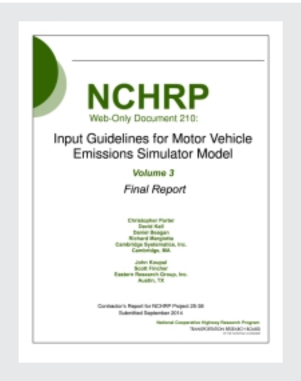

Input Guidelines for Motor Vehicle Emissions Simulator Model, Volume 3: Final Report

DETAILS

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Table of Contents

List of Tables

List of Figures

1.0 Introduction

This document is the Final Report for NCHRP Project 25-38, *Input Guidelines for Motor Vehicle Emissions Simulator Model (MOVES).* The other major product of this research is a resource document, titled *Developing Inputs for the Motor Vehicle Emissions Simulator Model: Practitioners' Handbook*, that provides information for practitioners on how to develop local inputs for the U.S. Environmental Protection Agency's MOVES model. Four tools, along with supporting documentation (*MOVES Tool Documentation*), were also developed to assist MOVES users in developing specific inputs. The Practitioners' Handbook is produced in two volumes:

- ***Volume 1 –*** *Regional-Level Inputs* (for county-scale applications of MOVES); and
- ***Volume 2 –*** *Project-Level Inputs* (for project-scale applications of MOVES).

This Final Report documents the research process for developing the Practitioners' Handbook and tools, and provides additional documentation not included in the handbook.

The objective of NCHRP Project 25-38 is to produce guidelines for transportation practitioners on methods, procedures, and datasets needed to develop and obtain transportation-related regional- and project-level inputs for using MOVES to estimate emissions of criteria pollutants, air toxics, and greenhouse gases. The guidelines are intended for all practitioners at state departments of transportation (DOT), metropolitan planning organizations (MPO), and other air quality agencies that are addressing transportation air quality analyses at the regional or project level. MOVES is the required on-road transportation emissions model for regulatory analysis purposes in the United States outside of California, and is the recommended model for nonregulatory purposes.

The project was undertaken over a two and one-half-year timeframe, from February 2012 through July 2014. The project consisted of a literature review; a survey of MOVES users at state and regional agencies; a sensitivity analysis of MOVES outputs to various inputs; investigation of datasets that could be used for MOVES input development; and the development of the Practitioners' Handbook. The document includes detailed examples for each input and is accompanied by tools to assist users in developing some inputs.

The research focused on the development of inputs for MOVES2010a (and version 2010b, which contained minor updates). The project was completed just as MOVES2014 was being released by the U.S. Environmental Protection Agency (EPA). Information is included in the document about important ways in which MOVES2014 input requirements may differ from MOVES2010 requirements, and about updates to the "default" data embedded in MOVES. However, MOVES2014 does not contain major changes in input requirements compared to

MOVES2010, and the information in the Practitioners' Handbook should continue to be relevant to MOVES2014.

EPA has published guidance on the use of MOVES for regulatory purposes, including State Implementation Plan (SIP) inventory development, regional conformity analysis, and hotspot analysis, as well as nonregulatory purposes, including greenhouse gas (GHG) analysis. The Practitioners' Handbook cites any recommended input data sources or methods contained in those guidance documents. However, the Practitioners' Handbook also identifies other potential data sources and processing options, and includes some examples illustrating these options. While these other data sources may be appropriate for regulatory use, inclusion in the Practitioners' Handbook does not imply endorsement for such purposes. EPA, through the MPO or statewide interagency process, will need to approve any data or methods when MOVES is used for regulatory purposes, and MOVES practitioners should ensure they follow standard requirements for consulting with EPA and other agencies in such situations.

The remaining sections of this report include:

- A task-by-task overview of the project work approach (Section 2.0);
- An overview of the literature review (Section 3.0);
- An overview of the method and findings for a survey of practitioners (Section 4.0);
- A description of the Practitioners' Handbook and its development process (Section 5.0);
- Findings of a sensitivity analysis conducted on various MOVES inputs (Section 6.0);
- Documentation of data analysis conducted to support the Practitioners' Handbook, including sources evaluated, analysis methods, and key findings (Section 7.0);
- Documentation of the data processing tools developed (Section 8.0); and
- Additional research and data collection needs to support MOVES input development (Section 9.0).

Appendices to the report include:

- Detailed findings of the literature review by input (Appendix A);
- An annotated bibliography (Appendix B);
- Detailed survey responses (Appendix C); and
- The survey instrument (Appendix D).

In the course of this research the project team identified a number of places were gaps in existing data limit the extent to which the full capabilities of the MOVES model can be utilized. In some cases, these gaps could be addressed through expansion of existing data collection programs, using widely available technologies. In other cases, additional research may be needed to demonstrate new/emerging data collection methods and how they could be adopted to support the use of MOVES. Opportunities for improved data collection and research are shown in Table 1.1.

Table 1.1 Data Collection and Research Opportunities to Support MOVES Input Development

Data or Research Item	Opportunity	Value
Data Collection		
Classified traffic data collection for VMT-based inputs	Develop more robust systems of permanent classification counters, and improve associated reporting of these data.	Support the development of more refined MOVES VMT, source type population, and temporal adjustment inputs.
Speed data and traffic networks	Make traffic management center networks consistent with (or crosswalked to) travel demand model networks.	Allow speeds from private sources to be matched with volume information.
	Acquire speed distributions built from disaggregate data, rather than just average speeds by link and time period.	Support more robust speed distributions representing all vehicles at all times of day.
Heavy-duty vehicle fleets and activity	Acquire data on the fraction of truck traffic that is from locally registered versus out-of-area vehicles, the expected "home" locations of these vehicles (where registered), and the characteristics of these vehicles. License plate surveys or administrative sources may be considered.	Improve characterization of heavy-duty fleet and emissions.
Off-network data	Collect data on vehicle fleets and activity at different facilities, including ports, intermodal terminals, transit centers, truck stops, and park-and-ride lots.	Identify representative characteristics for off-network facilities such as speed profiles and extended idle time, or illustrate ranges in these parameters for different types of facilities.
Research and Methodology Development		
Speed data by source type	Conduct research into whether emerging speed collection methods (such as video or Bluetooth) could link speeds with vehicle type information.	Facilitate development of source type-specific speed distributions.
Speed prediction methods	Test calibration of model speed distributions against an overall distribution of observed speeds on a network.	Improve model speed estimation to support forecast year speed distributions.
Traffic classification methods	Test use of methods such as video, radar, and lidar to combine length-based and axle-based data collection to refine vehicle classifications.	Improve data on observed VMT by vehicle type and source type distributions.
Truck short- versus long-haul populations	Examine broader use of truck registration data to infer use patterns.	Develop better, state-specific estimates of truck short- versus long-haul populations.

2.0 Project Work Approach

This research effort was undertaken in 11 work tasks which are described below. The initial research plan included only a detailed work effort for Tasks 1-4. A Project Panel meeting was held following Task 4, to approve a more detailed work plan for the remainder of the project.

Task 1 – Develop Plan for Reviewing Current Practices and Data Sources for MOVES

The objective of this task was to describe the sources and methods for developing inputs for MOVES and produce a synthesis of the general availability of and practices in use to develop inputs for MOVES for both regional and project-level analysis. Activities included reviewing existing MOVES-related surveys; developing a survey instrument and sampling plan for a new survey of practitioners; and developing a list of relevant documents for a literature review. The survey instrument is provided as Appendix D of this document. Work was initiated in the spring of 2012.

Task 2 – Execute the Approved Task 1 Plan and Collect/ Assemble Information

The objectives of this task were to conduct a literature review, including developing an annotated bibliography and summary of each MOVES input; and to conduct and compile the results of a web-based survey exploring how practitioners are developing (or planning to develop) MOVES inputs and priorities for additional guidance on input development. A summary of the literature review is provided in Section 3.0 of this report, and detailed findings are presented in Appendices A and B. The literature review and survey were conducted during the late spring, summer, and early fall of 2012.

Task 3 – Prepare a Technical Memorandum Summarizing the State of Practice for Developing Inputs for MOVES

The technical memorandum summarized the state of the practice based on the survey results and literature review conducted as part of Task 2. It was developed during the fall of 2012 and provided to the Project Panel for review before proceeding with Task 4.

Task 4 – Interim Report

As part of Task 4, the research team developed an interim report that included a revised version of the Task 3 technical memorandum, as well as a detailed work plan for Phase 2 and a draft outline of the handbook to be developed as the final product. The interim report was developed during the winter of 2013 and was reviewed by the Project Panel at a meeting in April 2013.

Task 5 – Conduct Additional Sensitivity Analysis

A sensitivity analysis was undertaken to test the sensitivity of MOVES outputs to key inputs. The focus was on inputs for which sensitivity findings were not already available. This analysis had two objectives: 1) to provide information to MOVES users to help decide whether expending additional effort to gather more detailed local data is worthwhile; and 2) to assist the project team in determining where to focus resources in developing information and sample datasets. The results of the sensitivity analysis are presented alongside the results of other sensitivity analyses in Section 6.0 of this report. A summary of findings is also provided in the Practitioners' Handbook, and relevant findings are quoted at the beginning of the discussion of each input in the document. The sensitivity analysis was conducted during the late spring and early summer of 2013.

Task 6 – Develop Draft Resource Text

The objective of this task was to develop draft resource document text describing the alternatives for each data input, how to develop the input using alternative methods, and recommended methods in different situations. An outline of the resource document was first approved by the Project Panel. The Project Panel recommended that the resource document be split into two volumes, one addressing the development of regional-scale inputs, and one addressing the development of project-scale inputs. The draft resource document text was developed in the summer and fall of 2013 and early winter of 2014, and was reviewed by the Project Panel at a meeting on January 31, 2014.

Task 7 – Collect and Analyze Data and Develop Sample Datasets

The objectives of this task were to collect and analyze supplemental data that may be used to create MOVES inputs for different situations, and to develop sample datasets that MOVES users could apply as an alternative to developing locally specific data inputs. The datasets that were obtained, evaluated, and analyzed included traffic monitoring data collected by the Federal Highway Administration (FHWA); intelligent transportation systems (ITS) monitoring data collected on freeway systems in two cities (Atlanta, Georgia and Jacksonville, Florida); vehicle trace data from a travel survey in Atlanta conducted using global positioning systems (GPS) technology; aggregated private vendor travel time data in the same two cities; travel demand forecasting model data from these cities; and instrumented vehicle data from a major port, to illustrate the development of off-network inputs. To the extent possible, vehicle activity data were collected from the same two cities so that different datasets could be directly compared.

In addition, a number of potential sources on commercial vehicle fleet and activity data were investigated to determine their utility in refining heavy-duty vehicle inputs.

Section 7.0 of this report describes the data acquisition and analysis process in detail. In some cases, the data sources were successfully used to develop sample MOVES inputs, or to illustrate how such inputs could be developed using local data. Data files are provided in the form of Excel workbooks made available in conjunction with the Practitioners' Handbook, and examples of the use of the data are incorporated throughout the document. In other cases, data sources proved inadequate for developing MOVES inputs, for various reasons. The data analysis was conducted from the summer of 2013 through the winter 2014.

Task 8 – Develop Tools

The objective of this task was to develop tools (spreadsheets, scripts, or other data processing software) that MOVES users can use to translate local data obtained from various sources into MOVES input formats. Four tools were developed:

- **MOVES Operating Mode Data Import Tool –** A utility program that assists MOVES users in taking vehicle trajectories from a traffic simulation model and converting them to operating mode distributions for input to MOVES.
- **MOVES Meteorology Data Import Tool –** A utility program that reads the National Climatic Data Center (NCDC) Local Climatological Data (LCD) in ASCII format and carries out most of the steps to convert it to MOVES temperature/relative humidity CSV input format.
- **MOVES Highway Statistics Analysis Tool –** An Excel workbook that calculates state-level road type distributions and vehicle-miles of travel (VMT) fractions by Highway Performance Monitoring Systems (HPMS) vehicle type, for all 50 states, from data reported by FHWA in the Highway Statistics Series.
- **MOVES VTRIS Analysis Tool –** An Excel workbook that provides summary tabulations from the 2012 Vehicle Travel Information System (VTRIS), for states reporting classified traffic count data to FHWA. This tool provides sample hour and day-of-week VMT fractions by state, road type, and vehicle class.

The opportunities for tool development were limited by the varied nature of local data sources. For example, state and metropolitan travel demand models are often used to develop inputs for VMT, speed distributions, and road type distributions. However, different modeling platforms and data formats are used and it is not practical to develop a tool that would interface with all platforms. Similarly, state registration data come in many formats and it is not possible to develop a single tool that will process all formats. The tools that were developed are described in Section 8.0 of this report and made available in conjunction with the Practitioners' Handbook. Tool development took place during the fall of 2013 and winter and spring of 2014.

Task 9 – Develop Examples

The objective of this task was to develop real-world examples of how MOVES inputs can be developed. While examples are provided throughout the Practitioners' Handbook for each input, the examples in Section 5.0 of the handbook provide a comprehensive overview of all MOVES inputs in one place. Three examples were developed:

- A regional (county)-scale example using limited data (such as might be available in a rural area) (Volume 1, Section 5.1);
- A regional (county)-scale example using more extensive data (such as might be available in an urban area with a well-developed travel model and traffic monitoring system) (Volume 1, Section 5.2); and
- A project-level example including both on- and off-network inputs (Volume 2, Section 5.1).

The examples are meant to be hypothetical rather than representing a particular area or project, although they draw from real-world data. The examples were developed in the spring of 2014.

Task 10 – Develop Draft and Final Practitioners' Handbook, Datasets, and Tools

The objective of this task was to prepare draft and final versions of the Practitioners' Handbook, datasets, and tools. The draft material in Task 6 was updated to incorporate the examples developed in Task 9 and documentation of the tools developed in Task 8. The draft final document, datasets, and tools incorporated Project Panel feedback on the Task 5-9 products, and integrated the products into a cohesive handbook with supporting materials. The draft Practitioners' Handbook was developed in the spring of 2014.

Task 11 – Develop Final Report

The objective of this task was to prepare the final report for the project, documenting the project's approach and activities (this report).

3.0 Literature Review

The literature review for this project was conducted during the spring and summer of 2012. The primary focus was on literature addressing the development of MOVES inputs. However, literature that generally discusses emissions modeling inputs, including data sources, data collection methods, and processing methods, was included as long as it is relevant to the development of MOVES inputs.

Appendix A identifies literature sources relevant to each input and briefly discusses the applicability of the source to developing guidance, tools, and/or data for that particular MOVES input. Inputs are discussed in the following categories:

- Fleet data, including distributions of vehicles by age and vehicle type;
- Regional activity inputs, or inputs that describe vehicle activity for county-level MOVES runs (e.g., for SIP or regional conformity analysis), including VMT distributions by vehicle type, temporal adjustments, road type distributions, and average speed distributions;
- Project-level inputs, or inputs unique to a project-level MOVES run, including link activity (e.g., average speeds or drive schedules), off-network data (e.g., starts), link characteristics, and link source types; and
- Other inputs, including meteorology, inspection and maintenance (I/M) programs, and fuel.

Appendix A also includes a review of three surveys conducted by other organizations on MOVES. These include:

- A 2011 survey by the Association of Metropolitan Planning Organizations (AMPO) regarding various air quality issues, including level of MOVES experience, development of MOVES data inputs, and MOVES training;
- A survey of five MPOs conducted on behalf of FHWA in 2011 to characterize the state of practice for preparing certain MOVES inputs; and
- A survey of Tennessee agencies conducted by the Tennessee DOT.

Appendix B includes an annotated bibliography of the referenced literature sources, with a general description of each source. The various sources can generally be characterized as follows:

- Sources that provide guidance generally accessible to practitioners on the development of MOVES inputs. These primarily include various U.S. EPA guidance documents (sources [28]-[34]). In addition, source [5] (Chatterjee and Miller, 1994), while two decades old now, is noteworthy for providing a comprehensive review of a number of data sources and methods which are still widely used today.

- Sources describing the use of a specific data collection method or study such as GPS, video, or freeway loop detectors, e.g., [1], [7],[19], [24].
- Sources discussing the preparation and use of outputs from travel demand or simulation models, such as [9], [21], [26], and [27].
- Data mining studies that use existing data sources in new ways, such as [8] and [19].

4.0 Practitioners' Survey

4.1 OVERVIEW

As part of the Phase 1 research for this project, a survey was conducted of agencies using or transitioning to the use of MOVES. The survey was conducted in July through September 2012. The objectives of the survey were to characterize how agencies are using the MOVES model, current practices in developing MOVES inputs (including data sources and processing methods), and needs for additional guidance or sample data inputs. This information was used to help identify and prioritize Phase 2 activities, and also to identify tools, data sources, and methods that could be highlighted in the Practitioners' Handbook.

This section provides a summary of the findings of a web-based survey of data sources and current practice for MOVES. Appendix C presents the survey responses in detail, and Appendix D contains the survey instrument.

The survey sample was recruited by distributing the web-based survey to as many transportation and air quality agencies as possible within areas that are subject to, or expected to be subject to, transportation conformity. Organizations that represent MOVES stakeholders in these communities assisted with distributing the survey, including the Association of Metropolitan Planning Organizations, American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on the Environment, AASHTO Air Quality Subcommittee, and the National Association of Clean Air Agencies. Survey information was also distributed at the Northern Transportation Air Quality Summit August 6-8, 2012 by members of the NCHRP 25-38 panel. Efforts were made to obtain survey responses from a cross-section of agencies by geographic region of the country and size of population served (both metropolitan and state). While the survey was primarily distributed by email, some phone calls were made to attempt to recruit agencies from categories underrepresented in initial responses, such as smaller MPOs.

After presenting respondents and uses of MOVES, the discussion of survey results is categorized into fleet data, regional activity inputs, and project activity inputs to mirror the organization of the literature review. For most survey questions there were about 70 responders for each question. Because most MPOs do not do project-level studies, the response rate dropped to about 50 for many of the questions related to project-level inputs.

4.2 RESPONDENTS AND USES OF MOVES

Seventy-nine responses were received representing up to 38 MPOs, 14 state DOTs, 22 state air agencies, and 5 agencies of other types, including city DOTs, metro air districts, and county public health agencies. (Not all respondents identified the name of their agency, and in a few cases, two people at a single agency responded.) As anticipated in the design of the sampling plan, the sample is biased toward regions or agencies that are subject to the requirements of transportation conformity, with enough staff and resources to have developed some familiarity with MOVES.

- About two-thirds of the respondents represented either MPOs with populations exceeding one million, or state or multistate jurisdictions. However, representation was also obtained from areas of other sizes, and 12 percent of respondents represented agencies serving a population under 200,000.
- Only three respondents indicated that their area was in full attainment of ambient standards for carbon monoxide (CO), ozone, and particulate matter (PM_{10}, $PM_{2.5}$). The remainder represented areas that were fully or partially classified as nonattainment or maintenance areas.
- More than half of the respondents indicated that they already had used MOVES, and most of the rest were transitioning to or planning to use MOVES. Only 4 percent indicated that they had no intent to use MOVES.
- The most common applications of MOVES were for SIP development and regional transportation conformity, with the majority of respondents using MOVES for both purposes. About 45 percent were using or planned to use MOVES for greenhouse gas analysis or policy/legislative evaluation. About 20 percent planned to use MOVES for mobile source air toxics (MSAT) analysis, either at a regional or project level.
- Very few agencies (4 percent of respondents) had used MOVES for project-level analysis, although 40 percent planned to use it at this level for conformity analysis, and about 30 percent planned to use it for environmental assessment/documentation or GHG analysis.

Fleet Data Inputs

Locally derived data, primarily state vehicle registration databases, were the most common source for age distribution inputs. For light-duty vehicles, 75 percent of respondents used either local data for age distributions, or a combination of locally derived data and MOVES defaults. For heavy-duty vehicles, 64 percent made some use of local data.

Similarly, the majority of agencies were using state registration data for vehicle source type distributions. MOVES defaults were often used with the local data to fill in gaps where needed. For example, MOVES default distributions may be used to proportion the light-duty truck population into the subset used as passenger vehicles and the subset used as commercial vehicles.

Regional Activity Inputs

About half of all respondents (51 percent) were using both travel demand forecasting model (TDFM) and HPMS data to estimate regional VMT by source type, while most of the rest (41 percent) were using one of these sources alone. Source type distributions were estimated from data on vehicle class groups, which were then disaggregated into the 13 MOVES vehicle classes using a surrogate data source. The most common surrogates used were the MOVES default source type distributions, source type distributions adopted from MOBILE, or state vehicle registration data. Table 4.1 summarizes responses on surrogate data sources. Based on comments provided, "other" responses typically indicated that data from another agency or MOBILE6.2 data were used.[1]

Table 4.1 Surrogate Data Used to Map VMT to MOVES Source Types

	Frequency	Percentage
MOVES defaults	17	29%
Registration data	11	19%
Other	17	29%
No surrogates used	3	5%
Don't know	11	19%

The source for VMT-by-month fractions and day-of-week fractions was fairly evenly split among HPMS data, MOVES defaults, and "other." The comments supplied with the "other" responses indicated that many MPOs were receiving these data from state agencies, and that often the data were from permanent traffic count stations which may or may not be part of the HPMS system. The source for VMT-by-hour fractions followed this same pattern with the difference that 11 percent of the responders indicated that VMT-by-hour fractions were derived from the TDFM or from traffic studies.

Many agencies used a mix of data sources for the road type distribution and ramp fraction inputs. The most common were the TDFM and HPMS data, or some combination of the two. Fifteen percent of respondents reported using MOVES defaults for these data. The source for VMT by speed bins was also dominated by TDFM and HPMS data, with 20 percent of respondents reporting using MOVES defaults for these data. Of those using TDFM output to estimate

[1] Throughout the survey, respondents who answered "other" often mentioned that they got the data from another agency, so use of the "other" category does not necessarily mean that a different underlying data source was used.

speed data, about 30 percent reported postprocessing the model results to improve the results for use with MOVES.

Project-Level Inputs

Link activity estimates are derived from a variety of sources. The most common source of traffic volume data reported was TDFM output (one-third of responders). Based on the comments, contractor data was also used, which suggests that volume data is probably being taking directly from traffic impact studies. For source type data, about 15 percent used local classified traffic counts; the remainder took data from state or regional analysis, MOVES defaults, or another source. Age distribution data was almost always from state-level or default sources.

For operating mode and vehicle speed data, 46 percent of respondents reported using TDFM speeds and 30 percent reported using either Highway Capacity Manual (HCM) and/or microsimulation to determine project-level speeds. Only 4 percent of respondents had developed vehicle-specific power (VSP) profiles for use in project-level analysis.

Responders had little experience with off-network activity estimates (including start fraction, parked fraction, and extended idle fraction). Eighty-one percent reported that their agency either had not estimated off-network data or did not know if their agency had done this.

Other MOVES Inputs

For temperature and humidity inputs, about one-third of respondents reported using National Climatic Data Center data and 44 percent reported using locally obtained data. For areas with an I/M program, about three-quarters developed program-specific inputs rather than using MOVES defaults. For fuel data, most respondents reported using data from local and/or state sources; only 17 percent reported using MOVES defaults.

About one-quarter of respondents reported that they had performed some type of sensitivity testing on MOVES inputs.

Input on NCHRP 25-38 Project Outcomes

Respondents were asked what datasets or methods/guidance would be the most important to their agency. Over 60 percent identified age distributions by vehicle class, source type population, and regional vehicle class splits as being “very important.” In contrast, just under one-third identified project-level vehicle class splits or project-level operating mode distributions as “very important.” This appears to reflect the more widespread use of MOVES for regional-level as compared to project-level analysis; however, guidance on these inputs was still important for those who plan to use MOVES at a project level. Meteorology data was also identified as “very important” by one-third of respondents. A variety of other free-response answers were provided to this question.

About one-third of respondents said they would prefer data sets to be provided as part of MOVES, with about one-half preferring another publication or on-line data center. Comments provided suggested that this might depend upon the specific dataset, timeliness of updates, etc.

Observations and Trends

There was no established best practice for estimating MOVES inputs identified in the survey. The majority of agencies appeared to be using the best data that is readily accessible. Where that information is insufficient, it is often augmented by MOVES defaults. Commonly used sources are the same as were often used for developing MOBILE inputs, e.g., HPMS, travel demand forecasting models, and state vehicle registration data, which rarely provide the full level of detail that MOVES is capable of accepting. New, locality-specific data collection efforts focused specifically on MOVES requirements have not been widely undertaken.

The bulk of experience to date with MOVES is in performing regional analysis by agencies with a history of doing similar work with MOBILE. That experience is also predominantly with criteria pollutants to meet SIP and regional conformity requirements. There is less interest in expanding the use of the model to MSAT or GHG analysis where there is not a clear requirement to do so, although a number of agencies are still planning to use MOVES for these purposes.

Project-level analysis is likely to be conducted by project sponsors (such as state or local DOTs) when required, rather than by MPOs. Very few agencies have experience with developing locally specific inputs for project-level analysis.

The Practitioners' Handbook is intended to help agencies fill in some gaps by showing how available data sources can be used to develop more detailed locality-specific MOVES inputs. It also provides agencies that are less familiar with common practice in developing emissions model inputs with information on how such inputs can be properly developed from commonly available data sources. Finally, it provides some sample data sets that agencies may be able to use to more closely represent local conditions than the data embedded in MOVES, with minimal additional effort on their part.

5.0 Practitioners' Handbook

The primary product of this research is a Practitioners' Handbook intended to assist MOVES users in developing local inputs. The resource document is presented in two parts: Volume 1 – Regional-Level Inputs (i.e., using the County Data Manager), and Volume 2 – Project- Level Inputs. Each volume includes the following sections:

- An introduction;
- An overview of MOVES inputs, including the name of the input as used in MOVES, a description, and EPA guidance;
- Sensitivity of model outputs to inputs, providing a summary of findings to help users understand which inputs may be most important to refine local data;
- Development of local input data, providing detailed information on alternative data sources for each input;
- Examples, providing comprehensive examples of the development of all MOVES inputs for hypothetical regional and project-level situations;
- References; and
- Acronyms.

Within the section on development of local input data, each volume has a subsection for each of 10 inputs. These inputs are listed in Table 5.1. The age distribution, meteorology, fuel, and I/M program inputs are substantially similar for both regional and project-level applications, but were repeated so that each volume functions as a stand-alone document.

Table 5.1 MOVES Inputs by Volume

Volume 1 – Regional Level	Volume 2 – Project Level
1. Age distribution	1. Age distribution
2. Source (vehicle) type population	2. Link source types
3. VMT	3. Link characteristics: traffic volumes
4. Temporal adjustments	4. Link characteristics: length and grade
5. Road type distribution	5. Link characteristics: average speed
6. Ramp fraction	6. Operating mode distributions and drive schedules
7. Average speed distribution	7. Off-network data
8. Meteorology	8. Meteorology
9. Fuel formulation and supply	9. Fuel formulation and supply
10. Inspection and maintenance programs	10. Inspection and maintenance programs

For each input, the following information is provided:

- Description and format;
- EPA guidance and source of data embedded in MOVES;
- Overview of data source options;
- Data sources, procedures, and methods;
- Sample data and tools; and
- Examples.

