The Use of MOBILE6 in Preparing National Onroad Emission Inventories

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ABSTRACT

The States face many challenges in the months ahead as they prepare to use MOBILE6 to calculate onroad emission inventories. This paper will share the experiences of EPA's contractor in preparing national onroad emission inventories using MOBILE6 for the first time. EPA sponsored the preparation of 1999 and 2000 national criteria pollutant onroad emission inventories using MOBILE6 as the tool for calculating emission factors. In addition, onroad emission inventories were also prepared for calendar years 1978, 1990, and 1996. Each of these emission inventories included computations for each of the 28 MOBILE6 vehicle types, for 12 roadway types, for each U.S. county by month. The 1999 results and inputs have been released to the States for review. This paper will discuss the methods used for converting from a MOBILE5-based procedure to a MOBILE6-based procedure, with a focus on important considerations such as the VMT distributions by speed and facility type and I/M program inputs. The procedure developed for creating a VMT file at the 28-vehicle type level will be explained. The significant computer time and size-based results for these national runs will be discussed. Comparisons between the national MOBILE6-based runs and comparable MOBILE5-based runs will be discussed in a general nature, as will important (and possibly unexpected) findings when comparing state-level results from MOBILE6 with MOBILE5-based results. The most important aspects for states to consider when reviewing the 1999 files will be indicated. Finally, the paper will discuss possible future improvements that could be made in preparing national MOBILE6-based emission inventories.

INTRODUCTION

EPA's long-awaited MOBILE6 model was first released in draft form for State review in 2001. This model has the capability to calculate emissions factors from highway vehicles and represents significant changes to the previous model, MOBILE5b, in both the underlying data and the model structure and capabilities. During the spring and summer of 2001, E.H. Pechan & Associates, Inc. (Pechan) developed the first national emission inventories of highway vehicles using a draft version of MOBILE6, under contract to EPA. The purpose of these inventories was for eventual inclusion in EPA's Emission Trends reports as well as in the National Emissions Inventory (NEI). MOBILE6-based emission inventories were prepared for the years 1978, 1990,

1996, 1999, and 2000. The 1999 inventory, MOBILE6 input files, and supporting data files were released to the States for review before inclusion of the data in the NEI.

To maintain consistency with previous Trends work, EPA desired to have the MOBILE6[1] model set up to resemble the procedures used in prior years with MOBILE5, where possible. In other words, the MOBILE5b input files previously developed for the Trends analysis for these years were essentially converted to MOBILE6 format, following EPA guidance. These resulting inventories were compared to similar inventories prepared using MOBILE5b.

The version of MOBILE6 used for this analysis was released specifically for use in this Trends project, and was referred to as MOBILE6T. This version of the model included coding and guidance for calculating PM, SO_2, and NH_3 emission factors, in addition to VOC, NO_x, and CO. However, the inclusion of PM, SO_2, and NH_3 at this time simply reflected emission factors for PM and SO_2 similar to those derived in EPA's PART5 model[2], while the NH_3 factors reflected those used in EPA's Trends analysis[3], based on testing by EPA in the 1980s. Nonetheless, the inclusion of these pollutants allowed the improved fleet information collected for MOBILE6 to be used in the calculation of emission factors for these pollutants. The release date of the MOBILE6T model was April 2001.

METHODOLOGY

As mentioned above, consistency with the methods used in developing the Trends inventories from previous years using MOBILE5b was an important consideration for EPA. EPA also desired to have emission data available at the 28 vehicle type level. Therefore, the database option from MOBILE6 was selected for processing the emission factors and calculating emissions.

Speeds

In prior versions of Trends, a matrix of speeds by vehicle type and road type was developed. These speeds were applied nationally, and are shown in Table 1. In MOBILE6, the speed corrections differ by facility type. Thus, based on EPA guidance, the following roadway types were modeled as 100 percent freeway VMT in MOBILE6T: Rural Interstates, Urban Interstates, and Urban Other Freeways and Expressways. The roadway categories modeled as 100 percent arterial VMT in MOBILE6T were: Rural Principal Arterials, Rural Minor Arterials, Rural Major Collectors, Rural Minor Collectors, Rural Locals, Urban Principal Arterials, Urban Minor Arterials, and Urban Collectors. Urban Local roadways were modeled as 100 percent local VMT. Thus, three external data files were created for use with the MOBILE6T command "VMT BY FACILITY". One of these files represented the MOBILE6T freeway roadway type and in this external data file, the column representing freeway VMT was filled with 1's and the remaining three columns were filled with 0's. Similar files were created for the arterial and local roadway types. For the three roadway types in Table 1 that fall in the freeway category, the speeds that need to be modeled are 35 mph, 40 mph, 45 mph, 55 mph, and 60 mph. An external "SPEED VMT" file was created for each of these freeway speeds. These files were prepared using the ROUTE56 model, which essentially follows the guidance given in the MOBILE6

