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EPA's National Mobile Inventory Model (NMIM), A Consolidated Emissions Modeling System for MOBILE6 and NONROAD

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ABSTRACT

EPA's National Mobile Inventory Model (NMIM) is a consolidated emissions modeling system for EPA's MOBILE6 and NONROAD models. It generates county inventories using MOBILE6 and NONROAD at scales ranging from individual counties to the nation. Its primary improvements over MOBILE6 and NONROAD are 1) the inclusion of all the required county data for the nation in a single database, 2) an easy-to-use graphical user interface, 3) "shortcuts" for generating national inventories, 4) tools for aggregation and post-processing, 5) estimation of 33 HAPS and 17 dioxin/furan congeners, and 6) distributed processing capability to enhance performance. When national inventories have previously been constructed from MOBILE6 and NONROAD, the necessary input data have been widely scattered in disparate formats and have required additional specialized software to convert this data into input files for MOBILE6 and NONROAD, to run the models, to integrate the results into a final inventory, and to post-process the results into forms suitable for the national inventories. NMIM accomplishes all of these tasks in a single package. NMIM's initial version in 2003 was intended to approximate the procedures previously used for calculating nationwide emissions for EPA's National Emissions Inventory. EPA subsequently has added the capability of incorporating much more county-specific information into the database, including monthly average hourly temperature and humidity, fleet distributions, speed distributions, and diesel fractions for MOBILE6 and county-specific allocation and activity files for NONROAD.

INTRODUCTION AND OVERVIEW

EPA's National Mobile Inventory Model (NMIM) is a consolidated emissions modeling system for EPA's MOBILE6 and NONROAD models. It was developed to produce, in a consistent and automated way, national, county-level mobile source emissions inventories for the National Emissions Inventory (NEI) and for EPA rule making. When national inventories have previously been constructed from MOBILE6 and NONROAD, the necessary input data have been widely scattered in disparate formats and have required additional specialized software to convert this data into input files for MOBILE6 and NONROAD, to run the models, to integrate the results into a final inventory, and to post-process the results into forms suitable for the national inventories. NMIM accomplishes all of these tasks in a single package. Although NMIM was designed to produce national inventories, because of its convenient assemblage of models, data, user interface, and post-processing, we expect the emissions modeling community to find additional uses for it. NMIM has also served as a test bed for some design and programming concepts that are being employed in EPA's MOVES model, which will ultimately replace MOBILE6, NONROAD, and NMIM. For example, both employ a Java framework, a MySQL database, and a similar distributed processing scheme.

NMIM comprises a Java framework, graphical and command line user interfaces, the MOBILE6 and

NONROAD models, a national county database, and postprocessing and aggregation capabilities. NMIM's primary improvements over MOBILE6 and NONROAD are 1) the inclusion of all the required county data for the nation in a single database, 2) an easy-to-use graphical user interface (GUI), 3) "shortcuts" for generating national inventories, 4) tools for aggregation and post-processing, 5) estimation of 33 hazardous air pollutants (HAPs) and 17 dioxin/furan congeners by ratio to various MOBILE6 and NONROAD output parameters, a step previously handled by separate post-processing software, and 6) distributed processing capability to enhance performance. NMIM specifically extends MOBILE6's capabilities by producing inventories rather than just emissions factors. NMIM provides consistency across both models and all pollutants by using a single input database for MOBILE6 and NONROAD and for criteria pollutants and HAPs.

However, NMIM is not a complete GUI front end for MOBILE6 and NONROAD, nor can it replace these models for all applications. Because it was designed primarily to generate national inventories, NMIM has features intended to speed its operation and minimize its output database size that also limit its applicability. For example, it will not produce hourly or by-model-year output from MOBILE6. In addition NMIM, like NONROAD, does not produce emissions inventories for aircraft, locomotives, and commercial marine vessels.

The paper begins with an overall explanation of how NMIM works, followed by the details of how it runs MOBILE6 and NONROAD. Next, we discuss the pollutant and source category inventories available from running NMIM. Then, we describe the NMIM County Database (NCD) and our plans for updating and improving it through the National Emission Inventory (NEI) process. Lastly, we explain how NMIM estimates various HAPs that are not direct outputs of MOBILE6 and NONROAD.

HOW NMIM WORKS

The NMIM user specifies a set of years and months, a geographic region (the whole US, any combination of whole states, or any combination of particular counties, including Puerto Rico and the Virgin Islands), a set of pollutants, and categories of on-road vehicles and non-road equipment. This collection of user requests is called a "run specification" or RunSpec, and can be saved in a file for later execution or for text editing. RunSpecs can be produced by the NMIM graphical user interface (GUI) or by using a text editor. NMIM RunSpecs can be executed from the GUI or from the command line.

Based on the RunSpec and information in the NMIM county database (NCD), NMIM writes input files for the MOBILE6 and NONROAD models. NMIM then runs these models, reads their output files, performs any necessary additional processing, and puts the the inventories into an output database. Additional processing includes multiplying MOBILE6 emission factors by VMT and estimating emissions of some other pollutants (see below) as ratios to pollutant inventories generated by MOBILE6 and NONROAD.