As previously noted, the overall research for this project was conducted in two phases. As part of the scoping for Phase 2, a list of potential activities was developed that could assist MOVES users in understanding different input data sources and contribute to the Practitioners' Handbook. These possible activities ranged from collecting and analyzing sample data, to showing how existing data sources could be combined to develop MOVES inputs, to conducting research and demonstration on new data collection methods. These candidate activities were evaluated according to level of effort and priority, where priority considered the importance of the data source (impact on outputs) and the extent to which guidance or improvements to the data source would be useful. The outcomes of this evaluation were documented in the Phase I Interim Report for the project (not published). Input from the NCHRP Project Panel was then used to shape the final set of activities undertaken as part of Practitioners' Handbook development in Phase 2.

6.0 Sensitivity Analysis

As part of this work, a sensitivity analysis was undertaken to test the sensitivity of MOVES outputs to key inputs. The focus was on inputs for which sensitivity findings were not already available. The sensitivity analysis examined the sensitivity of model outputs (emission rates) to the specific input parameters when they are varied across a typical range that might be observed in the real world. This analysis had two objectives: 1) to provide information to MOVES users to help decide whether expending additional effort to gather more detailed local data is worthwhile; and 2) to assist the project team in determining where to focus resources in developing information and sample datasets.

The Volpe Center and FHWA completed a sensitivity analysis for regional inputs in 2012 and were performing a similar analysis for project-level inputs, with results expected in 2014. All results in these studies are shown by the 13 source types. EPA has conducted a MOVES sensitivity analysis for temperature and humidity only. ERG also conducted a sensitivity analysis for the Coordinating Research Council (CRC) that examined how MOVES outputs change across the distribution of county-inputs provided by states for the 2011 National Emissions Inventory (NEI). A handful of other analyses conducted by MOVES users were also identified in the literature review and survey conducted in Task 2 of this project.

All of these sensitivity analyses were conducted using some version of MOVES2010. There may be minor differences in some impacts if the same analyses were conducted using MOVES2014. The overall conclusions, however, should not change significantly.

6.1 Scenarios Modeled

Sensitivity analyses were performed on the following MOVES inputs:

- **Source type population (Scenarios 1-4).** Independent of other inputs, source type population primarily influences off-network nonrunning emissions (e.g., start, evaporative, extended idle). Because there can be considerable effort in developing this input to accurately reflect all 13 source types, the project team examined the impacts of uncertainty in specific source type population fractions. Four input datasets were defined that reflect different amounts of light- versus heavy-duty vehicles (Scenario 1), passenger cars versus light-duty trucks (Scenario 2), single-unit versus combination trucks (Scenario 3), and short- versus long-haul trucks (Scenario 4).
- **Road type and average speed distributions (Scenarios 5 and 6)**. For these input tables two input data sets were defined that illustrate varying levels of

source type information, as described in Table 6.1. All other variables were held constant.

- **Month, day-of-week, and hour VMT fraction temporal adjustments (Scenarios 7-9).** The effects of time-of-day and seasonal distributions on emissions depend upon variations in temperature and humidity over the day or across seasons. Alternative input data sets were tested reflecting different month VMT fractions and hour VMT fractions to illustrate the importance of more detailed temporal adjustments. These specific percentage adjustments are listed in Table 6.1.
- **Grade (Scenarios 10-15).** Road grade is a new input for MOVES and not all users are familiar with data sources to develop this input or know what its impact might be. The project team selected six different scenarios to illustrate the effects of grade on emissions from different source types, ranging from -6 percent to +6 percent grade in 2 percent intervals.

For each of these scenarios, MOVES was run with alternative input datasets and the percentage differences in results of total emissions (running and nonrunning) for key pollutants (VOC, CO, NO_x, CO_2, and PM_{10})[2] compared across the range of inputs. The percent change in emissions for each pollutant was computed relative to the emissions using base case inputs as described in the next section.

For Scenarios 1-4, VMT was adjusted in addition to population. This was accomplished by taking the miles per vehicle ratio from the base case, modifying the population for each case, and multiplying the base ratio by the modified population to arrive at representative VMT. The road grade results (Scenarios 10-15) do not include evaporative emissions because MOVES project-level outputs do not include these emissions. Table 6.1 summarizes the scenarios.

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[2] While the sensitivity analysis was run with PM_{10} as the output, the percentage impacts should be identical or nearly identical for $PM_{2.5}$.

Table 6.1 Scenarios for Sensitivity Testing

Input	Scenario No.	Description
Source Type Population	1	Double the percentage of vehicles within heavy-duty source types (41-62) and reduce light-duty vehicles (11-32) by the amount of the heavy-duty increase.
	2	Shift 20% of passenger cars from passenger cars (21) to passenger trucks (31).
	3	Shift 25% of trucks (source types 51-62) from single-unit trucks (52 and 53) to combination trucks (61 and 62).
	4	Shift 25% of trucks from short-haul trucks (52 and 61) to long-haul trucks (53 and 62).
Source Type Detail	5	Make the road type distribution the same for all source types (as opposed to the MOVES national defaults, which have different road type distributions by six HPMS vehicle types). The road type distribution for passenger cars (21) was applied to all vehicle types.
	6	Change Average Speed Distribution input to account for slower relative speed of trucks compared to light-duty vehicles. Made heavy-duty vehicles (40-60) 5 mph slower than light-duty (10-30). Since speed bins in the model are demarcated in 5 mph increments, this was done by setting speed bin 16 to zero, adding speed bins 1 and 2 together, and shifting remaining fractions down one speed bin.
Temporal Adjustments (month and hour VMT fractions)	7	Change Month VMT Fractions to make summer (June to August) account for 5% more than MOVES defaults (27.4%). Decreased equal amount from all other months.
	8	Change Month VMT Fractions to make winter (December to February) account for 5% more than MOVES defaults (22.3%). Decreased equal amount from all other months.
	9	Change Hour VMT Fractions to show more overnight and early morning traffic (11% more on weekdays, 9% more on weekends for 8 p.m. to 8 a.m. time intervals).
Road Grade	10-15	Road Grade = -6%, -4%, -2%, +2%, +4%, +6%. Repeated for urban restricted and unrestricted access road types.

6.2 Base Case Inputs

The following base cases were used: Scenarios 1-6 were compared to a nationwide *July weekday* base case, while Scenarios 7-9 were compared to a nationwide *annual* base case. Scenarios 10-15 were compared to a project-level base case. The base cases depended heavily upon national default values embedded in MOVES. In Scenarios 7-9, the analysis was run for two counties – Suffolk, Massachusetts and Harris, Texas, since the widely varying meteorological inputs across counties could wash out temporal effects when run at the national scale. Scenario 7 was run for Harris County, to test the effects of a shift towards more summer VMT in a hot climate, and Scenario 8 was run for Suffolk County, to test the effects of a shift towards more winter VMT in a colder climate. Table 6.2 shows the specific base case assumptions used for each scenario.

Table 6.2 Base Case Inputs

Parameter	Scenarios 1-6	Scenarios 7-9	Scenarios 10-15
Year	2010	2010	2020[a]
Month	July	All months	July
Day	Weekday	Weekday and weekend	Weekday
Hour	All 24 hours	All 24 hours	Noon to 1 p.m.
Geographic Bounds	Nation	Suffolk County, Massachusetts and Harris County, Texas	Washtenaw County, Michigan
Road Type(s)	All	All	Urban arterial and urban highway
Vehicles/Fuel Type	All combination of gasoline and diesel vehicles available in MOVES plus CNG transit buses		
Age Distribution	1999 National defaults	1999 National defaults	County default
Average Speed Distribution	National default	National default	N/A
Fuel	National default	Local default	County default
Road Type Distribution	National default	National default	N/A
Ramp Fraction	National default	National default	N/A
I/M Program	National default	Local default	County default
Vehicle Type VMT	National default	Local default	N/A
Source Type Population	National default	National default	N/A
Temperature	National default	Local default	Local default
Humidity	National default	Local default	Local default
Links	N/A	N/A	2 links, 0.5-mile length, 500 vehicle volume, 30 mph average speed, road types 4 and 5
Link Source Type	N/A	N/A	2 links, derived from EPA project-level MOVES example
Link Drive Schedule	N/A	N/A	Default

[a] 2020 was selected rather than 2010 because the project-level scenarios were based on an EPA project-level example using 2020 inputs, and the post-2012 fuel type inputs are simpler.

6.3 OUTPUT SUMMARIES BY SCENARIO TYPE

The following section presents summary tables for each model input that was varied. Supporting data are provided in Section 6.5.

Source Type Populations

Table 6.3 shows the effects of source type population on emissions (Scenarios 1-4).

Table 6.3 Effects of Source Type Population on Emissions

Scenario	Description	VOC	CO	NO_x	CO_2	PM_{10}
1 – Light- versus heavy-duty vehicles	Double the number of vehicles within heavy-duty source types (40-60) and reduce light-duty vehicles (10-30) correspondingly.	6.90%	4.40%	35.60%	19.72%	66.30%
2 – Passenger cars versus trucks	Shift 20% of passenger vehicles from passenger cars (21) to passenger trucks (31).	1.59%	2.41%	1.16%	-0.06%	0.67%
3 – Single-unit versus combination trucks	Shift 25% of trucks from single unit trucks (52 and 53) to combination trucks (61 and 62).	2.21%	-0.40%	13.65%	8.52%	22.89%
4 – Short-haul versus long-haul trucks	Shift 25% of trucks from short-haul trucks (52 and 61) to long-haul trucks (53 and 62).	2.12%	-0.42%	7.77%	5.66%	9.70%

Note: Table shows the percent change in composite emissions (all source types) compared with a base case of national source type distribution embedded in MOVES.

Scenario 1 doubles the fraction of heavy-duty vehicles from 4.4 to 8.8 percent. This results in a substantial increase in NO_x, CO_2, and PM_{10} emissions (up to 66 percent) and a modest to moderate increase in VOC and CO emissions of 4 to 7 percent.[3]

Scenario 2 decreases the fraction of passenger cars and increases the fraction of passenger trucks by about 9 percent of all vehicles. The impact is modest, with all pollutants increasing by less than 3 percent.

Scenario 2 shows a slight reduction in CO_2 emissions – a counterintuitive outcome since light trucks on average have lower fuel economy and higher CO_2 emissions than passenger cars. This is because in all scenarios, emissions may change not only because of the differences in emission rates between vehicle types, but also because of differences in the average distance driven per vehicle. For example, passenger trucks are driven about 30 percent less, on average, than

[3] In this discussion, "modest" means less than 5 percent; "moderate" means 5 to 15 percent; "substantial" means 15 to 50 percent; and "very substantial" means greater than 50 percent.

passenger cars (as represented in the MOVES default data – 30.8 versus 43.3 miles per vehicle per day). For passenger trucks versus cars driven the same distance, the emissions differences would be higher than those shown. MOVES users should ensure that VMT fractions reflect actual distances driven by vehicle type, rather than source type populations.

Scenario 3 reduces the number of single-unit trucks by about six-tenths of a percent of all vehicles, and increases the number of combination trucks by the same amount. The impact is a moderate to substantial increase in NO_x, CO_2, and PM_{10} (up to 23 percent). Changes in VOC and CO are modest. The slight reduction in CO is likely due to the larger fraction of diesel vehicles in the combination truck category, compared to single-unit trucks which include a substantial fraction of gasoline vehicles.

Scenario 4 reduces the number of short-haul trucks by about six-tenths of a percent of all vehicles, and increases the number of long-haul trucks by the same amount. The impact is a moderate increase in NO_x, CO_2, and PM_{10} of up to 10 percent. Changes in VOC and CO are modest.

The impact of shifts in the heavy-duty vehicle population segment is greater than might be expected considering only the fraction of the vehicle population. This is because heavy-duty vehicles are driven much longer distances per vehicle, on average, than light-duty vehicles. For example, while the base source-type fraction of heavy-duty vehicles is 4.4 percent, the base VMT fraction is 7.6 percent.

While only one set of alternative assumptions was analyzed for each pollutants, the results of different assumptions should be linear: for example, shifting 50 percent of trucks from single-unit to combination, instead of 25 percent, should double the NO_x increase to about 27 percent.

Road Type and Average Speed Distributions

Table 6.4 shows the effects of road type and average speed distributions by source type on emissions. Changing the road type distribution to be the same for all source types (Scenario 5) has a modest impact on all pollutants except PM, for which the impact is moderate (around 10 percent in this scenario). If the average speed distribution is adjusted to assume that trucks travel slower than other vehicles (Scenario 6), the impact is roughly a 6 percent increase in PM_{10} and a 1 to 2 percent increase in other pollutants.

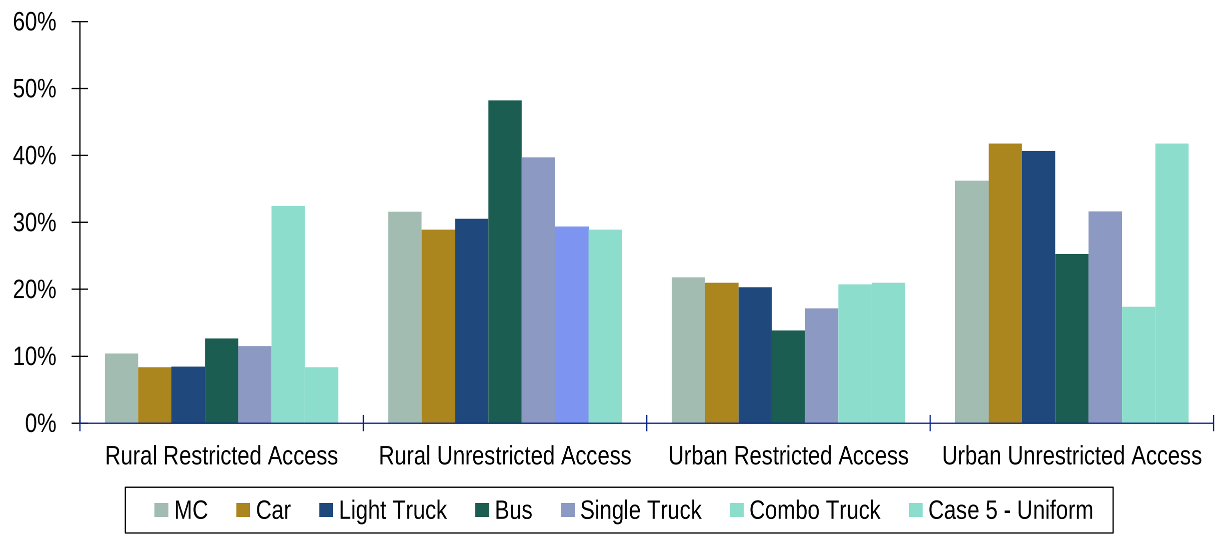
Table 6.4 Effects of Road Type and Average Speed Distributions by Source Type on Emissions

Scenarios	Description	VOC	CO	NO_x	CO_2	PM_{10}
5 – Road Type Distribution	Make the road type distribution the same for all source types as opposed to the MOVES national embedded distributions.	1.88%	0.64%	3.88%	1.83%	10.42%
6 – Average Speed Distribution	Reduce heavy-duty vehicle speed distribution by 5 mph.	1.22%	0.43%	2.36%	1.09%	5.67%

Note: Table shows the percent change in composite emissions (all source types) compared with a base case of national road type and speed distributions embedded in MOVES.

Figure 6.1 illustrates the road type distributions in the default (MOVES embedded assumptions) and Scenario 5 (uniform distribution) scenarios. Scenario 5 results will be driven by differences in road type distributions for trucks compared to the Scenario 5 uniform case, which is the same as the distribution for cars. For example, the MOVES defaults show a higher fraction of truck traffic on rural roads compared to Scenario 5. The increase in emissions in Scenario 5 may be largely due to the greater amounts of travel on urban roadway with low speeds and high emission rates (left side of the U-shaped emission rate curve) and especially urban unrestricted access roads, which involve more transient driving.

Figure 6.1 MOVES Embedded Road Type Distributions versus Scenario 5



Temporal Adjustments

Table 6.5 shows the effects of temporal adjustments on emissions. Changing the month fractions has a very modest effect on emissions of all pollutants – less than 1 percent in nearly all cases, except for PM_{10} in the cold climate winter month shift, which increased by about 2 percent. Changing the hour VMT fractions also had a very modest effect on overall emissions – about 1 percent or less for all pollutants for the scenario analyzed. While larger impacts will likely be seen for episodic events (e.g., very hot summer days), these results suggest that the effects of temporal distributions on *annual* emissions at a regional scale will be very modest. The direction of the effect varies by pollutant since different pollutants are affected differently by the temperature and humidity changes that occur across hours and months.

Table 6.5 Effects of Temporal Adjustments on Emissions

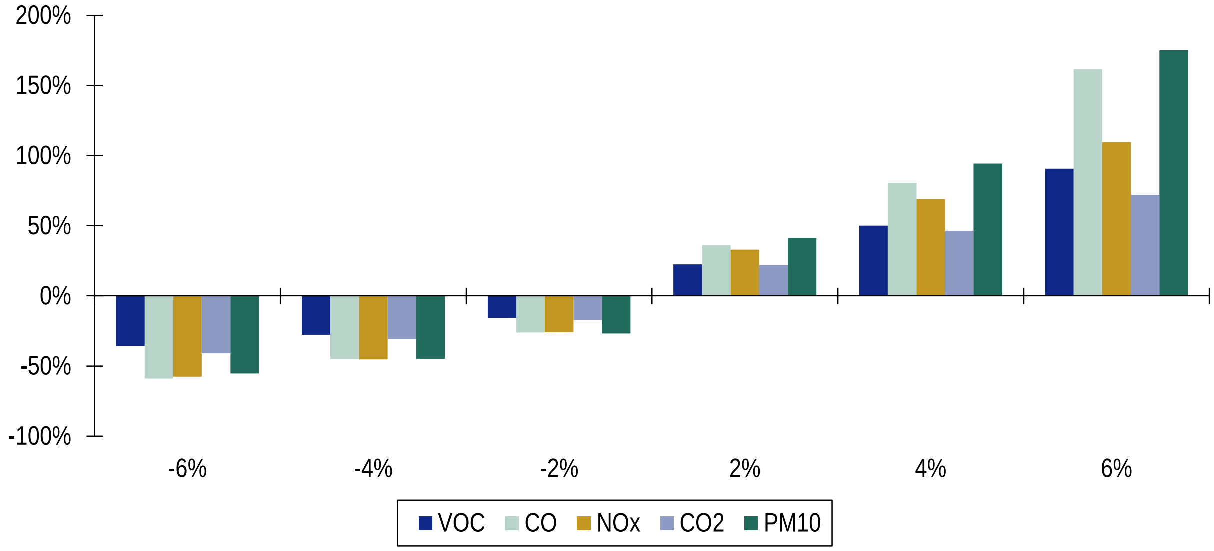
Scenario	Description	VOC	CO	NO_x	CO_2	PM_{10}
7 – Month Fractions (Summer)	Change Month VMT Fractions to make summer (June to August) account for 5% more than MOVES defaults (27.4%). Decrease equal amount from all other months. (Harris County, Texas)	0.08%	0.75%	0.10%	0.42%	-0.42%
8 – Month Fractions (Winter)	Change Month VMT Fractions to make winter (December to February) account for 5% more than MOVES defaults (22.3%). (Suffolk County, Massachusetts)	0.03%	0.67%	0.30%	-0.07%	1.90%
9 – Hour Fractions	Change Hour VMT Fractions to show more overnight and early morning traffic (8 p.m. to 8 a.m., 11% more on weekdays, 9% more on weekends). (Harris County, Texas and Suffolk County, Massachusetts)	-0.29% -0.21%	-1.05% -0.36%	-1.07% -0.40%	-0.75% -0.44%	0.39% 0.97%

Note: Table shows the percent change in composite emissions (all source types) compared with a base case of road type and speed distributions embedded in MOVES.

Road Grade

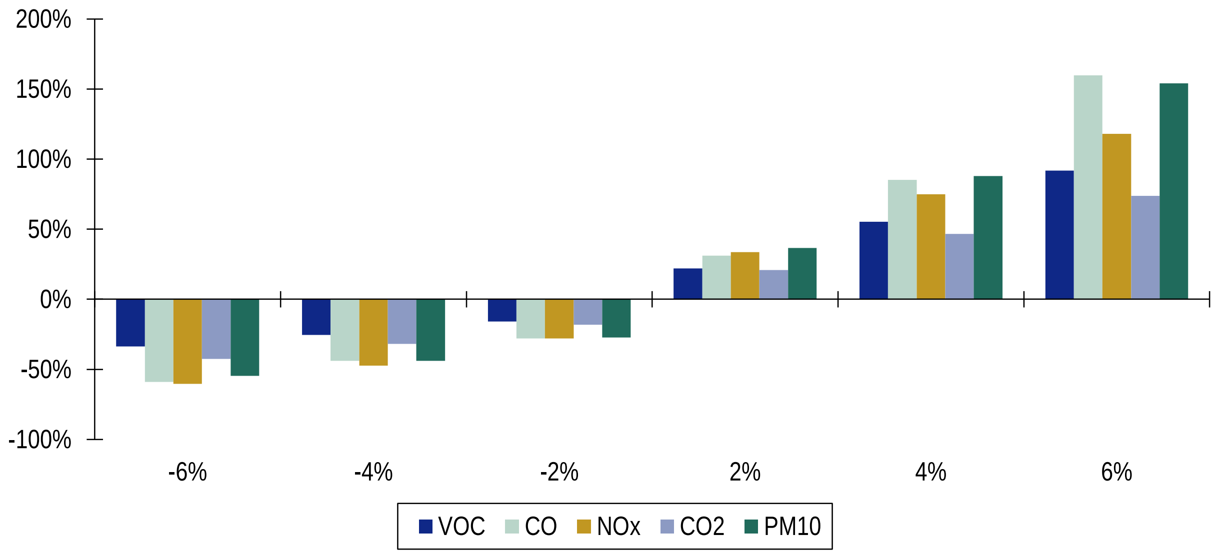
Figures 6.2 and 6.3 show the effects of road grade on emissions. The impact is substantial or very substantial at all grades tested, with emissions decreasing by up to about half on downhill grades, and increasing by 50 to 100 percent or more on steeper uphill grades. Impacts are of similar magnitude for unrestricted and restricted access roadways.

Figure 6.2 Percent Change in Emissions by Road Grade
Urban Unrestricted Access Roads



Note: Figure shows the percent change in composite emissions (all source types) compared with a base case of zero percent road grade. Emissions are for a 0.5-mile roadway link with average speed 30 mph.

Figure 6.3 Percent Change in Emissions by Road Grade
Urban Restricted Access Roads



Note: Figure shows the percent change in composite emissions (all source types) compared with a base case of zero percent road grade. Emissions are for a 0.5-mile roadway link with average speed 30 mph.

6.4 Comparison with Previous Sensitivity Analysis

Table 6.6 presents the results of this sensitivity analysis alongside the results of the sensitivity analyses conducted by the Volpe Center for FHWA,[4] by EPA staff,[5] and by ERG for the CRC.[6] The factors analyzed in this analysis were specifically chosen to fill in gaps from the Volpe work (the CRC research was published after the analysis was conducted). The focus here is on fleetwide composite emissions across all source types, whereas the Volpe study showed how emissions varied for each source type. The Volpe study also looked at running emissions only for most pollutants, with start emissions evaluated separately for meteorological inputs. The results presented here combine emissions from different processes. The EPA study looked specifically at the impact of meteorological inputs on emissions for gasoline and diesel vehicles.

Emissions impacts in Table 6.6 are characterized as "modest" (less than 5 percent), "moderate" (5 to 15 percent), "substantial" (15 to 50 percent), and "very substantial" (greater than 50 percent) compared to the indicated base case. Because presenting data for 13 source types would be overwhelming, representative results from the Volpe study are presented for passenger cars (PC) and long-haul combination trucks (CT).

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[4] Noel, G., and R. Wayson (2012). *MOVES2010a Regional-Level Sensitivity Analysis*. Volpe National Transportation Systems Center, prepared for Federal Highway Administration, DOT-VNTSC-FHWA-12-05.

[5] Choi, D., et al (undated). *MOVES Sensitivity Analysis: The Impacts of Temperature and Humidity on Emissions*. U.S. Environmental Protection Agency.

[6] Coordinating Research Council Project A-84: *Study of MOVES Inputs for the National Emissions Inventory*.

Some key findings from the various studies include:

- Age distribution has a substantial impact for passenger cars and a moderate impact for trucks.
- For source-type populations, the most important parameter is the split of light- versus heavy-duty vehicles. Single-unit versus combination trucks can be important for NO_X and PM, and short- versus long-haul split has somewhat lesser but still moderate importance for these pollutants. Impacts of truck splits on VOC are modest.
- The effects of temporal adjustments (month and hour fractions) on annual emissions at a regional scale will be very modest.
- Changing the road type distribution by source type has a modest to moderate impact.
- Changing ramp fractions has a modest impact on all pollutants, except the impact on passenger car PM is substantial.
- Changing the average speed distribution to reflect different congestion levels can have a substantial impact on most pollutants for both cars and trucks. The impact is less significant for NO_X than for VOC and PM.
- Road grades have a substantial or very substantial impact on all pollutants.
- The impact of meteorology (temperature and humidity) varies greatly depending upon the pollutant, process, source type, and temperature range.

