MOVES Versus MOBILE

Comparison of Greenhouse Gas and Criterion Pollutant Emissions

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The U.S. Environmental Protection Agency has released a new generation regulatory mobile emission model, called MOVES (motor vehicle emission simulator), to replace its current emission models, MOBILE and NONROAD. On its formal adoption, MOVES will have important implications for regional mobile emission inventories, particularly concerning transportation conformity to the 1990 Clean Air Act Amendment. MOVES will not only improve emissions inventory estimates, but it will also expand the capabilities to perform quantitative project-level emission inventories that are not possible with the latest version of MOBILE. MOVES is designed to estimate emissions at scales ranging from individual roads and intersections to county-, region-, and nationwide. The first objective of this paper is to provide a comprehensive documentation of the differences between MOVES and MOBILE in terms of model methodology, scope, and features. The second objective is to fill the void in the literature on the comparison of MOVES and MOBILE at the regional level through a real-world case study. Using Cook County in Illinois, the authors compared emission estimates of carbon dioxide and nitrogen oxides in the latest versions of both models. For this purpose, consistent local specific input data are incorporated into the models. The third objective is to provide insights on input data requirements for MOVES to practitioners and metropolitan planning organizations to facilitate their transition from MOBILE to MOVES in the near future.

Although the United States accounts for approximately 5% of the world's population, it is responsible for more than a quarter of the world's greenhouse gas (GHG) emissions, with the transportation sector accounting for 33% of global carbon dioxide (CO_2) emissions in 2008 (*1*). The 1990 Clean Air Act Amendment requires states to attain and maintain the National Ambient Air Quality Standards. The requirements of the Clean Air Act Amendment establish significant restrictions on transportation investments in areas already exceeding the standards, so that the regional and local air quality does not get any worse.

GHG emission credits, cap-and-trade, and carbon tax are examples of the policies aimed at reducing the levels of GHG emissions in the United States. GHG emission credits are aimed at reducing GHG emissions by assigning a monetary value to each ton of CO_2 removed from the atmosphere. Cap-and-trade sets a limit or cap on the amount of GHG pollution that each industrial firm is allowed to emit and provides economic incentives to firms that produce lesser emissions (*2*). Carbon tax is a tax levied on CO_2 emissions from traditional burning of fossil fuels, thereby providing incentives to reduce the use of high carbon fuels (*3*). On the international front, the Kyoto Protocol is an agreement linked to the United Nations Framework Convention on Climate Change on stabilizing GHG concentrations in the atmosphere. The core commitment under the Kyoto Protocol requires the committed 37 industrialized countries called Annex 1 countries to ensure that the total GHG emissions produced by them do not exceed the allowable levels of emissions (*4*). The protocol allows annex countries to meet the emission limits through mechanisms such as emission trading, clean development mechanism, and joint implementation. These mechanisms help to meet the allowable limits by transferring GHG emission credits between annex countries (emission trading), projects that reduce emissions in other annex countries (joint implementation), and emission reduction projects in non-annex countries (clean development mechanism).

The core technical foundation of all these policies on climate change is the requirement of accurate emissions data, which in turn depends on the emission models adopted in their estimation and their temporospatial resolution. Accurate and consistent emission estimation is important because the benefits received through these policies are based on the amount of emissions reported. Underestimation or overestimation of emissions can lead to serious policy implementation flaws with firms and countries paying more or less than they deserve.

Emission estimation is typically done through emission models. A number of energy and emission models were developed over the past decades to estimate emissions and energy consumption. Typically, all these models take into account the various factors affecting emissions, although they differ in their modeling approach, modeling structure, and in the data used to develop them (*5*). Emission models can be categorized as macroscopic and microscopic models (*6*). Macroscopic models use average aggregate network parameters to estimate networkwide energy consumption and emission factors. The primary macroscopic emission models used in the United States developed for regulatory purposes have been the U.S Environmental Protection Agency's (EPA) MOBILE and California Air Resources Board's EMFAC model. Both these models are conceptually similar because they use networkwide average speed as input to produce activity-specific emission factors, which when multiplied by vehicle activities, such as vehicle miles traveled (VMT), give the total emission inventories. The main drawback of these models is in the use of a single traffic-related variable to estimate emissions, thereby ignoring other important explanatory variables that can significantly affect emission estimates (*7*).

