

Making Use Of MOBILE6's Capabilities For Modeling Start Emissions

Jeffrey A. Houk
Federal Highway Administration Resource Center
12300 West Dakota Avenue, Lakewood, CO 80228
jeff.houk@fhwa.dot.gov

ABSTRACT

The MOBILE6 emissions factor model includes several new, but often unutilized, capabilities for capturing emissions from engine starts in an urban area. This paper highlights several simple methods to customize MOBILE model inputs and outputs in order to better characterize start emissions behavior. These include 1) addressing the impact of MOBILE6's default mileage accumulation rates on calculated grams per mile start emission factors; 2) modifying the default hourly start distribution to reflect local travel patterns; 3) modifying the default starts per day for trips that are not completed within the urban area (internal/external and through trips); 4) using travel model trips as a surrogate for MOBILE model starts; 5) assigning start emissions to the travel model zones where trips originate; and 6) modifying the starts assumptions for purposes of project-level analysis.

INTRODUCTION

The MOBILE6 model includes vastly expanded capabilities for modeling start emissions based on local vehicle activity, and for quantifying these emissions in emission inventories for SIPs and conformity determinations. This paper begins with a description of how MOBILE5 and MOBILE6 handle start emissions, and then discusses some ways that state and local agencies can go beyond the default methodologies of MOBILE6 to characterize start emissions in their areas.

The start emissions from the light duty passenger car, light duty truck and motorcycle vehicle classes (the only classes for which start emissions can be estimated separately in MOBILE6) collectively account for 28% of *total* on-road volatile organic compound (VOC) emissions (exhaust and evaporative combined), 31% of carbon monoxide (CO) exhaust emissions, and 20% of nitrogen oxides (NO_x) exhaust emissions in a typical 2001 summertime model scenario based on model defaults. Under wintertime conditions, start emissions can comprise up to 50% of total CO exhaust emissions. This is a significant portion of vehicle exhaust emissions in MOBILE modeling, and correctly accounting for these emissions can be critical to successful attainment demonstrations and conformity analyses. For example, rural areas that include start emissions for through trips (which do not have starts) will overestimate total emissions in the nonattainment area. Areas that are performing photochemical modeling should be concerned about how to correctly distribute start emissions spatially, and modelers performing air quality assessments for roadway projects need to consider whether it is appropriate to include start emissions in their emission rate estimates.

START EMISSIONS IN THE MOBILE MODEL

In the Federal Test Procedure (FTP) and in MOBILE5, the cold start (Bag 1) and hot start (Bag 3) emission rates are weighted by a default fraction of vehicle miles traveled (VMT) associated with hot and cold starts (43% cold start, 57% hot start). In MOBILE5, users had the option to modify the percentages of VMT representing the cold start, hot start and hot stabilized (Bag 2) operating modes, including zeroing out any of these conditions. The default operation of MOBILE5, however, was to use default fractions of hot versus cold start VMT and to report combined regionwide start and running

emission rates. It was possible, but not straightforward, to extract stand-alone start emissions from the model.¹

MOBILE6 handles start emissions quite differently. Basic start emission rates in MOBILE6 are still calculated using emissions test data from Bag 1 (cold start) and Bag 3 (hot start) of the FTP. These portions of the FTP cover a distance of 3.59 miles and last 505 seconds; they include both start and hot stabilized emissions due to the length of the cycle (the extra emissions from a start generally end after one or two minutes of vehicle operation). In order to extract the start emissions from these test cycles, a third cycle, the Hot Running 505, was developed. This driving cycle is identical to that of Bags 1 and 3 but does not include a start. Grams per mile emissions rates from the Hot Running 505 are subtracted from the emissions rates from Bags 1 and 3, and multiplied by the length of this test cycle (3.59 miles), to calculate start emissions in terms of grams per vehicle start. (Since the Hot Running 505 is not traditionally part of the FTP, EPA developed a correlation between this test cycle and the FTP for use with additional FTP data.)² In addition, rather than characterizing starts as either cold or hot, MOBILE6 varies the start emissions by the length of time that the vehicle was parked prior to the start: the soak distribution.³

Since MOBILE6 internally calculates start emissions separately, rather than treating start emissions as part of total exhaust emissions, they can now be reported separately. However, its default methodology for summing and reporting start emissions produces largely the same result as MOBILE5. Unless the user instructs the model to report emissions separately, the model sums the calculated emissions for each of the individual starts, divides the total start emissions by the default (or user-supplied) miles per vehicle per day, and adds the resulting grams/mile start emissions rate to the running emissions rate to report total exhaust emissions. The composite emissions rates in the MOBILE6 descriptive output include both start and running emissions, just as in MOBILE5, unless the user specifies otherwise as discussed below.

