EPA's Proposal for MOBILE6
Facility-specific Speed and Non-FTP Correction Factors

September 29, 1997

Abstract

In MOBILE5, speed adjustments were made based on emission results from the Federal Test Procedure (FTP) and on a number of cycles with varying average speeds. For MOBILE6 we propose to adjust for differences in roadway (facility) type as well as speed and non-FTP effects. EPA has developed new facility-specific inventory cycles, based on real-world driving studies, to address these purposes.

Background

EPA's highway vehicle emission factor model, MOBILE, which is used for inventory modeling, has historically been based primarily on testing of the FTP certification cycle. Correction factors for various conditions (e.g., average speed, temperature, fuels) are applied to emissions measured at the FTP "standard" conditions. The speed correction factors are based on test results for vehicles tested on both the FTP driving cycle and several other cycles, each having a different average speed.

"Real-World Driving"

The Clean Air Act Amendments of 1990 mandated a closer look at "real-world driving" - that is, driving modes that are not covered by the FTP. The FTP is used for certification of all vehicles sold in the US. A new Supplemental FTP rule was finalized in October 1996. This rule specifies new certification cycles and associated standards with more aggressive driving.

For the Federal Test Procedure Review Project, EPA collected both chase car data and instrumented vehicle data in Baltimore, MD, and Spokane, WA, which was supplemented by an instrumented vehicle study by Research Triangle Park (RTP) in Atlanta, GA, and a chase car study by California Air Resources Board (CARB) in Los Angeles, CA.

The Federal Test Procedure Review Project intent was to develop driving cycles for certification purposes, therefore inventory issues were not taken into consideration. For certification purposes, worst case conditions were included in the new test procedure cycles. The new certification cycles are not intended to represent the variety of in-use fleet driving patterns.

Transportation Models

The speed correction factors currently contained in MOBILE were not designed to estimate emissions for individual segments of the roadway system. Available transportation models represent the roadway system as a network of "nodes," which are usually intersections, connected by "links," which represent a particular type of roadway or "facility." Since transportation models generate link-specific estimates of speed and traffic volume, local officials have been using MOBILE to generate link-specific emissions estimates.

The driving patterns in the instrumented vehicle studies show that some types of facility-specific driving contain more frequent and more extreme acceleration and deceleration than others, which reach a similar speed but remain at a steady cruise. There is a need to quantify the emission differences for facility-specific speed related traffic control measures in inventory modeling. This approach requires facility-specific speed correction factors because, at a particular average speed, the pattern of vehicle operation could be substantially different for different types of roadways. At an average speed of 35 mph, for example, travel over surface streets is likely to be dominated by cruising in the vicinity of the speed limit at a low level of traffic congestion, while travel on a freeway could involve a high congestion level and much less cruise operation.

Sample Selection and Data

Facility-specific inventory cycles have recently been developed for use in the MOBILE model. These cycles will better represent actual fleet driving and will also include more aggressive "real-world driving". In a work assignment for EPA, Sierra Research developed eleven facility-specific and one non-freeway area-wide driving cycles. The cycles are based on chase car and instrumented vehicle data from Baltimore, Spokane and Los Angeles, which was collected during the FTP Revision Project for use in developing the supplemental certification cycles and new standards.

Cycle Construction Methodology

Sierra Research constructed the facility-specific cycles using randomly selected microtrips to match the speed-acceleration frequency distribution (SAFD) of all vehicle operation occurring under the conditions of interest (e.g., a particular facility type and congestion level). This approach ensures that the speed-time profile of the cycle is constructed from real speed-time profiles that reflect the proper proportion of a broad range of vehicle operation.

Sierra did a separate assessment of the highest load points (i.e. the highest combined speed/acceleration points), to make sure the cycles have a representative sample of the high load points. Another criteria for developing the cycles was to match the total proportion of specific power values in two groupings: between 200-299 mph/sec (moderate high load points) and 300+ mph/sec (extremely high load points).

Because microtrips begin and end at rest, a modification to this methodology was required to develop cycles representative of uncongested freeway operation. Sierra used appropriate trip segments (in lieu of microtrips) that were driven under the target levels of congestion on freeways.

Table 1 gives a description of the cycles which were developed for EPA by Sierra Research. More thorough descriptions of the cycle development methodology can be found in the final report by Sierra Research (see Report M6.SPD.001).