Table 6.6 Combined Sensitivity Analysis Results

MOVES Input	Source	Base Case	Comparison Made	VOC	NO_x	PM
Fleet Inputs						
Age Distribution by Vehicle Class	Volpe/FHWA	2010 National Default Age Distribution	Move 10% of vehicles to Group 1 (0-10 years); Move 10% of vehicles to Group 2 (11-20 years); Move 5% of vehicles to Group 3 (21-30 years); completed for several vehicle types	PC: Substantial (-29% to +24%) CT: Moderate (-5% to +6%)	PC: Substantial (-20% to +16%) CT: Moderate (-9% to +9%)	PC: Substantial (-19% to +21%) CT: Moderate (-7% to +7%)
Age Distribution by Vehicle Class	ERG/CRC	Submittals for 2011 NEI	Increase average age from 10th to 90th percentile	Very Substantial (+55% HC)	Substantial (+40%)	Substantial (+45%)
Source (Vehicle) Type Population:						
Light versus Heavy-Duty Vehicles	CS/ERG	2010 National Default Source Type Distribution	Double HD vehicles and reduce LD vehicles correspondingly	Moderate (+7%)	Substantial (+36%)	Very substantial (+66%)
Passenger Cars versus Trucks			Shift 20% of passenger vehicles from cars (21) to trucks (31)	Modest (+2%)	Modest (+1%)	Modest (+1%)
Single-Unit versus Combination Trucks			Shift 25% of trucks from single unit to combination	Modest (+2%)	Moderate (+14%)	Substantial (+23%)
Short-Haul versus Long-Haul Trucks			Shift 25% of trucks from short-haul to long-haul	Modest (+2%)	Moderate (+8%)	Moderate (+10%)
Source (Vehicle) Type Population:	ERG/CRC	Submittals for 2011 NEI	Increase source type fraction of total population from 10th to 90th percentile	Substantial (+45% HC)	Moderate (+14%)	Moderate (+14%)
Regional Activity Inputs						
Regional VMT by vehicle class	ERG/CRC	Submittals for 2011 NEI	Increase HPMS type fraction of total VMT from 10th to 90th percentile	Substantial (+40% HC)	Very Substantial (+110%)	Very Substantial (+150%)
Temporal Adjustments:						
Month VMT Fractions	CS/ERG	Default Month Distribution	Change Month VMT Fractions to make summer (Jun-Aug) or winter (Dec-Feb) account for 5% more than MOVES defaults (27.4%). Decrease equal amount from all other months	Modest (<1%)	Modest (<1%)	Modest (<2%)

MOVES Input	Source	Base Case	Comparison Made	VOC	NO_x	PM
Hour VMT Fractions	CS/ERG	Default Hour Distribution	Change Hour VMT Fractions to show more overnight traffic (8 p.m.-7 a.m., 11% more on weekdays, 9% more on weekends)	Modest (<1%)	Modest (<1%)	Modest (<1%)
Regional Activity Inputs (continued)						
Road Type Distribution	CS/ERG	MOVES National Embedded Distributions	Make the road type distribution the same for all source types	Modest (+2%)	Modest (+4%)	Moderate (+10%)
Ramp Fraction	Volpe/ FHWA	National Default (0.08)	0, 0.02, 0.04, 0.06, 0.10, 0.12 0.16, 0.20	Modest (-3% to +4%)	Modest (-2% to +3%)	PC: Substantial (-15% to +22%) CT: Modest (-3% to +5%)
Average Speed Distribution	Volpe/ FHWA	National Default Speed Distribution for Urban Interstate	LOS B, C, D, E, F	PC: Substantial (-14% to +33%) CT: Substantial (-29% to +49%)	PC: Moderate (-1% to +6%) CT: Substantial (-6% to +21%)	PC: Substantial (-6% to -16%) CT: Substantial (-20% to +53%)
Average Speed Distribution	CS/ERG		Reduce HD vehicle speed by 5 mph	Modest (+1%)	Modest (+2%)	Moderate (+6%)
Average Speed Distribution	ERG/CRC	Submittals for 2011 NEI	Decrease average speed from 90th to 10th percentile	Moderate (+8% HC)	Moderate (+10%)	Substantial (+16%)
Project-Level Inputs						
Project-Level Link Activity (Average Speed, Drive Schedules, or Operating Mode Distributions)	Volpe/ FHWA		TBD			
Off-Network Data (Start Fraction, Extended Idle Fraction, Parked Fraction)	Volpe/ FHWA		TBD			
Link Characteristics: Grade	CS/ERG	0% Grade, Urban Restricted and Unrestricted Road Types, 30 mph	-6%, -4%, -2%, +2%, +4%, +6% grade	2%: Substantial (-15% to +22%) 6%: Substantial to very substantial (-36% to +92%)	2%: Substantial (-26% to +33%) 6%: Substantial to very substantial (-58% to +118%)	2%: Substantial (-27% to +41%) 6%: Very substantial (-55% to +175%)

MOVES Input	Source	Base Case	Comparison Made	VOC	NO_x	PM
Link Source Types (Hour Fraction)			TBD			
Other Inputs						
Weather – Meteorology Data	Volpe/ FHWA	60º F	-40º, -20º, 0º, 20º, 40º, 60º, 80º, 100º, 120º F	Running: PC: Substantial above 60º F (up to 17%); no impact below. CT: No impact Starts: Substantial below 80º F; no impact above	Running: Substantial between 40 and 100º F (-20% to +32%); no impact outside that range Starts: Very Substantial at all temps below 80º F (>100%)	PC: Very substantial below 60º F (>100%); no impact above 80º F CT: Modest (<0.1%)
	Volpe/ FHWA	50% Relative Humidity	0%, 20%, 40%, 50%, 60%, 80%, 100% (No_x at 60º F and 80º F, all others at 80º F)	PC: Modest (-1% to +2%) CT: Modest (<1%)	Moderate (-12% to +15%)	Modest (<1%)
	EPA	75º F	-40º F to 120º F in 10º increments; Calendar years 2005, 2015, and 2025	Very substantial for gasoline (~+50-70%), Substantial for diesel (~+10-30%) at 20º F	Moderate for gasoline (~+5-8%, Substantial for diesel (~+15-18%) at 20º F	Very substantial (~+400-600% at 20º F) for gasoline Modest (<1%) for diesel
	EPA	0% Relative Humidity	0-100% relative humidity in 10% increments for 6-12 different temperatures	Modest (up to ~+5%)	Substantial (up to ~-25%)	Modest (<1%)
Inspection/Maintenance (I/M) Programs	N/A					
Fuel Formulation and Supply	N/A					

Note 1: Modest = <5%; Moderate = 5-15%; Substantial = 15-50%; Very Substantial = >50%.

Note 2: Unless noted, Volpe/FHWA results are for running emissions for passenger cars (PC) and combination trucks (CT). CS/ERG results are for combined vehicle fleet and all processes. EPA results are for gasoline versus diesel for all source types.

Table 6.7 provides a summary of MOVES inputs by sensitivity level. It takes the worst case result for each MOVES input from Table 6.6 and assigns it to one of the four sensitivity ranges. This was done separately for VOC, NO_x, and PM. In general temperature, VMT, speed, age, and population have either substantial or very substantial sensitivity for all three pollutants. The data sources that are critical for these inputs include registration data for age and population inputs; classified traffic counts and travel demand models for VMT; and real-world and/or modeled speed data. Month and hour VMT fraction inputs (based on seasonal and hourly traffic data) have modest sensitivity for all pollutants. Ramp fraction and source type detail for road type distributions and speeds have different sensitivity depending on the pollutant of concern.

Table 6.7 Summary of MOVES Inputs Falling in Different Sensitivity Ranges

Sensitivity Range	VOC	NOx	PM
Very Substantial (>50%)	Temperature, Speed, Age	Temperature, VMT, Speed	Temperature, VMT, Speed
Substantial (15-50%)	Population, VMT	Population, Age, Humidity	Population, Age, Ramp Fraction
Moderate (5-15%)	None	None	Source type detail for road type dist. and speed
Modest (<5%)	Source type detail for road type dist. and speed, Month VMT Fraction, Hour VMT Fraction, Ramp Fraction	Source type detail for road type dist. and speed, Month VMT Fraction, Hour VMT Fraction, Ramp Fraction	Month VMT Fraction, Hour VMT Fraction, Humidity

Note: The worst case sensitivity results are used for assigning inputs to the ranges in this table.

6.5 INPUT AND OUTPUT DATA

This section provides additional detail on inputs and outputs.

Table 6.8 Emissions by Source Type
Base Case for Scenarios 1-6

				Tons					g/mi				
ID	Source Type	Base Source Type Fract.	Base VMT Fract.	VOC	CO	NO_x	CO_2	PM_{10}	VOC	CO	NO_x	CO_2	PM_{10}
11	Motorcycle	3.60%	0.53%	272	737	34	20,286	1.5	5.03	13.63	0.63	375	0.03
21	Passenger Car	46.52%	54.42%	2,586	25,845	3,969	2,150,857	43.3	0.47	4.67	0.72	389	0.01
31	Passenger Truck	34.10%	28.32%	2,283	24,742	3,539	1,564,188	40.9	0.79	8.59	1.23	543	0.01
32	Light Commercial Truck	11.39%	9.46%	779	8,539	1,568	535,450	33.7	0.81	8.88	1.63	557	0.03
41	Intercity Bus	0.05%	0.09%	6	39	124	16,325	7.0	0.71	4.39	13.87	1,826	0.78
42	Transit Bus	0.03%	0.03%	2	23	27	3,999	1.4	0.72	7.63	9.17	1,342	0.48
43	School Bus	0.34%	0.10%	9	119	68	10,143	4.0	0.91	11.78	6.74	1,007	0.4
51	Refuse Truck	0.03%	0.06%	4	30	61	11,429	3.5	0.69	4.67	9.47	1,771	0.54
52	Single-Unit Short-Haul Truck	2.12%	2.18%	268	3,517	1,105	239,096	53.0	1.21	15.86	4.98	1,078	0.24
53	Single-Unit Long-Haul Truck	0.27%	0.37%	24	281	123	38,117	4.9	0.64	7.48	3.28	1,017	0.13
54	Motor Home	0.49%	0.13%	29	397	66	14,704	2.0	2.11	29.26	4.86	1,083	0.15
61	Combination Short-Haul Truck	0.48%	1.63%	86	448	1,619	342,902	80.4	0.52	2.7	9.75	2,064	0.48
62	Combination Long-Haul Truck	0.57%	2.67%	302	777	2,492	616,763	95.0	1.12	2.86	9.19	2,275	0.35

Note: Tons are for a July weekday. Grams/mile are converted from tons divided by miles traveled on a July weekday, by source type.

Table 6.9 Emissions by Source Type – Scenario 1
Double Heavy-Duty Vehicles

ID	Source Type	Base Source Type Fract.	Base VMT Fract.	Tons				
				VOC	CO	NO_x	CO_2	PM_{10}
11	Motorcycle	3.44%	0.49%	259	703	32	19,354	1.4
21	Passenger Car	44.38%	50.41%	2,468	24,658	3,787	2,052,076	41.4
31	Passenger Truck	32.53%	26.23%	2,178	23,605	3,376	1,492,350	39.0
32	Light Commercial Truck	10.87%	8.76%	744	8,147	1,496	510,859	32.1
41	Intercity Bus	0.10%	0.17%	13	79	248	32,650	13.9
42	Transit Bus	0.06%	0.06%	4	45	55	7,998	2.8
43	School Bus	0.69%	0.19%	18	237	136	20,286	8.0
51	Refuse Truck	0.06%	0.12%	9	60	122	22,857	6.9
52	Single-Unit Short-Haul Truck	4.24%	4.24%	535	7,034	2,210	478,192	106.1
53	Single-Unit Long-Haul Truck	0.54%	0.72%	48	561	246	76,234	9.7
54	Motor Home	0.98%	0.26%	57	794	132	29,409	4.0
61	Combination Short-Haul Truck	0.96%	3.17%	173	896	3,238	685,804	160.8
62	Combination Long-Haul Truck	1.15%	5.18%	605	1,553	4,983	1,233,527	190.0

Note: Tons are for a July weekday. Grams/mile values are not shown because they are the same as the Base Case (Table 6.7).

Table 6.10 Emissions by Source Type – Scenario 2
Shift Passenger Cars to Passenger Trucks

				Tons				
ID	Source Type	Base Source Type Fract.	Base VMT Fract.	VOC	CO	NO_x	CO_2	PM_{10}
11	Motorcycle	3.60%	0.55%	272	737	34	20,286	1.5
21	Passenger Car	37.21%	44.96%	2,069	20,676	3,175	1,720,685	34.7
31	Passenger Truck	43.40%	37.22%	2,906	31,492	4,504	1,990,964	52.1
32	Light Commercial Truck	11.39%	9.77%	779	8,539	1,568	535,450	33.7
41	Intercity Bus	0.05%	0.09%	6	39	124	16,325	7.0
42	Transit Bus	0.03%	0.03%	2	23	27	3,999	1.4
43	School Bus	0.34%	0.10%	9	119	68	10,143	4.0
51	Refuse Truck	0.03%	0.07%	4	30	61	11,429	3.5
52	Single-Unit Short-Haul Truck	2.12%	2.25%	268	3,517	1,105	239,096	53.0
53	Single-Unit Long-Haul Truck	0.27%	0.38%	24	281	123	38,117	4.9
54	Motor Home	0.49%	0.14%	29	397	66	14,704	2.0
61	Combination Short-Haul Truck	0.48%	1.69%	86	448	1,619	342,902	80.4
62	Combination Long-Haul Truck	0.57%	2.75%	302	777	2,492	616,763	95.0

Note: Tons are for a July weekday. Grams/mile values are not shown because they are the same as the Base Case (Table 6.7).

Table 6.11 Emissions by Source Type – Scenario 3
Shift Single-Unit to Combination Trucks

ID	Source Type	Base Source Type Fract.	Base VMT Fract.	Tons				
				VOC	CO	NO_x	CO_2	PM_{10}
11	Motorcycle	3.60%	0.52%	272	737	34	20,286	1.5
21	Passenger Car	46.52%	53.46%	2,586	25,845	3,969	2,150,857	43.3
31	Passenger Truck	34.10%	27.82%	2,283	24,742	3,539	1,564,188	40.9
32	Light Commercial Truck	11.39%	9.29%	779	8,539	1,568	535,450	33.7
41	Intercity Bus	0.05%	0.09%	6	39	124	16,325	7.0
42	Transit Bus	0.03%	0.03%	2	23	27	3,999	1.4
43	School Bus	0.34%	0.10%	9	119	68	10,143	4.0
51	Refuse Truck	0.03%	0.06%	4	30	61	11,396	3.5
52	Single-Unit Short-Haul Truck	1.59%	1.60%	200	2,634	827	178,813	39.7
53	Single-Unit Long-Haul Truck	0.20%	0.27%	18	210	92	28,506	3.6
54	Motor Home	0.49%	0.13%	29	396	66	14,662	2.0
61	Combination Short-Haul Truck	0.75%	2.52%	135	702	2,537	537,254	126.0
62	Combination Long-Haul Truck	0.90%	4.10%	474	1,217	3,904	966,336	148.8

Note: Tons are for a July weekday. Grams/mile values are not shown because they are the same as the Base Case (Table 6.7).

Table 6.12 Emissions by Source Type – Scenario 4
Shift Short-Haul to Long-Haul Trucks

ID	Source Type	Base Source Type Fract.	Base VMT Fract.	Tons				
				VOC	CO	NO_x	CO_2	PM_{10}
11	Motorcycle	3.60%	0.53%	272	737	34	20,286	1.5
21	Passenger Car	46.52%	53.80%	2,586	25,845	3,969	2,150,857	43.3
31	Passenger Truck	34.10%	28.00%	2,283	24,742	3,539	1,564,188	40.9
32	Light Commercial Truck	11.39%	9.35%	779	8,539	1,568	535,450	33.7
41	Intercity Bus	0.05%	0.09%	6	39	124	16,325	7.0
42	Transit Bus	0.03%	0.03%	2	23	27	3,999	1.4
43	School Bus	0.34%	0.10%	9	119	68	10,143	4.0
51	Refuse Truck	0.03%	0.06%	4	29	59	11,114	3.4
52	Single-Unit Short-Haul Truck	1.59%	1.57%	197	2,602	807	174,435	38.7
53	Single-Unit Long-Haul Truck	0.48%	0.63%	41	488	211	65,521	8.4
54	Motor Home	0.49%	0.13%	28	390	64	14,303	1.9
61	Combination Short-Haul Truck	0.36%	1.18%	63	328	1,183	250,589	58.8
62	Combination Long-Haul Truck	1.02%	4.54%	521	1,339	4,290	1,062,078	163.6

Note: Tons are for a July weekday. Grams/mile values are not shown because they are the same as the Base Case (Table 6.7).

Figure 6.4 VMT Fractions by Scenario for Source Type Shifts

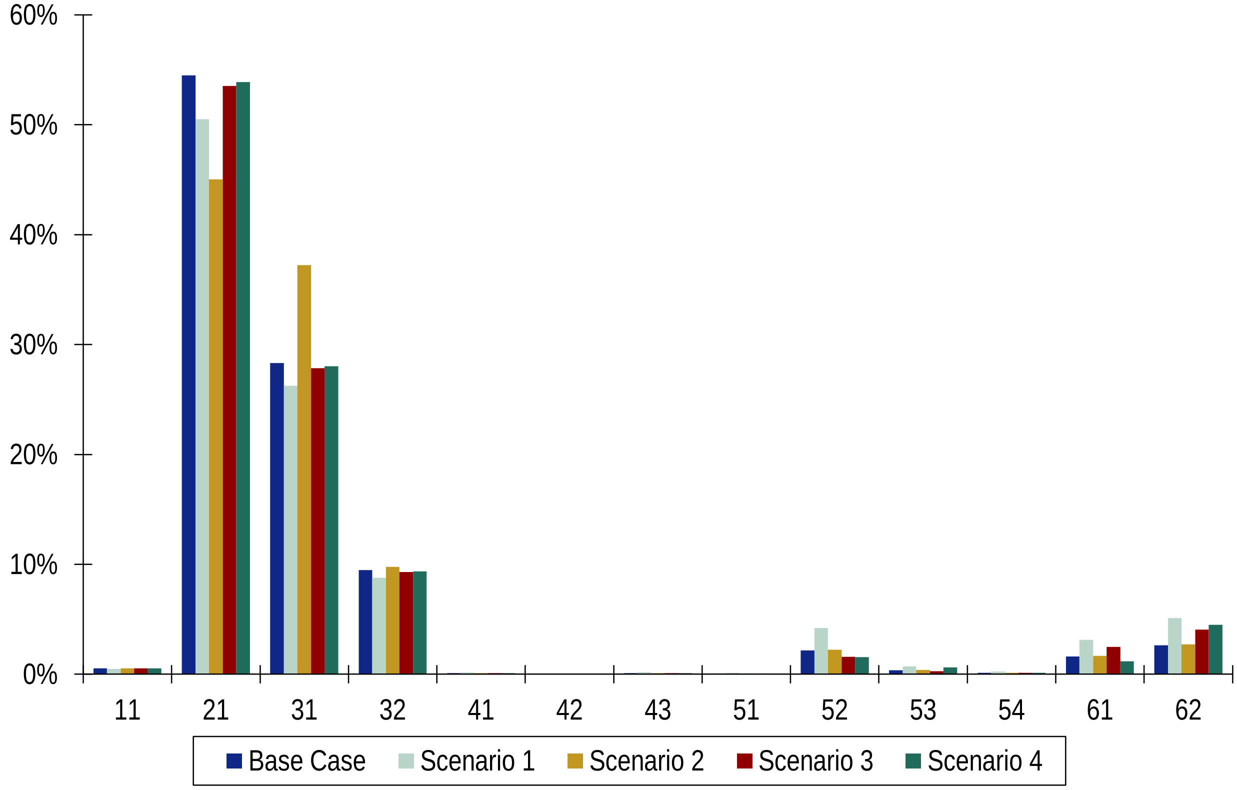


Table 6.13 Emissions for Different Road Type and Average Speed Distributions
Scenarios 5 and 6

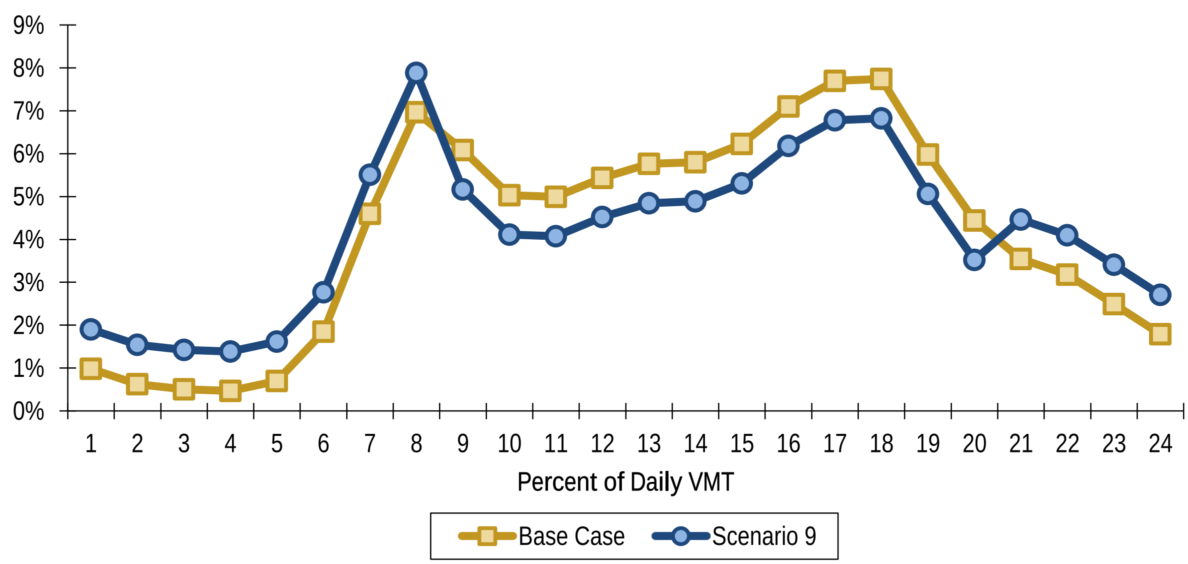
Scenario	Description	Tons					Grams/mile				
		VOC	CO	NO_x	CO_2	PM_{10}	VOC	CO	NO_x	CO_2	PM_{10}
0	Base Case	6,651	65,493	14,795	5,564,259	371	0.654	6.442	1.455	547	0.036
5	Road Type Variation	6,777	65,910	15,368	5,666,100	409	0.666	6.475	1.510	557	0.040
6	Decrease in Truck Speed	6,733	65,775	15,144	5,624,660	392	0.662	6.470	1.490	553	0.039

Note: Tons are for a July weekday. Grams/mile are converted from tons divided by miles traveled on a July weekday, by source type.

Table 6.14 Month Distributions (Percent of VMT by Month)
Scenarios 7 and 8

Month	Base	5% Increase Summer (Scenario 7)	5% Increase Winter (Scenario 8)
1	7.3%	6.8%	9.0%
2	7.0%	6.4%	8.6%
3	8.2%	7.6%	7.6%
4	8.2%	7.7%	7.7%
5	8.8%	8.2%	8.2%
6	8.8%	10.5%	8.3%
7	9.2%	10.9%	8.7%
8	9.3%	11.0%	8.8%
9	8.5%	7.9%	7.9%
10	8.7%	8.1%	8.1%
11	8.0%	7.5%	7.5%
12	8.0%	7.5%	9.7%

Figure 6.5 Example of Hour Distribution Shift
Scenario 9



Note: Shown for passenger cars, road type 5 (urban unrestricted access), weekday. Distributions for other road types and source types are similar.

Table 6.15 Effects of Road Grade

Road Type	Grade	VOC	CO	NO_x	CO_2	PM_{10}
Unrestricted Access	-6%	-36%	-59%	-58%	-41%	-55%
	-4%	-28%	-45%	-45%	-31%	-45%
	-2%	-16%	-26%	-26%	-17%	-27%
	+2%	22%	36%	33%	22%	41%
	+4%	50%	81%	69%	47%	94%
	+6%	91%	162%	110%	72%	175%
Restricted Access	-6%	-34%	-59%	-60%	-43%	-55%
	-4%	-26%	-44%	-47%	-32%	-44%
	-2%	-16%	-28%	-28%	-18%	-27%
	+2%	22%	31%	34%	21%	37%
	+4%	55%	85%	75%	47%	88%
	+6%	92%	160%	118%	74%	154%

Note: Table shows the percent change in composite emissions (all source types) compared with a base case of zero percent road grade. Emissions are for a 0.5-mile roadway link with average speed of 30 mph.

7.0 Data Analysis

7.1 Introduction

This section describes the supplemental data collected by the research team to create sample MOVES input datasets and illustrate the use of different types of data that may be available locally. Table 7.1 lists the MOVES inputs and corresponding data sources that were evaluated by the research team. The table also notes whether the effort was successful and any changes compared to the original proposed work approach. Some of the sample data were incorporated into the input-specific text and examples presented in the Practitioners' Handbook. In addition, sample data files are provided in Excel files.

Table 7.1 NCHRP 25-38 MOVES Input Data Analysis and Development

MOVES Input	Proposed Dataset and Analysis	Outcome
Temporal Adjustments	Examine VTRIS data to develop examples of temporal distributions by source type and road type in different states.	Spreadsheet prepared to permit queries by state; sample data shown.
Temporal Adjustments	Evaluate use of ITS, private vendor, and/or cell phone data for regional temporal adjustments by comparing with traffic recorder data for two or three sample areas.	Completed with available data in Jacksonville and Atlanta metro areas and for State of Florida.
Road Type Distribution and Ramp Fraction	Evaluate available datasets (VTRIS, ITS) to compare source type-specific patterns with regional average patterns; provide sample source type-specific road type distributions from different contexts.	Sources of road type distributions were limited and did not provide a good basis for making comparisons. Sample state-level source-specific distributions developed for states reporting in VTRIS.
Off-Network Data	Evaluate data from NHTS and two instrumented vehicle datasets to develop sample information on off-network activity.	Used primary data from Port of Houston study and secondary data from a truck study in Pennsylvania and a parking study in Massachusetts to develop examples for three different types of off-network facilities. Evaluated NHTS data but determined not to be useful for this purpose.
Link Source Types	Develop sample source type distributions for different states and road types using VTRIS; evaluate and compare use of ITS data for this purpose from two or three sample regions.	Developed state-level source type distributions using VTRIS data. ITS data not applicable.
Average Speed Distribution (Regional, Link)	Evaluate use of ITS, private instrumented vehicles data, GPS travel survey, and/or cell phone data for developing facility-specific or regional average speed distributions.	Multiple sources, including ITS, GPS surveys, and private provider data were evaluated and compared with travel demand model and postprocessed speed estimates, using data from Atlanta and Jacksonville.

A summary of the data sources proposed for analysis and actually analyzed is provided below.

Vehicle Travel Information System (VTRIS) – VTRIS consists of a network of permanent count locations on arterials and highways that can generally count, classify, and weigh trucks. These counters are typically part of the permanent count locations for the Highway Performance Monitoring System and the data are available through FHWA. The data include vehicle class, time, speed, functional classification of the roadway, and geometric information such as the number of lanes. VTRIS data reported to FHWA by 27 states for year 2012 were obtained and analyzed.

Highway Statistics Series – Highway Statistics is an annual publication of FHWA that provides a variety of information on the condition and use of the nation's highway system. Traffic volume data are provided based on data reported by states as part of the HPMS. Of interest to this research are tables providing estimates of VMT by state and roadway functional class, and by state and vehicle type. These tables can be combined to estimate road type distributions by source type at the state level.

Intelligent Transportation Systems Data – These data include public agency roadway loop data, video, Bluetooth, or short-duration count data collected by state or metropolitan transportation agencies as part of their ITS systems. Data were obtained for the Atlanta and Jacksonville metropolitan areas from the respective state DOTs (Georgia and Florida).[7] They were used to develop speed distributions and temporal distributions. The systems are only deployed on restricted access highways, so data from unrestricted access roads were not available from this source.

Bluetooth Data – Data were evaluated from Bluetooth readers deployed on a limited basis in both the Atlanta and Jacksonville areas. In Jacksonville, the First Coast MPO provided data from a pilot deployment of BlueTOAD readers for a one-week period in May 2013. In Atlanta, Bluetooth data for 2012 were obtained for three arterials monitored by Cobb County. However, both of these datasets were deemed to have too small geographic coverage to develop regionally representative speed distributions. (The Jacksonville set included 29 stations, mostly in the downtown area and along I-95). There were also data quality issues with the Jacksonville data. As use of this data collection mechanism moves beyond the experimental stage, it could serve as another source for MOVES speed data.

Private Vendor Speed Data – Aggregated travel speed monitoring data are available through private providers, typically obtained from anonymized

[7] Atlanta and Jacksonville were selected because both cities had multiple data sources readily available to the project team. Also, Atlanta represents a large metropolitan area while Jacksonville represents a mid-size area.

readings from in-vehicle consumer GPS devices. Data were obtained from NAVTEQ for Atlanta (via the Atlanta Regional Commission) and from INRIX for Jacksonville. A major challenge of working with this data was matching the networks with regional travel demand volume networks, so that speeds by link could be appropriately weighted by traffic volumes. The level of effort required to complete this matching ultimately exceeded the project resources and the speed data were not fully analyzed.

GPS Travel Surveys – In a number of U.S. cities, travel surveys have been conducted with a subset of the survey participants being instrumented with GPS devices to assist in tracking travel patterns. Data were obtained for Atlanta through the National Renewable Energy Laboratory Transportation Secure Data Center, which also processed the data to provide speeds by vehicle by link. These data were aggregated into speed distributions and compared these with other sources.

