

RESEARCH ARTICLE



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FEATURES AND CHARACTERISTICS OF MOVES 2010b SOFTWARE USED FOR ESTIMATING EMISSION FROM TRANSPORT SECTOR

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ABSTRACT



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This paper presents a survey on MOVES 2010b software. MOVES is a U.S. Environmental protection Agency's (EPA) Motor Vehicle Emission Simulator model. MOVES2010b is the latest version of the MOVES emissions modeling tool which is mainly used to estimate national, state, and county level inventories of criteria air pollutants, greenhouse gas emissions, and some mobile source air toxics from highway vehicles. This paper also describes the basic structure of this software its prominent features and characteristics which provide a further scope in vehicular emission studies.

Key words: MOVES 2010b; Emission; Simulator; Modeling; Inventories; Pollutants

INTRODUCTION

MOVES is the U.S. Environmental Protection Agency's (EPA) Motor Vehicle Emission Simulator. MOVES2010b is the latest version of the MOVES emissions modeling tool. MOVES2010b builds on the similar functionality of previous MOVES versions: MOVES2004, MOVESDemo, DraftMOVES2009, MOVES2010 and MOVES2010a. MOVES2010b can be used to estimate national, state, county zone and Link level inventories of criterion air pollutants, greenhouse gas emissions, and some mobile sources air toxics from highway vehicles. Furthermore, MOVES can also make projections for energy consumption (total, petroleum-based, and fossil-based).

MOVES is distributed free of cost by EPA pursuant to the GNU General Public License (GPL). It is written in Java™ and uses the MySQL relational database management system. Oracle Corporation owns, operates, and supports MySQL, and allows distribution of the database system pursuant to the GPL. The principal user inputs and outputs, and the internal working storage locations for MOVES are MySQL databases.

In the modeling process, the user defines vehicle types, time periods, geographical areas, pollutants, vehicle operating characteristics, and road types to be modeled. The model then performs a series of calculations, which have been carefully developed to accurately reflect vehicle operating processes, such as cold start or extended idle, and provide estimates of bulk emissions or emission rates. Specifying the characteristics of the particular situation to be modeled is done by creating a Run Specification, or RunSpec.

The MOVES model is different from previous EPA mobile source emissions models in that it was deliberately designed to work with databases. With this design, new data that may become available can be more easily incorporated into the model. In addition, MOVES allows and facilitates the import of data specific to a user's unique needs.

From the MOVES software results are obtained in the text format which are further edited in the MS-excel sheets for better understanding

The MOVES model includes a "default" database that summarizes emission relevant information for the entire United States. The data for this database comes from many sources including EPA research studies, Census Bureau vehicle surveys, Federal Highway Administration travel data, and other federal, state, local, industry and academic sources. The MOVES team continually works to improve this database, but, for many uses, up-to-date local inputs will be more appropriate, especially for analyses supporting State Implementation Plans (SIPs) and conformity determinations (1).

A STRUCTURE OF MOVES

The MOVES model incorporates input data that include vehicle fleet composition, traffic activities, fuel information and meteorology parameters and conducts modal-based emissions calculations using a set of model functions. Based on the resulting modal-based vehicle emission rates, emission inventories or emission factors are then generated for the desired geographic scale (macro, meso or micro scales) as well as temporal resolution (year, day and hour).

Four major functions constitute the basic framework of MOVES (2): an activity generator, a source bin distribution generator, an operating mode distribution generator, and an emissions calculator (Fig.1).

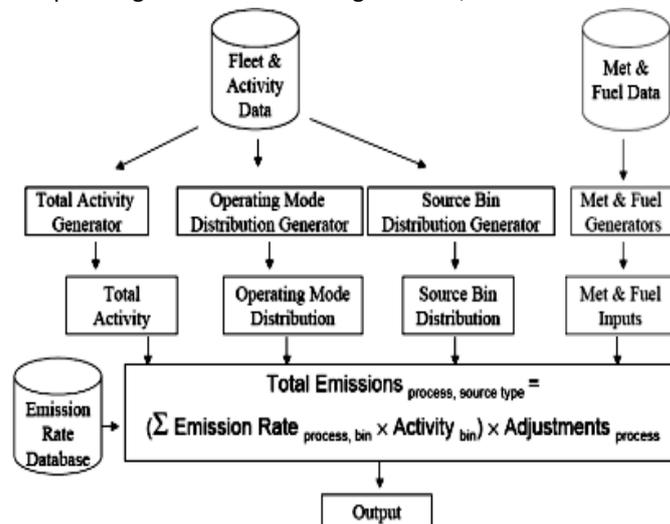


FIG. 1: General Model Structure of MOVES

Source: Beardsley, 2004 (3).