Stakeholder Comments

Through the stakeholder review process for this report, the question came up as to why the cycles' statistics differed from the statistics of the population of driving which the cycle is designed to simulate (or "target population"). For example, the highest average speed of the arterial/collector cycles is 24.8 mph. We know that much of the driving on arterial/collectors can have average speeds higher than that. The maximum speed of that cycle is 58.9 mph, while the maximum speed of the targeted population is 74.9 mph. See Table 2 for the new cycles' statistics compared to the target population statistics for each cycle.

The cycles were designed to represent driving which would result in the target population's emissions. Characteristics which were important to match in order to accomplish this are specific power, speed, and amount of acceleration, deceleration and idle. The factor which most impacts emissions, shown from previous experience, is power distribution. The average speed of the cycles do closely match the average speed of the target population, even though they do not cover the entire range of speeds. More importantly the cycles were designed to match the power distribution of the target population. We feel that the emissions generated from the cycles are a true representation of the emissions from the actual target population, including the broader range of speed distribution.

Testing

The sample for this analysis came from EPA Emission Factor testing performed at both the Automotive Testing Laboratories, Inc. (ATL), in Ohio and EPA's National Vehicle and Fuels Emission Laboratory (NVFEL), in Ann Arbor, Michigan, in the Spring of 1997. All of the vehicles at ATL were recruited at Inspection and Maintenance lanes run by the State of Ohio, and were tested in an as-received condition (without repairs). At the time of this analysis, a total of 50 1983 through 1996 model year vehicles had been recruited and completed testing in Ohio, and 23 1990 through 1996 model year vehicles recruited and tested in Ann Arbor. A total of 62 vehicles will be completed by the end of this work assignment in Ohio. If time allows, any additional vehicles tested will be added to the vehicle sample to update the analysis before the release of MOBILE6. The sample of 73 vehicles includes 18 light-duty trucks. Most of the 73 vehicles were fuel injection, with 3 carbureted passenger cars and 4 carbureted light duty trucks.

Table 1 New Facility-Specific/Area-Wide Speed Correction Cycles					
Cycle	Average Speed (mph)	Maximum Speed (mph)	Maximum Accel Rate (mph/s)	Length (seconds)	Length (miles)
Freeway, High Speed	63.2	74.7	2.7	610	10.72
Freeway, LOS A-C	59.7	73.1	3.4	516	8.55
Freeway, LOS D	52.9	70.6	2.3	406	5.96
Freeway, LOS E	30.5	63.0	5.3	456	3.86
Freeway, LOS F	18.6	49.9	6.9	442	2.29
Freeway, LOS “G”	13.1	35.7	3.8	390	1.42
Freeway Ramps	34.6	60.2	5.7	266	2.56
Arterials/Collectors LOS A-B	24.8	58.9	5.0	737	5.07
Arterials/Collectors LOS C-D	19.2	49.5	5.7	629	3.36
Arterials/Collectors LOS E-F	11.6	39.9	5.8	504	1.62
Local Roadways	12.9	38.3	3.7	525	1.87
Non-Freeway Area-Wide Urban Travel	19.4	52.3	6.4	1,348	7.25

In addition to the new cycles in Table 1, the following cycles were also tested in the above test programs (see Table 3 for information on these additional cycles):

- Federal Test Procedure (FTP), with additional hot running 505
- California Air Resources Boards (CARB) area-wide Unified Cycle (also referred to as LA92)
- NYCC (a low speed cycle which has previously been used for speed correction factors in the MOBILE model)
- ST01, start cycle based on instrumented vehicle data

The ATL dataset provides a stratified random sample, with strata corresponding to IM240