Cell Phone Data with Location Information – Anonymous cell phone data, typically obtained through triangulation from cell towers, is increasingly being used for a variety of applications in transportation planning. The project team would have needed to purchase these data for specific areas and it is still somewhat experimental in nature. We concluded that they would not provide any better information than we could obtain from the NAVTEQ and INRIX private vendor sources, which we were able to obtain at a lower cost or for free.

Travel Demand Forecasting Models – Data from the travel demand forecasting models maintained by the Atlanta and Jacksonville MPOs were used as a basis for comparing observed speeds and temporal distributions with other sources listed above. TDFMs are an important data source because they can provide forecasts of speed and volume data, in addition to coverage of existing roads that may not be covered by monitoring systems. However, the speed estimation routines in TDFMs are known to be far from perfect. Therefore, a variety of speed postprocessing methods were tested and the outcomes compared with observed speeds.

Data Sets for Off-Network Activity – Instrumented truck data from a study at the Port of Houston were analyzed to develop sample off-network activity inputs for an intermodal terminal. Two other studies were identified – a truck stop study in Pennsylvania and a parking lot study in Massachusetts – that were used to provide examples of developing off-network inputs for these types of facilities.

Supplemental Data on Commercial Vehicle Populations – Data sources were investigated that could be used to develop more detailed estimates of vehicle population, age distribution, and activity for different types of commercial vehicles. These included the Motor Carrier Management and Information System (MCMIS) maintained by the Federal Motor Carrier Administration (FMCSA), state motor carrier registration databases, and the International Registration Program (IRP).

Section 7.2 documents the data source and processing methods we applied for each source to obtain sample MOVES inputs. Section 7.3 compares sample data developed from these sources with each other and with embedded MOVES data.

7.2 DATA SOURCES

Vehicle Travel Information System (VTRIS)

A number of MOVES inputs describe VMT distributions and can be derived from traffic count stations that are maintained by state DOTs as part of Federal data collection requirements. These inputs include:

- VMT by HPMS vehicle class;
- Road type distributions – percent of VMT by road type; and
- Temporal adjustments – percent of VMT by hour, day of week, and month.

The network of traffic counting stations often includes a subset of stations that record vehicle classification. States report VMT by vehicle class to FHWA as part of the Vehicle Travel Information System, and this information is available at a state level from either the state DOT or through FHWA's Office of Highway Policy Information. In addition, although many MOVES users do not take advantage of this capability due to data limitations, temporal distributions can be provided for different vehicle types (including up to the 13 individual MOVES source types) and by road type for day and hour fractions. Table 7.2 shows the VMT-related MOVES inputs and disaggregation options.

Table 7.2 VMT-Based MOVES Inputs

Table Name	Contents	Provided by
HPMSVTypeYear	Total VMT	"HPMS" vehicle types (6)
roadTypeVMTFraction	Fraction of VMT by road type	MOVES source types (13)
monthVMTFraction	Fraction of VMT by month	MOVES source types (13)
dayVMTFraction	Fraction of VMT by day type (weekday, weekend)	MOVES source types (13) x road types (5)
hourVMTFraction	Fraction of VMT by hour of day	MOVES source types (13) x road types 5) x day types (2)

Summary of VTRIS Data Findings

States report their classified traffic count data to FHWA, much of which is stored as part of the VTRIS. As part of this research, VTRIS data reported for 2012 were investigated to determine the extent to which they could provide source type-specific temporal and road type distributions at the state level. Example data tables were developed, along with an Excel query tool to allow the user to develop distributions for individual states that reported data to VTRIS.

The research team determined that VTRIS data are suitable to develop temporal sample data tables for MOVES, such as hour and day fractions, at the state level. However, only one state (Maine) had sufficient data over the course of a year from which to develop month fractions, and only for rural roads. For geographic-specific data, the VTRIS data are not easily weighted to expand representatively by road types, and it appears preferable to make use of tables provided in Highway Statistics, as described in the next section.

The VTRIS data source, despite its richness, has other limitations. The extent of the classification counter network varies by state, but the number of stations is usually too small to derive distributions specific to vehicle type at anything below a state level, including for individual counties. Also, the vehicle classifications correspond with the six “HPMS” vehicle types and distributions for MOVES subclasses (e.g., short- versus long-haul trucks) must be assumed to be the same absent any better information. Only 27 states submitted data for VTRIS for 2012; the remainder are not included in this analysis, although it may be possible to obtain similar data directly from the state DOT. Alternatively, it may be possible for the MOVES user to “borrow” data from other states where VMT patterns are believed to be similar to their own state.

The VTRIS Dataset

The complete VTRIS data were obtained for calendar year 2012. Also obtained, but not processed, were partial year data for 2013. VTRIS includes four data text files: Automatic Traffic Recorders (ATR), Classification Counts, Stations, and Weigh-in-Motion (WIM). The ATR data includes unclassified counts and therefore was not of interest for this analysis. The WIM data also were not of interest. The Classification Counts file contains counts by station. The Station text file provides various geographic, administrative, and functional information about the counting stations used in the ATR, classification, and WIM data collection. For this research, the raw text records from these files were imported into Microsoft Access for processing, using the data formatting information included in the FHWA Traffic Monitoring Guide, Chapter 7.

In addition to obtaining the raw data in text file format, stations can be queried interactively on-line.[8] An example of such an on-line report for Rural Interstates in Alabama during 2012, consisting of the average of records from 16 stations, is shown in Figure 7.1.

8 https://fhwaapps.fhwa.dot.gov/vtris-wp/.

Figure 7.1 Sample On-Line VTRIS Report

W-2 Table

COMPARAISON OF WEIGHTED VS. COUNTED

By Direction

Federal Highway Administration
Office of Highway Policy Information
(HPPI)

12/6/2013

Axle Grouping Method: Vehicle Size & Weight
Averaging Method: Hour of Day
Functional Class(es): 1
State: AL
Period: 2012

Station Codes: 91811,91812,91851,91852,91853,91854,91895,91896,96331,96332,96371,96372,96511,96512,96551,96552

FHWA VEHICLE CLASS	AVERAGE DAILY COUNT	PERCENTAGE DISTRIBUTION TOTAL VEHICLES	PERCENTAGE DISTRIBUTION TRUCKS&COMB.	AVERAGE NUMBER WEIGHTED	PERCENTAGE DISTRIB. OF NO. WEIGHED
1 Motorcycles	7	0.04			
2 Passenger Cars	10,237	59.94			
3 Single Unit Trucks: 2-axle,4-tire	2,370	13.88			
4 Buses	169	0.99			
5 Single Unit Trucks: 2-axle, 6-tire	1,994	11.68	46.42	2,496	56.23
6 Single Unit Trucks: 3 axle	99	0.58	2.30	89	2.00
7 Single Unit Trucks: 4 axle, or more	8	0.05	0.19	3	0.07
8 Single Trailer Trucks: 4-axles, or less	328	1.92	7.64	240	5.41
9 Single Trailer Trucks: 5-axle	1,481	8.67	34.47	1,504	33.88
10 Single Trailer Trucks: 6-axle, or more	31	0.18	0.72	22	0.50
11 Multi-Trailer Trucks: 5-axle, or less	91	0.53	2.12	44	0.99
12 Multi-Trailer Trucks: 6-axle	28	0.16	0.65	25	0.56
13 Multi-Trailer Trucks: 7-axle, or more	236	1.38	5.49	16	0.36

AVERAGE DAILY TRUCKS 4,296

AVERAGE DAILY TRAFFIC 17,079

AVERAGE WEIGHTED 4,439

NUMBER OF AXLES(EST.) 41,279

Source: VTRIS On-Line Table W Generator. https://fhwaapps.fhwa.dot.gov/vtris-wp/.

The report generation capability of VTRIS provides summary information that is used to calculate national averages. In 2012, the classification count data submitted by 27 states is stored in the records in the VTRIS Classification Count text files. These VTRIS text files do *not* appear to include partial-day manual classification counts. This is a primary data collection technique used by many states. The manual counts are used to provide truck percentages that can be used with other reports, such as the ATR reports. However, manual classification methods do not typically collect data when visual observation is not possible, for example at night, and VTRIS may have excluded partial-day manually collected count records.

A number of data attribute fields in VTRIS can be equated to data attributes in MOVES. The VTRIS Function Classification (FC) for the road on which the counting station is located is the same Functional Classification attribute as used in the post-2010 state submittals of HPMS data, and is the same FC used in most data analysis managed by FHWA. It has the same meaning and purpose as the Road Types attribute in MOVES. The crosswalk between the VTRIS FC and the MOVES Road Type is shown in Table 7.3. Note the MOVES Road Type of 1 for Off-Road will have no correspondence in VTRIS.

Table 7.3 VTRIS Functional Classification (FC) as MOVES Road Type

FC Code	FC Description	MOVES Road Code	MOVES Road Type
1R	Interstate, Rural	2	Rural restricted access
2R	Principal Arterial, Rural		
3R	Principal Arterial, Rural	3	Rural unrestricted access
4R	Minor Arterial, Rural		
5R	Major Collector, Rural		
6R	Minor Collector, Rural		
7R	Local, Rural		
1U	Interstate, Urban	4	Urban restricted access
2U	Principal Arterial, Urban		
3U	Principal Arterial, Urban	5	Urban unrestricted access
4U	Minor Arterial, Urban		
5U	Major Collector, Urban		
6U	Minor Collector, Urban		
7U	Local, Urban		

The VTRIS classification of the vehicle can be one of seven types of classification systems, but those with less than the six vehicle types used in MOVES are not useful in this analysis. For those systems with more than six classes, the crosswalk between the VTRIS vehicle classifications, also known as FHWA Scheme F in the TMG, and the MOVES Vehicle Types is shown in Table 7.4.

The MOVES "HPMS" Vehicle Types correspond to the more detailed MOVES Vehicle Types as shown in Table 7.5.

Table 7.4 VTRIS Vehicle Classification as HPMS MOVES Vehicle Types

VTRIS Class	VTRIS Vehicle Classification Description	MOVES HPMS Vehicle Types
Class1	Motorcycles	10 Motorcycles
Class2	Passenger Cars	20 Passenger Cars
Class3	Other Two-Axle, Four-Tire Single-Unit Vehicles	30 Light-Duty Trucks
Class4	Buses, passenger-carrying buses with two axles and six tires or three or more axles	40 Buses
Class5	Two-Axle, Six-Tire, Single-Unit Trucks	50 Single-Unit Trucks
Class6	Three-Axle Single-Unit Trucks	
Class7	Four-or-More-Axle Single-Unit Trucks	

VTRIS Class	VTRIS Vehicle Classification Description	MOVES HPMS Vehicle Types
Class8	Four-or-Fewer-Axle Single-Trailer Trucks	60 Combination Trucks
Class9	Five-Axle Single-Trailer Trucks	
Class10	Six-or-More-Axle Single-Trailer Trucks	
Class11	Five-or-Fewer-Axle Multitrailer Trucks	
Class12	Six-Axle Multitrailer Trucks	
Class13	Seven-or-More-Axle Multitrailer Trucks	
Class14	Vendor Defined 1 Typically Unclassified	#N/A
Class15	Vendor Defined 2 Typically Unclassifiable	#N/A

Source: Cambridge Systematics, Inc.

Table 7.5 MOVES Vehicle Types as "HPMS" Vehicle Types

sourceTypeID	sourceTypeName	HPMSVtypeID	HPMSVtypeName
11	Motorcycle	10	Motorcycles
21	Passenger Car	20	Passenger Cars
31	Passenger Truck	30	Other 2-axle- 4-tire vehicles
32	Light Commercial Truck	30	Other 2-axle 4-tire vehicles
41	Intercity Bus	40	Buses
42	Transit Bus	40	Buses
43	School Bus	40	Buses
51	Refuse Truck	50	Single-Unit Trucks
52	Single-Unit Short-Haul Truck	50	Single-Unit Trucks
53	Single-Unit Long-Haul Truck	50	Single-Unit Trucks
54	Motor Home	50	Single-Unit Trucks
61	Combination Short-Haul Truck	60	Combination Trucks
62	Combination Long-Haul Truck	60	Combination Trucks

If all classification data submitted by the states were used to develop disaggregated MOVES data it would be misleading, if data for a station were incomplete. Two filters were employed.

The Vehicle Classification system reported in VTRIS had to include at least the six MOVES vehicle types. This means using only those records with (FHWA Scheme F) 13 classes or greater. While those records with 14 and 15 vehicle classes were selected, the actual reporting for vehicle classes 14 and 15 was not used. These classes represent "not available" or "not applicable."

Data had to be complete for a day, otherwise the hourly or summary data would be misleading. This meant that 24 hours worth of records occurring on successive days (for example beginning at 11:00 a.m. on Wednesday and ending at 11:00 a.m. on Thursday), which might be considered by the submitting state as a complete day, would be dropped. However, these data could not be used for day of the week or other summaries in any event. In the example above it could not be said that the day would be either Wednesday or Thursday. If the data were used, it would create a partial day for each day.

The data that were available from the VTRIS 2012 Classification Count text file consists of over 10 million records. Only 0.7 percent of those records, with a nonblank classification method, were identified as being collected by manual methods. This confirms the supposition that any data that were submitted using manual methods that had less than 24 hours of data for a station were not retained as VTRIS Classification Count records.

Over 4,000 stations remained after the filtering was done. However, a station could be for different lanes in the same location (e.g., right most travel lane, second lane from the right). Stations could also represent different directions on access control facilities (e.g., northbound and southbound reported separately). The number of stations by VTRIS Functional Classification and MOVES Road Type is shown in Table 7.6. As would be expected for a FHWA data collection program, those stations are primarily on Federal Aid Roads (i.e., excluding Rural Minor Collectors and Urban and Rural Local roads). However, the number of stations appears reasonably robust for each MOVES Road Type. On average each station represents data for over 87 days.

Table 7.6 Filtered Stations by VTRIS Functional Classification and MOVES Road Type

	VTRIS			MOVES	
FC	FC Description	Number of Stations	Percent of Stations by MOVES Road Type	Road Type	Number of Stations
1U	Interstates, Urban	1,005	73.6%	Urban restricted access	1,366
2U	Other Freeways and Expressways, Urban	361	26.4%		
3U	Other Principal Arterials, Urban	742	79.7%	Urban unrestricted access	931
4U	Minor Arterials, Urban	162	17.4%		
5U	Collectors, Urban	24	2.6%		
7U	Locals, Urban	3	0.3%		
1R	Interstate, Rural	610	100.0%	Rural restricted access	610
3R	Principal Arterial, Rural	917	62.7%	Rural unrestricted access	1,463
4R	Minor Arterial, Rural	329	22.5%		
5R	Major Collector, Rural	198	13.5%		
6R	Minor Collector, Rural	17	1.2%		
7R	Local, Rural	2	0.1%		
	Total	4,380			4,380

Source: Cambridge Systematics, Inc. from 2012 VTRIS data.

The number of locations, combining stations for the same location but with more than one station by lane or direction, is almost 1,400. Those locations are shown in Table 7.7. As would be expected this reduces the percentage of stations on multilane, multidirectional access restricted facilities, but does not appreciably change the assessment that a sufficient number of locations exist to use the VTRIS data to develop MOVES sample data.

Table 7.7 Filtered Stations by VTRIS Functional Classification and MOVES Road Type

VTRIS				MOVES	
FC	FC Description	Number of Stations	Percent of Stations by MOVES Road Type	Road Type	Number of Stations
1U	Interstates, Urban	273	73.58%	Urban restricted access	371
2U	Other Freeways and Expressways, Urban	98	26.42%		
3U	Other Principal Arterials, Urban	215	77.62%	Urban unrestricted access	277
4U	Minor Arterials, Urban	53	19.13%		
5U	Collectors, Urban	7	2.53%		
7U	Locals, Urban	2	0.72%		
1R	Interstate, Rural	190	100.00%	Rural restricted access	190
3R	Principal Arterial, Rural	321	56.71%	Rural unrestricted access	566
4R	Minor Arterial, Rural	149	26.33%		
5R	Major Collector, Rural	87	15.37%		
6R	Minor Collector, Rural	8	1.41%		
7R	Local, Rural	1	0.18%		
	Total	1,404			1,404

Source: Cambridge Systematics, Inc. from 2012 VTRIS data.

The selected stations represent a wide range of geographies, although Florida's and Virginia's intensive data collection programs dominate the selected stations by each state, as shown in Table 7.8. Although 27 states submitted information to VTRIS, and 26 remained after filtering eligible locations, some provided only a very small number of count stations. Not all road types may be covered in these states. Furthermore, the data from states with small numbers of stations for any given road type should be used with caution as they may not be representative of the State as a whole.

Table 7.8 Selected VTRIS Classification Locations by State

State	Rural Restricted	Rural Unrestricted	Urban Restricted	Urban Unrestricted	Total	Percent of U.S.
Arkansas	10	31	5	5	51	3.6%
Colorado	12	30	12	8	62	4.4%
Delaware	0	12	0	5	17	1.2%
Florida	20	82	44	79	225	16.0%
Hawaii	0	8	5	28	41	2.9%
Idaho	2	11	0	3	16	1.1%
Indiana	13	30	23	12	78	5.6%
Iowa	0	6	0	0	6	0.4%
Maine	2	13	0	0	15	1.1%
Maryland	4	2	2	1	9	0.6%
Massachusetts	0	0	8	2	10	0.7%
Minnesota	6	39	7	6	58	4.1%
Mississippi	12	39	13	15	79	5.6%
Missouri	14	59	39	4	116	8.3%
Montana	15	26	0	0	41	2.9%
Nebraska	6	13	3	6	28	2.0%
Nevada	4	6	4	2	16	1.1%
New Hampshire	1	0	3	0	4	0.3%
New Mexico	3	20	1	0	24	1.7%
New York	0	0	8	0	8	0.6%
Ohio	15	42	56	18	131	9.3%
Pennsylvania	3	19	4	8	34	2.4%
Rhode Island	1	1	45	1	48	3.4%
Virginia	46	75	87	73	281	20.0%
West Virginia	0	2	2	1	5	0.4%
Wyoming	1	0	0	0	1	0.1%
Total	190	566	371	277	1,404	

Source: Cambridge Systematics, Inc. from 2012 VTRIS data.

VTRIS Data Analysis

The MOVES inputs that could be developed for some or all of the states submitting to VTRIS are shown in Table 7.9, along with comments on whether VTRIS is an adequate data source for the development of each input.

Table 7.9 Sample State-Level Data Produced from 2012 VTRIS

Table Name	Data Shown	Comments
HPMSVTypeYear	VMT fractions by vehicle type are shown, which may be applied to current and/or local estimates of total VMT.	Not recommended as a source of light-duty fractions (type 10, 20, 30) due to difficulty in distinguishing these vehicle types. May be used for light versus heavy-duty fractions and for fractions within heavy-duty categories (40, 50, 60).
dayVMTFraction	Day fractions shown by HPMS vehicle type and road type.	Should be suitable for use. Apply caution for states and road types with small numbers of stations.
hourVMTFraction	Hour fractions shown by HPMS vehicle type, road type, and day type.	Should be suitable for use. Apply caution for states and road types with small numbers of stations.
monthVMTFraction	Month fractions shown by HPMS vehicle type for State of Maine, rural road types only.	In VTRIS, only Maine provided a full year of data. Some state DOTs may be able to provide similar data not submitted to VTRIS.
roadTypeVMTFraction	Road type VMT fractions are shown by vehicle type.	Not recommended for use at a state level. These should be developed from expanded sample data; direct measurements from VTRIS will be biased to road types where counters are located.

Queries were developed in Microsoft Access to summarize the 10 million records into records of volumes of MOVES Vehicle Types by date, by hour, by state and by MOVES Road Type and to export that information to Excel. The WEEKDAY function was applied to the calendar date to determine the day of the week. The resulting summary consisted of over 212,000 records.

To develop **day VMT fractions**, the MOVES dayID code for weekday, 5, was determined by using records with a day of the week Monday through Friday. The MOVES dayID code for weekends, 2, was determined by using records with a day of the week of Saturday or Sunday. Zeroes are entered for MOVES Road Type 1, off road, since VTRIS would have no information for this road type. There is no information in VTRIS, i.e., #N/A, for counts for any vehicle type on Urban Restricted Roads for the months of May (5), June (6), or July (7). The values for April may be used to populate the missing values for May and the values for August may be used to populate the missing values for June and July.

In order to develop the MOVES table of **hour VMT fractions**, the selected data records were summarized for Average Daily Traffic (ADT) count by Weekday ID, hour, MOVES HPMS Vehicle Type, and MOVES Road Type. Zeroes are again listed for all MOVES Road Type 1 because off-road counts are not included in VTRIS. While the expected value is for VMT, properly VTRIS records are ADTs for counting stations that cover segments of indeterminate lengths. If available, those lengths could be multiplied by the ADTs to develop VMT. For purposes of developing this table of intensity, however, an assumption is made that each section represents an equal length of roadway.

In order to develop the MOVES table of **month VMT fractions** it would be necessary to obtain VTRIS records from stations that provided counts for each day of the year. Only one state, Maine, provides classification stations with sufficient days and it provides it for only two road types, Rural Restricted and Rural Unrestricted. Also the VTRIS data are for 2012, a leap year.

In order to develop **VMT fractions by MOVES vehicle type**, the selected VTRIS records were summarized by MOVES Vehicle Type. The initial result of this processing is shown in Table 7.10. As noted previously, VTRIS reports ADT, not VMT. Using the ADT as a surrogate has two problems. First the classification collection methods are known to have difficulty distinguishing among MOVES vehicle types 10, 20, and 30. However more importantly for this table, VMT is being computed across all MOVES Road Types. For this purpose, the VMT should be a statistically derived and expanded sample. For comparison, the shares of VMT by MOVES Vehicle Type are computed using Virginia DOT published reports of adjusted VMT by Vehicle Type.[9] This comparison shows that the use of VTRIS ADT as a surrogate for VMT is most probably incorrect for this table. Instead it is recommended that these data be developed from tables in the readily available FHWA Highway Statistics Series. This will be discussed in the next section.

Table 7.10 HPMS Vehicle Type VMT Share for Base Year

HPMS VehtypeID	yearID	ADT	Initial VTRIS Base Year ADT Share	VA DOT 2010 VMT Share	Annual VMT (Millions)	Highway Statistics VMT Share
10	2012	400,744,619	13.0%	0.32%	10,932	0.6%
20	2012	1,927,347,975	62.7%	78.64%	2,092,050	68.3%
30	2012	496,484,406	16.1%	14.99%	548,568	20.6%
40	2012	9,980,043	0.3%	0.51%	10,766	0.5%
50	2012	6,7071,652	2.2%	1.24%	77,866	3.7%
60	2012	17,4407,174	5.7%	4.30%	121,973	6.2%

[9] Motorcycle VMT reporting is optional and Automatic Equipment has difficulty distinguishing between Classes 1, 2, and 3. The MOVES Vehicle Type percentages for Virginia DOT were computed according to http://www.virginiadot.org/info/resources/2010/VMTReport_220_2010.pdf.

Conclusions

VTRIS appears to be a useful source for MOVES temporal sample data for states that have provided data to FHWA. While examples from the entire VTRIS sample are shown in the Practitioners' Handbook, the Excel tool allows the user to summarize the data for a selected state. The VTRIS Classification Count data are developed from counts submitted by state DOTs. It is possible that classification counts are available that were not submitted or retained in VTRIS, and that these classification counts could be obtained directly from a state DOT and processed in the same manner as this VTRIS data.

The processing of the VTRIS data as summary records by state and by road type and by date has additional advantages. The VTRIS selected records can be filtered for select state, days of the week and Road Type to develop hourly percentages of usage for MOVES Vehicle Types. These filtered records can be used to develop tables and charts of hourly usage. Such tables and charts can be prepared for any combination of characteristics of Road Type, Day, and State. The Excel files were developed to allow such tables and charts to be developed interactively.

Highway Statistics Series

There is a source of readily available statistically sampled and expanded VMT by state. That VMT is reported in FHWA's annual Highway Statistics Table VM-2. The HSS also reports VMT by state by the six "HPMS" vehicle types used in MOVES in Table VM-4. Apparently because of the additional processing that is necessary to prepare this table, the release of this table lags by a year from the regular on-line release of HSS tables, and the location of this table is not included as a shortcut from the main HSS page for the most current year. Table VM-4 was obtained for 2010,[10] which required the use of Table VM-2[11] from the same year. An Excel file was prepared which uses the state information of percentage share of VMT by HPMS Vehicle Type by Road Type and applies that to the total VMT by state by Road Type. The product of the percentages of VMT by Vehicle Type and total VMT produces VMT by Vehicle Type.

The Excel file containing the 2010 data is provided as one of the products of this research. The file allows users to summarize road type distribution for the six HPMS vehicle types by state, using embedded pivot tables. A user could replace the 2010 VM-2 and VM-4 data with more current data tables as they are published by FHWA.

The analysis used reported VMT shares for each state. If shares were desired by Urbanized Area rather than by state, the use of VMT could be from Highway

10 http://www.fhwa.dot.gov/policyinformation/statistics/2010/xls/vm4.xls.

11 http://www.fhwa.dot.gov/policyinformation/statistics/2010/xls/vm2.xls.

Statistics Table HM-71 in place of Table VM-2. This total of VMT could be disaggregated for any Urban Area using the percentage shares by MOVES Vehicle Type as reported by Table VM-4 for the state in which the Urban Area is located. This method could only provide shares across Urban Restricted and Urban Unrestricted MOVES Road Types, since rural road VMT is by definition not reported in Highway Statistics Table HM-71.

The MOVES inputs that could be developed for all states based on HSS reports are shown in Table 7.11.

Table 7.11 Sample State-Level Data Produced from 2011 Highway Statistics

Table Name	Data Shown	Comments
HPMSVTypeYear	VMT fractions by vehicle type are shown, which may be applied to current and/or local estimates of total VMT.	HSS Tables VM-2, Total VMT by State by Road Type, and VM-4, Percentage Share VMT by Vehicle Type and Road Type, should be suitable for use.
roadTypeVMTFraction	Road type VMT fractions are shown by vehicle type.	HSS Tables VM-2, Total VMT by State by Road Type, and VM-4, Percentage Share VMT by Vehicle Type and Road Type, should be suitable for use.