NMIM has post-processing capability that can be applied after the inventory is generated. This includes aggregation over months, roadway types, vehicle types, and equipment types. Output can go into a database table or into a tab-delimited ASCII file. The format can be normalized (a pollutant on each line) or wide (a pollutant in each column.) NMIM can also process the output database into annual, monthly, or ozone season day (OSD) inventories and convert them into NIF3 format, which is required for NEI submissions. The user's post-processing selections can be made from the GUI and saved as an ASCII "aggregation specification" or AgSpec, which can be reloaded into the GUI, edited from the GUI or in a text editor, and run from the GUI or from the command line.

Temporal and Spatial Approximations for Efficient Running of National Inventories

NMIM employs two main techniques, adopted from previous NEIs, to make the production of national inventories tractable. The first is to assume that monthly time resolution is adequate for both meteorology and source activity and therefore to do twelve monthly runs instead of 365 daily runs. NMIM is designed to do only monthly runs and produces annual inventories by adding the twelve monthly inventories.

The second technique is to group similar counties, allowing NMIM to do a single MOBILE6 or NONROAD run for the entire group. For the national runs that OTAQ has performed to date, counties are in the same “county group” for a particular year if they are in the same state and have the same fuel properties and control programs. The assumption here, adopted from past NEIs, is that if the counties are in the same state, their temperatures are similar (California had two temperature groupings). The groups are defined in the CountyMap table of the NCD. One of the counties in each group is referred to as the representing county, since it represents the others. The representing county was chosen as the one with the highest VMT, so that the temperature and relative humidity data is from a county with a significant share of mobile source activity. This scheme resulted in about 100 county groups for NONROAD and about 200 for MOBILE6 in 2002, representing the 50 states plus the District of Columbia, a total of more than 3000 counties. It should be noted that county grouping is not mandatory; NMIM allows the user to employ county groups or to run all counties individually. In either case, the output contains inventories for all the individual counties in the selected geographic region.

NMIM Master and NMIM Worker: Distributed Processing

As a way of further improving performance, NMIM may be run in a distributed-processing mode, employing multiple computers. NMIM comprises two programs, Master and Worker. Both Master and Worker(s) have a simple text configuration file which specifies the path to a shared folder through which they communicate. The GUI used to produce RunSpecs and AgSpecs, discussed above, is on the Master. In standalone mode, one Master, one Worker, and the shared folder are on the same computer. In distributed mode, there are multiple workers on separate computers.

In either mode, to execute a RunSpec requires a Master, one or more Workers, and a shared folder. When a RunSpec is executed, the Master 1) reads the RunSpec—which defines the inventory in terms of geography, time, pollutants and sources, 2) writes appropriate MOBILE6 and NONROAD input files, 3) bundles these together with any external data files needed, and 4) posts them as “TODO” files on the shared folder. A TODO file always contains the data for a single MOBILE6 or NONROAD run for one county for one month. A Worker, seeing a TODO file on the shared folder, copies it to its local work space, executes MOBILE6 or NONROAD as appropriate, and posts the results back in the shared folder as a “DONE” file. The Master, seeing the DONE file, downloads it from the shared folder to its local workspace, extracts the MOBILE6 or NONROAD output file, processes it further as necessary, and inserts it into the output database specified by the RunSpec.

When running in standalone mode, one Master, one Worker, and the shared folder are all on the same computer. When running in distributed mode, the Master is on one computer, multiple workers are on separate computers, and the shared folder, which they all have access to, is on yet another computer (although it could be on the same computer as the Master or one of the Workers). Therefore, to execute NMIM in distributed mode requires only an ordinary local area network (LAN) where all the computers have access to a shared folder.

HOW NMIM RUNS MOBILE6

NMIM writes a MOBILE6 input file and executes MOBILE6 once for each month for each representing county (if the user chose the Geographic Representation option “County Group”) or for each county (if the user chose the Geographic Representation option “County”). The resulting emission factors are multiplied by the VMT for each county. Each MOBILE6 input file is constructed using data obtained from the NCD.

The MOBILE6 input files constructed by NMIM are designed to accommodate detailed user input and to use a consistent set of commands. In order to use consistent fuels data for all pollutants, the AIR TOXICS command is always used, even if no air toxics are requested by the user (NMIM always inserts the command to model acrolein in the MOBILE6 input file). Similarly, other commands, such as ALTITUDE, POLLUTANTS and EVALUATION MONTH are always explicitly used, rather than depending on MOBILE6 default settings and will always appear in NMIM MOBILE6 input files. The NMIM MOBILE6 input files always use the HOURLY TEMPERATURES command, rather than MIN/MAX TEMPERATURE command. The hourly RELATIVE HUMIDITY command is always used, rather than the ABSOLUTE HUMIDITY command. The BAROMETRIC PRES command is always used, since this value interacts with the relative humidity values. Average speed distributions are always specified using the SPEED VMT command, rather than the AVERAGE SPEED command.

Gasoline fuel parameters require the maximum amount of detail, which is necessary to properly model toxic emissions. The OXYGENATE command is used instead of the OXYGENATED FUELS command. This requires that all oxygen content values be expressed as volume percent instead of weight percent. GAS AROMATIC%, GAS OLEFIN% , GAS BENZENE%, E200 and E300 must always be specified. RVP OXY WAIVER command is always set to 1 (no waiver), because RVP values from the fuel surveys are assumed to already account for any RVP effect from oxygenated fuels. The FUEL RVP command is always required. The GASOLINE SULFUR command and FUEL PROGRAM command Option 4 are always used to explicitly set the sulfur content of gasoline. The same gasoline sulfur content is used for both commands and for all years. Each MOBILE6 run covers only a single month in a particular calendar year, so setting all possible sulfur values to be the same avoids complicated logic to determine which command is necessary and which of the possible years to change.