Start emissions in MOBILE6 are sensitive to most of the same variables as running exhaust emissions: vehicle type, age, mileage accumulation, fuel RVP, temperature, etc. MOBILE6 includes defaults for the number of starts per day, the distribution of those starts by hour of day, and the distribution of soak lengths, all of which can be modified by the user.

Starts are not estimated separately in MOBILE6 for heavy duty gas or diesel vehicles (HDVs) or buses, but areas can still address these issues for light duty passenger car (LDV), light duty truck (LDT) and motorcycle (MC) travel. These passenger vehicle classes account for approximately 88% of total vehicle miles traveled (based on the default MOBILE6 VMT distribution). As noted above, the start emissions from these passenger vehicle classes collectively account for 28% of *total* on-road VOC emissions (excluding refueling), 31% of CO exhaust emissions, and 20% of NO_x exhaust emissions in a typical summertime model scenario. Under wintertime conditions, start emissions can comprise up to 50% of total CO exhaust emissions. (These estimates are for calendar year 2001.) Start emissions are not estimated separately for particulate matter; only combined start and running emission factors are available for particulate matter.

Users may modify the starts per day and soak distributions, but EPA recommends that an instrumented vehicle study specific to the area in question be used to gather this data. However, such studies can be costly and difficult to design and implement. Information on these types of studies is available in the technical report behind the default start inputs in MOBILE6³ or a report from the University of Tennessee.⁴ Also, if areas do use local data based on instrumented vehicle studies, these data arguably fall under the EPA/FHWA 2002 Latest Planning Assumptions guidance.⁵ Under this guidance, local data used in MOBILE modeling for conformity purposes needs to be updated every five

years, unless a case can be made that the existing data are still accurate. Thus, alternative methods for developing start inputs might be more appropriate from an implementability standpoint.

The remainder of this paper focuses on ways that users can report start emissions from MOBILE6 separately, and develop estimates of start emissions that are more accurate for their area.

NEW METHODS FOR CHARACTERIZING START EMISSIONS

Obtaining Separate Estimates of Start Emissions from MOBILE

MOBILE6 provides two options for reporting start emissions separately from running exhaust emissions; the user can employ the EXPAND EXHAUST command to generate separate start and running grams/mile emissions rates in the descriptive model output (for the eight combined vehicle classes, or for each of the individual MOBILE6 vehicle classes for which start emissions are calculated), or can use the database output to report start emissions separately in varying degrees of disaggregation. Use of the database option usually requires some data reduction in a spreadsheet program; the Sierra Research MOBILE6 training materials posted on EPA's Office of Transportation and Air Quality (OTAQ) MOBILE6 web site include some instructions and examples. Using the database output, emissions can be calculated in terms of grams per hour, grams per day, grams per mile, or grams per start. (Given the large volume of data generated, considerable expertise in spreadsheet, database or statistical software would be needed to effectively handle MOBILE6 hourly output.) Start emissions cannot be quantified separately using the MOBILE model's SPREADSHEET command.

Regardless of the output format chosen, users can modify the start activity inputs using any or all of the following MOBILE6 commands:

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| STARTS PER DAY: | Allows users to specify the average number of starts (trips) per day by vehicle class. |
| START DIST: | Allows users to allocate engine starts (trips) by hour of day. |
| SOAK DISTRIBUTION: | Allows users to modify the default soak distribution, which defines, by hour of day, how long vehicles have been parked prior to an engine start. |

Each of these commands includes separate values for weekdays and weekends, so that users can enter data specific to the situation being modeled. MOBILE6 includes defaults for each of these commands, and the MOBILE6 User's Guide and MOBILE6 Technical Input Guidance contain guidance on their use and sources of data.

Addressing the Impact of MOBILE6's Default Mileage Accumulation Rates on Calculated Grams per Mile Start Emission Factors

As discussed above, MOBILE6 calculates emissions in grams per start, multiplies by the number of starts per day to calculate total daily start emissions, and then divides by the total miles per day to calculate a grams per mile start emissions rate. It performs this last calculation using the default or user-supplied mileage accumulation rate (MAR). EPA's guidance for MOBILE6 recommends that areas use the model's default mileage accumulation rates, because local sources of data are usually inaccurate.⁶ However, if default MARs are used, the resulting grams per mile start emission rates may not be appropriate for the area.