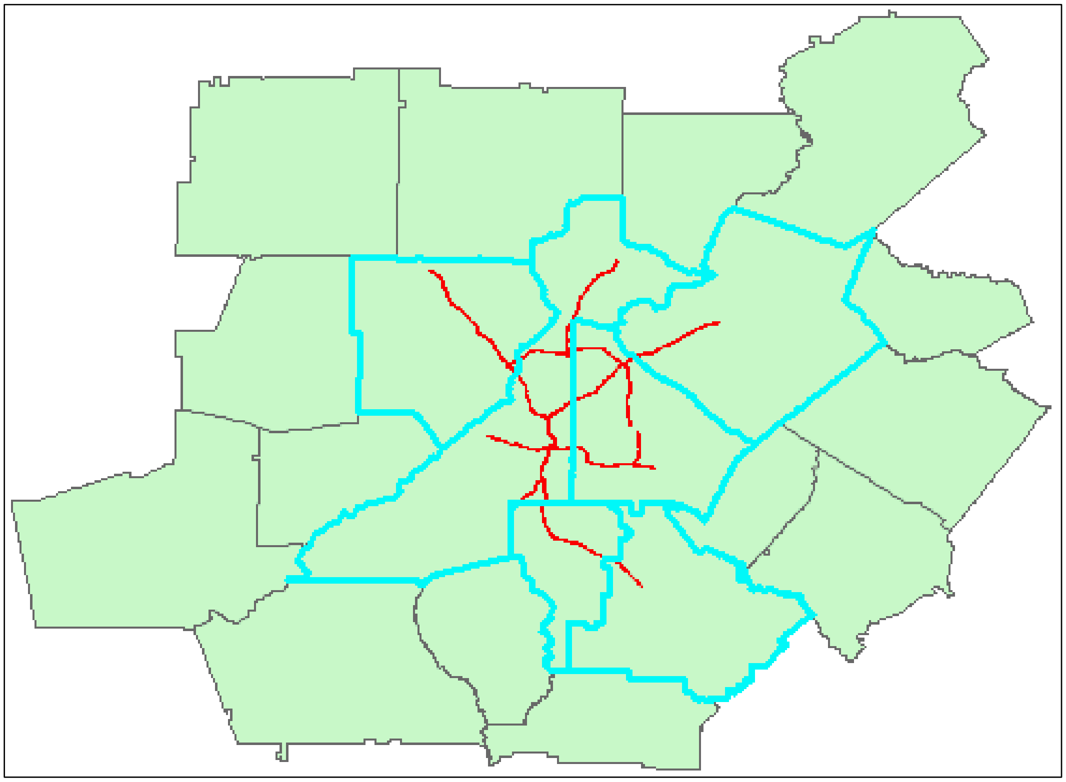
Intelligent Transportation Systems Data

The Georgia Department of Transportation (GDOT) maintains an archive of traffic data collected through a network of video cameras on freeways within a seven-county portion of the Atlanta metropolitan area. Video image processing is used to derive volumes, speeds, and lane occupancies at five-minute intervals. Each detector is associated with a segment length, which is about 0.37 mile between two adjacent detectors. Coverage on the regional freeway network is shown in Figure 7.2 in red lines, with the seven county area outlined in blue.

Similar to the ITS system in Atlanta, the Florida Department of Transportation (FDOT) collects ITS data on the freeways in Jacksonville metropolitan area. Video imaging and radar technologies are used to collect volumes, speeds, and lane occupancies at five-minute intervals. Each detector is also associated with a segment length, which is about 0.44 mile between two adjacent detectors.

For the purposes of this analysis, data were obtained for 2010 in Atlanta, and 2012 in Jacksonville, respectively. The years were chosen to be close to the time periods in other data sources for comparison purposes. The other reason to use 2010 data in Atlanta instead of more recent data is that their ITS system had a major upgrade in 2011, and the data was not complete during the upgrade period. Only weekdays' data are used for this study.

Figure 7.2 ITS Coverage in Atlanta



Since the archived data were collected at the lane level, additional aggregation procedures were applied to generate the total volumes and average speed across all at each directional detector site at five-minute intervals. These aggregation procedures and the associated quality controls were processed following FHWA guidelines. After the data aggregation and quality control (QC), MOVES speed bins were then assigned to each five-minute speed. The specific steps for processing the five-minute lane data into speed distributions for MOVES were as follows:

1. Conduct quality control checks on the data records, following guidelines published by FHWA (2004). All the speeds less than 5 mph were reset to null since past studies suggested that data were not reliable when speed was less than 5 mph. Null values due to reset speeds, and missing data due to equipment failures, were discarded from the dataset. In the Atlanta dataset, 37 percent of time intervals have a valid vehicle-hours of travel (VHT) number. The data were evaluated to ensure there was not a bias in the missing data to a specific time period (hour of the day).

2. Aggregate speeds and traffic volumes across lanes to obtain an average speed and total volume by direction for each link. This was done by summing the individual lane traffic volumes, and averaging the speed for each lane, weighted by the volume in the lane.

3. Calculate the VHT on each link as follows: VHT = Volume * length (mi)/speed (mi/hr).
4. Assign each five-minute link directional speed to a MOVES speed bin.
5. Sum the VHT in each speed bin across all link segments and all five-minute intervals in each hour time period.
6. Divide VHT in each speed bin by total VHT for the hour time period to obtain the fraction of VHT by speed bin for the hour. Repeat for all 24 hours.

In addition to missing data due to equipment failures, any observation that failed QC was also reset to a null value. Overall, 37 percent of the time intervals have a valid VHT number in Atlanta, and 50 percent of the time intervals have a valid number in Jacksonville. A closer look at the missing data in these two metropolitan areas showed no patterns in the amount of missing data by hour of the day. As such, all the processed data were included in the final aggregation to produce the hourly speed bin distributions.

After the speed bins were assigned, the final aggregation (described in detail in the next section) summed up all the VHT for each speed bin at each hour during a year, and the hourly VHT totals were also calculated. The hourly speed bin fractions are calculated by dividing the speed bin's VHT in that hour by the hourly total VHT.

Speed Data Aggregation

There are different ways of aggregating the data to create speed distributions. Two approaches were tested for this project using the Atlanta data:

- Aggregating five-minute interval speeds without any averaging; and
- Averaging each five-minute interval across a day of week and month and then creating a speed distribution based on the average for all time periods.

The first approach is clearly preferable for the purpose of MOVES inputs, since it creates what is as close as possible to an actual distribution of speeds that may be observed over the course of a day, month, or year. The second approach was demonstrated to illustrate the difference that can be introduced by the aggregation method. This is important because other sources of speed data – notably private vendor data – typically are provided at a higher level of aggregation, i.e., average speed by link across multiple days. Travel demand model speed outputs also represent average speeds, since they are derived from a deterministic equation using average volume and capacity as inputs.

A comparison of speed distributions for four representative time periods – overnight (5:00-6:00 a.m.), AM peak (7:00-8:00 a.m.), midday (11:00 a.m.-12:00 p.m.), and PM peak (5:00-6:00 p.m.) shows that averaging the data does produce significantly different speed distributions. The overall average speed is only slightly lower for the disaggregate data, but there is a substantially higher fraction of travel shown at lower speeds, which is important for emissions modeling. For example, in the peak periods, the aggregated data shows only 1 percent of VHT less than 27.5 mph, whereas the disaggregated data shows 11 percent in the AM peak and 18 percent in the PM peak. The comparison is shown in Table 7.12.

Table 7.12 Comparison of Aggregated and Disaggregated ITS Speeds
Atlanta Freeways

Parameter	Overnight (5:00-6:00 a.m.)	AM Peak (7:00-8:00 a.m.)	Midday (11:00 a.m.-12:00 noon)	PM Peak (5:00-6:00 p.m.)
Based on disaggregate five-minute Intervals				
Average speed	64.2	55.3	63.7	50.9
Percent of VHT < 27.5 mph	1%	11%	1%	18%
Based on average of five-minute speeds over day of week and month				
Average speed	64.4	57.4	64.0	54.3
Percent of VHT < 27.5 mph	0%	1%	0%	1%

Temporal Distributions

To create temporal distributions (VMT fractions by hour, day of week, and month), VMT (calculated as volume * segment length) was aggregated across all of the available five-minute observations for each respective time period (hour, weekday versus weekend, and month) and divided by total VMT to obtain the hour, day, or month fraction. This source is limited since only restricted-access roadways are covered, so unrestricted access road fractions cannot be developed for hour or day fractions. Also, the ITS data do not distinguish vehicle types, so separate distributions by source type cannot be developed.

Private Vendor Data

In recent years, there has been increasing availability of speed monitoring data from various technologies made available through private vendors. Sources include GPS data from mobile multifunction devices such as smartphones, phablets, tablets and a handful of in car bidirectional GPS, entertainment/ communication software packages offered by various auto manufacturers. Data are aggregated and resold by firms, including INRIX and NAVTEQ. The research team obtained NAVTEQ data for the Atlanta metro area and INRIX data for the Jacksonville metro area for purposes of this research.

Unlike the ITS systems that collect data mainly on freeways, private vendors' data cover a much wider range of roadway types. For example, compared to 105 directional freeway miles in the Jacksonville ITS dataset, the traffic management center (TMC) network in Jacksonville, with which the INRIX speed data are associated, has 388 directional miles on functional class 1 roads, and 3,983 directional miles on other FC roads.

The disadvantages of the private sources include:

- There is no volume data, which is important for weighting the speeds to obtain VHT distributions.
- TMC functional classes are not consist with HPMS functional classes:
  - While all TMC FC 1 roads are freeways, some TMC FC 2 roads are access-controlled expressways while others are arterials, so the classes do not line up neatly with MOVES road types; and
  - There is no urban or rural designation in the TMC FC, so this must be determined from a spatial overlay of the urbanized area boundaries.
- The data are typically provided as averages over multiple days for a given time period, rather than in disaggregate format to reflect day-to-day variations.
- Missing data are a concern. Some vendors use historical data to interpolate missing data, while others leave them blank.
- There is a cost for acquisition (unless the data have already been purchased for another use and can be licensed for this purpose as well).

Currently, the project team is attempting to match the NAVTEQ and INRIX networks to state DOTs' existing inventory maps to obtain volumes and other roadway characteristics.

Atlanta Metropolitan Area

NAVTEQ data were obtained for the Atlanta metro area through the Atlanta Regional Commission (ARC). The data had been purchased by ARC and were made available to the project team at no cost. The data are hourly average speeds aggregated across all days in 2010, for network links corresponding to the Atlanta NAVTEQ network. NAVTEQ does not reveal either the source or sample size of its data.

NAVTEQ data also has information for link length and link FC. There are five NAVTEQ FCs, where FC 1 links are freeways, and some FC 2 links are access-controlled expressways.

Jacksonville Metropolitan Area

INRIX data were obtained for the six-county Jacksonville metro area through the Florida DOT.[12] The data had previously been purchased by FDOT and were

[12] Baker, Clay, Duval, Nassau, Putnam, and St. John Counties.

made available to the project team for a modest additional licensing fee. The data included five-minute speed speeds on network links corresponding to the Jacksonville TMC network during July 2010 to June 2011. Similar to ITS data, the INRIX speed is the speed on a TMC link for a particular five-minute interval, not aggregated over other time periods. INRIX does not reveal either the source or sample size of its data.

INRIX also provided TMC configurations which included information such as TMC location, length, type (mainline or ramp), and functional class. The FC is the standard FC associated with the TMC network. There are five TMC FCs, where FC 1 TMC are freeways, and some FC 2 TMC are access-controlled expressways.

Spatial Joining of Speed and Volume Data

In both Atlanta and Jacksonville, significant difficulties were encountered in attempting to join speed data with traffic volume data. To be used to assist with speed calibration, it is necessary to join the geographic speed data obtained from private sources to travel model or other vehicle activity data, so that speeds can be weighted by traffic volumes to produce regional distributions of speed by VHT. If speed distributions are based on unweighted data, speeds on low-volume roads will be overrepresented, and speeds on high-volume roads will be underrepresented.

Speed data are typically associated with a traffic management center network while volumes obtained from a model are associated with the travel demand model network. Typically, these networks are disparate and may not be in close geographic alignment. Geographic information systems (GIS) procedures involving a combination of automated and manual coding must be applied in order to match the two networks with a reasonable degree of accuracy. The specific procedures applied, and issues encountered, are described below. In summary, two approaches were attempted. The first was to use traffic volumes from the travel demand model network. Attempts to automate the join process were unsuccessful and a significant amount of manual coding would have been required. A second approach was to use a network which had traffic volumes associated from the FDOT Office of Safety. However this network also turned out to be difficult to match. Finally, ARC staff assisted in providing matched speed and volume data for Atlanta, but by the time the data were available in the format required for this research, the available budget for this effort had been depleted.

Combining speed and volume data in other areas is likely to require extensive manipulation unless the data are produced and stored with the same geographic extent and projections. The approach utilized will necessarily depend on the locally available data for the state and/or MPO in question. Longer term, efforts to do this would benefit from efforts in the transportation planning/engineering community to move towards standardization of input file formats, specifically regarding geographies used for collection of data.

The remainder of this section illustrates the approaches attempted to join speed and volume data from Jacksonville.

Approach 1 – Use Model Network Volumes

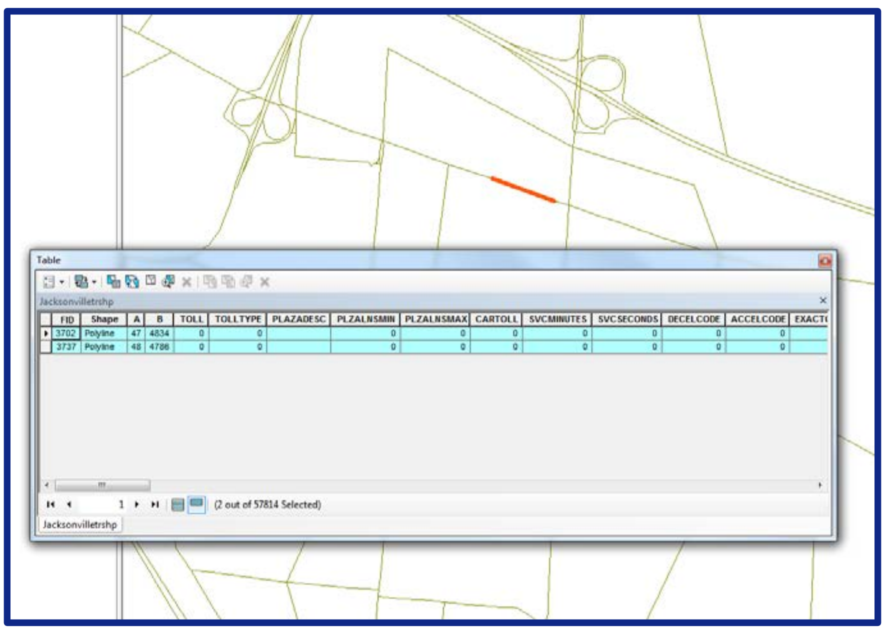
In this approach, an attempt was made to use the travel model loaded network with average annual daily traffic (AADT) to append speeds. The following files were used as data sources:

- Cube Voyager Loaded True Shape Network;
- INRIX shapefile with TMC codes used to associate with measured real world speeds in the INRIX database; and
- Road name table to allocate names to specific INRIX segments.

The first step in this process involved the export of the Cube "True Shape" network to an ESRI shapefile. This was done in order to allow geographic manipulation of the network via overlay techniques. The overlay was done as a sequence of steps set up to ensure the best possible matches. The steps were as follows:

1. The exported true shape links from Cube contained duplicate entries where roads are single line coded. Figure 7.3 illustrates the example.

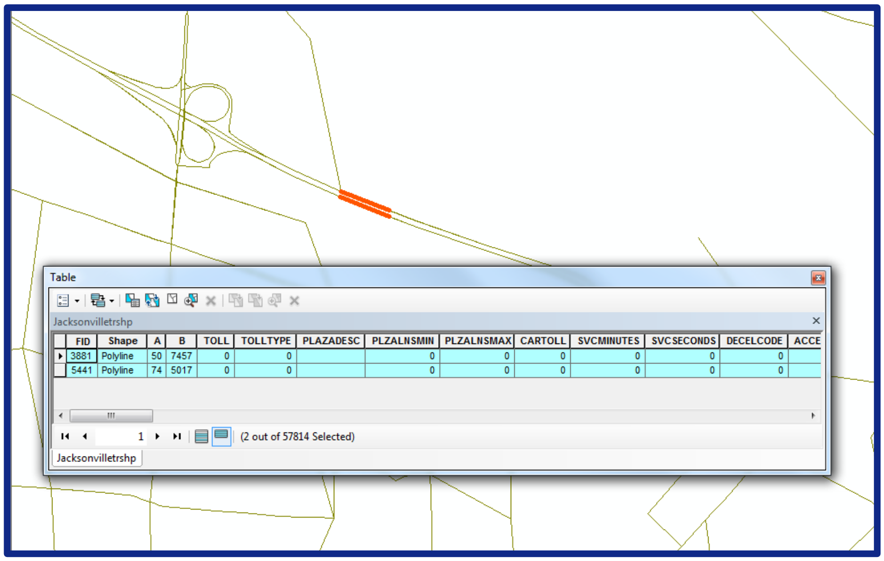
Figure 7.3 Apparent Single Link Represented by Two Records for Each Direction



   a. For such links, a direction attribute was added such that it became possible to distinguish between the directions for the overlay (spatial join) process.

b. Dual line coded links (single entries without duplicates) representing each direction of travel were left unchanged. Figure 7.4 illustrates.

Figure 7.4 Dual Line Coded Links Represented by a Record for Each Direction



2. Each direction on the TMC shapefile was selected and saved.

3. Each direction on the exported loaded network also selected and saved separately.

4. The road name table was joined to the TMC shapefile and used to further refine selection.

5. Interstate and dual line coded roadways were overlaid using matching selections on the INRIX and model loaded shapefile. This minimized instances of the wrong TMC code direction being transferred to the loaded network file.

   a. NB to NB.

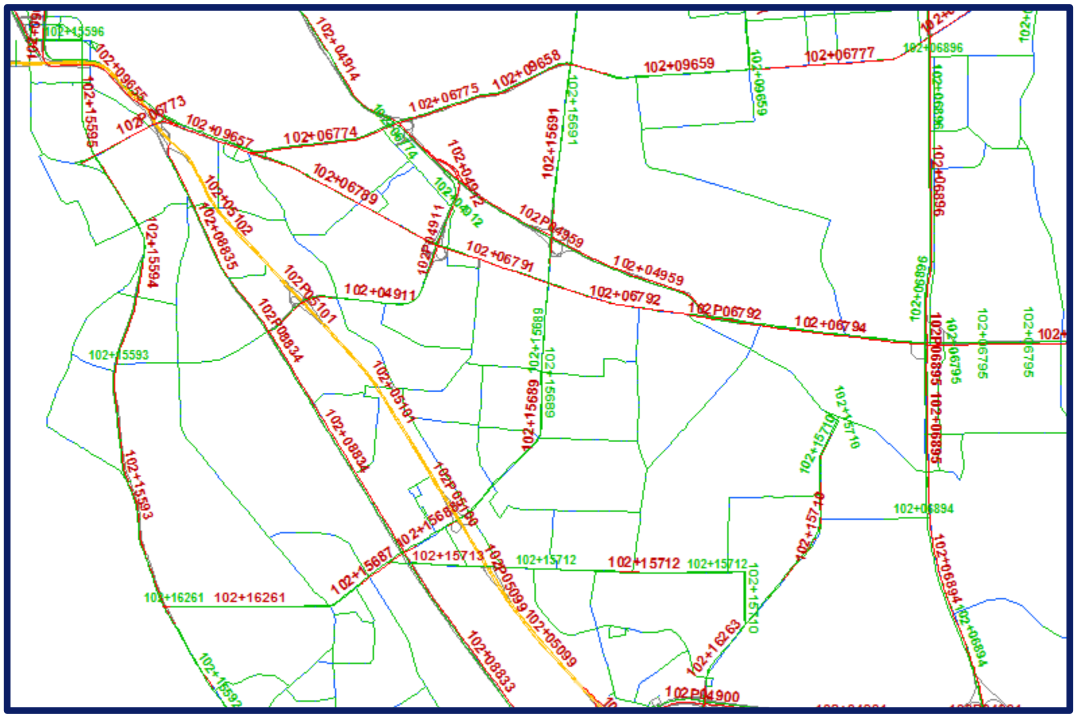
   b. SB to SB.

   c. EB to EB.

   d. WB to WB.

6. The overlay was then successively completed per direction and per road type (separate dual line coded or duplicate single line representation). Figure 7.5 illustrates the results of the overlay for a small area to the southeast of Downtown Jacksonville with the TMC codes displayed in red (INRIX file) and green (model file).

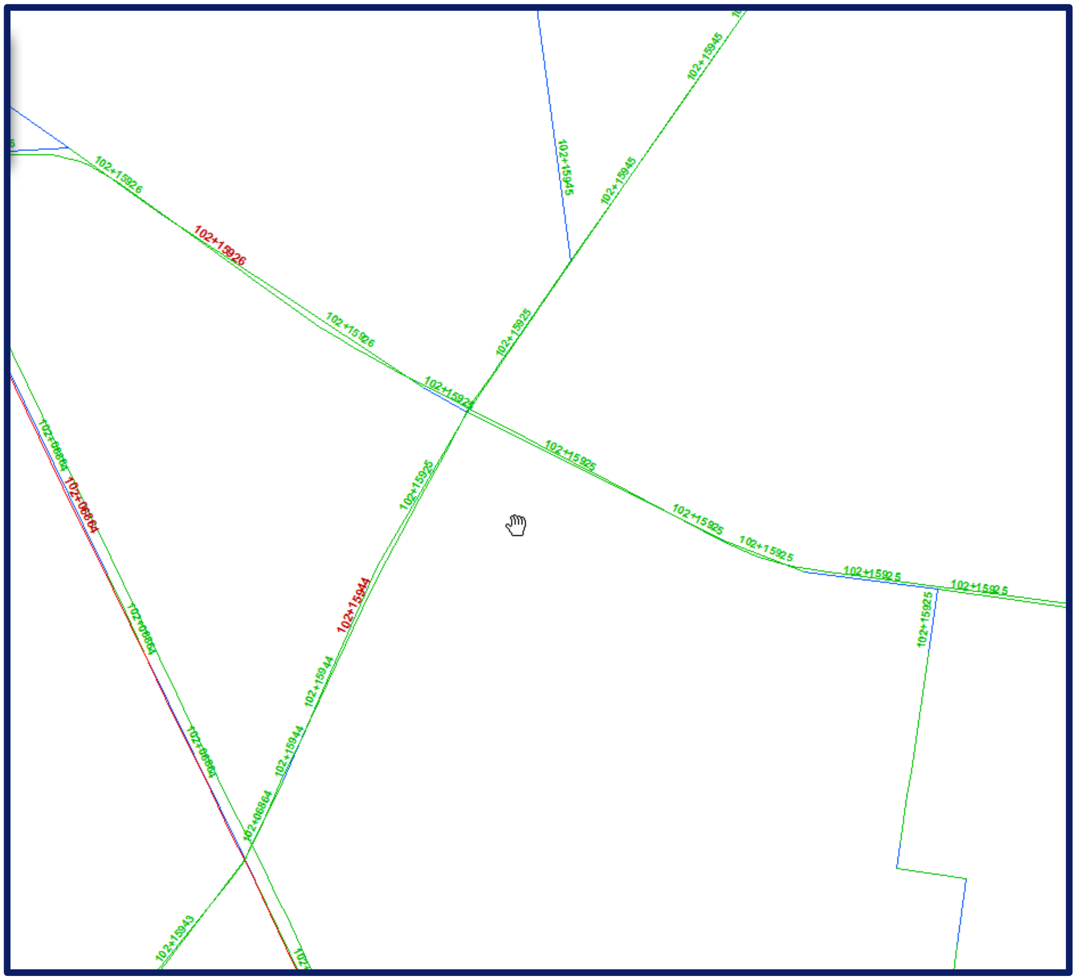
Figure 7.5 Overlay Result Example



Problems with this approach:

- At points where links intersect, the overlay produced inaccurate results. Figure 7.6 illustrates an example of this where several perpendicular links were assigned the same TMC code.
- The required correction of erroneous overlay results would be extensive for all instances of such occurrences.
- The model network did not directly contain HPMS functional class which would require a further spatial join to append.

Figure 7.6 Example of Spurious Overlay



Approach 2 – Use State DOT AADT Source Files

Owing to the problems with the first approach, a second approach was undertaken whereby a Florida DOT count data geographic file was used. The following lists the files utilized in the process:

- FDOT Office of Transportation Safety shapefile with AADT information encoded per segment;
- 2010 NAVTEQ-derived street network; and
- Correspondence table to link NAVTEQ network with TMC codes which provide the key for speed data.

In this approach, given the similar geographic extent of the NAVTEQ and the Safety Office network, the following sequence of steps was followed:

1. The 2010 NAVTEQ network was converted from a line shapefile to a point shapefile to aid in spatial join accuracy.
2. The FDOT Safety Office shapefile was then overlaid on the converted point file from step 1. The result of this process was a shapefile with both AADT attributes, and a key (called Link_ID) that allows for a correspondence with the TMC codes used to append speed data.
3. The updated shapefile was then joined in a tabular manner via the Link_ID key to a TMC, Link_ID correspondence file. This process allows the speed information from INRIX to be appended.
4. As was the case with the model approach, it was necessary to append HPMS functional classes to the shapefile with the TMC codes.
   a. This process was a spatial join and also produced inaccurate results with several incorrect HPMS categories being appended to specific model links. Examples include arterials being assigned to Interstates and vice versa.
   b. Given that ultimately, the required result was the MOVES road type categorizations, it was possible to enhance the accuracy by manually assigning controlled access facilities and using the HPMS code for urban/rural designations only.
   c. Interstates and all the expressway roads in Jacksonville were identified via selection and coded and MOVES types 2 or 4, depending on the HPMS code. It was thought that while not good enough for the road type categorization, the area type categorization implicit in the HPMS code is spatially accurate and could thus be used for this purpose.

GPS Data from Travel Surveys

A number of metropolitan areas have experimented with the use of GPS to support travel survey data collection. GPS traces can be used to identify vehicle speeds on specific roadways by time of day. Therefore, a sample of GPS records could be used to develop speed distributions for both urban restricted and unrestricted roadway types in the areas in which such surveys have been conducted. Because the survey includes a limited sample of travelers for a short-duration time period, the sample of speeds is much more limited than obtained from ITS data or other sources of continuous observation. The driving patterns of the sampled travelers are also not guaranteed to be representative of the overall distribution of traffic by type of road, time of day, or location. However, the GPS method does have the significant advantage of collecting disaggregated data (i.e., not averaged across multiple days) for all types of roadways.

The National Renewable Energy Laboratory (NREL) maintains an archive of GPS travel survey data through its Transportation Secure Data Center. The center addresses data privacy issues by providing easy access to nonspatial data, or by providing access to spatial data in a more restricted environment. One of the datasets is a GPS subsample in The 2011 Regional Travel Survey conducted by the Atlanta Regional commission. This GPS subsample includes 1,061 households that logged 40,000 trips. For GPS participants, data were recorded for a maximum of seven days.

NREL matched each individual trip to the roadway traveled, and reported the distance traveled and average speed by roadway functional classes on each trip.[13] The project team applied minimal processing to determine VHT speed distributions based on speeds and segment lengths by roadway type (restricted and unrestricted access).

Travel Demand Forecasting Models and Speed Postprocessing

Travel demand forecasting models can produce forecast year as well as historical year speed estimates and are widely used for estimating vehicle speed distributions for input to emissions models. However, state-of-practice travel demand models have a number of limitations for speed estimation. Postprocessing techniques can be applied to improve model speed estimates as well as to disaggregate volumes and speeds from time period (e.g., AM peak) to the hourly level.

While postprocessing methods do not eliminate some of the more fundamental limitations of speed estimation procedures, they represent the best that most agencies (short of having a large-scale microsimulation model with dynamic traffic assignment) have to work with for predicting speeds under future traffic conditions. The most common postprocessing method involves the use of the so-called Bureau of Public Roads (BPR) function with coefficients that are either locally calibrated or transferred from other areas. However, other volume-delay functions also have been developed, as discussed in the Practitioners' Handbook Volume 1, Section 4.7. In this research, data from the Atlanta and Jacksonville travel demand models were used to compare the speed distributions produced by various volume-delay functions with observed speeds from the ITS, private vendor, and GPS sources described above.