Table 2 Comparison of Key Representativeness Statistics for Facility-Specific Cycles								
Driving Cycle	Mean Speed (mph)		Maximum Speed (mph)		Maximum Accel Rate (mph/sec)		Total SAFD Difference (%)	High-Power Difference (%)
	Cyc.	Pop.	Cyc.	Pop.	Cyc.	Pop.		
Freeway High-Speed	63.2	62.7	74.7	80.9	2.7	5.8	9.41	0.16
Freeway LOS A-C	59.7	59.2	73.1	83.2	3.4	6.8	12.12	0.39
Freeway LOS D	52.9	52.0	70.6	75.8	2.3	6.1	15.10	0.35
Freeway LOS E	30.5	32.1	63.0	71.3	5.3	8.5	25.17	0.18
Freeway LOS F	18.6	19.9	49.9	69.5	6.9	9.6	23.83	0.06
Freeway LOS G	13.1	14.4	35.7	49.1	3.8	5.7	18.80	0.10
Freeway Ramp	34.6	35.4	60.2	79.1	5.7	9.3	42.74	0.99
Arterial LOS A-B	24.8	25.2	58.9	74.9	5.0	14.9	17.04	0.40
Arterial LOS C-D	19.2	18.9	49.5	71.3	5.7	10.4	16.86	0.21
Arterial LOS E-F	11.6	12.0	39.9	56.8	5.8	10.2	17.86	0.24
Local Roadways	12.8	14.6	38.3	62.7	3.7	12.5	21.80	0.11
LA92 Cycle	24.6	26.3	67.2	80.3	6.9	10.4	30.27	0.19

pass or fail outcome. Twenty of the vehicles in the ATL sample failed the IM240 test. The total sample (NVFEL and Ohio) was re-sorted into emission level groups of low and high by LA4 Running Emissions which passed or failed the following cutpoints: HC .8 g/mi; CO 15 g/mi; NOx 2.0 g/mi, where

LA4 Running Emissions = (Running 505 * (0.206 + 0.273)) + (Bag 2 * 0.521)

Preliminary Analyses

The data were looked at initially from two angles to determine if the effect was different by:

1. Emission levels (low vs. high emitting vehicles).
2. Roadway type (freeways vs. arterial/collectors).

Table 3 Additional Tested Cycles					
Cycle	Average Speed (mph)	Maximum Speed (mph)	Maximum Accel Rate (mph/s)	Length (seconds)	Length (miles)
LA4	19.6	55	3.3	1368	7.45
Running 505	25.6	56.7	3.3	505	3.59
Unified Cycle (LA92)	24.6	67.2	6.9	1435	9.81
ST01	20.15	41	5.1	248	1.39
NYCC	7.07	27.7	6.0	600	1.18

The data were looked at both in emission space (gram/mile) for each pollutant and as speed correction factors, and ratios of the speed cycle to the LA4 running emission factors. Statistically the data shows differences for emission levels for all three pollutants. See Figures 1a, 1b, and 1c.

The speed overlap range for freeway and arterial/collector roadways in the average speed of the cycles was limited to 13.1 to 24.8 mph. NOX showed a strong statistical difference in an analysis of variance for both low and high emission levels. HC had a weaker statistical difference, but shows some difference for the low emission level. For CO the variance in the data was so great, even though the ratio of the means graphically shows a difference, it is not there statistically. See Figures 2a, 2b, and 2c. Note that figures 2a-c represent only low emitters from the new facility cycle data, and do not include the higher emission level data.

Comparison to MOBILE5

One major difference between MOBILE5 and MOBILE6 is that we will be separating start and running emissions in the newer version. All correction factors will be applied separately also. Speed/non-FTP correction factors in MOBILE6 will be applied only to running emissions, whereas the speed correction factors in MOBILE5 and previous versions were applied to the entire FTP weighted trip.

As can be seen from figures 2a, b and c, the data which will be used to develop speed/non-FTP correction factors for MOBILE6 is consistently higher due to the non-FTP effects in the new driving cycles.

Figure 1a.