For example, areas with higher than default miles per day will tend to overestimate start emissions. The model's grams per mile emissions rate is calculated by dividing total daily start emissions by a default miles per day per vehicle estimate; when this emissions rate is multiplied by local VMT to calculate the inventory, if the area's miles/vehicle/day are higher than the model's default, the resulting inventory calculation will overcount start emissions. Likewise, areas with lower than default miles per day will tend to underestimate start emissions, all else being equal. (One could argue that areas with higher miles per vehicle per day actually have more trips (and thus more starts) per day, and that the opposite would be true for areas with lower than default miles per vehicle per day. This discussion assumes that these areas have the same number of trips per vehicle per day, but that they are longer or shorter than the MOBILE default assumption.)

The default miles/vehicle/day estimate in MOBILE6 for the vehicle classes for which start emissions are estimated separately is 31.24 miles per day. (This is a registration-weighted daily average for the LDV, LDT, and MC classes, based on default fleet data.) However, the 2001 National Household Travel Survey (NHTS)⁷ reports daily vehicle travel estimates ranging from 25.09 miles per day in the New York metropolitan area to 39.48 miles per day in the Dallas/Ft. Worth area. (For purposes of this discussion, it is reasonable to assume that the vehicle classes (cars, light trucks and motorcycles) for which start emissions are estimated in MOBILE6 are similar to the vehicles in the households covered by the NHTS, but areas wishing to use local data should gather information specific to their fleets.) If the grams/mile start emissions rates from MOBILE were applied to these local VMT estimates, New York would underestimate start emissions by about 20% (because its actual miles/day number is lower than the model default) and Dallas would overcount them by about 26% (because its miles/day number is higher than the model's). Based on the examples of the contribution of start emissions to total emissions given in the introduction, the effect on total emissions of using local MAR data could range from about 2% to as high as 13%, depending on the pollutant in question and time of year.

One way areas can address this problem is by reporting start emissions in grams per day (using the model's database output option), and dividing by their own miles/vehicle/day estimates. The impacts of this approach are shown in the following table, which compares the start emissions (both in terms of the total start emissions, and grams per mile emissions rate) calculated using the model's default MAR, and local MAR combined with grams/day emissions rates. Table 1 shows how significant the impact of local MAR data can be on total calculated start emissions for Denver in calendar year 2001:

Table 1. Impact of default MAR and local MAR on start emissions in Denver.

	Mileage Accumulation Rate, LDV/LDT/MC	MOBILE6 CO start emissions	Calculated emissions rate	Total CO start emissions (51,311,000 total VMT, LDV/LDT/MC)
MOBILE6 Default data	31.24 miles/day	387.4 gm/day	12.40 gm/mile	700 tons/day
Denver data (from NHTS)	35.87 miles/day	387.4 gm/day	10.80 gm/mile	610 tons/day

While the use of NHTS data illustrates the scope of the issue, users can also address this issue by developing local MAR estimates, which have multiple benefits for MOBILE modeling. Guidance for doing this can be found in the MOBILE6 Technical Guidance⁶ and in EIIP volume IV, Chapter 1.⁸ If

NHTS data are available for the area, the area might also be able to scale up the default MAR estimates in the model by the ratio of local daily MAR to the model's default MAR (31.24 miles/vehicle/day). (Again, this would only apply for the vehicle classes for which MOBILE6 estimates start emissions separately.) Note that using a local MAR rather than the model defaults will result in other changes to the calculated emission rates; the MAR is used to “age” the vehicle fleet, so changes to the MAR that increase or decrease average mileage accumulation will result in the modeling of a dirtier or cleaner fleet. While this may be appropriate for the area, users need to be aware of this impact.

Areas can also address this issue by reporting start emissions as a separate category in the emissions inventory, as discussed later in this paper.

Modifying the Default Hourly Start Distribution to Reflect Local Travel Patterns

As mentioned above, MOBILE6 uses a default distribution of starts by hour of day to calculate hourly start emissions rates, or users can input local data using the START DIST command. The default start distribution was based on an instrumented vehicle study involving 186 LDVs in Baltimore and Spokane.³ Unlike the starts per day and soak distribution, EPA does not stipulate use of an instrumented vehicle study to gather local data for this input.

MOBILE6 also includes an input for VMT by hour of day, and like the start distribution, users may use the default distribution or input local data with the VMT BY HOUR command. Local inputs can easily be developed through data from automated traffic recorders (for more information, see the MOBILE6 technical report M6.SPD.004)⁹. The defaults are based on a weighted average of daily travel from Charlotte, Chicago, Houston and New York, as described in the MOBILE6 technical report M6.SPD.003.¹⁰ Note that the source for these defaults is different than the source of the default hourly start distribution.