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To overcome the drawbacks of macroscopic models and meet the growing need for developing emission estimates on a local scale, microscopic emission models have been developed (*8*). Examples of early microscopic models in the United States are the comprehensive modal emission model (*9*) and Virginia Polytechnical Institute's microscopic energy and emission models (*10*). These models incorporate the effects of different instantaneous speed and acceleration profiles on vehicle emissions, thereby representing real driving conditions. The EPA has recently released the final version of the next-generation microscopic mobile source emission model called MOVES (motor vehicle emission simulator). MOVES includes and improves on the capability of the other microscopic emission tools and replaces EPA's current mobile source emission models (MOBILE for on-road emission estimates and NONROAD used for off-road estimates). MOVES will replace MOBILE as the approved model for state implementation plans (SIPs) and regional or project-level transportation conformity analyses (*11*).

Since MOVES is a new model, there have been few studies reported in the literature comparing MOBILE and MOVES. There is a need for such comparative studies because it is important to understand how different the emission estimation would be with the new emission model compared with current models, which will have important implications on mobile emission inventories. To fill this void in the literature, this study compares the model methodology, capability, and data requirements of MOVES (MOVES2010) and MOBILE (MOBILE6.2) models. Moreover, model estimates are compared using Cook County, Illinois, as a case study. Converters released by EPA (*12*) for converting data available in MOBILE format into MOVES-compatible format are employed for maintaining consistency in the input parameters between the models. The case study also explores the reasons for any difference between the model estimates. A comprehensive list of input data requirements for MOVES is presented and possible sources for obtaining these inputs are identified. This is to aid practitioners and transportation planning agencies in their gradual transition from MOBILE to MOVES in the near future.

The modeling framework of MOVES and MOBILE is presented in the next section. A detailed side-by-side comparison between MOVES and MOBILE is presented, followed by a discussion on input data requirements for MOVES and a literature survey on model comparison. Next, a model comparative analysis using CO_2 and nitrogen oxide (NO_x) emission estimates for Cook County is presented.

COMPARISON OF MOVES AND MOBILE

Methodology and Model Capabilities

Table 1 highlights the prominent differences in methodology, scope, and features between the MOBILE and MOVES models. Some differences are described in more detail in the following subsections.

MOBILE

MOBILE is the phasing-out EPA regulatory model for estimating road vehicle emission factors in grams per mile (as opposed to total emissions). MOBILE estimates emissions from processes such as running exhaust, start exhaust, hot soak, diurnal, resting and running losses, crankcase, refueling, and brake and tire wear emissions. Emission levels in MOBILE are associated with factors such as vehicle populations and activity; local conditions such as temperature, humidity, and fuel quality; and emission control policies such as vehicle emission standards. MOBILE uses average trip speeds as key input to determine the emission factors. The output from the model is in the form of emission factors (in g/mi), which are then multiplied with VMT off model to estimate total emissions as shown in Equation 1. Several generations of MOBILE models were released and each generation of the MOBILE model has become more sophisticated in its approach to modeling average in-use emissions and with updated facilities to tailor emission factor estimates to specific times and geographic locations (*13*).

$$\text{total emissions} = \text{travel activity} \times \text{emission factor} \quad (1)$$

MOVES

MOVES is EPA's next-generation emission model to replace MOBILE for emission factor estimation. Furthermore, MOVES also provides total emission estimation that MOBILE does not. Other key distinctive features of MOVES that presumably make it superior to MOBILE are (*a*) a modal-based approach, as opposed to an average speed-based approach, for emission factor estimation; (*b*) availability of MySQL database management versus external Excel spreadsheet type of data management scheme; (*c*) geographical scale at macro-, meso-, and microscales compared with a single large regional scale; and (*d*) more sophisticated GHG estimation mechanisms and total energy consumption estimation available. These key features are briefly described in the next paragraphs.

MOVES follows a modal approach for emission factor estimation compared with the driving cycle-based approach followed by MOBILE and calculates emission inventories or emission factors by using a set of modal functions. The modal approach refers to estimating emissions based on vehicle operating modes defined by a number of factors including speed, acceleration, and road grade. The driving cycle-based approach is essentially based on the average speed of the speed trace (representing a trip) to derive emission rates. In MOVES, operating modes are binned according to second-by-second speed and vehicle-specific power (VSP). VSP represents the power demand placed on a vehicle under various driving modes and speeds. Vehicle activities are also binned (source bins), according to vehicle characteristics that significantly influence fuel (or energy) consumption and emissions. After distributing total activities into different bins, MOVES assigns an emission rate for each unique combination of source and operating mode bins and the emission rates are aggregated for each vehicle type. A few correction factors are applied to the emission rates to adjust for the influence of temperature, air conditioning, and fuel effects to obtain the total emissions as shown in Equation 2 (*14*).

$$\begin{aligned} &\text{total emissions}_{\text{emission process,vehicle type}} \\ &\quad = \left(\sum \text{emission rate}_{\text{emission process,bin}} \times \text{activity}_{\text{bin}}\right) \\ &\qquad \times \text{adjustments}_{\text{process}} \end{aligned} \quad (2)$$

where emission rate for each emission process is estimated for each source type and operating mode bin; adjustments are applied to emission rates to reflect the conditions for the location and time specified by user. Adjustments are also made for temperature, humidity, air conditioning, inspection and maintenance program, and fuel properties.