Facility Cycles Ratio of Means, HC by Emitter Level Groups

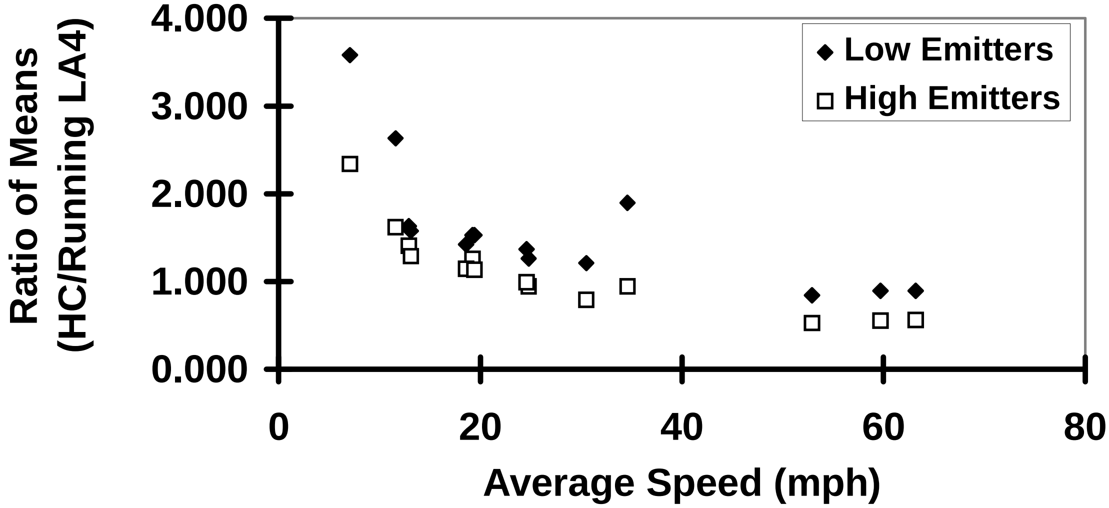


Figure 1b.

Facility Cycles Ratio of Means, CO by Emitter Level Groups

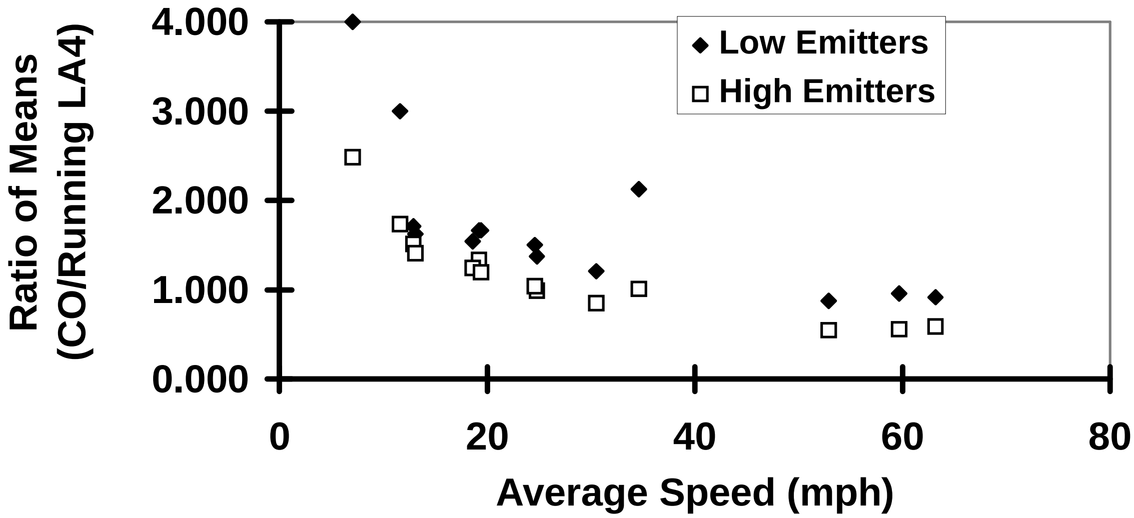


Figure 1c.