Since one would expect that the distribution of starts by hour should have some logical relationship to the distribution of VMT by hour, modelers may consider using their hourly VMT distribution (HVMT) as a surrogate for the hourly start distribution. This is especially true for areas without travel models, or for areas that would like to obtain a rough idea of the impact that a local start distribution might have on their MOBILE6 results. To examine the effects of this, Table 2 documents the results of three MOBILE runs. The first uses defaults for both the start and hourly VMT distributions; the second uses the default start distribution but local HVMT data (for Galveston, Texas);¹¹ and the third uses the Galveston HVMT distribution for both VMT by hour and starts by hour. (Otherwise, these runs are based on typical summer conditions and MOBILE defaults for the year 2000. Total composite emissions rates are reported, with calculation of refueling emissions disabled.)

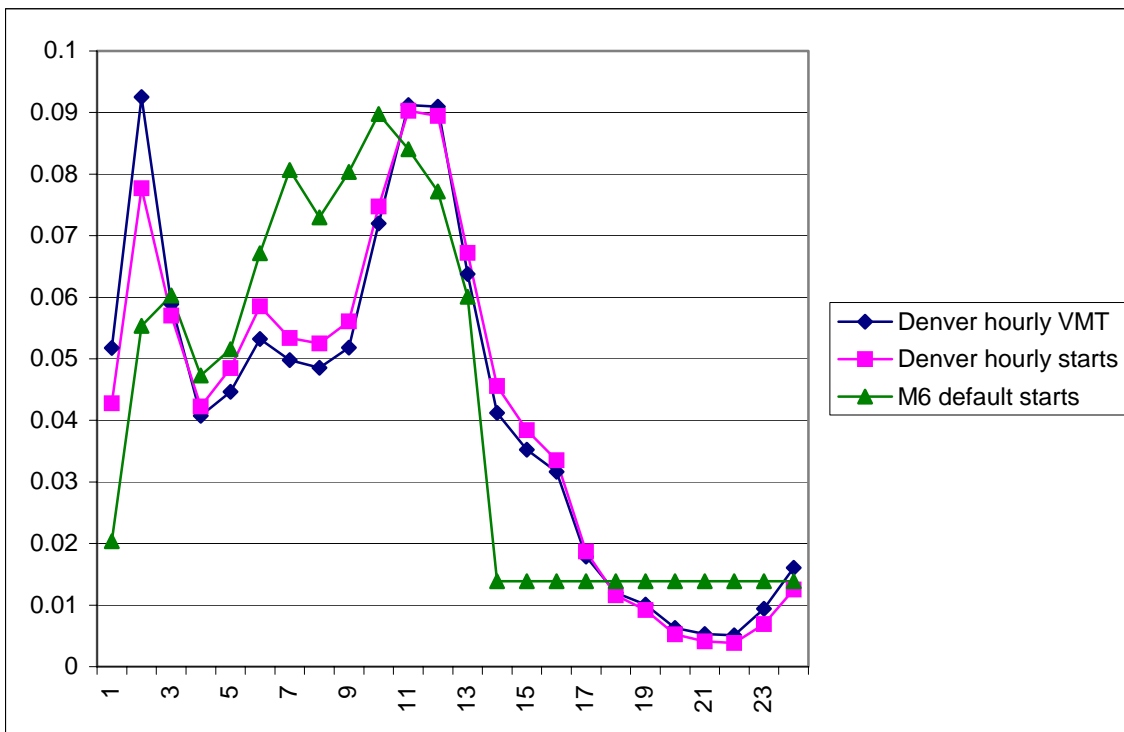
Table 2. Impact of local hourly start and VMT distribution in Galveston.

Pollutant	Emission Rates with Default Inputs	Local HVMT	Percent Difference	Local HVMT and HVMT-based Start Distribution	Percent Difference
VOC	1.750 gm/mi	1.763 gm/mi	0.74%	1.801 gm/mi	2.91%
CO	20.925 gm/mi	21.074 gm/mi	0.71%	21.669 gm/mi	3.56%
NOx	2.933 gm/mi	2.933 gm/mi	0.00%	2.939 gm/mi	0.20%

It can be seen that while use of a local hourly VMT distribution has a reasonably significant effect on CO and VOC emissions, use of this same data to represent the start distribution has a much greater effect on all pollutants. (Differences of less than one percent may seem insignificant, but sometimes these small emissions differences are enough to impact the successful completion of an attainment demonstration or conformity determination.) Use of the hourly VMT distribution affects running emissions, but not start emissions, and use of an hourly start distribution affects start emissions, but not running emissions.