TABLE 1 Comparison of MOBILE and MOVES Models

Criterion	MOBILE6.2	MOVES2010
Model methodology	Average speed based Emissions by speed characterized by set of driving cycles Lacked flexibility to analyze different driving patterns	Modal activity based Emissions stored by unique combination of source and operating mode bins Any driving pattern can be analyzed as a sum of appropriate modes
Software interface	Model embedded calculation	Graphical user interface allows easier use Relational database structure with all inputs, outputs, default activities, base modal emission rates and all intermediate calculation data stored and managed in MySQL database Allows multiple-computer processing
Emission sources	On-road	On-road and off-road
Spatial scale	Single large regional scale	Three scales of analysis: macroscopic, mesoscopic, and microscopic
Pollutants	Criteria pollutants, hydrocarbons, particulate matter, air toxics, GHGs—CO_2, methane	All pollutants estimated by MOBILE6.2 plus new pollutants: sulfur dioxide (SO_2), ammonia (NH_3), nitrogen oxides (NO_2, NO), energy consumption
Emission process	Running exhaust Start exhaust Hot soak Diurnal Resting loss Running loss Crankcase Refueling Brake wear Tire wear	Running exhaust Start exhaust Extended idling Off-gassing (well-to-pump) Evaporative fuel permeation Evaporative fuel vapor venting Evaporative fuel leaking Brake wear Tire wear To be added in future versions: Energy and emissions from vehicle manufacture and disposal
Roadway classification	Freeway Arterial and collector roads Local Freeway on- and off-ramps	Rural restricted access Rural unrestricted access Urban restricted access Urban unrestricted access
Vehicle classification	28 vehicle classes Vehicle types match historical emission standards classifying vehicles according to weight and fuel type	13 vehicle classes Vehicle types compatible with HPMS data collection and more consistent with many control strategies
Fuel types	Gasoline Diesel Compressed natural gas	Gasoline Diesel fuel Compressed natural gas (CNG) Liquid propane gas (LPG) Ethanol (E85) Methanol (M85) Gaseous hydrogen Liquid hydrogen Electricity
Temporal scale	Analysis years: 1952–2050	Analysis years: 1999–2050
Speed	Single speed for ramps and local roads	Speed distribution for all roadway types by area type (urban or rural)
Emission estimation	Trip-based vehicle average speed	Distributes total activity into source and operating mode bins
Meteorology data	User supplied	Default county-specific temperature and humidity values; users can overwrite the default data with local specific data
Fuel supply	User supplied	Default county-specific fuel supply values; users can overwrite the default data with local specific data
Inspection and maintenance program	User supplied	Default county-specific inspection and maintenance program values; users can overwrite the default data with local specific data
Age distribution	User supplied—registration distribution	Default national age distribution for years 1999–2050
Output	Emission factors	Emission inventories or emission factors, total energy consumption
Other significant features of MOVES over MOBILE	None	Inclusion of advanced technology vehicles (e.g., hybrid gasoline-electric vehicles) Sophisticated modal-based estimation procedures for transportation energy consumption and GHG emissions Converters to translate MOBILE6 inputs to MOVES

MOVES is a data-driven model with all inputs, outputs, default activities, base modal emission rates, and all intermediate calculation data stored and managed in the MySQL database. This design also provides users with flexibility in constructing and storing their own database under the unified framework in MySQL. MOVES is designed to estimate emissions at scales ranging from individual link level to county, regional, and national levels. The macroscopic or national scale is the default selection in MOVES. Data collected on a nationwide level is apportioned or allocated to states or counties. With the mesoscopic or county scale, the model will replace national default allocations with user-supplied data. Microscopic or project scale is the finest level of modeling in MOVES. It allows the user to model the emission effects from a group of specific roadway links or a single off-network common area (*15*).

MOVES adopts a much more sophisticated, modal-based estimation procedure than the simplistic fuel economy approach in MOBILE for computing transportation energy consumption and GHG emissions (*16*). MOBILE calculates CO_2 based on carbon molecular mass balance (i.e., CO_2 emission rates are estimated in a simple fashion based on fuel economy performance estimates built into the model). However, the fuel economy rates do not account for changes in speed and other localized factors (*13*). Conversely, MOVES calculates CO_2 from total energy consumption based on source and operating mode bins accounting for the carbon content of the fuel and oxidation factor. The methodology followed by MOVES in calculation of CO_2 is consistent with the methods to calculate CO_2 in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* and is in line with International Panel on Climate Change guidelines (*17*).