Total Activity Generator: The basic activity data in MOVES are vehicle population and vehicle miles traveled (VMT) for base year 1999 (4). The MOVES activity function, Total Activity Generator (TAG), first grows the base year vehicle population and VMT to a target analysis year using growth factors and then allocates them by road type, vehicle class, vehicle age and time period pursuant to nationwide observed and projected data from various sources. The MOVES activity function also conducts a data conversion process because all the activities

used for computing emissions in MOVES, except for vehicle starts, are specified in units of time. For example, the model defines source hours operating (SHO) as basic activities to estimate evaporative and running exhaust emissions, as well as tire and brake wear emissions (2).

Source Bin Distribution Generator: MOVES classify vehicles into different source bins. Source bins are defined to represent unique combinations of vehicle class, model year group, vehicle weight, engine size and technology, and fuel type (2, 4). The Source Bin Distribution Generator (SBDG) produces source bin fractions that are subsequently used to derive weighted emission rates.

Operating Mode Distribution Generator: The Operating Mode Distribution Generator (OMDG) classifies vehicle operating modes into different bins associated with vehicle specific power (VSP) and speed, and develops mode distributions based on 40 pre-defined driving schedules (2). MOVES emissions rates are a direct function of VSP, a measure that has been shown to have a better correlation with emissions than average vehicle speeds (5, 6), and users can input locally-specific VSP distributions. VSP represents the power demand placed on a vehicle when the vehicle operates in various modes and at various speeds. This function produces operating mode fractions for each bin, which are used as one of several inputs for computing base emission rates.

Emission Calculator: The emission calculator function in MOVES combines modal-based emission rates with the associated vehicle activities. In MOVES, base emission rates for each emission process, distinguished by source bin and operating mode, are first adjusted by a series of factors accounting for I/M programs, fuel supply, temperature and air conditioning. Weighted emission rates are then developed based on these adjusted emission rates, using source bin fractions and operating mode fractions, provided by the source bin distribution generator and operating mode distribution generator, respectively (2). Finally, weighted emission rates, in units of grams per second or grams per start, are matched with activities (e.g., source hours operating or vehicle starts) provided by the total activity generator. The model then generates emissions amount by area, time period, vehicle class, model year and fuel type.

Data Management: MOVES is built on a Java platform, and uses MySQL, a relational structure query language and database system (2). The input, output, default activities, base modal emission rates and all intermediate calculation data in MOVES are stored and managed in relational tables of the MySQL database. MOVES model functions query and manipulate MySQL data pursuant to scenario parameters specified in the graphical user interface.

BASIC FEATURES OF MOVES 2010b MODEL

To estimate emissions, MOVES applies a simple concept: total vehicle emissions are the product of vehicle activities, base emission rates and a series of adjustment factors. measured, and how vehicle activities and emission rates are paired spatially and temporally. Table 1 highlights modeling features of MOVES 2010b (1).

TABLE 1 MOVES 2010b Modeling Features.

FEATURES	MOVES 2010b
Model Version	MOVES 2010b (June 2012)
Program language	Java (version 1.7.0)
Data management	MySQL (version 5.5.12)
Emission sources	On-road; off-road
Geographic area	<ul style="list-style-type: none"> • Nationwide • State • County • Zone and Link • Custom domain

Road type	<ul style="list-style-type: none">• Rural roadways with restricted vehicle access• Rural roadways with unrestricted vehicle access• Urban roadways with restricted vehicle access• Urban roadways with unrestricted vehicle access• Off-network
Temporal scale	Analysis year: 1990, 1999 – 2050 <ul style="list-style-type: none">• Month: each month of a year• Day: weekdays and weekends• Hour: each hour of a day
Vehicle class	LDA <ul style="list-style-type: none">• Passenger Car LDT <ul style="list-style-type: none">• Passenger Truck• Light Commercial Truck M&HDT <ul style="list-style-type: none">• Refuse Truck• Single Unit Short-haul Truck• Single Unit Long-haul Truck• Combination Short-haul Truck• Combination Long-haul Truck• Motor Home BUS <ul style="list-style-type: none">• Transit Bus• School Bus• Intercity Bus MCY <ul style="list-style-type: none">• Motorcycle
Fuel type	<ul style="list-style-type: none">• Gasoline• Diesel• Compressed Natural Gas (CNG)• Liquid Propane Gas (LPG)• Electricity• Place holder fuel type
Vehicle model year	1960 – 2050
Pollutant	<ul style="list-style-type: none">• Total Gaseous Hydrocarbons• Non – Methane Hydrocarbons• Non – Methane organic Gases• Total Organic Gases• Volatile Organic Gases• Carbon Monoxide• Oxides of Nitrogen

