U.S. Department
of Transportation
Federal Highway
Administration

The MOBILE Model and Transportation Planning:

A Brief Overview

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What is the MOBILE Model?

MOBILE is a computer model developed by the U.S. Environmental Protection Agency (EPA) for estimating emissions of air pollutants by motor vehicles. Since its introduction in 1978, successive versions of the model have improved its accuracy in estimating vehicle emissions, while adding new capabilities to evaluate measures that reduce emissions.

Using information on the types and ages of vehicles and on local driving conditions, MOBILE estimates emissions of various pollutants during each mile that different types of vehicles are driven. These emissions rates are combined with transportation planners' estimates of the number of miles vehicles are driven within the region to estimate area-wide total emissions of each pollutant by highway vehicles, usually during a day or year.

Vehicle Emissions and Air Quality Planning

Estimates of motor vehicle emissions developed using MOBILE play a key role in transportation planning to improve air quality in the Nation's urban areas. They are used to assess the contribution of motor vehicles to current air pollution levels, to identify how vehicle emissions can be reduced, and to assess the consistency between local areas' transportation and air quality plans.

State Implementation Plans

Under the Federal Clean Air Act, the EPA sets nationwide standards for maximum permissible levels of air pollution, while States retain primary responsibility for monitoring air quality and choosing measures to comply with these standards. When an area is found to violate Federal air quality standards, the State in which it is located is required to develop and implement a plan (a State Implementation Plan, or SIP) for eliminating the violation and then maintaining the standard.

Among the required elements of a SIP are a comprehensive inventory of current emissions from all sources in that area, and projections showing how actions to be taken by the State will produce the emissions reductions necessary for it to attain the national air quality standards. Except in California (which has developed its own emissions model), planners use MOBILE to estimate current motor vehicle emissions, as well as to analyze the effectiveness of measures to reduce them.

Conformity

The 1990 amendments to the Clean Air Act strengthened its requirement that local transportation plans and programs conform with the intent of an area's prevailing SIP to bring pollution levels into compliance with Federal air quality standards. The strengthened conformity rule requires metropolitan planning organizations (MPO's) in nonattainment and maintenance areas to document that the regional emissions consequences of implementing their transportation plans and programs are consistent with the emissions reductions projected in the adopted SIP.

While the criteria and procedures for demonstrating conformity differ based on a number of factors, the effects of transportation investments on motor vehicle emissions must be analyzed using the latest EPA-approved emissions model. Again, this means that analysts making conformity determinations will use MOBILE to estimate vehicle emissions.

How MOBILE Works

Estimating the emissions of pollutants by motor vehicles is a complex process. MOBILE includes most types of highway vehicles in common use, and it attempts to account for many of the conditions that can cause their emissions to vary. Nevertheless, it is important for both users of the model and officials who must base important decisions on its results to be aware of the difficulty of the model's task.

A Complex Task

The highway vehicle fleet is comprised of many different types of vehicles, ranging from motorcycles to heavy-duty trucks. Different types of vehicles use widely varying engine designs, operate on different fuels, and emit a variety of pollutants both at the tailpipe and from their fueling systems. Each class of vehicles includes models of different ages that met different emission standards when they were new, and have experienced widely varying use and maintenance over their lifetimes.

Further, emissions from a single vehicle can vary dramatically from mile to mile depending on whether the engine is still cold or it has warmed up. Driving conditions such as its speed, acceleration, road grade, the load it is carrying, and the use of accessories such as air conditioning can also be factors. Emissions can also differ depending on the exact characteristics of the fuel being used (for example, gasoline formulations can vary widely by season and among regions), as well as conditions such as the temperature, humidity, and altitude at which vehicles are driven.

Light-duty gasoline vehicles, mostly passenger automobiles

Light-duty gasoline trucks, including many used as passenger vehicles

Medium-duty gasoline trucks used primarily for local commercial transportation

Heavy-duty gasoline vehicl such as trucks and some buse

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What the Model Does

MOBILE calculates representative emission factors for different types of vehicles and the entire fleet for any year its user selects. These factors represent the average amount of pollution emitted by different vehicles per mile they are driven.

Pollutants.

MOBILE estimates emission factors for three pollutants:

- carbon monoxide (CO)
- hydrocarbons (HC)
- oxides of nitrogen (NO_x).

Carbon monoxide is one of the six "criteria" pollutants for which the EPA has established national air quality standards. Hydrocarbons and oxides of nitrogen combine in sunlight to produce ozone and nitrogen dioxide — two additional criteria pollutants. Carbon monoxide and nitrogen oxides are by-products of a motor vehicle's operation that are emitted through its tailpipe, while hydrocarbons are released both at the tailpipe and through evaporation from vehicles' fuel storage and delivery systems.