Input Data Requirements

This section focuses on determining the appropriate inputs and their corresponding sources to develop emission inventories. This would help the transportation planning agencies in making the gradual transition to MOVES from current emission models. The MOVES model includes an extensive default database of vehicle activity, vehicle fleet, meteorology, fuel supply, and inspection and maintenance program for the entire United States. The data included in this database are composed from a variety of sources and are not necessarily the most accurate information available for performing regional or project-level emission analysis (*18*). Considerable effort is needed to obtain accurate local data for regional or project-level analysis. Input data requirements and sources for both MOVES county scale and project-level analyses are presented in Table 2.

Most of the essential inputs required by MOVES are similar to those previously used in MOBILE, such as VMT, age distribution, fuel supply, and meteorological data. However, MOVES requires more data and in different format compared with MOBILE. EPA has developed converters to allow users to convert MOBILE inputs into a MOVES-compatible format. These converters are spreadsheet tools that take MOBILE-formatted input files and convert them to MOVES format. Figure 1 shows a conversion of a MOBILE registration distribution file (*a*) into an equivalent MOVES age distribution file (*b*). For this conversion, the user is required to enter the year of the registration distribution and import MOBILE-formatted registration distribution. Once this information is entered, the converter automatically outputs MOVES age distribution. Detailed instructions on capabilities of each spreadsheet and instructions are provided in the corresponding spreadsheets (*12*).

Literature Review on State-of-the-Art Model Comparison

Since MOVES is a new model, there have been few studies reported in the literature comparing MOBILE and MOVES. Previous studies on comparative analysis between MOVES and other emission models are briefly discussed in this section to provide a proper background for understanding the study motivation.

In a study by Sonntag and Gao (*19*), a comparison between emission rates for methane (CH_4) and CO_2 was made between the macroscopic module of MOVES2004, an earlier draft version released in 2004, and MOBILE6.2. The results showed that the difference in CH_4 emission rates suggested the importance of alternative engine fuel types on future emission rates considered in MOVES. The results also showed that the temporal aggregation levels significantly affected the CO_2 results in MOVES. Emission rates estimated at the hourly aggregation were approximately 19% higher than daily aggregation. This was because the energy consumption rates tend to increase with increased modeling resolutions. The emission rates obtained from MOBILE6.2 are similar to the daily aggregation results from MOVES.

In a study by Bai et al. (*20*), the authors estimated CO_2 and CH_4 emissions in Los Angeles County for 2 years, 2002 and 2030, with MOVES and EMFAC. The macroscopic module of MOVES-HVI Demo, an intermediate draft version released in 2007, and the burden module used for calculating regional (area-specific) emission inventories in EMFAC2007 were used. The results showed that for year 2002, MOVES produced similar CO_2 emissions but lower CH_4 emissions than EMFAC. However for year 2030, MOVES predicted higher emissions for both pollutants than EMFAC. The authors found the CO_2 emission difference to be a function of VMT estimation. Higher CO_2 emissions for year 2030 were attributed to the substantial increase in forecasted light-duty truck VMT in MOVES compared with EMFAC. Conversely, the authors found the CH_4 emission difference to be dependent on base emission rates. MOVES has lower emission factors for the base year because it was developed based on recent vehicle test data, as compared with EMFAC. For year 2030, MOVES assumes higher CH_4 start emission factors which, when combined with MOVES' higher future projected vehicle population, result in higher emissions. Similarly, Beardsley et al. (*21*) compared MOVES2010 and MOBILE6 total emissions for three sample urban counties. Their results showed that MOBILE6 underestimated both NO_x (especially from light-duty vehicles) and particulate matter (PM). With respect to hydrocarbons, the results showed that MOBILE6 overestimated their emissions, especially from newer technology cars.

Most of these studies have focused on the macroscopic scale, while the data collected on a national level are allocated to states or counties. These allocation factors are proportional to the fraction of total U.S. VMT that occurs in the counties. VMT was computed from the federally mandated inventory Highway Performance Monitoring System (HPMS). However, the allocation does not take into account factors that may differ between counties (e.g., age distribution) (*11*). The main advantages of using local specific data would be to better represent the vehicle activity and conditions for the purposes of transportation conformity and SIP. In this study, a comparative analysis between MOBILE6.2 and MOVES2010 is made at the mesoscopic or county scale level, utilizing the local specific data for Cook County. Use of the county scale of analysis, instead of the default national scale, results in more accurate emission estimates.