Jacksonville Travel Demand Model

For the Jacksonville metro area, travel demand model data and outputs were obtained, including road types, capacity, volumes, and speeds by link, along with network shapefiles, from the Northeast Regional Planning Model V4.0 (NERPM4) maintained by First Coast MPO. The base year for the model was 2005, which was used to develop speed distributions. Model facility types were classified by the project team into the MOVES facility types (restricted and

[13] Instead of FHWA's HPMS functional class, NREL used NAVTEQ functional class. In this study, NAVTEQ FC 1 is assumed to be access-controlled roads, while other NAVTEQ FC roads are assumed to be nonaccess-controlled.

unrestricted access). While some portions of the model cover areas categorized as "rural" area type, only the segments falling within the urban area boundaries were used for this comparison.

The Jacksonville model contains four time periods (AM peak, midday, PM peak, and overnight). The model speeds are not postprocessed and are therefore specific to time period rather than hour. The model speeds are calculated using a BPR equation with coefficients specific to facility and area type as shown in Table 7.13. The model network was coded with hourly lane capacities. The capacity was adjusted to reflect the congestion during peak hours (the "CONFAC" factor described in the model documentation),[14] an adjustment which essentially determines the speeds based on the peak-hour v/c ratio, rather than the v/c ratio over the entire time period.

Table 7.13 BPR Coefficients Used in Jacksonville Model

Facility Type	BPR Coefficient (α)	BPR Exponent (β)
Freeways/Expressways/Parkways	0.450	6.75
Divided Arterials	0.490	4.35
Undivided Arterials	0.500	3.75
Local Roads/Transit Only Driveway Links	0.510	3.15
Centroid Connectors/Externals/Transit Only Platform-Escalator and Walk Access Link	0.100	2.50
One-Way Facility Unsignalized/Class 1b/Class II-III	0.530	4.50
Frontage Road Class 1b/Class II-III/Transit Skyway Links	0.475	5.25
Ramps	0.475	4.85

For this research project, the project team applied a postprocessing procedure to develop speeds by hour. This procedure used the same equation and coefficients as used for the model calculations. However, the CONFAC factor was not applied as this is not appropriate if the calculation is done for individual hours. VMT within each model period was further disaggregated to individual hours using the MOVES embedded hourly VMT distribution. Hourly speeds for each link were then calculated using the estimated hourly volume and link-specific hourly capacity from the model.

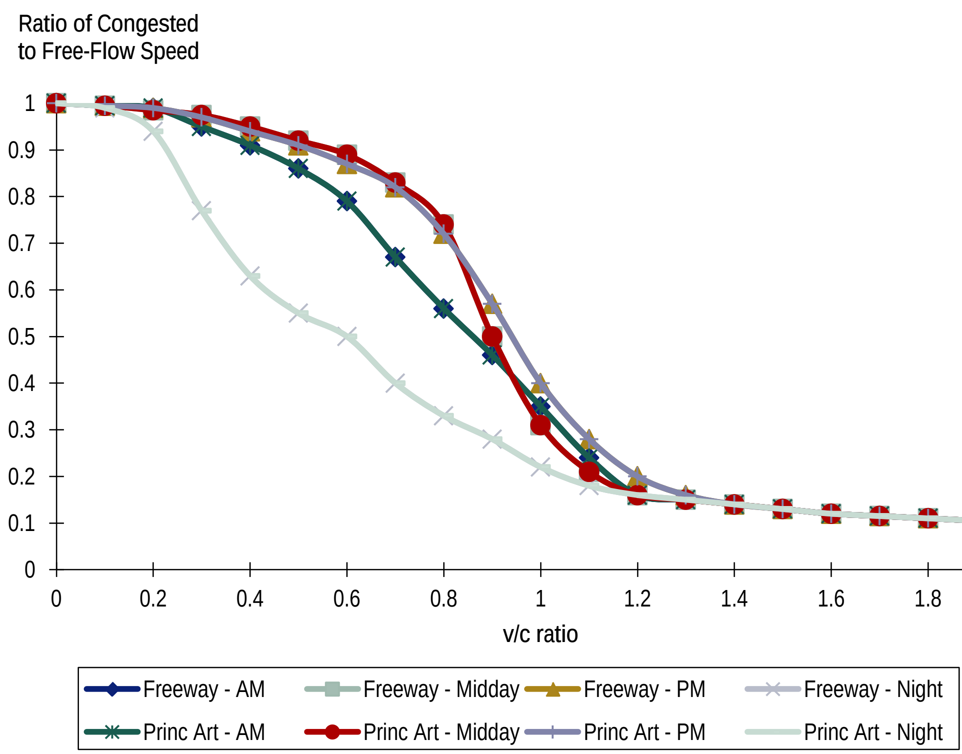
[14] The Corradino Group and PBS&J, Inc. (2009). *Northeast Regional Planning Model V4.0: Draft Technical Report 1 and 2: Model Data, Calibration, and Validation*. Prepared for First Coast MPO and Florida DOT – District 2.

Atlanta Travel Demand Model

For the Atlanta metro area, travel demand model data and outputs were obtained, including road types, capacity, volumes, and speeds by link, along with network shapefiles, from the model maintained by the Atlanta Regional Commission. The base year for the model was 2000 and forecast year data was available for 2010. The 2010 data were used for closer comparability with the other data sources. Model facility types were classified by the project team into the MOVES facility types (restricted and unrestricted access). While some portions of the model cover areas categorized as "rural" area type, only the segments falling within the urban area boundaries were used for this comparison. Because ARC had already conducted postprocessing on model outputs to develop MOVES inputs, the MOVES input files were also obtained directly from ARC.

The Atlanta model contains four time periods (AM peak, midday, PM peak, and night). The model speeds are postprocessed. Rather than using the BPR curve or another function, ARC has developed its own table of factors which relate the ratio of congested speed to free-flow speed to v/c ratio. These factors are specific to facility type and time period. Sample factors for freeways and principal arterials are shown in Figure 7.7. Speeds are developed for each hour of the day so as to be compatible with MOVES inputs.

Figure 7.7 ARC Model Volume-Delay Factors



Source: Atlanta Regional Commission (2008). *The Travel Demand Forecasting Model for the Atlanta Region 2008 Documentation*. Note that these may not reflect current modeling practice.

The project team also developed and applied additional postprocessing methods using the BPR curve and other functions, as described in Section 7.3, so that the results of these postprocessing procedures could be compared with observed speeds from the ITS, GPS, and private vendor sources.

National Household Travel Survey

The National Household Travel Survey (NHTS) is conducted by the U.S. DOT every six to eight years. The survey provides information on trip, vehicle, and household characteristics for a sample of travelers nationwide. The most recent NHTS, conducted in 2009, collected one-day travel data from 150,000 households. Analysis of survey data can be conducted at the state level and for the 50 largest metropolitan areas, using an on-line query tool or by obtaining the data from U.S. DOT.

Information was collected on vehicles owned by households, including the type of vehicle, model year, odometer reading, and annual miles driven. The NHTS was investigated as a potential supplemental source in identifying age distributions and source type populations for light-duty vehicles. For source type population input, its utility was investigated for identifying the proportion of light-duty vehicles that are automobiles (type 21) versus light trucks (type 31). The vehicle types in the NHTS and corresponding MOVES source types are shown in Table 7.14.

Table 7.14 NHTS Vehicle Types

Code	NHTS VEHTYPE	MOVES Source Type
01	Automobile/Car/Station Wagon	21
02	Van (Mini, Cargo, Passenger)	31
03	Sports Utility Vehicle	31
04	Pickup Truck	31
05	Other Truck	31
06	RV (Recreational Vehicle)	54
07	Motorcycle	11
08	Golf Cart	N/A
97	Other	N/A

For age distribution, it is necessary to know the average annual mileage for each type of vehicle and age group, in order to weight the age groups. Three indicators of annual mileage can be developed:

1. A estimate self-reported by the survey respondent (ANNMILES);
2. A revised estimate based mainly on reported odometer readings (BESTMILE); and
3. Computed travel miles from the trip file (TOTMILES).

For each trip, household vehicle ID is available, if a personal vehicle is used. The trip records also have a driver flag. For such trips, trip distances are aggregated over the household vehicle ID to establish an estimate of VMT.

The project team found a wide variation of annual mileage across these estimation methods, states, vehicle types, and age groups, in ways that were not always consistent. Furthermore, vehicles were grouped into five-year age categories and these categories would need to be further broken out by year to develop MOVES inputs. Therefore, given that age distributions for light-duty vehicles can be fairly reliably developed from registration or I/M program data, the project team does not recommend the NHTS as a supplemental or alternative source for age distributions. Sample mileage accumulation data are shown in Table 7.15.

Table 7.15 Sample Mileage Accumulation Estimates
2009 NHTS

State	Vehicle Type	MOVES Type	Age Category	ANNMILES	AVG BESTMILE	AVG TOTMILES
AZ	Automobile/Car/Station Wagon	21	0-5 Years	16,392	14,356	12,817
AZ	Automobile/Car/Station Wagon	21	5-10 Years	8,335	9,446	13,420
AZ	Automobile/Car/Station Wagon	21	10-15 Years	7,308	7,890	11,770
AZ	Automobile/Car/Station Wagon	21	15-25 Years	6,806	7,885	4,257
AZ	Automobile/Car/Station Wagon	21	Older Than 25 Years	2,860	3,814	968
AZ	Sports Utility Vehicle	31	0-5 Years	13,926	16,353	44,221
AZ	Sports Utility Vehicle	31	5-10 Years	9,835	11,706	9,975
AZ	Sports Utility Vehicle	31	10-15 Years	13,145	12,502	12,229
AZ	Sports Utility Vehicle	31	15-25 Years	3,992	5,843	3,944
AZ	Sports Utility Vehicle	31	Older Than 25 Years	7,822	7,716	7,314
DE	Automobile/Car/Station Wagon	21	0-5 Years	12,272	11,489	13,042
DE	Automobile/Car/Station Wagon	21	5-10 Years	9,297	11,630	13,408
DE	Automobile/Car/Station Wagon	21	10-15 Years	6,449	8,738	7,175
DE	Automobile/Car/Station Wagon	21	15-25 Years	3,213	8,354	2,168
DE	Automobile/Car/Station Wagon	21	Older Than 25 Years	1,749	5,155	177
DE	Sports Utility Vehicle	31	0-5 Years	13,496	13,025	11,908
DE	Sports Utility Vehicle	31	5-10 Years	14,918	18,274	18,160
DE	Sports Utility Vehicle	31	10-15 Years	9,209	12,552	26,480
DE	Sports Utility Vehicle	31	15-25 Years	2,382	1,916	–

State	Vehicle Type	MOVES Type	Age Category	ANNMILES	AVG BESTMILE	AVG TOTMILES
FL	Automobile/Car/Station Wagon	21	0-5 Years	11,079	12,044	11,801
FL	Automobile/Car/Station Wagon	21	5-10 Years	9,329	11,051	10,240
FL	Automobile/Car/Station Wagon	21	10-15 Years	8,083	9,852	8,478
FL	Automobile/Car/Station Wagon	21	15-25 Years	5,841	8,533	5,962
FL	Automobile/Car/Station Wagon	21	Older Than 25 Years	2,289	6,664	3,852
FL	Sports Utility Vehicle	31	0-5 Years	11,972	13,656	13,325
FL	Sports Utility Vehicle	31	5-10 Years	11,159	13,201	12,526
FL	Sports Utility Vehicle	31	10-15 Years	9,847	12,155	9,440
FL	Sports Utility Vehicle	31	15-25 Years	7,167	8,795	5,541
FL	Sports Utility Vehicle	31	Older Than 25 Years	2,612	5,373	7,812

The project team also computed the fraction of MOVES type 21 and 31 vehicles for each state. These fractions are generally consistent with other data sources and appear with expected patterns (e.g., more rural states have a higher proportion of trucks). Therefore, the NHTS could serve as a supplemental source if problems are encountered obtaining or analyzing registration data. The proportion of source type 21 and 31 can be used to break out total VMT for these categories if classification counts do not appear reliable. These proportions by state are shown in the Practitioners' Handbook Volume 1, Section 4.2.

Off-Network Activity

Off-network activity (motor vehicle activity which occurs off the roadway network) can be modeled using the project-level input scale of analysis in MOVES. Examples of off-network locations include parking lots, with vehicle start-up and evaporative emissions; truck stops, with long-duration idle emissions; and bus terminals or ports, with low-speed and short-duration idle emissions.

Off-network data in a form directly suited to developing MOVES inputs are not collected often; and when such data are collected, they are likely to be site-specific and not representative of other off-network facilities. For the purposes of creating illustrative examples of the use of off-network data, the project team collected and analyzed preexisting data from three different types of facilities:

1. A study at the Port of Houston which gathered data on drayage movements by instrumenting trucks;
2. Traffic count data at a parking lot in Massachusetts (ins and outs by 15-minute time interval); and
3. Data collected on truck idling at rest areas and truck stops in Pennsylvania.

These examples are fully described in the Practitioners' Handbook Volume 2, Section 4.07.

Commercial Vehicle Data

One of the most challenging problems in developing MOVES inputs is to develop state or locally specific data on truck populations (source types 51-54 and 61-62). Vehicles registered in one state are often driven in other states, so VMT data are often used, in conjunction with average miles driven per vehicle, to infer source type population in the modeling domain. However, VMT data based on traffic counters typically only distinguish two types of trucks – single-unit and combination (tractor-trailer). Neither VMT nor registration data can readily distinguish the use pattern of the truck (short- versus long-haul). The research team investigated alternative sources of commercial vehicle data that could potentially provide insights into use patterns, as well as age distributions and annual mileage accumulation, to facilitate the development of locally specific truck activity data. These included primarily the Motor Carrier Management Information System, as well as state commercial vehicle registration databases and the International Registration Program.

Motor Carrier Management Information System

The Motor Carrier Management Information System contains information on the safety fitness of commercial motor carriers. It is maintained by the Federal Motor Carrier Safety Administration and data can be made available to the public with varying levels of detail. MCMIS data are collected from the MCS-150 form reporting required of motor carriers. Truck owners (carriers) are required to report information, including state of registration; the number of trucks in their fleet by type (single-unit, tractor); total annual miles driven by all trucks in their fleet; use of their trucks (freight versus service, and type of freight carried); and number of trucks registered for intrastate only versus interstate use. The database collects records from interstate and intrastate carriers registered in the United States as well as from interstate carriers registered in Canada and Mexico, segregated by state. The 2012 database reported the activity of over one million firms.

For this research, the 2012 MCMIS database was obtained from FMCSA and explored to determine its potential use in characterizing total truck registrations by truck type and state, and average annual VMT by truck, which can be used to convert VMT estimates to source type population estimates, or vice versa.

Not all firms reported total VMT. These entries were eliminated from the sample. In addition, some firms reported VMT totals that were very low or improbably high. Given that firms are responsible for self-reporting their data, there is no way to systematically eliminate all faulty entries from the sample. In order to eliminate a substantial percentage of faulty records, all firms that reported an annual total of one million miles or greater per truck were eliminated from the sample. In addition, firms that reported annual totals of under 1,000 miles per truck were eliminated. This left a remaining sample of 2.1 million trucks representing 59 billion annual VMT. Despite reporting errors that are common with this type of self-reported data, the data retains a significant degree of validity due to the size of the population and a lack of evidence that instances of misreporting were uniformly biased in one direction.

The result of the analysis shows an average utilization of 29,000 miles per truck per year for trucks certified for interstate commerce. For trucks certified only for intrastate commerce, the average is lower at 24,000 miles per year. Since fully utilized trucks can have annual utilization of more than 100,000 miles per year, the data indicates that a substantial number of registered trucks were not fully utilized in 2012. Table 7.16 shows the profile of trucks based on intrastate- and interstate-certified carriers.

Table 7.16 Profile of Carriers by Type from MCMIS Database

Carrier Type	Total Annual Mileage	Total Power Units	Annual Mileage Per Power Unit
Interstate Carriers	43.25 billion	1,482,198	29,180
Intrastate Carriers	15.70 billion	653,096	24,039

Source: Cambridge Systematics, Inc. analysis of 2012 MCMIS data from FMCSA.

FHWA's Highway Statistics, Table MV-9, also provides estimates of trucks registered by state, based on reporting by states. A comparison of the FHWA data and MCMIS data is shown in Table 7.17. Both 2010 and 2011 FHWA data are shown since there was a significant increase in total trucks reported in 2011, possibly due to changes in reporting procedures. (The term "tractors" in FHWA reporting is intended to mean all heavy truck power units, including single units and tractors.) Table 7.17 also compares trucks per 1,000 population between the two datasets as an indicator of how "truck-intensive" a state is. Long-haul trucks are often used in states other than those in which they are registered, and in-state truck registrations may not be a good proxy for the in-state population of trucks (especially combination long-haul trucks). A wide variation among states can be seen, as well as some large variations between the FHWA and MCMIS datasets.

The data in Table 7.17 provide justification for using VMT-based rather than registration-based methods for estimating heavy truck source type populations. States with relatively low truck registrations are likely to undercount truck populations active in the state, while states with relatively high registrations are likely to overcount them. There is some variation in truck VMT per capita among states, but not nearly as much as the variation in registrations per capita.

Table 7.17 Registered Trucks by State

State	FHWA Truck Tractors 2010	FHWA Truck Tractors 2011	MCMIS 2012 Registrations	Population	Trucks/,1000 (FHWA 2011)	Trucks/1,000 MCMIS 2012
Alabama	90,446	37,645	44,282	4,822,023	8	9
Alaska	4,394	4,644	11,559	731,449	6	16
Arizona	22,867	41,970	29,034	6,553,255	6	4
Arkansas[a]	24,523	39,033	19,105	2,949,131	13	6
California[d]	132,573	248,756	92,802	38,041,430	7	2
Colorado	8,921	28,928	56,328	5,187,582	6	11
Connecticut	2,420	7,161	27,960	3,590,347	2	8
Delaware	1,534	3,329	7,954	917,092	4	9
Dist. of Columbia	231	42	1,547	632,323	0	2
Florida[b]	241,681	64,757	87,876	19,317,568	3	5
Georgia[a]	84,895	69,272	82,871	9,919,945	7	8
Hawaii	1,218	2,817	3,392	1,392,313	2	2
Idaho	32,126	21,499	17,372	1,595,728	13	11
Illinois[c]	70,750	145,834	72,679	12,875,255	11	6
Indiana	58,316	212,908	49,939	6,537,334	33	8
Iowa[a]	49,410	73,196	42,575	3,074,186	24	14
Kansas	28,263	39,407	37,620	2,885,905	14	13
Kentucky[a]	27,415	30,075	43,435	4,380,415	7	10
Louisiana	42,815	34,350	24,282	4,601,893	7	5
Maine[a]	3,624	8,725	21,140	1,329,192	7	16
Maryland	17,101	12,484	50,858	5,884,563	2	9
Massachusetts[b]	13,142	13,199	41,705	6,646,144	2	6
Michigan	17,211	65,319	97,797	9,883,360	7	10
Minnesota[a]	35,733	67,507	96,371	5,379,139	13	18
Mississippi[a]	8,776	22,802	19,117	2,984,926	8	6
Missouri	53,902	68,558	46,904	6,021,988	11	8
Montana	19,667	22,106	13,877	1,005,141	22	14
Nebraska	36,305	57,830	31,613	1,855,525	31	17
Nevada[a]	7,846	7,898	10,063	2,758,931	3	4
New Hampshire	5,815	5,354	14,614	1,320,718	4	11
New Jersey[b]	13,808	40,900	57,222	8,864,590	5	6
New Mexico	13,177	11,848	17,984	2,085,538	6	9
New York	7,136	38,764	124,053	19,570,261	2	6
North Carolina	46,434	69,983	51,659	9,752,073	7	5
North Dakota	9,961	32,334	15,209	699,628	46	22
Ohio	41,809	98,067	62,460	11,544,225	8	5
Oklahoma[a]	13,110	56,350	38,255	3,814,820	15	10
Oregon	21,385	25,419	34,080	3,899,353	7	9

State	FHWA Truck Tractors 2010	FHWA Truck Tractors 2011	MCMIS 2012 Registrations	Population	Trucks/,1000 (FHWA 2011)	Trucks/1,000 MCMIS 2012
Pennsylvania	71,377	77,655	104,536	12,763,536	6	8
Rhode Island[b]	3,472	1,982	8,158	1,050,292	2	8
South Carolina	21,631	25,683	24,880	4,723,723	5	5
South Dakota[a]	19,609	23,615	14,544	833,354	28	17
Tennessee[a]	64,921	47,210	37,123	6,456,243	7	6
Texas[a]	183,937	220,577	124,396	26,059,203	8	5
Utah	63,468	28,998	22,760	2,855,287	10	8
Vermont	2,943	3,614	6,701	626,011	6	11
Virginia	42,258	37,598	36,196	8,185,867	5	4
Washington[a]	35,279	42,657	50,982	6,897,012	6	7
West Virginia	11,582	8,386	19,365	1,855,413	5	10
Wisconsin[a]	53,538	61,877	76,148	5,726,398	11	13
Wyoming[a]	4,411	10,374	11,890	576,412	18	21
Total	1,889,166	2,421,296	2,135,272	313,914,040		

Source: FHWA, Highway Statistics 2011, Table MV-9; and analysis of FMCSA Motor Carrier Management and Information System by Cambridge Systematics, Inc.

[a] State did not report active registrations and registers vehicles annually. Annual transaction data shown.

[b] State did not report active registrations and offers multiyear registrations. Data estimated from current and previously published data.

[c] State did not report current year data. Previous year data shown for private vehicles.

[d] State data estimated from Department of Motor Vehicles published data.

Other Commercial Vehicle Data Sources

Motor carrier registration data may also be obtained directly from state entities. For example, the Texas Motor Carrier Database includes information collected directly from all registered motor carriers in the State. Its collection is independent of the State's vehicle registration database and it is updated monthly. The database contains the vehicle identification numbers (VIN) for all commercial vehicles. From this source, data on the size and characteristics of engines, as well as make and model, can be decoded. It is available through a web interface[15] and on CD from the Texas Department of Motor Vehicles.

The **International Registration Plan** collects data from motor carrier fleets for the purpose of apportioning registration fees for carriers operating in multiple states. Information reported includes vehicle type, age, fuel type, weight, and miles driven by state. In theory these data, if obtained in disaggregate format, could be used to estimate truck VMT, miles per vehicle, and age distribution by

[15] Texas Motor Carrier Registration Database, available at: http://apps.txdmv.gov/apps/mccs/truckstop/.

vehicles registered outside of a state but operating within the state. However, efforts to acquire data for purposes of this research were unsuccessful.

The **Freight Analysis Framework** (FAF) does not provide direct information on vehicle population, but it does provide information on truck flow patterns that can help to identify short- versus long-haul movement. The FAF is produced by FHWA to provide detailed data and analysis on freight movement in the U.S. The FAF integrates information from a number of transportation and commodity flow data sources to allow a more detailed assessment of travel and population related to goods movement in each county of the U.S. Included in the FAF are data on average annual daily traffic for long-haul trucks reported for specific segments of highways by county. The FAF provides data on long-haul trucks miles and population, which can be compared to local registration data on combination trucks to develop an adjustment for long-haul truck population. This can be used to calculate long-haul truck population by county, assuming that major roads in the FAF represent all long-haul trucks. Forecasts of data items contained in FAF are available from a private source, the TRANSEARCH database produced by Global Insight. Illustrative FAF data are used in the Practitioners' Handbook Volume 1, Section 4.2 to show how they could be used to supplement other information on source type population.

The California Hybrid, Efficient, and Advanced Truck Research Center (CalHEAT) undertook the **California Truck Inventory and Impact Study** to better understand the various types of trucks used in California, their relative populations, and how they are used. As part of the study, the population of 1.5 million trucks and buses registered in California was characterized based on Polk registration data. A custom classification system was developed that used the model of the truck to sort the vehicles into six different use categories. These categories distinguish short- and long-haul uses as well as single-unit and combination trucks, and therefore provide a sample source of data roughly corresponding to MOVES source types. The study also produced data on VMT, fuel type, fuel use, age distribution, and CO_2 emissions by truck category. The methodology could potentially be applied to truck registration data from other states. Examples of the data resulting from the CalHEAT study are shown in Practitioners' Handbook Volume 1, Section 4.02, Source Type Population.

7.3 Sample Data and Comparisons

Sample data from VTRIS and Highway Statistics for VMT by vehicle type, road type distributions, and temporal distributions are provided in the corresponding sections of the Practitioners' Handbook, and the full data (where users can create pivot tables and charts by state, road type, and vehicle type) are provided in Excel files.

The research team performed a considerable amount of work to develop and compare speed distributions from the various data sources. Examples are provided in the Practitioners' Handbook Volume 1, Section 4.7. Additional details are provided below.

Speed Distributions

Speed distributions were compared from the following sources:

- Atlanta:
  - Travel demand model, postprocessed by ARC;
  - Travel demand model, postprocessed by project team;
  - GDOT ITS data (freeways only); and
  - GPS travel survey data.
- Jacksonville:
  - Travel demand model, not postprocessed;
  - Travel demand model, postprocessed by project team; and
  - FDOT ITS data (freeways only).

It is challenging to compare speed distributions because there are numerous metrics that could be applied, and because each hour of the day has a different distribution. Simple statistics such as average speed do not capture the variation in speeds that is critically important to emissions modeling. The following methods and metrics were used to compare the distributions here:

- Focusing on four "representative" time periods – 5:00 a.m. to 6:00 a.m. (overnight period), 7:00 a.m. to 8:00 a.m. (AM peak), 11:00 a.m. to 12:00 p.m. (midday), and 5:00 p.m. to 6:00 p.m. (PM peak).
- Presenting graphs to allow visual comparisons.
- Providing summary statistics of average speed by time period and percent of VHT less than 27.5 mph (representing congested conditions with higher emissions).
- Calculating running emissions for each distribution, based on representative emission rates by speed. This approach does not indicate how well a speed prediction approach performs against observed speed data, but it does show how much difference the choice of different speed estimation methods can make on emissions.

First, Figures 7.8 and 7.9 are provided to show the impact of speeds on emissions. These figures show running emissions expressed relative to the lowest emissions rate at any speed (usually around 60 mph). The emissions are calculated using representative factors from Hillsborough County, Florida for 2006, with input data embedded in the MOVES model, for the 7:00-7:59 a.m. hour. These figures show that NO_x and CO_2 equivalent emissions (CO_2e) decline rapidly up to about 20-25 mph (freeways) or 30-35 mph (arterials), them much more slowly. VOC declines more steadily up to the 50-60 mph range. $PM_{2.5}$ also declines with speed but in a more irregular manner. All pollutants increase slightly above 60 mph.