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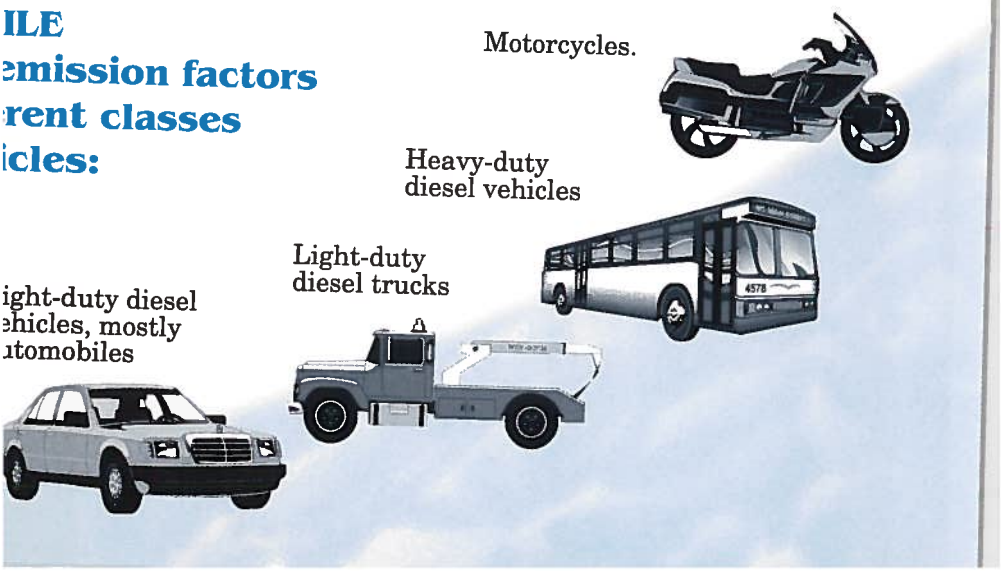

Basic Emission Rates.

For each of the eight vehicle types, MOBILE first calculates basic emission rates for each model year in service during the calendar year being analyzed. Basic emission rates represent a model year's average emissions under specified driving conditions during the selected analysis year. These rates depend on the emissions of each model year's vehicles when they were new, as well as on how much those vehicles' emissions have increased as a result of their usage since they entered the fleet.

MOBILE's data on basic emission rates come from two sources: measurements taken on samples of privately owned cars and other light-duty vehicles loaned to the EPA, and tests conducted by manufacturers to certify that their engines comply with prevailing emission standards. Actual emissions of all three pollutants (HC, CO, and NO_x) from test vehicles' tailpipes are measured in laboratories under carefully specified conditions (temperature, fuel composition, etc.), using equipment that simulates their operation over a pattern of acceleration, braking, and idling intended to represent a typical trip in an urban area. Measurements of evaporative hydrocarbon losses during vehicle operation and storage (and refueling, if desired by the user) are apportioned over typical usage patterns — the average number of trips or miles driven in a day, for example — and added to the tailpipe emission rate.

Real-World Adjustments.

MOBILE then adjusts these basic emission rates to reflect differences between actual driving conditions and the controlled test conditions, including different temperatures, driving speeds, mix of cold and warmed-up operation, and tampering with emissions control systems by vehicle owners. Some of the data needed to make these adjustments must be supplied by the user, while the model provides built-in values for others. MOBILE can also adjust emission rates to reflect changes in fuel characteristics (such as the use of reformulated gasoline) and the type of vehicle inspection and maintenance program a State operates.

The adjusted emission rates for vehicles of each model year are then weighted by their relative usage to develop an average emission factor for all vehicles of that type during the analysis year. MOBILE assumes that progressively fewer vehicles from each older vintage remain in service and that vehicles are driven less as they age, although many users alter the model's built-in age profile of the fleet using local vehicle registration data.

After calculating average emission factors for each of the eight vehicle types, MOBILE uses the typical fractions of total vehicle miles traveled (VMT) in an urban area — by vehicles of different types — to develop fleetwide emission factors. Although a single run of the model generates emission factors for all three pollutants, analysts typically conduct separate runs using summer and winter temperatures since ozone occurs primarily on hot summer days, while high CO accumulations are primarily a cold weather phenomenon.

An Example: How MOBILE Calculates Average Emissions Rates for Automobiles During 1995

Step 1

MOBILE calculates the HC, CO, and NO_X emissions rates for 1970 model year cars under test conditions by combining 1970 cars' original emissions rates with the increase resulting from accumulated use since those cars were new.

Step 2

Using inputs supplied by MOBILE's user, these emissions rates are adjusted to reflect differences between local driving conditions and test conditions.

Step 3

The adjusted emissions rates for 1970 model year cars are weighted by the fraction of automobile VMT driven by 1970 cars during 1995 to estimate their contribution to the emission rate for the entire automobile fleet.

Step 4

MOBILE repeats Steps 1, 2, and 3 for model years 1971 through 1995. The contributions of each model year are added together to calculate the average HC, CO, and NO_X emissions rates for all automobiles during 1995.

MOBILE repeats this process for the seven remaining vehicle classes.