TABLE 2 Input Data Requirements for MOVES

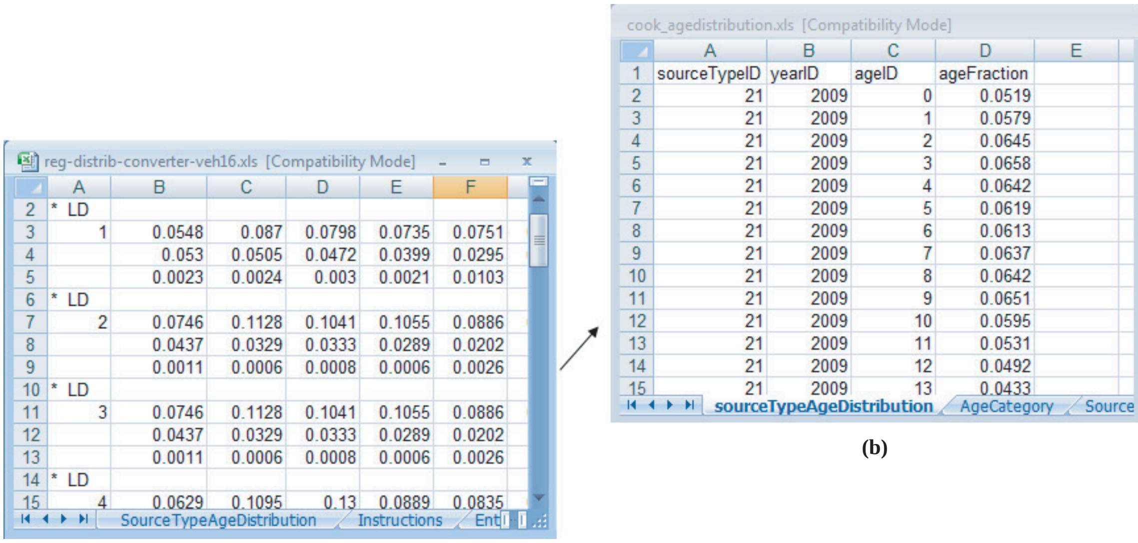
Data Item	Description	Source
Mesoscopic or County-Level Analysis		
Vehicle type VMT[a]	Annual VMT by HPMS vehicle class for the year and geographic area being modeled	Travel demand forecasting models or from MOBILE input data
Source type population[a]	The number of vehicles in the geographic area being modeled for each vehicle type, such as passenger cars, passenger trucks, etc.	State motor vehicle registration data or local transit agencies. If population is not available for a particular source type, MOVES default split of that source type within the HPMS vehicle class can be utilized or from MOBILE input data
Average speed distribution[a]	The average speed data specific to vehicle type and road type and time of day and type of data for geographic area being modeled	Can be obtained by postprocessing the output from travel demand network model or from MOBILE
Road type distribution[a]	The fraction of VMT by road type for the geographic area being modeled	Travel demand forecasting models or from MOBILE input data
Source type age distribution[a,b]	Vehicle age distribution	MOVES default data MOBILE input data
Meteorology[a,b]	Temperature and humidity	MOVES default data MOBILE input data
Fuel supply[b]	Fuel supply parameters and associated market share for each fuel	MOVES default data
Inspection and maintenance program[b]	Inspection and maintenance program parameters	MOVES default data
Microscopic or Project-Level Analysis		
Link	Roadway link characteristics	User defined
Link drive schedule	Speed–time trace second by second and percentage grade for roadway links	Users have to incorporate the speed–time trace from traffic simulation or dynamic traffic assignment models
Operating mode distribution	The vehicle operating mode distribution specifies amount of time spent by vehicle fleet in different operating modes.	For roadway links, this information is optional if the speed–time trace data table is provided. For off-network links, this information is required. The off-network data should be derived for each traffic analysis zone (TAZ), quantifying how many trip starts (or number of trips from the origin–destination table) are associated with each TAZ.
Link source type fraction	Vehicle fleet composition for each roadway link	Users have to calculate the percentage of link traffic volume driven by each vehicle type
Off-network link	Off-network links can be defined to represent traffic analysis zones for estimating vehicle start emissions.	Users have to calculate the number of starts for each TAZ, fraction of time spent in idling, and fraction of vehicle population parked.
Source type age distribution[a,b]	Vehicle age distribution	MOVES default data MOBILE input data
Meteorology[a,b]	Temperature and humidity	MOVES default data MOBILE input data
Fuel supply[b]	Fuel supply parameters and associated market share for each fuel	MOVES default data
Inspection and maintenance program[b]	Inspection and maintenance program parameters for nonattainment areas	MOVES default data

[a]Parameters can be incorporated from existing MOBILE input data using converters.
[b]Parameters can be obtained from MOVES default database.