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- Ammonia
 - Nitrogen Oxide
 - Nitrogen Dioxide
 - Nitrous Acid
 - Sulfur Dioxide
 - Primary Exhaust PM10-Total
 - Primary PM10-Organic Carbon
 - Primary PM10-Elemental Carbon
 - Primary PM10-Sulfate Particulate
 - Primary PM10-Brakewear Particulate
 - Primary PM10-Tirewear Particulate
 - Primary Exhaust PM2.5-Total
 - Primary PM2.5-Organic Carbon
 - Primary PM2.5-Elemental Carbon
 - Primary PM2.5-Sulfate Particulate
 - Primary PM2.5-Brake wear Particulate
 - Primary PM2.5-Tirewear particulate
 - Total Energy Consumption
 - Petroleum Energy Consumption
 - Fossil Fuel Energy Consumption
 - Brake Specific Fuel Consumption
 - Methane
 - Nitrous Oxide
 - Atmospheric CO₂
 - CO₂ Equivalent
 - Benzene
 - Ethanol
 - MTBE
 - Naphthalene Particle
 - 1,3-Butadiene
 - Formaldehyde
 - Acetaldehyde
 - Acrolein
 - Naphthalene gas

Emission
process

- Running Exhaust
- Start Exhaust
- Brakewear
- Tirewear
- Evap permeation
- Extended Idle Exhaust
- Well-to-Pump
- Refueling Spillage Loss
- Refueling Displacement Vapor Loss
- Evaporative Permeation
- Evaporative Fuel Vapor Venting/Fuel Leaks

- Crankcase Running Exhaust
- Crankcase Start Exhaust
- Crankcase Extended Idle Exhaust

Pre-loaded default activity data	Nationwide totals with county allocation factors, national default vehicle fleet and VMT distributions, national default driving schedules
Primary activity measurement	Vehicle operating time (SHO – Source Hours Operating)
Emission rate data	Dynamometer test data and on-board test data for average speed bins
Meteorology data	County-specific hourly temperature and relative humidity by month; users can also define met data for sub-county zones if desired
I/M program parameters	County-specific I/M programs; users can also update I/M default values using “IM Importer.

Model features summarized based on user guide for Moves 2010b (1).

MOVES 2010b CHARACTERISTICS

MOVES has several notable characteristics:

- MOVES include data for both emission rates and pre-specified vehicle activities. Therefore, in addition to producing detailed emission factors, MOVES produces national, state or county level emission inventories. MOVES emissions are aggregated from a more comprehensive breakdown of road types, engine technologies, and fuel source categories.
- MOVES develop running emission rates associated with vehicle operating modes. The emission rates are dependent on second-by-second VSP and speed. Accordingly, MOVES pairs travel activities with these modal-based emission rates, allocated in units of time. MOVES converts activity from vehicle miles traveled (VMT) or other activity measurements into units called Source Hours Operating (SHO). An SHO unit is simply a measure of the number of hours a given travel activity occurs.
- MOVES distributes activity data using several temporal resolutions (hours of a day, weekday vs. weekend, each month of a year) and the final emissions inventory can be aggregated into various target time frames.
- MOVES expands, relative to the MOBILE and EMFAC models, the modeling applications available to users. When complete, the tool will estimate emissions for all criteria pollutants plus greenhouse gases and it will also estimate associated energy consumption. MOVES will address on-road plus off-road mobile sources and the “upstream” emission processes that accompany refining, production, and marketing of the conventional and alternative/advanced fuels used to power the on-road fleet (this is referred to as a Well-to-Pump assessment).
- MOVES classifies vehicles based on activity patterns as well as emissions performance and the classification results represent a subset of the Highway Performance Monitoring System (HPMS) vehicle types. This classification scheme better connects activity data and emission data in terms of characterizing vehicles.
- Finally, MOVES incorporates functions to quantify the uncertainties of the emissions modeling results (although it does not address uncertainty associated with the embedded travel activity data).

CONCLUSION

It is concluded that Moves 2010b is the latest version of MOVES emission modeling tool among MOVES2004, MOVESDemo, DraftMOVES2009, MOVES2010 and MOVES2010a. This new emission modeling system estimates emissions for mobile sources covering a broad range of pollutants and allows multiple scale

analysis. MOVES currently estimate emissions from cars, trucks and motorcycles. The purpose of the tool is to provide an accurate estimate of emissions from mobile sources under a wide range of user-defined conditions.

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