User's Guide for translating MOBILE5 average speeds to MOBILE6 "SPEED VMT" inputs. Similar files were created representing the speeds 15 mph, 20 mph, 25 mph, 30 mph, 35 mph, 40 mph, and 45 mph on the arterial roadway type. For the speeds on the arterial roadway types, the appropriate speed bin in the "SPEED VMT" file was filled with 1's and the remaining speed bins were filled with 0's. For the freeway roadway type, the speeds were adjusted to exclude the speeds of ramp VMT. The local roadway type in MOBILE6T includes no speed adjustments, so no speed files were created for the local roadways.

In each of the MOBILE6T input files, 13 scenarios were prepared for each set of monthly inputs for a given county. One scenario was used to model emission factors on local roadways, five scenarios were used to model emission factors on freeways using the five freeway speeds listed above, and seven scenarios were used to model emission factors on arterial roadways using the seven arterial roadway speeds listed above.

VMT

EPA requested that the emissions for this work be maintained for all 28 MOBILE6 vehicle types. Thus, the emission factors in the MOBILE6 database output format were needed for calculating the onroad emissions. The 1999 VMT file previously developed for MOBILE5 emission calculations had to be expanded from the 8 MOBILE5 vehicle types to the 28 MOBILE6 vehicle types. The VMT data base was expanded to the 28 MOBILE6 vehicle types using the 1999 calendar year-specific default VMT mix by vehicle type information provided in the MOBILE6 output files. Each MOBILE6 output file provides the fractional VMT attributed to each of the 28 MOBILE6 vehicle types. These VMT fractions were summed for each of the 8 MOBILE5 vehicle types, and the distribution of VMT for the MOBILE6 subcategories of each MOBILE5 vehicle type were calculated by dividing the MOBILE6 VMT fraction by the total MOBILE6 VMT fraction for each of the MOBILE6 vehicle types included in a given MOBILE5 vehicle category. Table 2 shows this distribution. Each of the VMT records in the 1999 VMT data base, at the state/county/roadway type/MOBILE5 vehicle type level of detail was then multiplied by the fraction of VMT in each of the corresponding MOBILE6 vehicle type categories to obtain total annual VMT at the state/county/roadway type/MOBILE6 vehicle type level of detail. This procedure was also applied to VMT data provided by the States in MOBILE5 format, as well as the 1999 VMT calculated based on VMT data from the Federal Highway Administration.

Registration Distributions

The 1999 MOBILE6 model runs all included the default MOBILE6 registration distribution, as this is adjusted internally to represent the specific calendar year being modeled. Additionally, the "EVALUATION MONTH" input was set to "1" to model months from January through June and to "2" to model months from July through December. The setting of "2" prompts MOBILE6 to recalculate the 1999 registration distribution modeling an additional half-year of fleet turnover.

Reformulated Gasoline

Reformulated gasoline (RFG) was modeled in the appropriate MOBILE6 input files by including the "FUEL PROGRAM" command with the value set to "2" to indicate reformulated gasoline, and either an "N" to model northern RFG parameters or "S" to model southern RFG parameters. The "N" corresponds to the ASTM class "C", as modeled in MOBILE5, and the "S" corresponds to the MOBILE5 ASTM Class B input. In addition to the "FUEL PROGRAM" command, the "SEASON" command was included in each scenario for the input files modeling RFG. Without this command, MOBILE6 would apply the winter RFG rules to the scenarios modeled with the "EVALUATION MONTH" command set to "1" (January) and summer RFG rules to the scenarios modeled with the "EVALUATION MONTH" command set to "2" (July). In actuality, the summer RFG rules should be applied in the months from May through September, so the "SEASON" command is used and set to "1" during these months and to "2" during all remaining months. The county coverage of the RFG program was unchanged from the MOBILE5 inputs.