Estimating Total Emissions

MOBILE calculates average emissions per mile of the three pollutants (HC, CO, and NO_X), for each class of vehicles. These emission rates must be multiplied by estimates of VMT by each type of vehicle to estimate its contribution to overall emissions. Since MOBILE does not provide these VMT estimates, planners must develop them from other sources such as transportation models or traffic counts. When VMT estimates for different types of vehicle are unavailable, MOBILE's estimate of the weighted average emission rate for the entire vehicle fleet is sometimes multiplied by total VMT for all vehicle classes to estimate their combined emissions.

How Accurate is MOBILE?

Because measures of actual emissions from large numbers of motor vehicles operating under real-world conditions are unavailable, it is impossible to test the accuracy of MOBILE directly. Like other complex models, however, its reliability seems likely to depend on how closely its actual use conforms to the purposes it was designed to serve.

Estimating the SIP Inventory

In a few cases where emissions estimates produced by earlier versions of the model could be compared to actual measurements, such as where long tunnels trapped emissions from vehicles passing through them, it appeared that the model might significantly underestimate actual emissions of some pollutants. More recent versions of MOBILE, however, have corrected many of the possible sources of this tendency that were identified by researchers.

For example, the newest version of the model (MOBILE5, released in 1993) increased HC emissions rates to include recently discovered sources of evaporative losses, sharply increased emission rates of some pollutants during both low- and high-speed driving, and assumed faster increases in the emission rates of high-mileage vehicles. As a result, its estimates of vehicle emissions of all three pollutants are significantly higher than those produced by earlier versions of the model.

While sources of potential error still remain — principally the failure of current emissions testing procedures to reflect actual driver behavior and to include certain operating conditions that can sharply raise emission rates — much of the model's original tendency to understate vehicle emissions may already have been remedied. Transportation planners' capabilities to use travel models and other data sources to develop the inputs required for accurate emissions estimation using MOBILE, such as VMT by different classes of vehicles, variation in travel speeds on different facilities, and the mix of travel by cold and warmed-up vehicles, are also improving as their experience in working with the model grows.

Analyzing Control Strategies

Another important concern is MOBILE's accuracy in estimating the effects of measures to **reduce** vehicle emissions, since a State's decision to include a control strategy in its SIP requires it to achieve the promised emissions reductions. MOBILE probably provides reasonable estimates of emissions reductions from

control measures that reduce the average emissions rates of large numbers of vehicles by amounts that can be reliably anticipated.

Tighter emissions standards currently required for new vehicles and changes in the composition of fuels (such as reformulated and oxygenated gasoline) are examples of control measures whose effectiveness is likely to be estimated reliably. MOBILE's predictions of emissions reductions from vehicle inspection and maintenance programs — which are based primarily on experience with pilot programs — are also likely to be reasonably accurate, at least for actual programs that resemble those prototypes.

Demonstrating Conformity

Demonstrating that a local transportation plan or Transportation Improvement Program conforms with an adopted SIP requires planners to estimate the likely change in vehicle emissions if it is implemented. The reliability of this demonstration depends on MOBILE's accuracy in estimating the effect of relatively minor changes in the travel speeds on specific facilities as their capacity is increased or their operation is more effectively managed.

Of course, the accuracy of a conformity determination also depends on the ability of transportation models to predict changes in travel speeds and traffic volumes on specific facilities where capacity enhancements or operational improvements are planned. While MOBILE can probably indicate the direction of any resulting change in total emissions, its estimate of the magnitude of that change should probably be interpreted very cautiously.

Using MOBILE Wisely

MOBILE is an important tool for transportation planning to achieve air quality goals. The EPA's substantial investment in developing the model over the past two decades and its ongoing program of research to improve the model's accuracy and expand its capabilities ensure that it will remain the dominant model for estimating motor vehicle emissions and analyzing ways to reduce them.

However, it is important that users of MOBILE understand the measurements and procedures the model uses to calculate emission factors. In addition, users need to appreciate the strengths and limitations of the model in different applications, such as estimating motor vehicles' contribution to total regional emissions, evaluating strategies to reduce vehicle emissions, and assessing the emissions impacts of transportation investment programs.

For More Information. To help both users of MOBILE and those whose decisions rely on its results to understand how the model works and appreciate its usefulness and limitations, the Federal Highway Administration (FHWA) has prepared two reports:

Evaluation of MOBILE Vehicle Emission Model, FHWA-PD-94-038, December 1994

Data Aggregation Issues in the Application of the MOBILE Emissions Factor Model, FHWA-PD-95-033, August 1995.

These documents provide a detailed view of the data and computation procedures used in developing MOBILE's emission factors, together with an evaluation of its use in estimating regionwide vehicle emissions and the effectiveness of strategies to reduce them. Copies of both reports are available from the Environmental Analysis Division, Air Quality Technical Team, 400 7th Street, S.W., Washington, D.C. 20590 (telephone 202-366-2069).

Additional materials relating to MOBILE, including instructions for use of the model, are accessible via the Office of Mobile Sources (OMS) bulletin board section of the Technology Transfer Network, operated by the EPA's Office of Air Quality Planning and Standards (OAQPS). Information on using the OAQPS TTN is available by calling (919) 541-5384 during normal business hours.