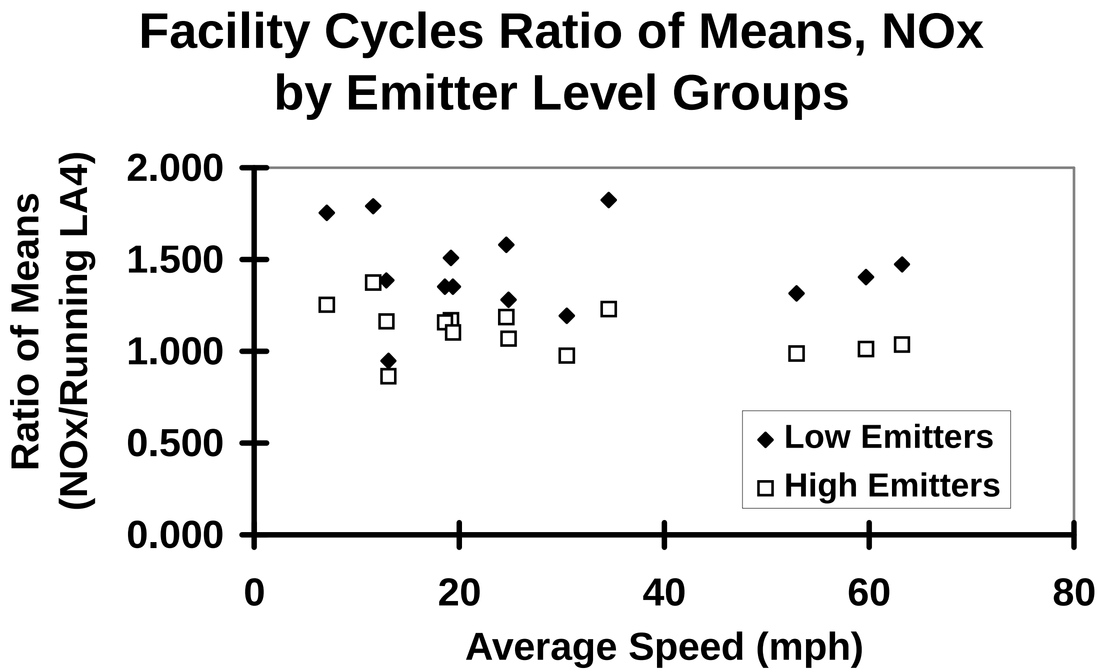


Figure 2a.

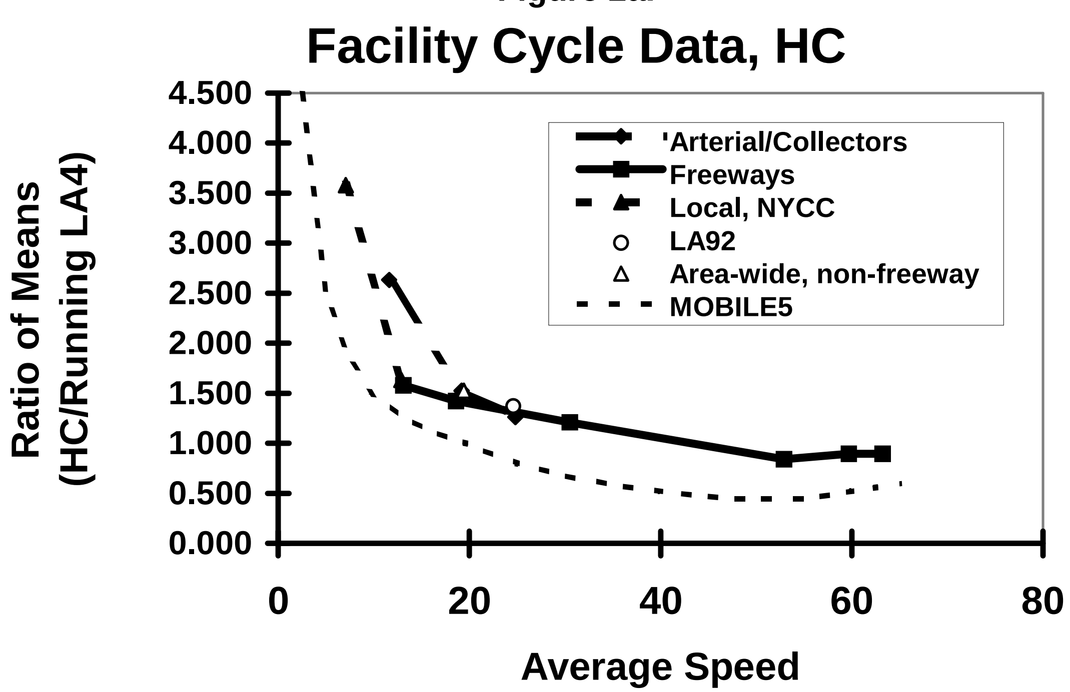


Figure 2b.