Inspection and Maintenance Program Inputs

Modeling an Inspection and Maintenance (I/M) program in MOBILE6 requires the most complex set of inputs of any highway vehicle control program. The sources used for developing the MOBILE5 I/M program inputs include a summary prepared by OTAQ showing the basic characteristics of I/M programs planned by the States[4] and inputs prepared for previous *Trends* inventories. In general, the MOBILE6 I/M program inputs were developed by converting the MOBILE5-based I/M program inputs developed previously for EPA's Trends report 1999 to MOBILE6-based inputs using ERG's ROUTE56[5] program. These inputs were then reviewed and any necessary changes were made. It should be noted that the MOBILE6T version used in this analysis, the only exhaust I/M test type allowed for vehicles from the 1996 and later model years was onboard diagnostic (OBD) testing.

National Low Emission Vehicle Program

Emission factors using the MOBILE6 defaults are calculated assuming the National Low Emission Vehicle (NLEV) program begins in 2001, with 100 percent of new 2001 model year vehicles meeting the LEV emission standard. However, the implementation schedule of the NLEV program for the Northeast Ozone Transport Commission (OTC) States is shown below:

Model Year	Federal Tier I Standards	Transitional LEV Standards	LEV Standards
1999	30%	40%	30%
2000		40%	60%
2001 and later			100%

In addition, Massachusetts, New York, Vermont, Maine, and Connecticut adopted LEV programs on their own that differ from the NLEV implementation schedule for the remaining OTC States.

Thus, a separate implementation schedule external data file was developed for the OTC States and the other four States with their own LEV program. For MOBILE6 to access the implementation schedule of these other LEV programs, the command line "94+ LDG IMP" was added to the input files representing areas with a LEV program in place in 1999. The appropriate external LEV implementation file name was also referenced in the command line. (Note that California also does not follow the NLEV default schedule, but California provided its own emissions, as discussed below.)

Fuel Sulfur Inputs

Two new inputs related to fuel sulfur content were needed for the MOBILE6 modeling. The "GASOLINE SULFUR" command was used and set to a value of 340 ppm in all scenarios and the "DIESEL SULFUR" command was used and set to a value of 500 ppm in all scenarios. These values were applied in all States and all 12 months.

Other MOBILE6 Inputs

A number of the area-specific inputs used in the MOBILE6 modeling were the same as those used in the 1999 MOBILE5 modeling. These include monthly average daily maximum and minimum temperatures, monthly RVP values, altitude, and oxygenated fuel inputs.

State-Supplied Data

Eight States provided EPA with 1999 annual VMT reported by roadway type and by the 8 MOBILE5 vehicle types in NIF format that was accepted by EPA for use in this analysis. These States include: Alabama, California, Colorado, Maine, Massachusetts, Mississippi, Tennessee (Hamilton County only), and Utah. The VMT data for each state was converted to units of million miles, where necessary. For each state except California, the VMT was expanded from the 8 MOBILE5 vehicle type level to the MOBILE6 28 vehicle type level, in the same manner as discussed above for the national VMT. Monthly and annual emissions of the seven criteria pollutants were calculated using MOBILE6 emission factors in the same manner as the remaining states. California and Colorado were the two exceptions to this methodology and are discussed individually below.

California provided EPA with emissions for all pollutants except NH_3. These emissions were reported at the county level, for each of the 8 MOBILE5 vehicle types. These values were used at the level provided with no changes. NH_3 emissions were calculated for California by multiplying the VMT provided by California by the national average NH_3 emission factors at the 8 vehicle type level. Based on the data provided, the California emissions are only reported at the 8 vehicle type level with no breakdowns by roadway type and no data for ozone season day emissions.

Colorado provided emission values for PM_{10} exhaust, in addition to VMT. Thus, the PM_{10} exhaust emissions for Colorado were not based on MOBILE6 emission factors. All other criteria pollutant emissions, and PM_{10} brake wear and tire wear emissions were calculated based

on the VMT provided by Colorado. The PM_{10} exhaust emission values provided by Colorado were provided at the same level of detail as the provided VMT. Thus, these emissions were allocated to the 28 vehicle type level using the same factors that were used to expand the VMT from 8 vehicle types to 28 vehicle types. These annual PM_{10} emissions were then apportioned to the monthly emission level by multiplying the PM_{10} by national monthly temporal factors discussed above.