COMPARISON OF EMISSION ESTIMATES: COOK COUNTY, ILLINOIS

The purpose of this case study is to compare the emissions of NO_x and CO_2 between MOBILE6.2 and MOVES2010 and to explore the reasons for the difference in emission estimates. To maintain consistency between the two models, the same inputs were incorporated in both. MOVES scenario runs are specified in the mesoscopic scale. Both models are run for the same scenario at the matched temporal and spatial scales (i.e., a weekday in the month of July 2009 for Cook County, Illinois). Cook County is the second most populous county in the United States after Los Angeles County. Cook County has the highest population, the highest population density, the largest extent of urban land cover, and the highest level of vehicular traffic of all the counties in the Chicago metropolitan area (*22*). Cook County is classified as a nonattainment area for 8-h ozone and annual $PM_{2.5}$ standard (*23*), which has caused inspection and maintenance programs to be a prerequisite for vehicle registration. Fuel supply in Cook County is reformulated gasoline.

The year 2009 was selected because it is the latest VMT data available in HPMS. The models are compared on emissions for CO_2, representing GHGs, and NO_x, representing a local criteria pollutant for the running exhaust emission process. Table 3 shows the mileage and annual VMT by functional classification in Cook County based



(a) (b)

FIGURE 1 Conversion of age distribution from (*a*) MOBILE to (*b*) MOVES format.

on the latest 2009 HPMS data. Table 4 compares and explains the input parameters used by MOBILE and MOVES in this study. Local specific data for MOVES are obtained from the existing MOBILE input files for Cook County provided by the Illinois EPA, HPMS, and MOVES default database. The two model input sets are kept as consistent as possible to minimize avoidable discrepancies in modeling.

The detailed emission output from MOBILE gives the emission factors by age (from 0 to 24 years) for each pollutant and road type being modeled. To aggregate the emission factor by road type, the emission factor for each age group is multiplied with its corresponding VMT fraction and, when summed up for all age groups, gives the aggregated emission factor for each road type. The emission factors are multiplied with the corresponding VMT off model to estimate total emissions as shown in Equation 1. Because total emissions are directly obtained from MOVES, no postprocessing is required.

RESULTS

The emission inventories for running exhaust of NO_x and CO_2 for a weekday in July 2009 are presented in Table 5. Total energy consumption is an additional output given by MOVES2010 as CO_2 is calculated based on total energy consumption. The different road type categorization in MOBILE and MOVES are matched based on the MOVES vehicle type mapping provided by EPA (*12*). From the results, it can be seen that MOBILE underestimates both NO_x and CO_2 by 17% and 16%, respectively, from those estimated by MOVES. From the equations on calculation of total emissions, it is clear that emission estimates are dependent on vehicle activities and associated emission factors. The same vehicle activity data from HPMS is incorporated into both models. Hence the difference in emission estimation is solely dependent on emission factors, which in turn depend on the methodology incorporated by the models in calculation of emission factors.

An additional comparison is performed by incorporating different age distributions between MOBILE and MOVES. Default MOVES age distribution for Cook County is utilized instead of obtaining it from the Illinois EPA MOBILE input data. From the results, it is seen that the difference in NO_x emissions between the two models changed from 17% to 30%, whereas the difference in CO_2 emissions changed from 16% to 15%. Hence, changing the age distribution affected NO_x emission totals more than for CO_2. The default age distribution from MOVES assumes higher fractions of older vehicles compared with the MOBILE input. There is a significant reduction in the emission rates for NO_x from newer vehicles compared with older vehicles, due to ever more stringent emission control requirements. In the case of CO_2, its emission level has more to do with the completeness in combustion, fuel efficiency, vehicle weight, and chemical composition of fuel (Environmental Protection Agency, personal communication, Oct. 21, 2010).

MOVES incorporates more features and functions than MOBILE, as indicated in Table 1. Calculation of emission factors in MOVES represents a more accurate characterization of on-road emissions than use of emission factors by MOBILE based on average speed. This is due to the previously mentioned modal-based approach followed by MOVES in calculation of emission factors that can account for different patterns of acceleration, cruising, and deceleration as well as average speed. MOVES provides a detailed breakdown of emission factors by source and operating mode bins, which takes into account the vehicle characteristics and second-by-second drive schedule

TABLE 3 Mileage and Annual VMT in Cook County, Illinois (Based on 2009 HPMS Data)

Facility	Annual VMT (in thousands)	Miles
Interstate	11,272,833	213.91
Other principle arterials	7,642,364	641.7
Minor arterials	6,059,233	1,024.9
Collectors	4,441,824	1,204.3
Local roads	3,532,968	8,181.9
System totals	32,949,222	11,266.7

NOTE: 1 mi = 1.61 km.