Facility Cycle Data, CO

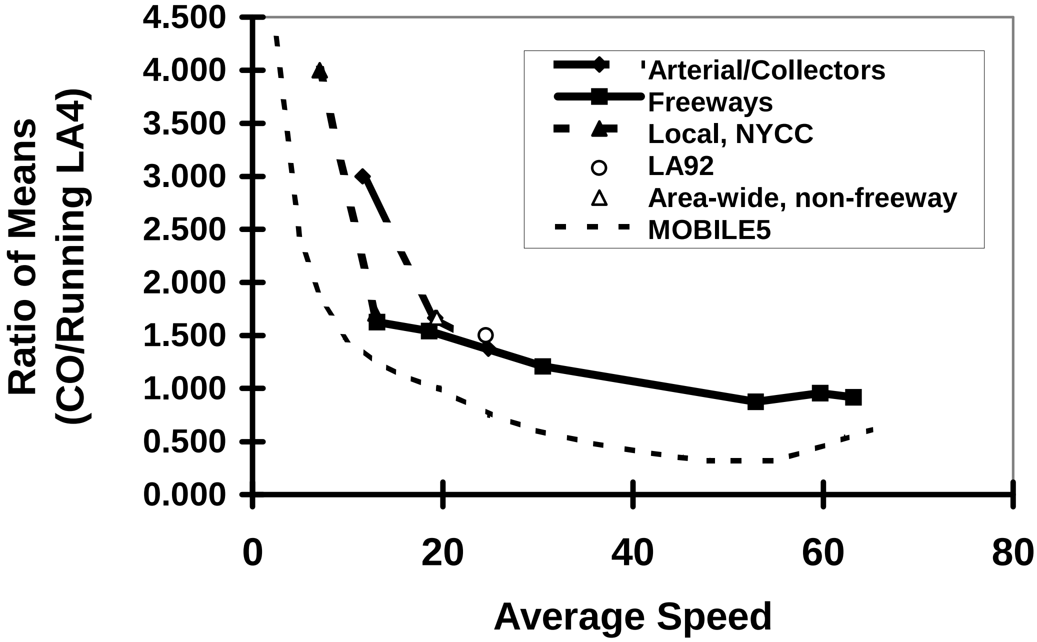
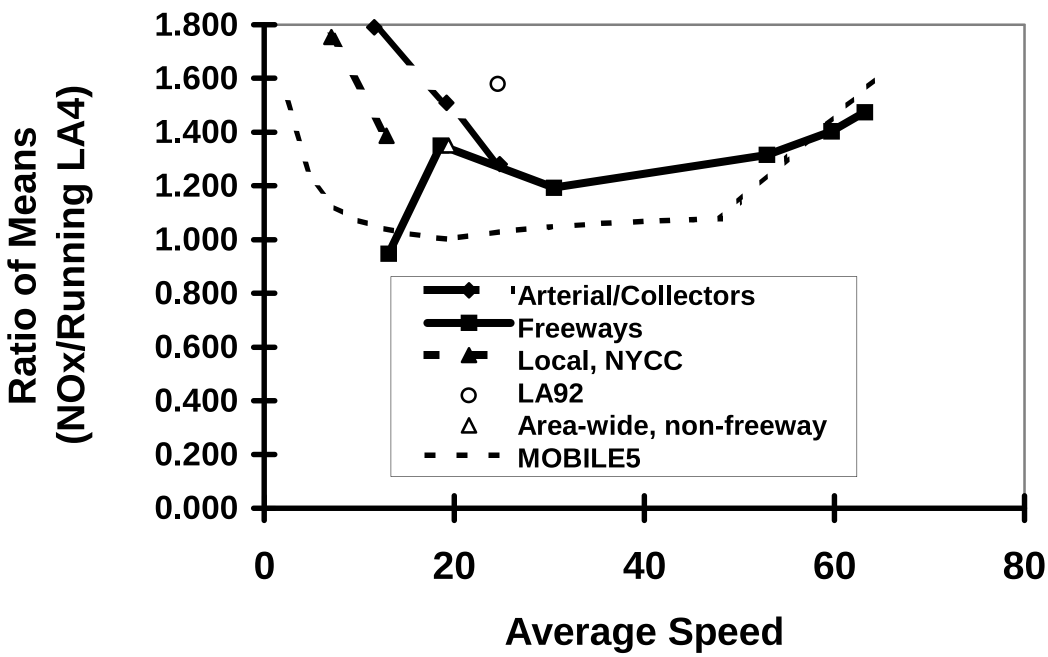


Figure 2c.