Some counties have local emission control programs. The basic information for these programs is stored in the NCD and used to create the appropriate commands for the input file when needed. Inspection and maintenance (I/M) programs for counties are stored in external data files and accessed using the I/M DESC FILE command.

In addition to the basic required information, NMIM can also include county specific data that is normally provided to MOBILE6 using external data files. Nearly any of the valid MOBILE6 commands can be used, including commands used to model local Low Emission Vehicle (LEV) phase-in programs and local natural gas vehicle fractions. Diesel sales fractions are stored in an external file and used to create the appropriate input command.

Not all MOBILE6 commands are used by NMIM. The VMT FRACTIONS and VMT BY FACILITY commands are not needed, since these commands are only needed to create composite emission rates. NMIM converts all emission rate results from MOBILE6 to tons using the county specific VMT for each vehicle class and roadway type. Only weekdays are modeled by NMIM. Commands that apply to

weekend variations are not used. Since all gasolines are explicitly defined, both the SEASON and FUEL PROGRAM command Option 2 are never used. Options such as NO CLEAN AIR ACT can be used as needed by NMIM as "global" inputs that affect all counties and all months and do not need to be stored in the NCD.

MOBILE6 has only 4 facility or roadway types: freeways, arterials, ramps, and locals. Ramp speed is fixed at 34.6 MPH and local speed at 12.9 MPH. Distributions of average speeds are specified separately for freeways and arterials using the SPEED VMT command. If only a single MOBILE6 scenario were run, the same distribution of average speeds would be applied to all vehicle types. Separate specification of average speed distributions for all combinations of the twelve roadway types and all twenty-eight MOBILE6 vehicle types would require running approximately 168 MOBILE6 scenarios.

In order to avoid running so many MOBILE6 scenarios, while retaining reasonable flexibility, NMIM groups vehicle class-roadway type combinations into 18 groups, shown in Table 1. These groups are those that have been used in past NEIs, and provide flexibility in assigning average speeds while limiting the number of MOBILE6 runs necessary to generate an inventory. Since nine of these combinations use the MOBILE6 freeway facility type and nine use the arterial facility type, a total of nine MOBILE6 scenarios are needed to model the eighteen vehicle class/roadway type combinations. Average speed distributions for each of these eighteen vehicle class/roadway type combinations can be specified for each county.

Table 1. The 18 vehicle class-roadway type combinations in NMIM.

<i>M6Vtypes*</i>	<i>Road Types</i>	<i>M6 Ftype</i>
LDV	Rural Interstate	Freeway
LDT	Rural Interstate	Freeway
HDV	Rural Interstate	Freeway
LDV	Urban Interstate	Freeway
LDT	Urban Interstate	Freeway
HDV	Urban Interstate	Freeway
LDV	Urban Freeways & Expressways	Freeway
LDT	Urban Freeways & Expressways	Freeway
HDV	Urban Freeways & Expressways	Freeway
LDV,LDT	Rural Principal Arterial	Arterial
LDV,LDT	Rural Minor Arterial	Arterial
HDV	Rural Principal Arterial	Arterial
LDV,LDT	Rural Major Collector	Arterial
LDV,LDT	Rural Minor Collector, Rural Local	Arterial
HDV	Rural Minor Arterial	Arterial
LDV,LDT	Urban Principal Arterial, Urban Minor Arterial, Urban Collector	Arterial
HDV	Rural Major Collector, Rural Minor Collector, Rural Local	Arterial
HDV	Urban Principal Arterial, Urban Minor Arterial, Urban Collector	Arterial

* Reference MOBILE6.2 User Guide, Appendix B

LDV = MOBILE6 Vehicle Types 1 and 16.

LDT = MOBILE6 Vehicle Types 2-5.

HDV = MOBILE6 Vehicle Types 6-15.

Because MOBILE6 can model only one particle size at a time, if both PM10 and PM2.5 are desired, NMIM runs a tenth MOBILE6 scenario to obtain emission factors for the extra particle size. This

approximation is justified because PM is relatively insensitive to speed.

HOW NMIM RUNS NONROAD

NONROAD estimates fuel consumption and emissions of total hydrocarbons (THC), carbon monoxide (CO), nitrogen oxides (NOX), sulfur dioxide (SO₂), and particulate matter (PM). NMIM then processes the monthly results as needed to produce annual and ozone season day emissions. Additional pollutants are produced by NMIM as ratios to these outputs.

The NONROAD Model reads a set of ASCII instructions, known as an “opt file” (for options). NMIM creates this file from data in the NCD. As employed in NMIM, the opt file is limited to one state and specifies month and year, fuel properties, temperature, and the counties for which to calculate emissions, which may be all or a subset of the counties in the state. NONROAD internally produces emissions for the whole state and then allocates the emissions for each SCC to the requested counties. Output is produced only for the county or counties selected in the NMIM RunSpec.