Figure 7.8 Relative Emissions by Speed
Urban Restricted Access

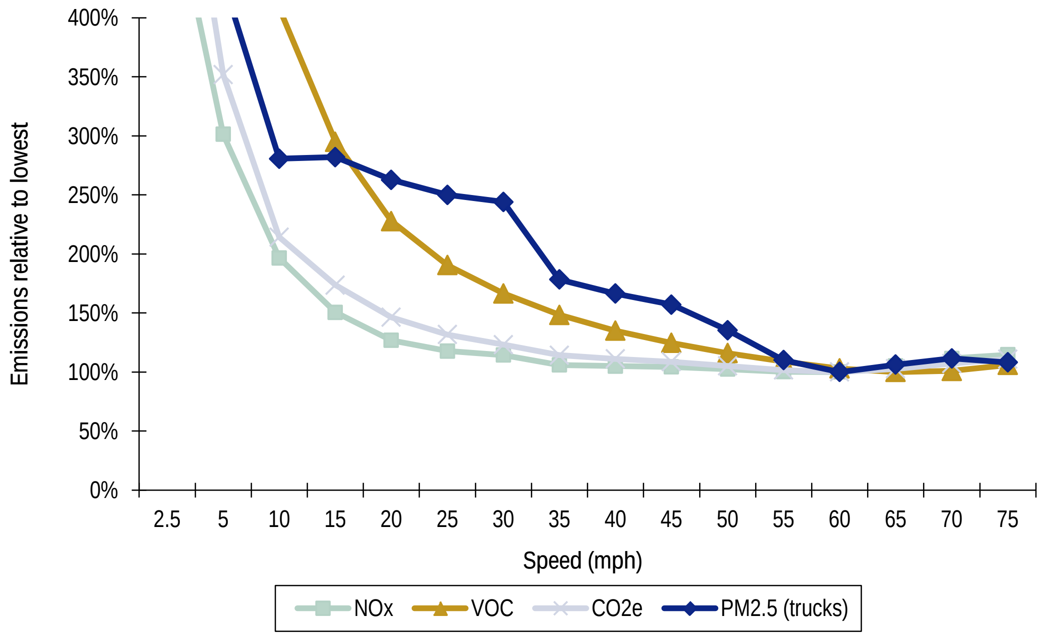
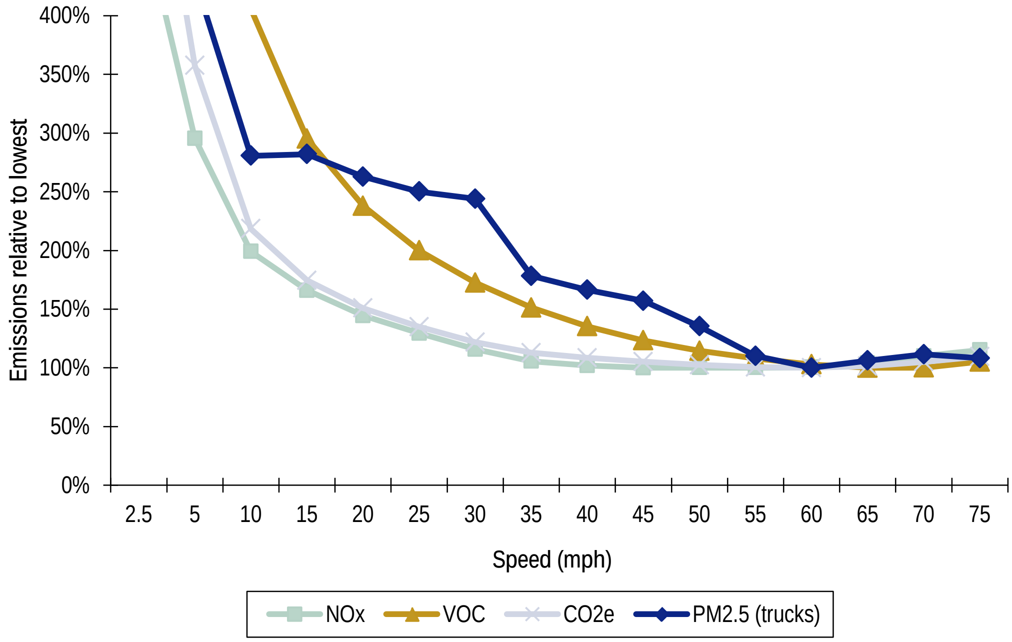


Figure 7.9 Relative Emissions by Speed
Urban Unrestricted Access



Visual Inspection of Speed Distributions

Figures 7.10 through 7.12 show the speed distributions for freeways in the Atlanta region from the model, ITS, and GPS data sources. The model shows a relatively large fraction of VHT at low speeds (<20 mph) and midrange speeds (35-55 mph) in the peak hours compared to the ITS data. It also shows small peaks around 25 and 40 mph in the midday and night periods. The ITS data show a more even distribution of speeds from about 10 to 50 mph. Compared to the ITS data, the GPS data show less travel at low speeds (<30 mph) and more in the midrange (30-50 mph).

Figures 7.13 through 7.15 show speed distributions for Jacksonville freeways. The unprocessed model results show more travel at low speeds (<20 mph) than either the processed results or the ITS data. Both sets of model results also show a strong peak at 65 mph (free-flow on many road segments), whereas the ITS data show higher speeds somewhat more evenly distributed over the 60-75 mph range. The AM and PM peak hour distributions are fairly similar in the observed ITS data, whereas the model shows higher levels of congestion in the PM peak compared to the AM peak.

Figure 7.10 Speed Distribution – Atlanta Freeways
Travel Demand Model (Postprocessed)

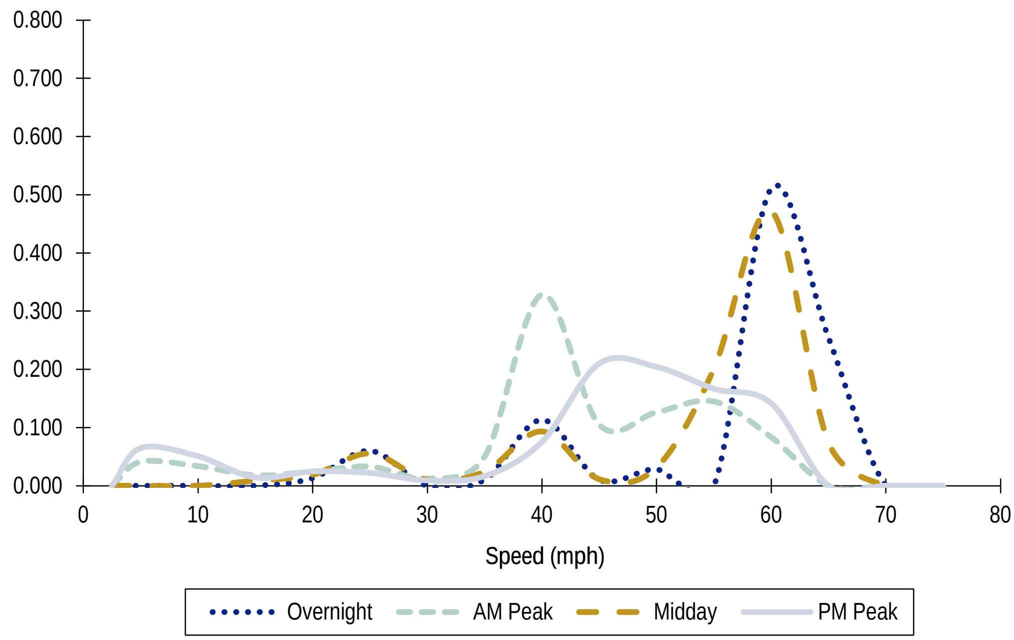


Figure 7.11 Speed Distribution – Atlanta Freeways
ITS

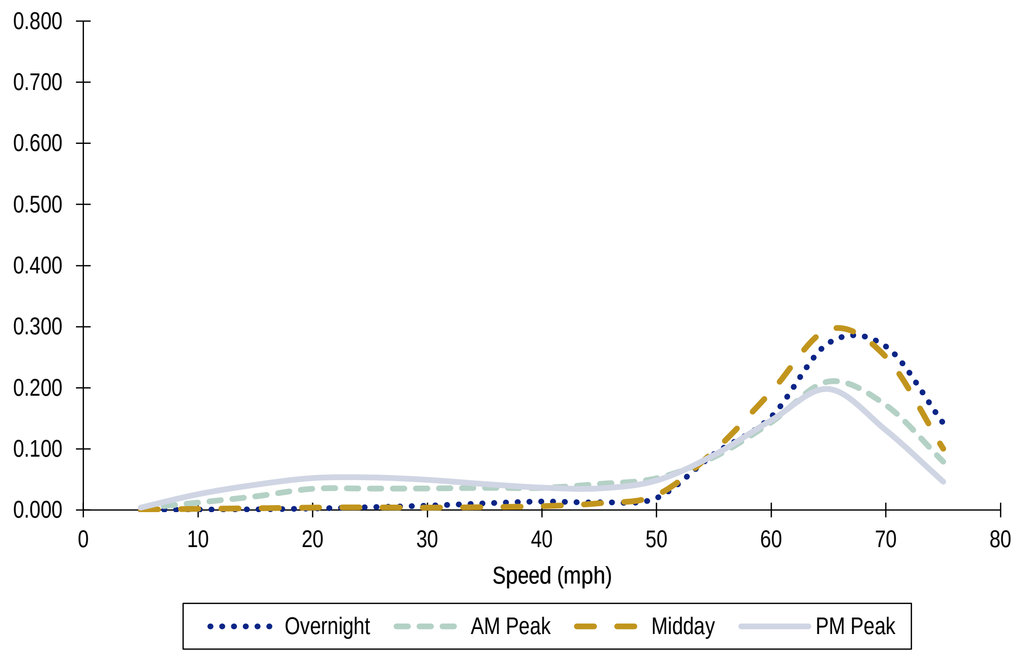


Figure 7.12 Speed Distribution – Atlanta Freeways
GPS Travel Survey

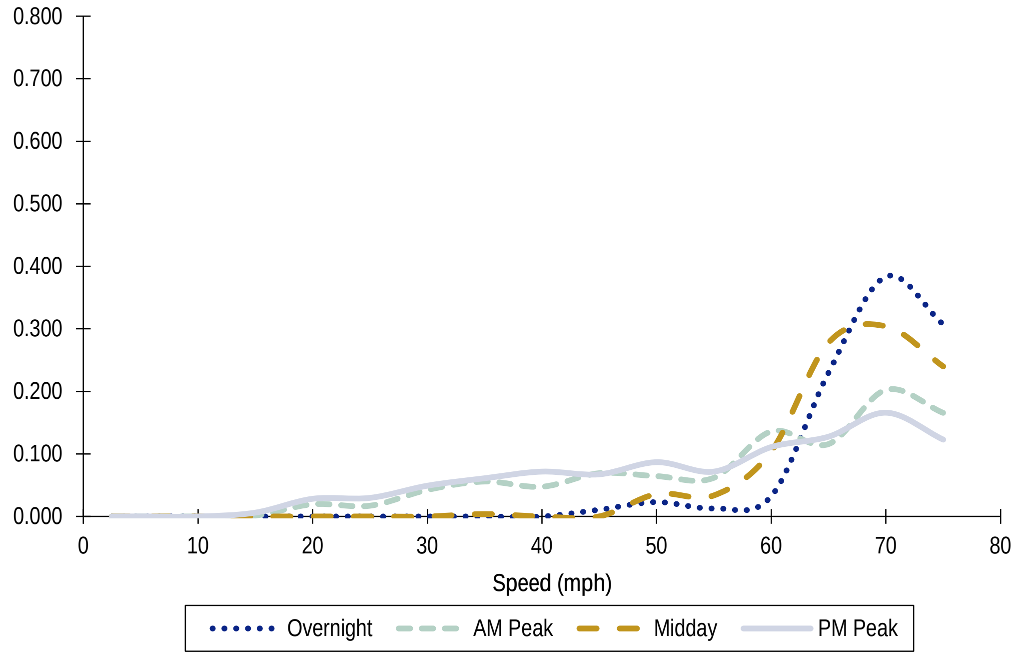


Figure 7.13 Speed Distribution – Jacksonville Freeways
Travel Demand Model (Not Postprocessed)

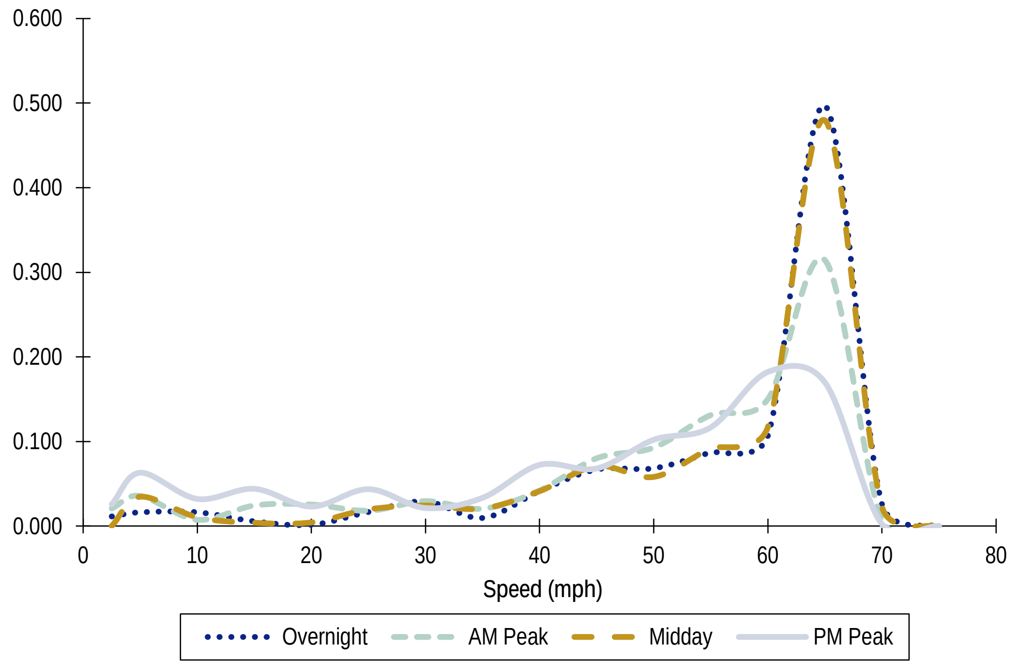


Figure 7.14 Speed Distribution – Jacksonville Freeways
Travel Demand Model (Postprocessed)

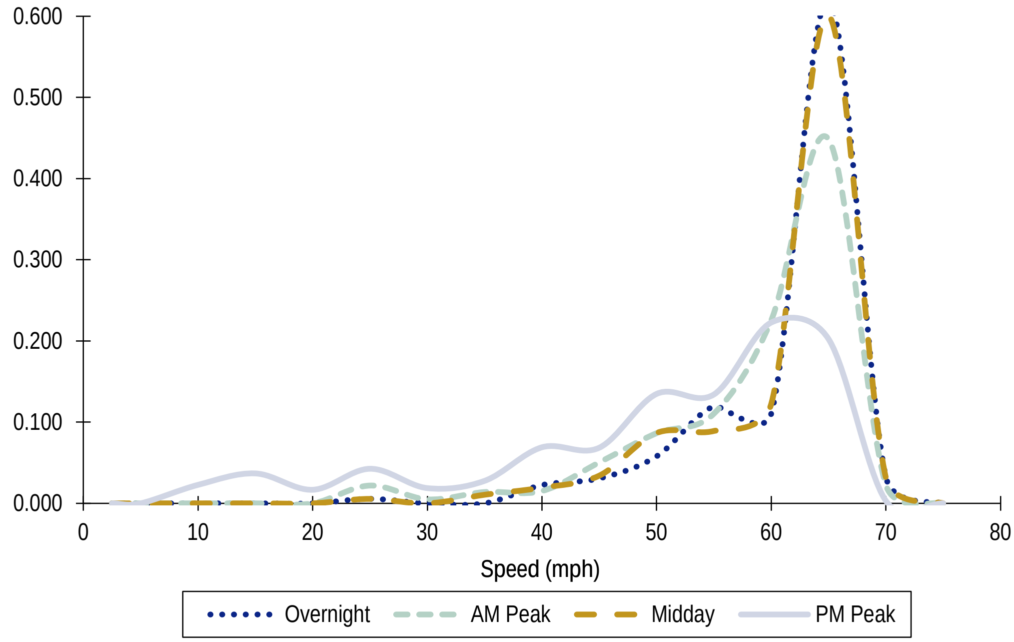
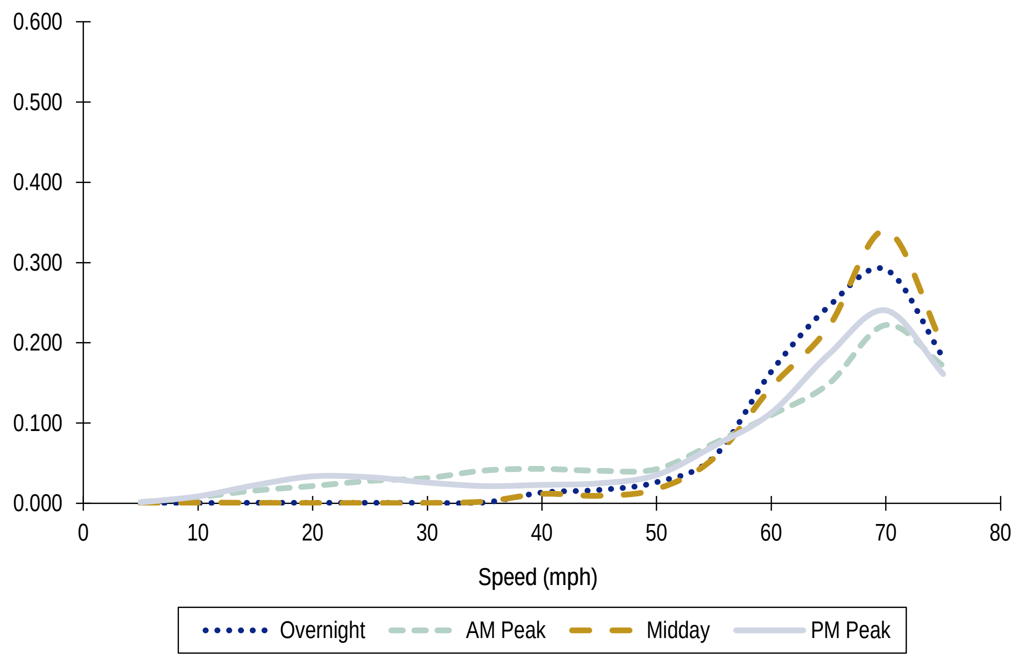


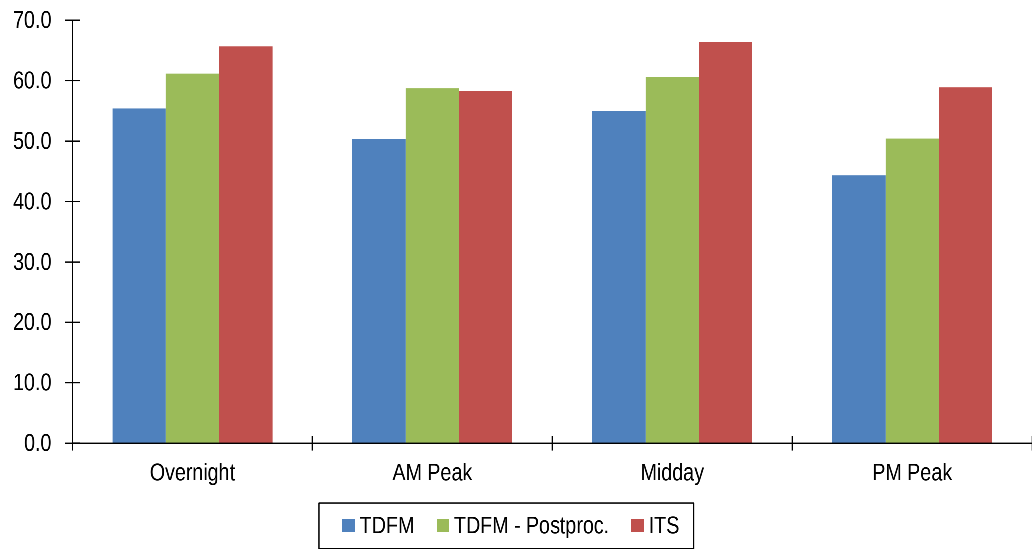
Figure 7.15 Speed Distribution – Jacksonville Freeways
ITS



Average Speeds

Next, average speeds are shown for each city, road type, time period, and processing method. Figures 7.16 and 7.17 show Jacksonville and Atlanta freeways, and Figures 7.18 and 7.19 show Jacksonville and Atlanta arterials.[16]

Figure 7.16 Average Speed – Jacksonville Freeways



[16] ARC has updated its speed postprocessing procedures and the local adjustment factors used in this example (Postproc. 1) are no longer used. The results are shown only to illustrate the difference that the choice of alternative postprocessing methods can make.

Figure 7.17 Average Speed – Atlanta Freeways

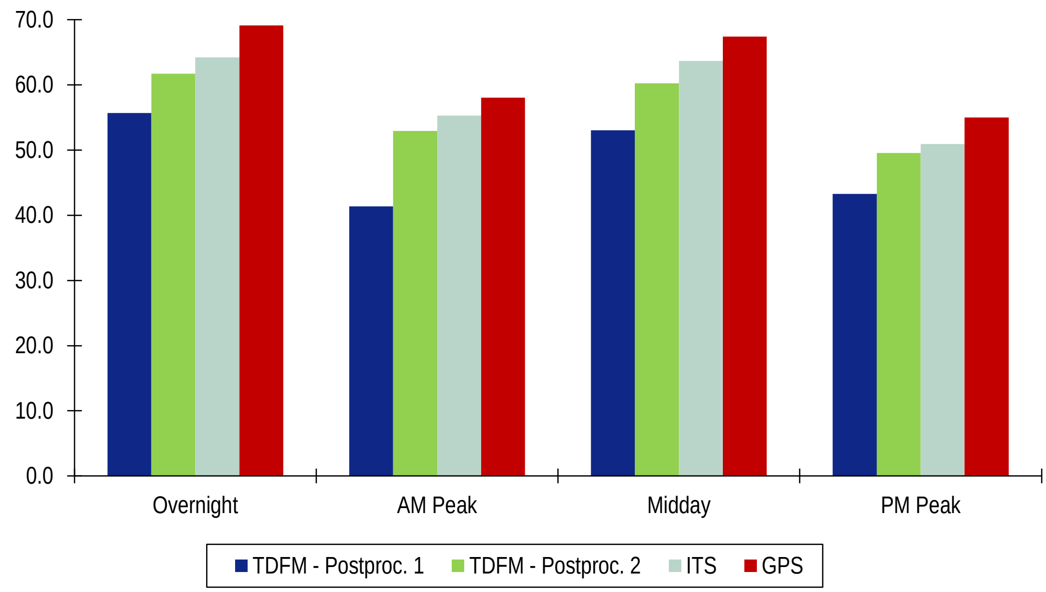


Figure 7.18 Average Speed – Jacksonville Arterials

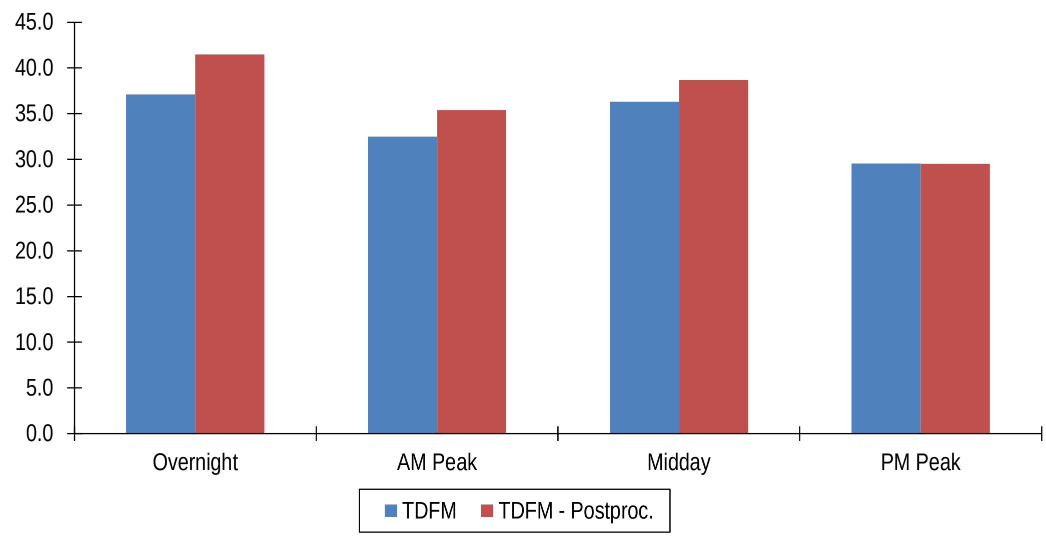
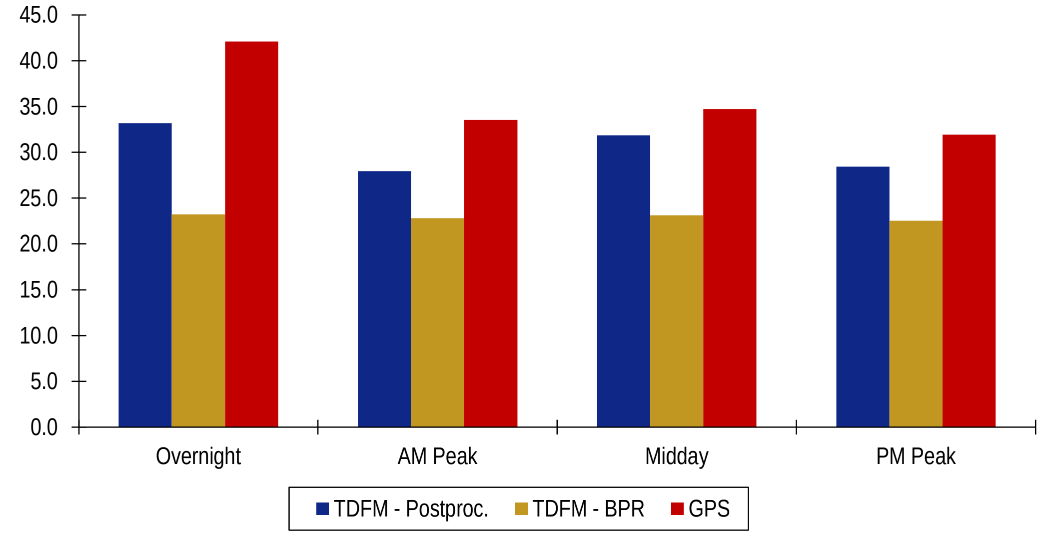


Figure 7.19 Average Speed – Atlanta Arterials



It is apparent that the average speed estimates differ substantially, by up to 20 percent or even more. For the freeway system, the ITS data can probably be taken as the closest to "ground truth" as they cover the network comprehensively, throughout the year, and at a fine level of temporal detail. The only potential known bias in the ITS data is from missing observations at very low speeds.

In both Atlanta and Jacksonville, the model estimated speeds are considerably lower on average than the ITS speeds. Postprocessing improves this substantially in Jacksonville, but even the postprocessed speeds are 5-10 percent lower than the observed ITS speeds. In Atlanta, the average speeds from the GPS travel surveys are even higher than the ITS speeds. It is not clear what aspect of the household survey sampling procedure might create such a bias. It is clear, however, that the use of model "free-flow" speeds, typically set at posted speed limits of up to 65 mph, underrepresent high-speed vehicle travel once the volume-delay functions are applied, as the *average* speeds observed in off-peak periods ranged from 64 to 67 mph.

Low-Speed Travel

Table 7.18 compares the fraction of VHT at lower speeds (less than 27.5 mph) from each data source. Consistent with the above charts, in most cases the ITS data show less low-speed travel than the model data. In Jacksonville, postprocessing moves the model low-speed fractions closer to the observed ITS fractions for most time periods.