The MOBILE6 Technical Guidance suggests that it may be possible to use data from travel demand models to distribute vehicle starts during the day.⁶ The number of trips for each time period covered by the travel model could be summarized and converted to a percentage of daily trips by time period, and then the MOBILE defaults could be used to further disaggregate the travel model time period trip estimates into hourly trip estimates. For example, if an area’s travel model covers four time periods of the day, the MOBILE hourly estimates of start percentages for the 6am, 7 am and 8 am hours could be used to break out the trips from the travel model’s am peak period, and so forth. (This is analogous to the approach that EPA recommends for expanding Highway Performance Monitoring System (HPMS) vehicle count data into the 28 MOBILE6 vehicle types.) Figure 1 shows how the default start distribution compares to the local travel model start distribution and the local hourly VMT distribution for Denver.¹² The Denver hourly start distribution is from travel survey data used in the regional travel model, and the hourly VMT data are from traffic counts.

Figure 1. Comparison of default start distribution to Denver start and VMT distributions.



Given the significant impact of modifying the start distribution, we recommend that areas develop local start distribution inputs, using either travel model data or their hourly VMT distribution to represent the hourly start activity. Further uses of travel model data to define local start activity are discussed later in this paper. However, hourly VMT distributions should be calculated carefully, using a representative sample of data from traffic recorders or information from a properly validated travel

model. If local data are sparse or questionable, it may be difficult to justify using them in place of the model's defaults.

Modifying the Default Starts per Day for Trips That Are Not Started or Completed Within the Urban Area (external/internal and external/external (through) trips)

Areas that apply grams per mile start emissions rates to all regional VMT are almost certainly overcounting start emissions. In nearly every urban area, and especially, in rural areas, some significant portion of VMT is made up of through traffic (external/external (X/X) trips that begin and end outside of the study area), and external/internal (X/I) travel (trips that begin outside of the study area). These trips do not have start emissions, but if a start emissions rate is applied to the portion of the VMT on these trips that is inside the study area (for example, by using the model's default combined start and running exhaust emissions rates), an area will include emissions for starts that are not occurring within the area.

The Denver Regional Council of Governments reports a total of 60,600,000 daily VMT for their modeling region in 2001.¹³ Of this 810,000 miles of daily travel are attributed to through (X/X) trips, and another 9,050,000 miles of travel are attributed to internal/external (I/X) trips. Under Denver's classification, some of the I/X trips originate outside the area and end inside, and the remainder originate inside and end outside (in other words, this trip classification in Denver includes both "X/I" and "I/X" trips). Assuming a 50/50 split between these two types of trips, and adding the through (X/X) trips, a total of 5,335,000 daily VMT can be attributed to trips that do not have an engine start in the area. This represents about 8.8% of total VMT in the region; if Denver were to apply start emissions rates to total VMT, instead of only the portion of VMT that has an associated start, daily start emissions would be overestimated by approximately 9%. By extension, since about 50% of total winter CO emissions are represented by starts, Denver would overestimate total CO emissions by approximately 4.5%.

The MOBILE6 model provides a variety of options for dealing with this issue. The easiest approach may be to generate separate emission rates for the X/X and X/I trips. (This may be necessary anyway, to account for the fact that many or most of these vehicles are not subject to the local I/M program.) The MOBILE6 emission rates for these trips would be modeled with STARTS PER DAY set to zero, to account for the fact that there are no start emissions associated with these trips in the nonattainment area. The internal/external and internal/internal trips would be modeled normally (with the default or locally-estimated number of starts per day), and then the appropriate emission factors would be applied to the VMT associated with each trip type.

This issue can also be addressed by reporting start emissions separately in the descriptive output, and not applying the start exhaust emissions rate to through and X/I VMT. As a refinement, grams per start emissions rates can be calculated from the database output, and start emissions can be calculated as a separate category in the inventory based on local estimates of the number of trips that have starts associated with them within the area (see the next two sections).

Areas could also develop a modified regional starts per day estimate based on factoring in X/X and X/I VMT, and use this in place of the model's defaults. Rather than the default 7.28 starts per day for LDGVs, an area might use 6.28 starts per day for the portion of total daily VMT represented by commute trips originating outside the area, or might develop other estimates for starts based on how much start activity is generated within the study area by vehicles from households outside of the area. (For example, it might be reasonable to assume that vehicles originating outside the area have only 50% of the number of starts that vehicles based in the area have, and that the remainder of their daily travel activity (e.g., school and shopping trips) takes place outside of the area.) However, it could be quite difficult to apply this approach without extensive data gathering, or use of hard-to-support assumptions.