The NONROAD Model includes a group of files that specify equipment populations, emission factors, deterioration rates, activities, and allocations from the state to the county level. County-specific allocation, population, seasonality, and activity files that will override the default files can be specified in the NCD.

The fuel properties required by the NONROAD Model are not the same as those in the NCD. The NONROAD Model requires “Oxygen Weight %” in its opt file. The conversion from NCD fuel properties to oxygen weight percent is performed by NMIM as follows:

$$\begin{aligned} \text{oxywtpct} = & \\ & \text{etohvolume} * 0.3448 * \text{etohmktshare} + \\ & \text{mtbevolume} * 0.1786 * \text{mtbemktshare} + \\ & \text{tamevolume} * 0.1636 * \text{tamemktshare} + \\ & \text{etbevolume} * 0.1533 * \text{etbemktshare} \end{aligned}$$

These conversion factors are detailed under the OXYGENATE command in the MOBILE6 User's Guide.¹

POLLUTANTS FOR WHICH INVENTORIES ARE PRODUCED BY NMIM

Hydrocarbons may be expressed in one of five forms, listed in Table 1 below. The conversion factors are those used in the MOBILE6 and NONROAD models and depend on fuel and engine type.

Table 1. Hydrocarbon forms available from NMIM. (MOBILE6 User Guide).

<i>Hydrocarbon Form</i>		<i>Includes FID HC</i>	<i>Includes Methane</i>	<i>Includes Ethane</i>	<i>Includes Aldehydes</i>
Total Hydrocarbons	(THC)	Yes	Yes	Yes	No
Non-methane Hydrocarbons	(NMHC)	Yes	No	Yes	No
Volatile Organic Compounds	(VOC)	Yes	No	No	Yes
Total Organic Gases	(TOG)	Yes	Yes	Yes	Yes
Non-methane Organic Gases	(NMOG)	Yes	No	Yes	Yes

Table 2 lists all pollutants for which NMIM produces inventories. The pollutant codes are those

specified by the National Inventory Format Version 3.0 (NIF3).² Numeric codes are Chemical Abstracts Service Registry Numbers³ (CASRN) with the hyphens removed.

The “Ratio to” columns (MB for MOBILE6, NR for NONROAD) indicate that the pollutant is calculated by NMIM, after the MOBILE6 or NONROAD model is run, by ratio to the pollutant in these columns. A blank “Ratio to” column indicates that the pollutant is calculated inside MOBILE6 or NONROAD. The ratio depends on source type, expressed as a source classification code (SCC), and fuel characteristics. The complete list of these ratios may be found in the NCD SCC table and SCCToxics table. Ratio units are g/gallon, g/mile, and g/g of PM or VOC. For highway vehicles, naphthalene is ratioed to exhaust PM and to evaporative VOC. For non-road, it is ratioed to exhaust PM10 only. SOA is present to provide input to REMSAD (Regional Modeling System for Aerosols and Deposition⁴).

The “Six HAPs” category represents the first HAPs studied for mobile sources. They are selected individually in the NMIM RunSpec. The 27 “Add’l. HAPs” (additional HAPs) are selected as a group in the NMIM RunSpec. The 17 dioxin/furan congeners are also selected as a group. Pollutants in Table 2 without a category listed may be selected individually in the NMIM RunSpec. All pollutants are output separately, even if they are selected as a group.

Table 2. List of pollutants for which inventories are produced by NMIM. (See text.)

<i>Pollutant Code</i>	<i>PollutantName</i>	<i>Category</i>	<i>Ratio to</i>	
			<i>MB</i>	<i>NR</i>
CO	Carbon Monoxide			
HC	Hydrocarbons (choice of five forms)			
NOX	Nitrogen Oxides			
SO2	Sulfur Dioxide			
PM10-PRI	Primary PM10 (Filterables and Condensibles)			
PM25-PRI	Primary PM2.5 (Filterables and Condensibles)			PM10*
NH3	Ammonia			Gal*
75070	Acetaldehyde	Six HAPS		VOC
107028	Acrolein	Six HAPS		VOC
71432	Benzene	Six HAPS		VOC
106990	1,3-Butadiene	Six HAPS		VOC
50000	Formaldehyde	Six HAPS		VOC
1634044	MTBE	Six HAPS		VOC
100414	Ethyl Benzene	Add’l. HAPS	VOC	VOC
100425	Styrene	Add’l. HAPS	VOC	VOC
108883	Toluene	Add’l. HAPS	VOC	VOC
110543	Hexane	Add’l. HAPS	VOC	VOC
120127	Anthracene	Add’l. HAPS	PM10	PM10
123386	Propionaldehyde	Add’l. HAPS	VOC	VOC
129000	Pyrene	Add’l. HAPS	PM10	PM10
1330207	Xylene	Add’l. HAPS	VOC	VOC
16065831	Chromium (Cr3+)	Add’l. HAPS	Mile	Gal
18540299	Chromium (Cr6+)	Add’l. HAPS	Mile	Gal
191242	Benzo(g,h,i)perylene	Add’l. HAPS	PM10	PM10
193395	Indeno(1,2,3,c,d)pyrene	Add’l. HAPS	PM10	PM10
205992	Benzo(b)fluoranthene	Add’l. HAPS	PM10	PM10