TABLE 4 Input Parameters Used in MOBILE6.2 and MOVES2010

Input Parameter	MOBILE	MOVES
Version	MOBILE6.2	MOVES2010
Pollutant or GHG	NO_x, CO_2	NO_x, CO_2
Process	Running exhaust	Running exhaust
Road type	Freeway Arterial, collector roads Local Freeway ramps	Rural restricted access Rural unrestricted access Urban restricted access Urban unrestricted access
Vehicle	Passenger cars (gasoline)	Passenger cars (gasoline)
Min. and max. temperature	13°F and 29°F	13°F and 29°F
Absolute humidity	21.2	21.2
Calendar year	2009	2009
Month	July	July
Altitude	Low	Low
Vehicle type VMT	Volume estimates are obtained from HPMS.	Volume estimates from HPMS are converted into equivalent MOVES tables of VMT by HPMS class by using the EPA converters.
Source-type population	Source type population is required to calculate start and evaporative emissions. In MOBILE, these emissions are calculated in grams per mile and hence are related to VMT.	In MOVES, start and evaporative emissions are related to source type population. This is because relationship between VMT and vehicle starts or evaporative emissions are not consistent (*24*). These data are developed from MOBILE registration data for Cook County, which are converted into MOVES equivalent format using EPA converters.
Average speed distribution	Local data for Cook County specified in MOBILE format. Speed estimates for Cook County in MOBILE are obtained from Chicago Metropolitan Agency for Planning.	Converted from MOBILE input file using EPA converters
Road-type distribution	VMT fractions by road type are calculated from HPMS.	VMT fractions by road type are calculated from HPMS.
Source-type age distribution	Local data—MOBILE format. Age distribution ranges from 0 to 24 years.	Converted from MOBILE input file using EPA converters. Age distribution ranges from 0 to 30 years.
Meteorology	Local data for Cook County specified in MOBILE format	Converted from MOBILE input file using EPA converters
Fuel supply	Local data—MOBILE format	MOVES default database for Cook County. Due to lack of converters for inspection and maintenance program, MOVES default data were utilized. Nevertheless, both MOVES and MOBILE use the same Reformulated Gasoline Fuel Program for Cook County.
Inspection and maintenance program	Local data—MOBILE format	MOVES default database for Cook County. Due to lack of converters for inspection and maintenance program, MOVES default data were utilized. Nevertheless, all MOVES inspection and maintenance effectiveness values were empirically generated from MOBILE6.2 (*24*).

NOTE: °F = (°C × 1.8) + 32.

based on speed and VSP. The emission factors in MOBILE are associated with average speeds that correspond to a baseline driving cycle and can account for differences in average speed only. Studies (*25, 26*) have shown that VSP has better correlation with emissions than use of a single traffic-related variable (average speed). With respect to GHG emissions as stated earlier, MOVES2010 calculates CO_2 from total energy consumption based on source and operating mode bins accounting for the carbon content of the fuel and oxidation factor. MOBILE6.2 calculates CO_2 emission rates based on carbon molecular mass balance, which does not account for changes in speed and other localized factors.

With respect to data differences, MOVES includes a much larger extensive data set reflective of real-world data compared with MOBILE, which is mostly based on certification data. MOVES

TABLE 5 Comparison of Emission Inventories Between MOBILE6.2 and MOVES2010

Emission Total	Unit	MOBILE6.2	MOVES2010	Difference (%)
NO_x	Tons/day	20.64	24.97	+17.10
CO_2	Tons/day	19,851.72	23,509.94	+ 16
Total energy consumption	Joules/day	None	327,133,092.8	—

NOTE: 1 ton = 907 kg.