The issue of excess start emissions associated with external trips is especially important for rural areas to consider. Many rural areas experience a large volume of through interstate VMT that may have only one stop (and resulting start) within the area (e.g., at a gas station or rest area) or no stops at all. (Again, starts are not estimated separately in MOBILE6 for HDVs, but areas can still address this issue for LDV, LDT and MC travel.) Thus, even though the other starts activity inputs to the model may be valid (e.g., the number of starts per day for vehicles based in the area, and the soak distribution), rural areas can still overestimate start emissions. Areas might want to use just running exhaust emissions on through facilities, or use the STARTS PER DAY command with only 1.0, or 0.5, or some other estimate of starts for the portion of travel on X/X or X/I trips. To estimate the fraction of VMT due to through and X/I trips in rural areas, several methods are available. For commute trips between rural counties, data on daily commute flows between counties are available through the Census.¹⁴ Data could potentially also be obtained through use of accident data (Pennsylvania and Utah are using this technique for determining the percentage of traffic not subject to I/M inspections) or remote sensing data.⁸

Note that the STARTS PER DAY command also affects hot soak evaporative emissions (evaporative emissions that occur within one hour at the end of a trip). Even though a trip may not have a start within the study area, it would still have a hot soak if the trip ends within the area. Areas need to consider how elimination of one or more starts for certain trip types might affect calculated hot soak emissions, to ensure that emissions from hot soaks are not inadvertently excluded from the VOC inventory calculations. It might be necessary to perform an additional MOBILE6 run with a different STARTS PER DAY input to capture the hot soak emissions.

Using Travel Model Trips as a Surrogate for MOBILE Model Starts

MOBILE6 includes default estimates of the number of starts per day by vehicle type (based on the same instrumented vehicle studies used to develop the default start distributions). Some users have expressed interest in using the number of daily vehicle trips in their travel model as a surrogate for daily vehicle starts, but EPA discourages this, and with good reason: most travel model trips do not capture all starts. Travel models are not good at addressing trip chaining, for example; if a driver stops for a cup of coffee on the way to work, the travel model typically will not capture this as two trips (one to the coffee shop, and one to work), but this activity still results in two vehicle starts. For this reason, EPA does not recommend that users modify the starts per day estimates without data from an instrumented vehicle study.

In order to link travel model trips with MOBILE starts, users can calculate a ratio of model trips to MOBILE starts and develop conversion factors. These conversion factors could then be applied to the MOBILE start emission rates (in grams per start) in order to create a local estimate of start grams per trip. For example, MOBILE6 includes roughly eight starts per day for light duty vehicles; if the local travel model estimates five trips per day for these same vehicles, then the MOBILE start emissions rates in grams per start could be multiplied by 8/5 in order to convert them to grams per trip (as defined in the travel model). The total grams/day of start emissions (based on the MOBILE default number of starts per day) should be used as a “control total” to ensure that start emissions are not inadvertently over- or under-counted in the conversion process. This approach results in the same daily total for start emissions, while allowing areas to use travel model output to quantify total starts and distribute those starts by location.

It is also possible to use the travel model to distribute trips by time of day, as discussed earlier in this paper. Trip chaining is an issue, but even though multiple vehicle starts may occur during the same travel model trip, it should be reasonable to assume that “chained” trips occur reasonably close together in time, e.g., within the same MOBILE hour.

There are several documented methods of using travel models and travel surveys to generate estimates of start activity, including starts per day.^{11, 15, 16, 17} At some point in the future, depending on the capability of individual urban areas' travel demand models, this may be a viable alternative to instrumented vehicle studies for gathering these data. Until such time, however, users should base their daily estimates of start emissions on the MOBILE default assumptions, even as they distribute these emissions temporally (and geographically—see below) based on local data.

Assigning Starts to Travel Model Zones

Since MOBILE6 can report start emissions separately in terms of grams per day (or hour), users can now calculate start emissions separately and assign start emissions to the zones in which trips originate. As discussed earlier, it is relatively simple to use MOBILE6's database output to calculate grams per start (by day or hour); these start emissions can then be assigned to the zones. There are several available studies that describe methodologies that could be used to do this.^{17, 18, 19} This will be particularly useful in areas that are conducting photochemical modeling for ozone SIPs. Portland, Oregon has also used this technique in development of a gridded regional air toxics emissions inventory.¹⁹

Rather than using one grams/start figure for all starts, one can use the hourly grams per start emissions values from the database output for the various hours of the photochemical modeling emissions inventory. Again, the total start/day emissions can be used as a control total to ensure that starts are not over- or under-counted (and to catch calculation errors).