<i>Pollutant Code</i>	<i>PollutantName</i>	<i>Category</i>	<i>Ratio to</i>	
			<i>MB</i>	<i>NR</i>
206440	Fluoranthene	Add'l. HAPS	PM10	PM10
207089	Benzo(k)fluoranthene	Add'l. HAPS	PM10	PM10
208968	Acenaphthylene	Add'l. HAPS	PM10	PM10
218019	Chrysene	Add'l. HAPS	PM10	PM10
50328	Benzo(a)pyrene	Add'l. HAPS	PM10	PM10
53703	Dibenzo(a,h)anthracene	Add'l. HAPS	PM10	PM10
540841	2,2,4-Trimethylpentane	Add'l. HAPS	VOC	VOC
56553	Benz(a)anthracene	Add'l. HAPS	PM10	PM10
7439965	Manganese	Add'l. HAPS	Mile	Gal
7440020	Nickel	Add'l. HAPS	Mile	Gal
83329	Acenaphthene	Add'l. HAPS	PM10	PM10
85018	Phenanthrene	Add'l. HAPS	PM10	PM10
86737	Fluorene	Add'l. HAPS	PM10	PM10
91203	Naphthalene	Add'l. HAPS	PMVOC	PM10
1746016	2,3,7,8-Tetrachlorodibenzo-p-Dioxin	Dioxin/furan	Mile	Gal
19408743	1,2,3,7,8,9-Hexachlorodibenzo-p-Dioxin	Dioxin/furan	Mile	Gal
3268879	Octachlorodibenzo-p-dioxin	Dioxin/furan	Mile	Gal
35822469	1,2,3,4,6,7,8-Heptachlorodibenzo-p-Dioxin	Dioxin/furan	Mile	Gal
39001020	Octachlorodibenzofuran	Dioxin/furan	Mile	Gal
39227286	1,2,3,4,7,8-Hexachlorodibenzo-p-Dioxin	Dioxin/furan	Mile	Gal
40321764	1,2,3,7,8-Pentachlorodibenzo-p-Dioxin	Dioxin/furan	Mile	Gal
51207319	2,3,7,8-Tetrachlorodibenzofuran	Dioxin/furan	Mile	Gal
55673897	1,2,3,4,7,8,9-Heptachlorodibenzofuran	Dioxin/furan	Mile	Gal
57117314	2,3,4,7,8-Pentachlorodibenzofuran	Dioxin/furan	Mile	Gal
57117416	1,2,3,7,8-Pentachlorodibenzofuran	Dioxin/furan	Mile	Gal
57117449	1,2,3,6,7,8-Hexachlorodibenzofuran	Dioxin/furan	Mile	Gal
57653857	1,2,3,6,7,8-Hexachlorodibenzo-p-Dioxin	Dioxin/furan	Mile	Gal
60851345	2,3,4,6,7,8-Hexachlorodibenzofuran	Dioxin/furan	Mile	Gal
67562394	1,2,3,4,6,7,8-Heptachlorodibenzofuran	Dioxin/furan	Mile	Gal
70648269	1,2,3,4,7,8-Hexachlorodibenzofuran	Dioxin/furan	Mile	Gal
72918219	1,2,3,7,8,9-Hexachlorodibenzofuran	Dioxin/furan	Mile	Gal
CO2	Carbon Dioxide			
SOA	Secondary Organic Aerosol		VOC*	VOC*

* Ratios for the pollutants are in the NCD SCC table. All others are in the SCCToxics table.

SOURCE CATEGORIES FOR WHICH INVENTORIES ARE PRODUCED BY NMIM

NMIM's output is always in terms of source classification codes (SCC), which are described in the SCC table. For highway output, NMIM additionally distinguishes four emission types (exhaust, evaporation, brake wear, and tire wear). For NONROAD, NMIM additionally distinguishes two emission types (exhaust and evaporation) and also reports the NONROAD power classes, which subdivide a given SCC by horsepower range.

The VMT in the BaseYearVMT table is in terms of the 28 MOBILE6 vehicle classes. In NMIM output, however, these 28 vehicle classes are aggregated into the 12 vehicle classes that correspond to SCC

codes. These 12 vehicle classes are shown in Table 3. The NCD M6VClass table defines the correspondence between these two sets of vehicle classes .

Table 3. The twelve vehicle classes that correspond to SCCs.

<i>Class</i>	<i>Description</i>	<i>Class</i>	<i>Description</i>
LDGV	Light duty gasoline vehicles	LDDT	Light duty diesel trucks
LDGT1	Light duty gasoline truck 1	2BHDDV	Class 2b heavy duty diesel vehicles
LDGT2	Light duty gasoline truck 2	LHDDV	Light heavy-duty diesel vehicles
HDGV	Heavy duty gasoline vehicles, include buses	MHDDV	Medium heavy-duty diesel vehicles
MC	Motorcycles	HHDDV	Heavy heavy-duty diesel vehicles
LDDV	Light duty diesel vehicles	BUSES	Diesel buses

SCC output also distinguishes twelve roadway types, listed in Table 4 below. The twelve roadway types are those used by the Federal Highway Administration’s (FHWA) Highway Performance Monitoring System (HPMS).⁵ These roadway types, in combination with the twelve vehicle types, result in 144 SCCs for highway mobile sources.