Facility Cycle Data, NOx



Aside from the roadtype differences, the overall shape of the curve is similar. The data appear to look flatter at higher speeds than in previously modeled high speed data. This may be due largely to the fact that the old speed cycles all started from 0 mph and accelerated to higher than the average speed of the cycle. This extra acceleration, which is not generally found on cruising vehicles on limited access freeways, adds to the power demand, therefore increasing emissions in the old high speed cycles. The acceleration to reach freeway speeds is now contained in the separate ramp cycle. This additional ramp cycle will allow this effect to be weighted appropriately with freeway driving. The effect from starting and ending at 0 mph is less pronounced in the lower speed cycles since they inherently have a higher percentage at idle, while not having to accelerate at higher rates to reach the higher speeds.

Proposal for MOBILE6

Based on our preliminary analysis we propose for MOBILE6 to differentiate by roadway type for NOX for both low and high emission levels, and HC for just low emission levels. We propose to use one speed curve for HC high emission level, and for CO both low and high emission levels for both road types. The speed/non-FTP corrections will be applied to the temperature and fuel corrected base running emissions.

A detailed report describing the facility based speed equations analysis along with the database used will be made available for stakeholder review before the release of MOBILE6.

The current plan for MOBILE6 is to output emission factors by facility-type. The methodology for weighting together the speed-corrected facility-type emissions into a single area-wide running emissions rate is under development. There will be no more need for operating mode inputs. Instead, the user would input average speed per %VMT combinations by roadway types. The VMT fractions would be used to weight the facility-specific emission factors at each speed to an area-wide running emission factor which would be representative of a specific urban area. Guidance on the %VMT weighting is being prepared and a report will be available in late 1997. We will utilize the LA92 and non-freeway area-wide cycles emissions data to validate the weighting procedure.

Modeling Speed Ranges Outside of the Average Speed of the Cycles

An important issue which we are still investigating is how to account for speed ranges outside of the average speed of the cycles for which the data were collected, particularly for arterial/collectors and local roadways. Potentially we could just join the curves for arterial/collector and freeways. If the modeler would like to model an arterial at 35 mph, it might be reasonable to use the freeway speed/non-FTP curve to get emissions for this case. We invite input on helping us resolve these issues.

Low-Speed Curve

The current low-speed data available to us is:

1. Local and NYC cycles which were tested in facility-cycle testing program, described above.

2. Old low-speed data for 2.5, 3.6, 4.0, 7.1 (NYCC), and 12.0 mph. This data was the basis for low-speed correction factors in the past few versions of the MOBILE model.

We would like to utilize the older data for the lower speed range by normalizing the previously used curve to fit the new data for the NYC and local cycles, by linking with the NYC cycle which is present in both data sets. This analysis has not yet been performed. Some of the issues involve the different technologies and model year groups. The results from this approach will be included in EPA's Facility Analysis Report, which will be posted for review in December, 1997.

Table 4
Low-Speed Cycles

Cycle	Average Speed (mph)	Maximum Speed (mph)	Maximum Accel Rate (mph/s)	Length (seconds)	Length (miles)
LOWSP1	2.5	10.0	2.4	601	0.42
LOWSP2	3.5	14.0	2.5	719	0.64
LOWSP3	4.1	16.0	3.4	555	0.70
NYCC	7.07	27.7	6.0	600	1.18
SCC12	11.7	29.1	3.3	360	1.17
Local Roadways	12.9	38.3	3.7	524	1.87

Signal Density Issues

In the previous proposal on speed/non-FTP correction factors, dated March 7,1997, the issue of signal density was raised. There were many comments received on this topic. Detailed information on the arterial/collector cycle microtrip relationship to signals and types of signals has been documented by Sierra Research and is included in the report describing the new cycles. This is an area where decisions on the direction we should take for the MOBILE6 model has not yet been made. More discussion and a proposal will be included in EPA's Facility Analysis Report for Stakeholder review.

Comments

Comments on this report and its proposed use in MOBILE6 should be sent to the attention of Connie Radwan. Comments may be submitted electronically to mobile@epamail.epa.gov, or by fax to (313)741-7939, or by mail to "MOBILE6 Review Comments", US EPA Assessment and Modeling Division, 2565 Plymouth Road, Ann Arbor MI 48105. Electronic submission of comments is preferred. In your comments, please note clearly the document that you are commenting on. Please be sure to include your name, address, affiliation, and any other pertinent information.