%(1975,102 F) 1%(1975,42 F) -0.3%(2025, 102 F) -2%(2025,42 F) -2%(2005,42 F)	-1%(1975,102 F) -1%(1975,42 F) -1%(2025,102 F) -1%(2025,42 F) 8%(2025,75 F)
Hourly Temperature (hourly temperatures using temperature cycle variations: The percent differences here are for a given hour of the day and model year. They are not results which have been averaged over an entire day. The daily averages tend to lessen the effects.)	min.	constant temperature (-100%)	(NMHC) 12% to -13% (102 F)	-35%((102 F) to 27%(92 F)	-24%(102 F) to 11%(92 F)
	max.	34 F temperature range (+42%)	(NMHC) -5%(102 F) to 3%(72 F)	-11%(92 F) to 7%(72 F)	-5%(92 F) to 4%(72 F)

Average Daily Temperature and Humidity [For each of a set of daily average temperatures (42, 72, 82, 92, 102, and 107 F) with a 24 F temperature range (the difference between the minimum and maximum temperatures is 24 F) variations of absolute humidity are made. Emission results are determined and compared for each of these average daily temperatures with the absolute humidity set to 53.7, 75, 98.5, 107, and 149.5 grains/lb for a range of calendar years.]	min.	-28% (54grains/lb)	(NMHC) –1% to 0% (all temperatures and all years)	–2% to 0% (all temperatures and all years)	6%(2025) 7%(2005) 7%(2000) 7%(1975)
	max.	100% (150grains/lb)	(NMHC) 0% to 1% (all temperatures and all years)	0% to 6% (all temperatures and all years)	-14%(2025) -15%(2005) -15%(2000) -16%(1975)
VMT Mix (Effects on Light Duty Trucks Emissions Only) (The vehicle miles traveled fractions for light duty trucks 2 were increased and decreased while holding the total proportion of vehicle miles traveled by all light duty trucks constant and equal to the MOBILE6 default values for calendar years 1975, 2000, 2005, 2007, and 2020)	min.	all LDT vehicle miles traveled fractions equal (approx. a 55% decrease in LDT2 fractions)	(NMHC) LDGT 8%(1975) 13%(2020) LDDT 0%(1975) -21%(2000) 0%(2020)	LDGT 5%(1975) 12%(2000) 5%(2020) LDDT 0%(1975) -19%(2000) 0%(2020)	LDGT 4%(1975) 5%(2000) 18%(2020) LDDT 0%(1975) 4%(2000) 0%(2020)
	max.	increase vehicle miles traveled fractions for LDT2 by 20%	(NMHC) LDGT -5%(1975) -2%(2000) -3%(2020) LDDT 0%(1975) 8%(2000) 0%(2020)	LDGT -3%(1975) -1%(2020) LDDT 0%(1975) 8%(2000) 0%(2020)	LDGT -3%(1975) -1%(2000) -3%(2020) LDDT 0%(1975) 4%(2000) 0%(2020)
VMT Mix (Effects on Heavy Duty Truck Emissions Only) (The vehicle miles traveled fractions for heavy duty vehicles were increased and decreased while holding the total proportion of vehicle miles traveled by all heavy duty vehicles constant and equal to the MOBILE6 default values for calendar years 1975, 2000, 2005, 2007, and 2020)	min.	all HDV vehicle miles traveled fractions equal (approx. a 60% decrease in HD2B and HD8B fractions)	(NMHC) HDGV 15%(1975) 37%(2000) 31%(2020) hddv -10%(1975) -20%(2000) -15%(2020)	HDGV 19%(1975) 49%(2000) 15%(2020) HDDV -8%(1975) -28%92000) -17%(2020)	HDGV 19%(1975) 11%(2020) HDDV -7%(1975) -26%(2000) -17%(2020)
	max.	increase vehicle miles traveled fractions for HDV2B and HDV8B by 20%	(NMHC) HDGV 0%(1975) -6%(2000) -5%(2020) HDDV 0%(1975) 4%(2000) 3%(2020)	HDGV 0%(1975) -8%(2000) -2%(2020) HDDV 0%(1975) 6%(2000) 4%(2020)	HDGV 0%(1975) -2%(2020) HDDV 0%(1975) 5%(2000) 4%(2020)