Table 4. Twelve Roadway Types

Interstate: Rural	Interstate: Urban
Other Principal Arterial: Rural	Other Freeways and Expressways: Urban
Minor Arterial: Rural	Other Principal Arterial: Urban
Major Collector: Rural	Minor Arterial: Urban
Minor Collector: Rural	Collector: Urban
Local: Rural	Local: Urban

Emissions are estimated by the NONROAD Model for 214 SCCs. SCCs distinguish between equipment types, fuels (gasoline, diesel, LPG, and CNG) and between two stroke and four stroke gasoline engines. In addition, NONROAD produces horsepower categories, and NMIM retains these in its output.

Within NMIM and the NONROAD Model, the non-road SCCs are grouped into 12 segments, listed in Table 5.

Table 5. NONROAD Model equipment segments.

Recreational	Lawn/Garden	Logging	Oil Field
Construction	Agriculture	Airport Support	Pleasure Craft
Industrial	Commercial	Underground Mining	Railroad

Any single SCC always falls under only one of these segments, corresponding to its most typical application, although it may be used in other segments as well. For example, skid steer loaders are in the construction segment, although they are also used in agriculture. Fuels are gasoline, diesel, LPG, and CNG. NMIM users must choose a segment and fuel; individual SCCs may not be selected. Output, however, is by individual SCC.

THE NMIM COUNTY DATABASE (NCD)

The NMIM County Database (NCD) contains all the county-specific information needed to run MOBILE6 and NONROAD. It also contains the list of pollutants and the ratios of HAPs, dioxins/furans, and some metals to various NONROAD and MOBILE6 outputs that are used to estimate inventories of these non-

standard pollutants. This database is in MySQL, which is an open source data base management system that is available from www.mysql.com. The tables in the database are listed in Table 6.

Table 6. Tables in the NMIM County Database.

<i>Table</i>	<i>Contents</i>
BaseYearVMT	VMT by year, county, M6VClass, and HPMSRoadType.
County	For each county, Federal Information Processing System (FIPS) codes for the county and state, altitude, beginning and end of ozone season, Stage 2 information, Natural Gas Vehicle (NGV) fraction file name
CountyMap	The representing county for each county, one for NONROAD and one for MOBILE6.
CountyMonthHour	Monthly average hourly temperature and humidity table used if “Use yearly weather data” is not selected or there is no data for the requested year in the CountyYearMonthHour table.
County NRFile	References to external NONROAD files pertaining to a county.
CountyVMTMonth Allocation	Mileage allocation factors for the twelve months of the year, by county.
CountyYear	Stage2 percent input to the NR model, plus external file references for MOBILE6 and NR.
CountyYearMonth	Gasoline, diesel, and natural gas fuel IDs for each county for each year and month.
CountyYearMonth Hour	Historical hourly temperature and relative humidity.
DataSource	Defines datasource identifiers used in other tables.
Diesel	Diesel sulfur content associated with each diesel ID.
EmissionType	Associates emission types (exhaust, evap, brake, tire) with EmissionTypeID used in other tables
FileType	Defines the set of valid external files and their 3-character extensions.
Gasoline	Detailed fuel properties associated with each gasoline ID.
Hour	Defines the hour identifiers.
HPMSRoadType	Defines the twelve HPMS road type identifiers.
M6VClass	Defines the 28 vehicle classes used in MOBILE6. These are the valid combinations of M6Vtype and fuel.
M6VType	Defines the fuel-independent vehicle types used in MOBILE6.
NaturalGas	Natural gas sulfur content associated with each natural gas ID.
PollutantCode	Associates NIF pollutant codes and pollutant names with PollutantCodeID used in other tables.
SCC	Associates with each SCCID an SCC code and description, and ratios for NH3, PM25, and for converting between HC forms.
SCCToxics	SCC and fuel property-dependent ratios for calculating HAPs, dioxin/furans, and metals.
State	Associates state names and abbreviations with state FIPS codes used in other tables.
VMTGrowth	The annual VMT growth rate for a M6VClass by county and year.
VMTMonth Allocation	Factors for allocating annual VMT to the 12 months, by M6VType and HPMSRoadType, used if there are no county-specific values in CountyVMTMonthAllocation.

Temperature and Humidity

The NCD contains monthly average hourly temperature and humidity for historical years in the CountyYearMonthHour table. It contains 20-year averages (1981 to 2000) of monthly average hourly temperature and humidity in the CountyMonthHour table. The user can select whether to use the historical or 20-year average data. When historical data is not present in the database, the program automatically uses the 20-year average. MOBILE6 uses the hourly temperatures directly. NONROAD does not use hourly temperatures, but rather daily minimum, maximum and average temperatures. For NONROAD, NMIM calculates minimum and maximum from all 24 hourly temperatures, but calculates the average from the hourly temperatures from 6 AM to 9 PM (hourly intervals 7 to 21). The historical and 20-year average hourly temperatures and were developed by Air Improvement Resources (AIR), Inc. for EPA under contract, from data obtained from the National Climatic Data Center. County temperatures were determined by weighting nearby temperature stations by their distance from the population-based centroid for each county. For Puerto Rico and the Virgin Islands, averages were calculated using the five calendar years 1999 through 2003.

Fuel Properties

The CountyYearMonth table contains gasoline, diesel, and natural gas fuel identifiers for each county for each month of each calendar year. Highway vehicles and non-road equipment have separate fuel identifiers. The identifiers are associated with fuel properties in the Gasoline, Diesel, and NaturalGas tables.