MOBILE6T Header Information

EPA requested that evaporative and exhaust VOC emissions be calculated and maintained separately. In order for MOBILE6 to separately output exhaust and evaporative VOC emission factors in the database output format, two MOBILE6T input files were required for every county modeled. In addition, separate input files were needed to obtain PM_{10} and $PM_{2.5}$ emission factors, since MOBILE6 can only report one of these pollutants for a given input file. Thus, the first of the two input files modeled for each county needed was used to obtain the exhaust VOC emission factors and PM_{10} emission factors (as well as NO_x, CO, SO_2, and NH_3 emission factors). The header commands used for one of these sample MOBILE6T input files is shown below:

```
MOBILE6 INPUT FILE :
>HEADER 01 001 EHX AND PM10

DATABASE OUTPUT    :
WITH FIELDNAMES    :
NO DESC OUTPUT     :
DAILY OUTPUT       :
DATABASE EMISSIONS : 2211 1111
AGGREGATED OUTPUT  :
PARTICULATES       :
EMISSIONS TABLE    : M60100110.TB1  REPLACE
```

The header commands used to obtain the evaporative VOC emission and $PM_{2.5}$ emission factors in the second input files are shown below:

```
 MOBILE6 INPUT FILE :
>HEADER 01 001 EVAP AND PM2.5
DATABASE OUTPUT    :
WITH FIELDNAMES    :
NO DESC OUTPUT     :
DAILY OUTPUT       :
DATABASE EMISSIONS : 1122 2222
AGGREGATED OUTPUT  :
PARTICULATES       : ECARBON SO4 OCARBON GASPM LEAD BRAKE TIRE
POLLUTANTS         : HC
EMISSIONS TABLE    : M60100125.TB1  REPLACE
```

RESULTS

When running the number of input files required for a national run through MOBILE6, the run time becomes an important factor in allocating resources and setting schedules. The MOBILE6 run time for a single input file is significantly greater than the time required to run

MOBILE5 on a comparable file. For example, running one year of files with MOBILE6 required approximately 128 hours, or over 5 days, for a total of 286 input files. The amount of time required to run each input file varied, with files that had I/M programs modeled taking significantly longer to run than input files without I/M programs. The total computer hard drive capacity taken up by the resulting 286 database output files was over 937 Megabytes. In calculating the emissions by month at the 28 vehicle type level, it was necessary to process each State individually due to constraints of the database program used (FoxPro). When processing the comparable MOBILE5 output files to calculate monthly emissions for 8 vehicle types, all states could be processed in one database file.

Table 3 compares national 1999 emissions calculated with MOBILE5b and MOBILE6T. To make this comparison representative of just the difference between the models used, the MOBILE6T results are those calculated prior to the incorporation of State data. In other words, the VMT totals in both the MOBILE5b and MOBILE6T calculations are the same. These results show that the total emissions differences for NO_x are almost negligible at the national level, with less than 1 percent difference between the two models. However, the differences are more significant when comparing individual vehicle types. On the other hand, the CO differences are the most pronounced, with MOBILE6T producing emissions more than 40 percent higher than the MOBILE5b emissions. VOC shows approximately a 12 percent increase from MOBILE5b to MOBILE6T. It should be noted that these differences between models are dependent upon the calendar year being modeled and these results should not be extrapolated to other years.

Another observation that was made in studying the emission comparisons from MOBILE5b to MOBILE6T was that the largest percentage differences were observed in States that had area-specific registration distributions included in MOBILE5b. As discussed above, all of the MOBILE6T modeling was performed using the MOBILE6T registration distribution defaults. For instance, at the State level, the VOC percentage differences between the two models ranged from about 1 percent to about 15 percent. In contrast, the States that were modeled with State-specific registration distributions showed VOC differences in the range of 25 to 50 percent. In general, for all pollutants, the range of the percent difference in emissions between the two models was different for the States that had their own registration distributions than the range for those that did not.

CONCLUSIONS

As the States evaluate their onroad emission estimates and corresponding MOBILE6 input files and VMT for the 1999 NEI, they should keep in mind the general differences between results calculated with MOBILE5b versus those calculated with MOBILE6. As shown in Table 3, the magnitude of these differences will vary by pollutant and vehicle type. The actual MOBILE6 input files used to create the MOBILE6T inventories can be obtained from EPA for review. State review of these files should focus on area-specific inputs, such as I/M programs. Changes in how I/M inputs can be modeled in the January 2002 final release version of MOBILE6 will cause the I/M inputs used in this analysis to need to be updated. Based on the discussion above, States with their own current registration data should compare results using the State data with that using the MOBILE6 default data and consult with EPA if it is desired to

include the local registration data in the NEI. States that have also prepared their own VMT data files should submit those to EPA for inclusion in the NEI.

REFERENCES

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KEYWORDS

onroad emission inventory
criteria pollutants
MOBILE5
MOBILE6

Table 1. Average speeds by road type and vehicle type.