Considering Starts for Purposes of Project-Level Analysis

MOBILE6's capabilities for enhancing the characterization of starts for regional-scale analyses also have their uses for project-level analysis; for example, calculating the benefits of a proposed transportation control measure (TCM), or performing carbon monoxide hotspot modeling for conformity or National Environmental Policy Act (NEPA) analysis purposes. For TCM analysis, the user must consider the effect of the TCM on both VMT and starts. For example, a park and ride project may reduce VMT by shifting commuters to transit, but the commute trips will still generate starts (to drive to and from the park and ride lot rather than to and from the workplace). On the other hand, a TCM such as telecommuting or ridesharing can eliminate some vehicle trips entirely, thus eliminating the associated start emissions. The location of starts may also be a factor to consider. For example, the impact of starts associated with a suburban park and ride lot may not be important if the emission reduction benefits of the lot are needed in the central business district. Now that MOBILE6 has made it relatively simple to extract start and running emissions from total exhaust emissions, TCM analysts should start to consider exactly what to include in quantifying the benefits of TCMs.

For more detailed analysis, the user can also consider the impact of projects on start and soak activity. A park and ride lot may result in a reduction in the total number of starts per day for its users (someone who takes transit to work from a park and ride is less likely to drive a motor vehicle during the day to meetings or lunch). The same lot may result in a shift in the time of day when starts occur (users may need to leave home earlier to catch the bus or train, and their evening trips may be delayed by the return commute), leading to changes in the start and soak distributions. Advanced users of MOBILE6 may be able to obtain survey data or make reasonable assumptions about start and soak activity in order to refine the emissions estimates for such projects. This is a fertile area for future research.

In carbon monoxide hotspot modeling exercises, both EPA⁶ and FHWA recommend that only running emissions be used for most projects. By the time most vehicles reach a location subject to

hotspot modeling (such as a major arterial intersection or freeway interchange), one would expect that the vehicles are fully warmed up and that start emissions are not a factor. Of course, there are obvious exceptions to this. When modeling an intersection near a downtown parking structure during the p.m. peak, or modeling a parking lot for a major sports venue, inclusion of start emissions would clearly be appropriate. Depending on the scope of the project (and the analysis resources available), one may wish to also modify the start and soak distributions as discussed above to more accurately capture vehicle activity at locations like this. FHWA currently has a research study underway to examine these issues in more detail and to develop guidance.

Finally, the impact of start emissions should be considered in other types of project-level analysis. For example, when preparing a corridor-level emission analysis for a highway project, the analyst should consider the likely operating condition of the vehicles using that facility. A new roadway in a suburban area would likely experience some start emissions in the morning peak hour, and few or no start emissions in the evening peak hour. The opposite would be true for a roadway in a central business district location. Because of the significant impact of starts on total estimated emissions, consideration of whether it is appropriate to include these emissions for a given project is critical for development of accurate emissions estimates.

RECOMMENDATIONS

Based on the discussion above, the following recommendations represent a good starting point for addressing start emissions in most modeling applications. Advanced MOBILE6 model users should consider the other enhancements to MOBILE6 modeling methodologies discussed in this paper, and investigate the impact of some of these refinements based on the unique characteristics of the geographic areas they model.

- 1) If your region's local daily mileage accumulation rate is much different from MOBILE6 defaults, use local MAR data or calculate start emissions separately. Use of the model's gm/mile start emissions rates will almost certainly introduce inaccuracies into the regional emissions inventory.
- 2) Use a local start distribution (starts by hour), or use the hourly VMT distribution as a surrogate.
- 3) Factor out start emissions for VMT on trips that do not have a start in the area (X/X and X/I trips).
- 4) For photochemical modeling, use travel model data and the MOBILE6 capabilities to calculate emissions per start to assign start emissions to zones/model grids.
- 5) In most cases, do not include start emissions in project-level analysis, and consider how a TCM will impact starts when analyzing the benefits of TCMs.

Again, local inputs may not be a good substitute for the model defaults if they are based on limited or questionable data. In general, if areas are confident that they have good data on local travel activity, they should use those data, but should document their approach. Poor quality local travel data or outputs from an out-of-date travel model may not be appropriate replacements for the model's default travel activity measures.