For gasoline, the fuel properties were determined by the Eastern Research Group, Inc., (ERG) under contract to EPA using gasoline survey data.⁶ The fuel properties stored in the Gasoline table are:

- o Average Reid Vapor Pressure (RVP)
- o Average sulfur content
- o Maximum sulfur content
- o Ethanol (ETOH) percent by volume of ethanol blended gasolines
- o Ethanol blend market share
- o MTBE (Methyl Tertiary Butyl Ether) percent by volume of ether blended gasolines
- o MTBE blend market share
- o ETBE (Ethyl Tertiary Butyl Ether) percent by volume of ether blended gasolines
- o ETBE blend market share
- o TAME (Tertiary Amine Methyl Ether) percent by volume of ether blended gasolines
- o TAME blend market share
- o Aromatic content
- o Olefin content
- o Benzene content
- o E200 (vapor percentage of gasoline at 200 Degrees Fahrenheit)
- o E300 (vapor percentage of gasoline at 300 Degrees Fahrenheit)

The gasoline properties were derived from several surveys:

- o EPA's Reformulated Gasoline survey, 2000⁷
- o EPA's Oxygenated fuel program summary, 2001⁸
- o TRW (previously NIPER) fuel survey, 1999⁹
- o Alliance of Automobile Manufacturers of America (AAMA) survey, 1999¹⁰

Market share for oxygenated gasolines was obtained from the EPA Oxygenate Type Analysis Tables¹¹ and the Federal Highway Administration website.¹²

If the methyl-tertiary butyl ether (MTBE) percent volume content was less than 0.1 percent, MTBE content was assumed to be zero with a zero percent market share. Similarly, if the ethanol percent volume content was less than 0.1 percent, ethanol content was assumed to be zero with a zero percent market share. For any area which reported non-zero values for tert-amyl methyl ether (TAME) or ethyl tert-butyl ether (ETBE), the entire market share was assumed to be MTBE, since it was not possible to distinguish the market share between these specific oxygenates.

All gasoline properties are area-wide averages, except for oxygenates, which are allowed to have market shares. Three fuels (winter, summer, and spring/fall) were determined for each county and assigned to months by season. Months representing seasons varied by location. Spring/fall gasoline properties were derived from summer and winter fuels by interpolation. Gasolines in Puerto Rico and the Virgin Islands were assumed to be similar to gasolines in Collier County, Florida. Details of how the fuel survey data were applied to individual states and counties are described in the ERG report to EPA.¹³ The NCD allows counties to have different NR and highway gasolines, but none do as of this writing, because data have not been available to make this distinction.

For diesel fuel and natural gas, the only fuel property stored is sulfur content, in the Diesel and NaturalGas tables, respectively. A sulfur content of 30 ppm for natural gas was used for all counties in all states for all months of the year. Non-road and highway diesel sulfur values tend to differ in the same county because they are subject to different regulations.

Database Improvement

As part of the NEI process, States and regional and local organizations are being asked to review the NCD and provide more accurate data, if available. This review includes the county data and also the external files that can be referenced by MOBILE6 or NONROAD, such as fleet distributions and equipment allocations. The development of this database improvement system promises to extend NMIM's advantages beyond convenience to include the production of better mobile source inventories.

ESTIMATION OF HAZARDOUS AIR POLLUTANT (HAP) EMISSIONS

The hazardous air pollutants for which inventories are produced by NMIM are listed in Table 2 above. The "six HAPs" are produced internally by MOBILE6. In all other cases, as indicated in the "Pollutants" section above, HAP inventories were generated by ratios to various MOBILE6 and NONROAD outputs.

HAPs are estimated using data sources and methods developed for the 1999 NEI for HAPs, version 3,^{14,15} with some modifications, described below. NMIM does not estimate HAP emissions for compressed natural gas (CNG) engines.

HAPs are estimated in NMIM using one of three approaches:

- 1) Gaseous HAPs – Apply toxic to VOC ratios to VOC estimates.
- 2) Poly-Aromatic Hydrocarbons (PAHs) – Apply toxic to PM10 ratios to PM10 estimates.

- 3) Metals, Dioxins and Furans – For NONROAD, multiply HAP gram per gallon emission factors by county level fuel consumption estimates. For MOBILE6, multiply HAP gram per mile emission factors by county level VMT estimates.

The NCD SCCToxics table provides a complete listing of toxic ratios and emission factors for all SCCs and fuel combinations. The above approaches are described in more detail in the following sections.

Gaseous HAPs

NMIM uses the toxic to VOC ratios described in the documentation for the 1999 NEI for HAPs, version 3, and summarized in Volume 1, Appendix D, Table 1 of the documentation. Separate ratios are used for evaporative and exhaust emissions for each of the following four categories of gasoline blends:

1. Baseline Gasoline. All cases that do not fall into categories 2-4 below. Ratios are in variables “ExhBaseGas” and “EvapBaseGas” in the SCCToxics table.
2. WO (Winter Oxygenate) Gasoline / Ethanol or ETBE - Used where the fuel contains ethanol which is greater than or equal to 5% by volume or ETBE greater than or equal to 5% by volume. Ratios are in variables “ExhEthGas” and “EvapEthGas” in the SCCToxics table.
3. WO (Winter Oxygenate) Gasoline / MTBE / TAME - Used where the fuel contains MTBE which is greater than or equal to 12% by volume or TAME greater than or equal to 13% by volume. Ratios are in variables “ExhMTBEGas” and “EvapMTBEGas” in the SCCToxics table.
4. RFG/MTBE/TAME - Used where the fuel is RFG and where the fuel contains oxygenate greater than 5% by volume and where the fuel contains MTBE which is less than 12% by volume or TAME less than 13% by volume. Ratios are in variables “ExhRFGGas” and “EvapRFGGas” in the SCCToxics table.