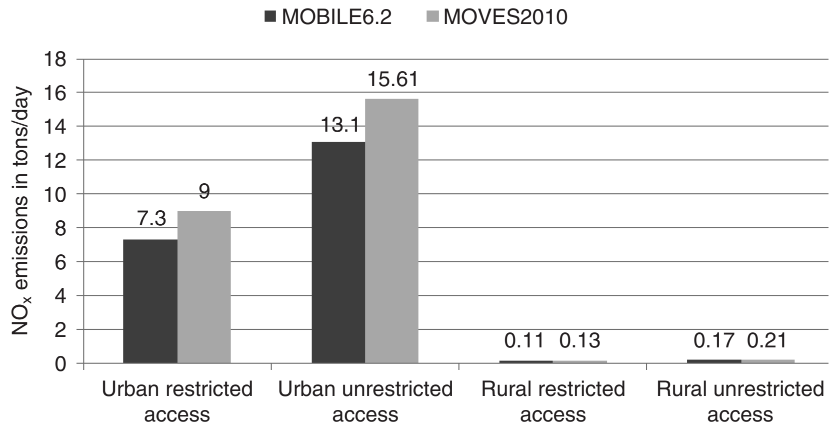


FIGURE 2 Cook County NO_x emissions by road type.

includes the first in-use data on light-duty vehicles meeting Tier 1 and national low emission vehicle standards. MOBILE6.2 data include in-use data for pre-1994 vehicles; 1994 and later vehicle emissions are primarily based on certification data. In addition, MOVES includes first in-use PM data for light-duty vehicles with temperature effects, whereas MOBILE includes PM-based certification data with no temperature effects. For heavy-duty trucks, MOVES incorporates first in-use data including speed effects and crankcase, start, and extended idle emissions compared with certification data incorporated into MOBILE with no speed effects or crankcase, start, and extended idle emissions (*27*).

Breakdown of emissions by road type, displayed in Figures 2 and 3, shows that emissions from urban road types are more than those from the rural road types from both models. Among the urban road types, emissions from arterials, collectors, and local roads collectively are higher than from freeways and highways. These trends are reflective of the differences in vehicle activities among the road types with maximum vehicle activity from the urban unrestricted road types. MOBILE reports fewer emissions for all road categories compared with MOVES for the same reasons already presented above.

CONCLUSION

In this study, a comparative analysis of the features of MOVES2010 and MOBILE6.2 has been presented. In comparison to the macroscopic emission models such as MOBILE and EMFAC, MOVES has improved capabilities, such as use of a modal-based approach to estimate emissions rather than applying speed correction factors to baseline emission factors, flexibility through the use of graphical user interface and relational database, the ability to model emissions at three levels of analysis for both on-road and off-road, and finer characterization of advanced technology vehicles and fuel technologies. In light of these new features, MOVES is expected to significantly improve emission estimates at regional and project levels—the scales that are important for transportation conformity analyses.

Using a case study of Cook County, Illinois, emissions of CO_2 and NO_x were estimated with the mesoscopic or county scale of MOVES2010 and MOBILE6.2. With emission estimates, MOBILE underestimated both NO_x and CO_2 compared with MOVES. The underlying methodological differences in emission factor estimation contributed to the observed differences between the two models as the same vehicle activity is applied to both models. In addition, the difference in CO_2 estimates is due to modal-based estimation of CO_2 from total energy consumption in MOVES2010 compared with the simplified fuel economy rates in MOBILE6.2. The different emission estimates among the different road types are reflective of their corresponding vehicle activities. The comparative assessment of the two models therefore focused on methodology, capability, and data differences between MOBILE and MOVES that result in differing emission estimates. These differences will have important implications in state transportation conformity and SIP documentation because the new model estimates may suggest reallocation of

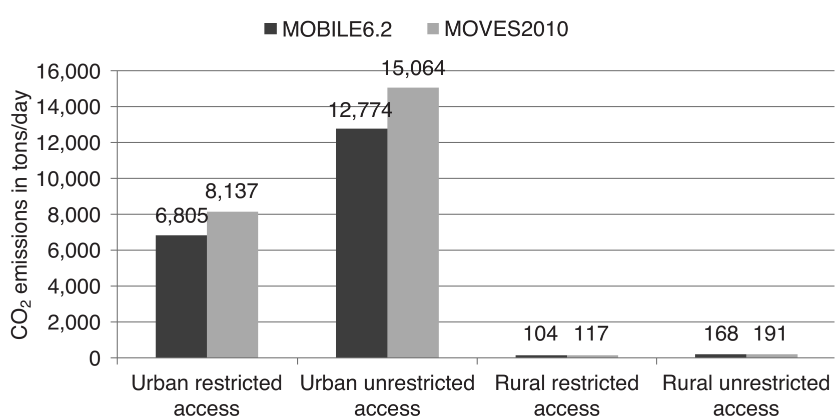


FIGURE 3 Cook County CO_2 emissions by road type.

statewide emission budget and modified transportation improvement projects to maintain and improve the state air quality designation status. Further and more thorough investigation into the technical, operational, and institutional implications of the transition between the two models is necessary.

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