CONCLUSION

MOBILE6 provides a wide variety of new ways of handling start emissions in emissions inventory and project-level analysis activities. Some of them are quite simple (such as factoring out start emissions for through traffic), and others can be very complex (modifying the soak distribution to reflect activity at a park and ride lot). However, all agencies should examine these new techniques and apply those that seem appropriate for their area, given the available data and resources.

Proposals for developing refined procedures for handling start emissions should be vetted through an area's interagency consultation process. This is particularly important because agencies responsible for transportation conformity determinations must generally follow the same MOBILE modeling procedures that were used for development of the SIP. An area may want to forego an advanced, data-hungry procedure for developing start inputs for the SIP, if it means that this same data must be collected repeatedly for future conformity determinations. Also, consider latest planning assumption issues, and consider the resource load in the future associated with updating local inputs.

According to EPA, these data will be useable in the new MOVES model, so work today in the MOBILE6 context will be useful in the future.

REFERENCES

¹*User's Guide to MOBILE5 (Mobile Source Emission Factor Model)*, U.S. Environmental Protection Agency, May 1994, EPA-AA-AQAB-94-01.

²*Final Determination of Hot Running Emissions from FTP Bag Emissions*, U.S. Environmental Protection Agency, November 2001, EPA420-R-01-059 (M6.STE.002).

³*Soak Length Activity Factors for Start Emissions*, U.S. Environmental Protection Agency, April 2001, EPA420-R-01-011 (M6.FLT.003).

⁴Everett, J. and I. Sacs, "An Alternative Methodology for Collecting Local Vehicle Start Information for Use in MOBILE6," Presented at the 81st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2002.

⁵Joint Environmental Protection Agency, Federal Highway Administration and Federal Transit Administration memorandum, *Use of Latest Planning Assumptions in Conformity Determinations*, January 18, 2001, available at www.fhwa.dot.gov/.

⁶*Technical Guidance on the Use of MOBILE6 for Emission Inventory Preparation*, U.S. Environmental Protection Agency, January 2002.

⁷*2001 National Household Travel Survey*, U.S. Department of Transportation, available at nhts.ornl.gov.

⁸*Preferred and Alternative Methods for Gathering and Location Specific Emission Inventory Data*, Emission Inventory Improvement Program, Volume IV, Chapter 1, July 1996, available at www.epa.gov/ttn/chief/eiip/.

⁹*Guidance for the Development of Facility Type VMT and Speed Distributions*, U.S. Environmental Protection Agency, November 2001, EPA420-P-99-004 (M6.SPD.004).

- ¹⁰*Development of Methodology for Estimating VMT Weighting by Facility Type*, U.S. Environmental Protection Agency, April 2001, EPA420-R-01-009 (M6.SPD.003).
- ¹¹*Estimating Regional Mobile Source Emissions*, National Highway Institute course No. 152071, Texas Transportation Institute, 2003.
- ¹²MacRae, B. 2003. Colorado Department of Public Health and Environmental, *personal communication*.
- ¹³Sabina, E. 2003. Denver Regional Council of Governments, *personal communication*.
- ¹⁴*County-to-County Worker Flow Files*, U.S. Census Bureau, available at www.census.gov/population/www/cen2000/commuting.html.
- ¹⁵Venigalla, M., and D. Pickrell, "Soak Distribution Inputs to Mobile Source Emissions Modeling: Measurement and Transferability," Presented at the 81st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2002.
- ¹⁶*Use of Locality-Specific Transportation Data for the Development of Mobile Source Emission Inventories*, Emission Inventory Improvement Program, Volume IV, Chapter 2, September 1996, available at www.epa.gov/ttn/chief/eiip/.
- ¹⁷Nair, H., and C. Bhat, "Modeling Soak-Time Distribution of Trips for Mobile Source Emissions Forecasting: Techniques and Applications," Prepared for the Texas Department of Transportation by the Center for Transportation Research, University of Texas at Austin, August 2000.
- ¹⁸Venigalla, M., and D. Pickrell, "Implications of Transient Mode Duration for Spatially Disaggregated High Resolution Emission Inventory Studies," Volpe National Transportation Systems Center, *Transportation Research Record* 1997, 1587, 63-72.
- ¹⁹Stein, B., and D. Walker, "Link-Based Calculation of Motor Vehicle Air Toxin Emissions using MOBILE 6.2," Prepared for the Portland Air Toxics Assessment Study Team by the Portland METRO Planning Department, October 2002.

KEYWORD

Emission Inventories

Mobile Sources

MOBILE6

Exhaust Emissions

CO

VOC

NOx

PM