Speeds on Rural Road Types (miles per hour)						
Vehicle Type	**Inter-state**	**Principal Arterial**	**Minor Arterial**	**Major Collector**	**Minor Collector**	**Local**
Light-Duty Vehicles	60	45	40	35	30	30
Light-Duty Trucks	55	45	40	35	30	30
Heavy-Duty Vehicles	40	35	30	25	25	25

Speeds on Urban Road Types (miles per hour)						
Vehicle Type	**Inter-state**	**Other Freeways & Express-ways**	**Principal Arterial**	**Minor Arterial**	**Collector**	**Local**
Light-Duty Vehicles	45	45	20	20	20	20
Light-Duty Trucks	45	45	20	20	20	20
Heavy-Duty Vehicles	35	35	15	15	15	15

Table 2. 1999 MOBILE5 to MOBILE6 VMT fractions by vehicle type**.**

MOBILE6 Vehicle Type	MOBILE5 Vehicle Type	Fraction of MOBILE6 Vehicle Type VMT within MOBILE5 Vehicle Type Category
LDGV	LDGV	1.000000
LDGT1	LDGT1	0.230998
LDGT2	LDGT1	0.769002
LDGT3	LDGT2	0.684995
LDGT4	LDGT2	0.315005
HDGV2B	HDGV	0.791357
HDGV3	HDGV	0.028332
HDGV4	HDGV	0.018042
HDGV5	HDGV	0.034140
HDGV6	HDGV	0.073438
HDGV7	HDGV	0.036310
HDGV8A	HDGV	0.000141
HDGV8B	HDGV	0.000000
HDGB	HDGV	0.018240
MC	MC	1.000000
LDDV	LDDV	1.000000
LDDT12	LDDT	0.291307
LDDT34	LDDT	0.708693
HDDV2B	HDDV	0.119373
HDDV3	HDDV	0.034668
HDDV4	HDDV	0.026859
HDDV5	HDDV	0.011303
HDDV6	HDDV	0.068204
HDDV7	HDDV	0.104153
HDDV8A	HDDV	0.133362
HDDV8B	HDDV	0.475354
HDDBT	HDDV	0.011353
HDDBS	HDDV	0.015369

Table 3. Comparison of national 1999 emissions calculated with MOBILE5b and MOBILE6T.

Vehicle Type	VOC	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$	NH_3
	Annual 1999 Emissions Calculated with MOBILE5 (1,000 tons)						
LDGV	2,865	2,813	26,502	136	58	34	173
LDGT1	1,166	1,141	11,111	69	25	15	60
LDGT2	593	535	5,421	24	11	7	18
HDGV	375	455	4,263	17	11	8	4
MC	42	12	183	0	0	0	0
LDDV	3	7	7	1	1	1	0
LDDT	2	5	4	0	1	1	0
HDDV	286	3,644	2,249	118	188	165	6
TOTAL	***5,332***	***8,612***	***49,740***	***366***	***296***	***230***	***261***
	Annual 1999 Emissions Calculated with MOBILE6T (1,000 tons)						
LDGV	3,276	2,413	37,354	140	53	29	171
LDGT1	1,347	986	18,491	73	22	13	64
LDGT2	737	436	9,148	26	10	6	21
HDGV	307	445	3,672	16	10	7	4
MC	27	15	173	0	0	0	0
LDDV	4	9	10	1	2	1	0
LDDT	5	6	8	0	1	1	0
HDDV	250	4,258	1,281	99	150	132	6
TOTAL	***5,954***	***8,569***	***70,136***	***355***	***249***	***191***	***267***
	Percentage Change in Emissions from MOBILE5 to MOBILE6T (%)						
LDGV	14.4	-14.2	40.9	3.5	-9.2	-12.3	-0.8
LDGT1	15.5	-13.6	66.4	4.8	-11.6	-15.0	7.3
LDGT2	24.2	-18.4	68.7	5.7	-9.4	-11.5	13.9
HDGV	-18.2	-2.2	-13.9	-2.9	-10.1	-2.1	0.0
MC	-35.8	20.8	-5.2	0.1	3.7	9.5	0.1
LDDV	72.1	29.5	45.3	3.0	30.3	33.1	0.5
LDDT	143.9	34.8	90.7	2.5	24.9	27.2	0.6
HDDV	-12.4	16.9	-43.0	-16.5	-20.0	-19.6	-0.3
TOTAL	***11.7***	***-0.5***	***41.0***	***-2.9***	***-16.0***	***-17.0***	***2.1***

Note: MOBILE6T emissions do not include State-provided data.