It should be noted that NMIM uses a different set of criteria to determine which toxic to VOC ratios to use than that used in the 1999 NEI final version 3 for HAPs. In the 1999 NEI inventory, ratios for different fuel types were weighted according to whether the county participated in the Federal or California Reformulated Gasoline Program or a winter oxygenated fuel program, and the percentage of the year the county participated in these programs. For example, if a county participated in the Federal Reformulated Gasoline Program for 4 months, the RFG/MTBE/TAME fraction would be weighted by a factor of 0.33, and the baseline fraction by 0.67 to develop a composite annual fraction, which would then be applied to VOC. This approach does not adequately account for reformulated and oxygenated gasoline use outside counties participating in the program, or use outside the fuel program season. One result is an underestimate of the non-road MTBE inventory. Thus, when comparing the unofficial NMIM 1999 estimates with those of the 1999 NEI, NMIM estimates for 1999 result in substantially higher nationwide MTBE than those in the 1999 NEI for HAPs.

In some cases, HAP profiles for specific non-road equipment and engine type combinations are available. However, for many equipment/engine type combinations, no speciation data are available. In such instances, default values for 2-stroke gasoline engines, 4-stroke gasoline engines, and diesel engines are used. These default values represent an average fraction for various equipment types within an engine category.

Polyaromatic Hydrocarbons (PAHs)

All PAHs emitted in exhaust are estimated as fractions of PM10, although the data used to calculate mass ratios includes both gas and particle phase PAH emissions. The data used to develop the PAH fractions are described in the documentation for the 1999 NEI for HAPs. Evaporative naphthalene emissions from on-road vehicles is estimated as a fraction of VOC. NMIM does not currently estimate evaporative naphthalene emissions for non-road equipment.

Metals, Dioxins, and Furans

NMIM estimates on-road emissions using g/mile emission factors developed for the 1999 NEI for HAPs, version 3.

The approach used by NMIM to estimate non-road county level metal emissions differs in a number of respects from the approach used in the 1999 NEI for HAPs, version 3. In the 1999 NEI, nationwide metal emissions for gasoline engines were obtained by applying a mass per gallon emission factor by nationwide gasoline consumption from the NONROAD model. For diesel engines, a mass per brake-horsepower emission factor was multiplied by nationwide energy output. The resultant nationwide emission estimates were then spatially allocated to counties relative to the county proportion of PM10 emissions compared to the national PM10 emissions, as obtained from the NONROAD model.

In contrast, NMIM multiplies mass per gallon emission factors for gasoline engines by county level fuel consumption to obtain a county level inventory estimate. For diesel engines, mass per brake horsepower emission factors were converted to mass per gallon emission factors using the following equation:

$$\text{grams per gallon} = \frac{(\text{micrograms per brake-horsepower hour } (\mu\text{g/bhphr}) * \text{average fuel density (lb/gallon)})}{\text{fuel consumption per brake-horsepower hour (lb fuel/bhphr)}} * 1,000,000$$

where:

$$\text{average fuel density} = 7.01 \text{ lb/gal}$$

$$\begin{aligned} \text{fuel consumption per brake horsepower hour} &= 0.408 \text{ lb for engines less than 100 hp} \\ &= 0.367 \text{ lb for engines greater than 100 hp} \end{aligned}$$

The fuel consumption per brake horsepower hour estimates are from the NONROAD model.¹⁶ The gram per gallon metal emission factors for gasoline and diesel engines are contained in the NCD SCCToxics table.

Mass per gallon emission factors for dioxins and furans from non-road engines were calculated by multiplying the highway vehicle emission factors in grams per mile by fleet average fuel economy estimates. The assumed fuel economy for gasoline vehicles was 21.5 miles per gallon; for diesel vehicles it was 7 miles per gallon. Resulting gram per gallon emission factors are contained in the NCD SCCToxics table.

SUMMARY AND CONCLUSIONS

NMIM is a consolidated modeling system for MOBILE6 and NONROAD designed to produce national inventories. A standard input configuration has been designed to provide consistency between

MOBILE6 and NONROAD and between criteria pollutants and HAPs. NMIM's run specification can be constructed from its GUI or by a text editor. It can be executed from the GUI or from a command line. It is capable of standalone operation and can also take advantage of multiple computers on a LAN through a simple distributed processing scheme. Post-processing capabilities include the production of output in NIF3 format. The inclusion of a database improvement system into the NEI process promises to extend NMIM's advantages beyond convenience to include the production of better mobile source inventories.

DISCLAIMER

This paper does not necessarily represent official EPA policy. The primary purpose in presenting this paper is to facilitate the exchange of technical information and to inform the regulatory and scientific community of ongoing work within EPA. Mention of commercial products or organizations does not constitute an endorsement by EPA.

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