Table 7.18 Low-Speed Travel Fractions

Source	Overnight (5:00-6:00 a.m.)	AM Peak (7:00-8:00 a.m.)	Midday (11:00 a.m.-12:00 p.m.)	PM Peak (5:00-6:00 p.m.)
Jacksonville: Road Type 4 – Restricted Urban				
TDFM	6.8%	13.2%	7.3%	23.2%
TDFM – Postproc.	0.6%	2.2%	0.5%	11.9%
ITS	0.2%	7.5%	0.2%	9.9%
Atlanta: Road Type 4 – Restricted Urban				
TDFM – Postproc.	7.3%	15.0%	8.3%	17.6%
TDFM – BPR (Jax)	3.3%	5.8%	3.6%	7.6%
ITS	0.9%	10.7%	1.3%	17.6%
GPS	0.0%	3.8%	0.0%	6.4%
Jacksonville: Road Type 5 – Unrestricted Urban				
TDFM	24.5%	35.8%	25.6%	45.9%
TDFM – Postproc.	18.4%	27.2%	20.2%	46.0%
Atlanta: Road Type 5 – Unrestricted Urban				
TDFM – Postproc.	22.9%	44.1%	28.9%	41.1%
TDFM – BPR	55.3%	56.6%	55.6%	58.0%
GPS	3.6%	23.2%	22.4%	28.3%

Emissions

Emission factors by speed for Hillsborough County, Florida for 2006 were used to develop an estimate of how much emissions might vary depending upon the choice of speed estimation method. The emission factors are calculated as the weighted average of emissions by speed (using the midpoint of the speed bin), weighted by VHT in each speed bin. The emission factors for each speed distribution are show in Tables 7.19 and 7.20. (The relative difference compared to the ITS emissions rate is shown in the sample data provided in Practitioners' Handbook Volume 1, Section 4.7). Conclusions that can be drawn include:

- For Jacksonville freeways, the unpostprocessed model emissions are significantly higher than the emissions calculated based on ITS observed speeds. The largest differences are observed for VOC (30-70 percent higher), followed by truck $PM_{2.5}$ (20-40 percent higher), CO_2e (10-30 percent higher), and NO_x (up to 20 percent higher).
- The postprocessing of Jacksonville model speeds brings the emissions estimates much closer to the estimates based on observed ITS speeds, within 5 percent in most cases.

- For Atlanta freeways, use of the ITS and GPS speed distributions leads to fairly similar emissions results. The model speeds postprocessed using ARC's procedures show significantly higher emissions in peak periods, especially for VOC and truck $PM_{2.5}$, which are about 10-30 percent higher depending on the time period.
- Alternative postprocessing of Atlanta model speeds, using the BPR function with Jacksonville's coefficients, provides emission estimates that are much closer to the ITS and GPS-based estimates (within 3 percent in all cases).

Table 7.19 Composite Emissions (g/mi), VOC and NO_x

Metro Area/Source	VOC				NO_x			
	Overnight (5:00-6:00 a.m.)	AM Peak (7:00-8:00 a.m.)	Midday (11:00 a.m.-12:00 p.m.)	PM Peak (5:00-6:00 p.m.)	Overnight (5:00-6:00 a.m.)	AM Peak (7:00-8:00 a.m.)	Midday (11:00 a.m.-12:00 p.m.)	PM Peak (5:00-6:00 p.m.)
Jacksonville								
TDFM	0.36	0.43	0.34	0.53	1.85	1.98	1.83	2.15
TDFM – Postproc.	0.26	0.27	0.26	0.33	1.69	1.68	1.69	1.75
ITS	0.26	0.31	0.26	0.31	1.75	1.78	1.76	1.79
Atlanta								
TDFM – Postproc. 1	0.29	0.42	0.30	0.45	1.68	1.89	1.67	1.97
TDFM – Postproc. 2	0.27	0.31	0.27	0.34	1.71	1.72	1.69	1.77
ITS	0.27	0.32	0.27	0.35	1.74	1.78	1.73	1.82
GPS	0.26	0.29	0.26	0.31	1.79	1.75	1.76	1.75

Table 7.20 Composite Emissions (g/mi), CO_2e, and $PM_{2.5}$

Metro Area/Source	CO_2e				$PM_{2.5}$ (Combination Long-Haul Trucks)			
	Overnight (5:00-6:00 a.m.)	AM Peak (7:00-8:00 a.m.)	Midday (11:00 a.m.-12:00 p.m.)	PM Peak (5:00-6:00 p.m.)	Overnight (5:00-6:00 a.m.)	AM Peak (7:00-8:00 a.m.)	Midday (11:00 a.m.-12:00 p.m.)	PM Peak (5:00-6:00 p.m.)
Jacksonville								
TDFM	525	577	516	641	0.85	0.98	0.83	1.13
TDFM – Postproc.	462	465	463	498	0.68	0.71	0.69	0.86
ITS	473	496	475	499	0.67	0.81	0.67	0.80
Atlanta								
TDFM – Postproc. 1	470	557	474	580	0.75	1.04	0.77	1.03
TDFM – Postproc. 2	468	487	466	506	0.70	0.82	0.70	0.89
ITS	473	500	472	520	0.69	0.84	0.68	0.92
GPS	480	487	475	491	0.67	0.80	0.66	0.84

8.0 Tool Development

Four tools were developed that are designed to assist MOVES users with preparing inputs. The tools are:

- **MOVES Operating Mode Data Import Tool** – Utility program that assists MOVES users in taking vehicle trajectories from a traffic simulation model and converting them to operating mode distributions for input to MOVES.
- **MOVES Meteorology Data Import Tool** – Utility program that reads the National Climatic Data Center Local Climatological Data in ASCII format and carries out most of the steps to convert it to MOVES temperature/relative humidity CSV input format.
- **MOVES Highway Statistics Analysis Tool** – Excel spreadsheet that calculates state-level road type distributions and VMT fractions by HPMS vehicle type, for all 50 states, from data reported by FHWA in the Highway Statistics Series.
- **MOVES VTRIS Analysis Tool** – Excel spreadsheet that provides summary tabulations from the 2012 Vehicle Travel Information System, for states reporting classified traffic count data to FHWA. This tool provides sample hour and day of week VMT fractions by state, road type, and vehicle class.

The software and data input requirements for these tools are documented in the *MOVES Tool Documentation* that accompanies the tools.

The Operating Mode Data Import Tool is a stand-alone utility that requires the Microsoft.Net Framework to run. The user is responsible for any preprocessing required to convert the output from their traffic simulation model to a generic format employed in the trajectory input file for this tool. This includes mapping of vehicle types (which vary for different models) to the 13 MOVES source types. The tool prepares a file directly usable for MOVES operating mode distribution input in the Project Data Manager.

To run the meteorology data import tool, called LCD-to-MOVES, the user creates a directory, then downloads the 12 monthly Local Climatological Data files from the National Climatic Data Center web site. The user provides the program with the location of these files. The program will, in turn, extract a summary of the hour information from the 12 files and output a single 12-month MOVES-ready meteorological input file.

The Highway Statistics Analysis Tool and VTRIS Analysis Tool were originally developed for the purpose of creating sample data on temporal VMT and road type distributions, using available data from states as reported to FHWA. It was then determined to provide the tools to users so that they could examine data from their own state, in addition to the summary tables and charts presented in the Final Report and Practitioners' Handbook. The Highway Statistics Analysis

Tool can be easily updated by pasting in the latest year's data tables from Highway Statistics Tables VM-2 and VM-4. The VTRIS Analysis Tool utilizes data created from queries in Microsoft Access and therefore cannot be easily updated. However, users could create similar data tabulations for their own state using classified traffic count data collected by their state DOT.

9.0 Additional Research and Data Needs

In the course of this research the project team identified a number of places were gaps in existing data limit the extent to which the full capabilities of the MOVES model can be utilized. In some cases, these gaps could be addressed through expansion of existing data collection programs, using widely available technologies. In other cases, additional research may be needed to demonstrate new/emerging data collection methods and how they could be adopted to support the use of MOVES.

Of course, resources for data collection are always limited. Practitioners and researchers can use the sensitivity information provided in Section 6.0 of this report to help in prioritizing improvements to data collection procedures and methods, focusing on the MOVES inputs which are of greatest significance to determining emissions outputs. The utility of data for other purposes – not just MOVES use – is also a consideration in determining where to direct resources.

Needs are discussed in two categories:

- Data collection; and
- Research and methodology development.

9.1 Data Collection

Classified traffic data collection for VMT-based inputs – Traffic counts are the primary basis for developing local inputs for VMT, road type distribution, and hour, day, and month temporal adjustments. Classified traffic counts can allow MOVES users to make fuller use of the model's capabilities by supporting source type-specific distributions for road type and temporal adjustments. However, the network of classification counters is usually too thin to develop such distributions at anything less than a state level. Even at a state level, only about half of all states report classified count data to FHWA so that it is readily available in a consistent format. A more robust system of permanent classification counters (so that 24-hour and seasonal adjustments can be developed), along with reporting of this data, would support the development of more refined MOVES inputs. This would be especially useful in states where traffic patterns vary significantly across geographies, due to seasonal patterns, local industry mix, or other factors.

Speed data and traffic networks – Public agencies are increasingly acquiring traffic speed monitoring data from private sources, or expanding their own monitoring systems through methods such as Bluetooth technology. However, these data are not always readily translated into MOVES inputs for speed distribution. If traffic management center networks were made consistent with (or crosswalked to) travel demand model networks, speeds could be matched with volume information. Acquiring speed distributions built from disaggregate data, rather than just average speeds by link and time period, would support the development of more robust MOVES inputs.

Heavy-duty vehicle fleets and activity – The migration of vehicles, especially heavy duty trucks, across state lines poses challenges for developing locally specific age and source type distributions for these vehicle classes. State registration may not be a good representation of the heavy-duty vehicle fleet within that state. To improve local inputs, data are needed on the fraction of truck traffic that is from locally registered versus out-of-area vehicles, the expected "home" locations of these vehicles (where registered), and the characteristics of these vehicles. License plate surveys are one way of obtaining this information but are only useful if registration data can be obtained from other states; cross-state cooperation is needed. Partnerships with the International Registration Program could also be explored to consider the use of data collected through this program (which allocates motor fuel tax revenue to states based on use) in conjunction with multistate registration data on commercial vehicles.

Off-network data – While off-network facilities (such as ports, intermodal terminals, transit centers, truck stops, and park-and-ride lots) vary greatly in their individual fleet and activity characteristics, there are few examples of data available to assist in developing representative characteristics for such sources. The data collection conducted at the Port of Houston using portable activity monitors and license plate surveys is a good example of how data on heavy-duty vehicle activity at other ports and intermodal facilities could be collected. Data could be compared from multiple facilities to identify representative characteristics such as speed profiles and extended idle time, or to illustrate ranges in these parameters for different types of facilities.

9.2 Research and Methodology Development

Speed data by source type – Traffic speeds have been observed to differ significantly for cars versus trucks. Most speed monitoring methods do not readily distinguish by source type. Research could be conducted into whether emerging speed collection methods (such as video or Bluetooth) could link speeds with vehicle type information so that source-type speed distributions could be developed.

Speed prediction methods – Predicting speed using volume-delay functions based on coarse, nontime-dependent road network parameters (such as volume-to-capacity ratios) is, and always will be, an imperfect art. However, given the wealth of sources on observed speeds, it may be worth revisiting this issue to see whether methods can be improved, and calibrated against an overall distribution of speeds on a network, rather than simply comparing on a link-by-link basis. Also, volume-delay functions in common use do not do a good job of describing a distribution of speeds around free-flow average in uncongested conditions. In the long run, real improvement to speed distributions will need to come from the broader use of dynamic simulation models to better account for intersection operations, time-varying effects, and stochastic behavior.

Traffic classification methods – The options for classified traffic counts have expanded from traditional tube counters (using axle-based methods) to include video, radar, and lidar. Length-based methods could potentially be combined with axle-based methods to refine vehicle classifications, to assist in developing VMT and source type population inputs at both the regional and project scale. Potentially, video systems could become sophisticated enough to differentiate between most light-duty cars and trucks based on body characteristics.

Truck short- versus long-haul populations – Differentiating truck populations used in short- versus long-haul activity is one of the most challenging issues to address in developing local MOVES inputs. The research conducted by CalHEAT on trucks in California was an innovative approach to using registration data to infer use patterns, which can inform short- versus long-haul breakdowns. Similar research could be conducted in other states, with a focus specifically on characteristics important for MOVES inputs.

Expanded use of fleet-based telematics data to measure heavy-duty vehicle activity – The widespread use of GPS equipment, especially on fleet vehicles, provides an opportunity to gather better data on truck activity. GPS and other data collection methods will be the subject of NCHRP Project 08-101, *Measuring Regional Heavy-Duty Diesel Vehicle Activity and Goods Movement*, to be initiated in Fiscal Year 2015.

A. Literature Review Findings

Sections A.1-A.4 describe literature related to fleet, regional-level activity, project-level activity, and other MOVES inputs, respectively. Section A.5 provides an overview of surveys conducted by other organizations on the use of MOVES.

A.1 Fleet Data Inputs

This section discusses literature related to vehicle fleet inputs, including the distribution of vehicles by age and vehicle type (source type).

Age Distribution

Age distribution is a series of fractions that sum to 1, representing the percentage of vehicles that fall within each age category. MOVES requires these fractions for 31 age categories (bins) that each contain one year of vehicles, except for the final category, which represents all vehicles 30 years old and older. MOVES requires a separate age distribution for each of 13 MOVES source (vehicle) types. This information is used in emissions analyses because older vehicles typically have higher emission rates due to older technology in those vehicles as well as deterioration. This input was required with MOBILE6, but had a slightly different format.

[5] Chatterjee and Miller (1994). The study identifies numerous data sources that can be used for developing model inputs, including age distribution profiles for fleets. The study discusses the use of vehicle registration data and inspection and maintenance records, both of which can be used to obtain age distributions.

[20] Malcolm et al. (2003). In this study, vehicle activity and vehicle fleet data were collected in the South Coast Air Basin in southern California. Average traffic speed, density, flow rates, and license plate data were captured with a digital video camera and subsequently analyzed using vehicle registration databases and VIN decoders. This method could be used in an expanded area to establish vehicle age distribution.

[14] FHWA (2009). The information collected in the U.S. DOT 2009 National Household Travel Survey included vehicle model year, which may be used as an existing data source to help build age distribution profiles for light-duty vehicles. Locality-specific profiles could be developed for states and for major metropolitan areas, since records are associated with individual metropolitan areas if they are located in the 50 largest areas. It may be possible to develop locality-specific profiles for other areas in states which paid for add-on samples, but this would require working with the state NHTS data coordinator to obtain data coded with the needed geographic identifiers (e.g., county).

[15] FTA (no date). The Federal Transit Administration annually collects data from transit operators to populate the National Transit Database (NTD). The database includes number of vehicles by type and age for each reporting transit operator, so age distributions could be developed for the regional public transit vehicle fleet.

Source Type (Vehicle) Population

Source type (vehicle) population is simply the total number of vehicles for each of the 13 MOVES source (vehicle) types, as shown in the example in Table A.1. It is a new input for MOVES that was not required under MOBILE6 and is used to calculate nonrunning emissions, such as vehicle starts and evaporative emissions. It can often be obtained from the same vehicle registration data that is used for age distributions, but there are also other methods of creating this input based on the travel activity of each vehicle type in a county.

Table A.1 Example Source Type (Vehicle) Type Population Input

yearID	sourceType	sourceTypeID	sourceTypePopulation
2002	Motorcycle	11	1,622
2002	Passenger Car	21	39,398
2002	Passenger Truck	31	21,126
2002	Light Commercial Truck	32	7,058
2002	Intercity Bus	41	29
2002	Transit Bus	42	18
2002	School Bus	43	201
2002	Refuse Truck	51	27
2002	Single Unit Short-Haul Truck	52	1,413
2002	Single Unit Long-Haul Truck	53	113
2002	Motor Home	54	300
2002	Combination Short-Haul Truck	61	354
2002	Combination Long-Haul Truck	62	316

[5] Chatterjee and Miller (1994). This study suggests using vehicle counts, vehicle registration data, and inspection and maintenance records for developing vehicle population data for use in emissions inventory development.

[14] FHWA (2009). The 2009 NHTS collected vehicle information, including vehicle type. This data may assist a user in supplementing vehicle population data on light-duty vehicles, in particular, factoring total light-duty vehicle population by type. However, this source does not cover commercial vehicles and also will not reflect through traffic. The NHTS sample size is probably adequate for state-level analysis and possibly for the 50 largest MSAs. Survey data might also be usable for other geographic subareas (e.g., counties or aggregations of counties) in states with oversamples.

[8] Cohen and Chatterjee (2003). The purpose of this report is to use available data and information to develop an improved understanding of the magnitude and spatial/temporal distribution of different types of commercial vehicle travel. The study compared different data sources, concluding that there are significant discrepancies among the available data sources, and that some data sources are useful to answer one particular question, but other sources were needed to answer other questions. The study highlights the challenges faced with developing source type population data for use in MOVES using existing data sources. While the study is based on reviews of a multitude of sources, the following were specifically identified:

- Commercial vehicle survey data (Detroit, Atlanta, Denver, and the Piedmont-Triad area);
- California Department of Motor Vehicle data (Los Angeles, San Francisco, San Diego, and Sacramento);
- National Transit Database (198 cities in the United States);
- United Postal Service data;
- School bus fleet surveys (largest 100 school districts);
- Taxi Fact Book (all major U.S. cities);
- Airport Ground Access Planning Guide (27 U.S. cities); and
- Vehicle Inventory and Use Survey (VIUS).

[19] Lindhjem and Shepard (2007). This report analyzes data compiled by FHWA from the Highway Performance Monitoring System, weigh-in-motion sensors, and other data sources (visual observation, weigh stations, and other special projects) with the objective of improving heavy-duty vehicle modeling capability. Vehicle weights and mix of vehicle classes are investigated depending upon a number of regional and temporal factors by vehicle and roadway types. The methods described in this study can be used to develop vehicle characteristics as well as weight and class fractions of the in-use heavy-duty vehicle fleet, which are directly applicable for source type population development for MOVES modeling.

[20] Malcolm et al. (2003). The video data collection method used in this study is applicable for collecting source type population data. Digital cameras are used to capture license plate data, which is matched to registration data using VINs from which specific vehicle information may be obtained and classified through postprocessing. However, this approach may not be practical for all road types (e.g., off-network and rural, where traffic volumes are low).

[4] Caltrans (no date). This web site describes the use of in-pavement weigh-in-motion sensors for collecting truck data, as well as an extensive existing dataset from California from which heavy-duty vehicle source type population data could be developed. Vehicle weight, length, and classification data are collected. California data may or may not be representative of other areas, but the method of data collection could offer a viable source for data development in other areas with WIM programs. However, these programs typically only sample vehicles on major highways.

A.2 Regional Activity Inputs

Regional VMT by Vehicle Class

This input (called HPMSVTypeYear within MOVES) requires annual VMT for each of six HPMS vehicle types, as shown in Table A.2. It may be constructed from two separate factors, the annual VMT for all vehicle types and the percent distribution of VMT among the six HPMS vehicle types. Since MOBILE6 was an emission rate model and did not have an inventory mode option it did not require annual VMT (although it would be necessary information to create an emissions inventory after the MOBILE6 run). MOBILE6 had distribution of VMT among vehicle types programmed into it and did not request this information as an input.

VMT by the six HPMS vehicle classes may be obtained directly from the HPMS at a county or state level. Forecasts may be developed using travel demand model estimates of total VMT (or light and heavy-duty VMT) factored by the fraction of current VMT by vehicle type from the HPMS. Other sources may also be used, especially to refine estimates for specific vehicle types, as described below.

Table A.2 Example Region VMT by Vehicle Class Input

HPMS Vehicle Type	HPMSVtypeID	yearID	HPMSBaseYearVMT	baseYearOffNetVMT
Motorcycle	10	2002	165,354	0
Passenger Car	20	2002	35,332,808	0
Light Truck	30	2002	20,086,413	0
Buses	40	2002	383,910	0
Single Unit Truck	50	2002	1,934,527	0
Combination Truck	60	2002	4,240,177	0

Chatterjee and Miller (1994). This report (which was developed considering MOBILE's need for VMT distributions by a set of types not consistent with the HPMS classes) describes a number of methods that can be used to develop VMT distributions by vehicle class. HPMS and other classification counts can be used to determine VMT by road type and vehicle type. Network-based travel demand models can be used to determine VMT by road type, and to a limited extent vehicle type. Vehicle registration data and inspection and maintenance records (in areas where such programs exist) can be used to determine VMT distributions by vehicle type (based on total registrations by type and possibly annual mileage driven) although the applicability of these sources to heavy-duty vehicles may be limited.

[15] FTA (no date). The NTD includes annual mileage by vehicle type and age for each reporting transit operator in the U.S., so VMT could be estimated for the regional public transit vehicle fleet.

[8] Cohen and Chatterjee (2003). The purpose of this report is to use available data and information to develop an improved understanding of the magnitude and spatial/temporal distribution of different types of commercial vehicle travel. The report reviews a number of data sources on commercial vehicle activity as previously noted. Some of these might be used to support the development of VMT inputs, e.g., by disaggregating heavy-duty VMT by source type.

[10] Farzaneh, et al. (2011). This paper describes the use of the FHWA Freight Analysis Framework, a commodity origin-destination database, in conjunction with highway network routing procedures, truck registration data, and MOBILE6.2 emission factors to estimate the air quality impacts of freight movement in a multistate corridor. The FAF data and assignment method can be used to help estimate freight truck VMT on major highway links, for state-level studies as well as interregional corridor studies. FAF is also a useful tool for forecasting truck VMT as it provides forecasts of future freight flows. However, the FAF database is limited primarily to heavy trucks carrying freight over longer distances and is not a complete accounting of all truck sources.

Temporal Adjustments

Temporal adjustments include month, day, and hour VMT fractions, i.e., the fraction of total annual VMT that occurs in a given month, the fraction of total monthly VMT that occurs on weekdays versus weekends, and the fraction of total daily VMT that occurs in a given hour, respectively. In all three cases MOVES requires these fractions for each of the 13 MOVES source types. For day and hour VMT fraction it also requires them by the four MOVES road types.

[19] Lindhjem and Shepard (2007). This report analyzes data compiled by FHWA from HPMS traffic monitoring and other sources on heavy-duty vehicle activity. The study developed temporal profiles by month, day of week, and time of day. These inputs are directly related to MOVES modeling. The data analysis approach may also be useful to users in developing state or locally specific temporal adjustments to MOVES activity.

[20] Malcolm et al. (2003). The video data collection method used in this study would allow a user to develop reasonable temporal adjustments for the applicable roadway types and source types. However, the method is probably more costly than using existing traffic counters for developing temporal adjustments, unless video cameras already are being used to collect traffic data for other purposes across a broad enough sample of roads to be representative of regional conditions.

[2] Boriboonsomsin, Sheckler, and Barth (2012). This study describes the use of wireless communication or telematics technology, increasingly adopted by the fleet management industry, to collect a variety of data on heavy-duty vehicle operations. The dataset used in this study comes from a collective fleet of more than 2,000 Class 8 trucks traveling across the U.S. for the entire year of 2010. The data were used to observe temporal patterns among other things. However, the data source is currently applicable only to a limited set of participating fleets, which may or may not be representative of the entire heavy vehicle population. The method may have broader applicability if telematics technology is employed on a wider range of vehicles.

[1] Bar-Gera (2007). This study validated GPS data on traffic speeds and travel times collected using cellular phones against data collected using dual magnetic loop detectors and floating cars. The cellular phone-based data collection method has direct applicability for developing temporal profiles, since vehicle activity would be tracked at all hours of the day. However, since the data are anonymous, it would not be possible to develop temporal distributions specific to each source type. This could be done in theory of a set of cell phone users who would be willing to identify the type of vehicle they are using could be recruited.

[18] Lee et al. (2011). This study used portable emissions monitoring systems (PEMS) to track activity for refuse trucks. PEMS could be used to develop temporal profiles for specific types of vehicles when PEMS are installed for emissions monitoring purposes.

[17] Hatzopoulou and Miller (2010). A micro-simulation activity-based travel demand model for the Greater Toronto Area was extended with capabilities for modeling and mapping of traffic emissions and atmospheric dispersion. Hourly link-based emissions and zone-based soak emissions were estimated. This study makes use of advanced travel demand forecasting model capabilities; while the approach is useful for developing temporal adjustments for MOVES emissions modeling, considerable model enhancement work would be required in most regions which do not have similar time of day modeling capabilities.

Road Type Distribution

This input is a set of five fractions that sum to 1, which represents the percent of VMT on each of five road types used in MOVES. These road types are off-network, rural restricted access, rural unrestricted access, urban restricted access, and urban unrestricted access. MOVES requires this distribution for each of the 13 source (vehicle) types. Table A.4 shows an example of this input for one type of vehicle (this would be repeated for each of the 13 vehicle types). This was an input in MOBILE6, but different roads types were used (highway, arterial/ collector, local, ramp). This information is required for emissions modeling because the traffic conditions on different types of roads affect the emission rates.

For example, arterials and local roads have more stop and go conditions with more acceleration/deceleration patterns than highways. This information is usually fairly easy to obtain from a travel demand model that has links coded as different roadway types or from HPMS, although travel demand models would typically only provide a single distribution (rather than one for each vehicle type), and the six HPMS vehicle classes need to be mapped to 13 MOVES classes.

Table A.3 Example Road Type Distribution Input

Road Type	roadTypeID	roadTypeVMTFraction
Off-Network	1	0
Rural Restricted Access	2	0.166473
Rural Unrestricted Access	3	0.24494
Urban Restricted Access	4	0.235751
Urban Unrestricted Access	5	0.352836

[5] Chatterjee and Miller (1994). This study identifies numerous existing data sources that can be used for developing model inputs, including road type distributions for fleets. The vehicle miles traveled section in Chapter 4 describes sources of VMT on different types of roads, such as continuous counts, short-term counts, HPMS, and travel demand models. Possible sources of error for each of these are also discussed. A method for improving estimates of VMT on local roads is provided in Chapter 8. Although not discussed directly in this document, once VMT is developed for various roadway segments from one of these, it can be used to develop road type distributions since the road type of each segment is known.

[2] Boriboonsomsin, Sheckler, and Barth (2012). The telematics-based dataset used in this study was used to determine road type distributions for the instrumented truck fleets, among other things. The method presented in this study offers a very accurate data collection method that already is being used in commercial fleets. However, the existing data set is currently limited to participating fleets, primarily Class 8 trucks.

[19] Lindhjem and Shepard (2007). This report analyzes data compiled by FHWA from HPMS traffic monitoring and other sources on heavy-duty vehicle activity. HPMS traffic count data can be used to develop distributions of activity by vehicle type and road type, for roads that are part of the HPMS network. However, appropriate expansion factors need to be used to ensure that monitored locations are representative of the entire road network.

[1] Bar-Gera (2007). This study validated GPS data on traffic speeds and travel times collected using cellular phones against data collected using dual magnetic loop detectors and floating cars. The cellular phone-based data collection method has direct applicability for developing road type distributions, by associating vehicle trajectories with road links and types. However, since the data are anonymous, it would not be possible to develop road type distributions specific to each source type.

[18] Lee et al. (2011). This study used PEMS to track the activity for refuse trucks. PEMS data can be mapped, using the GPS coordinates to activity on specific roadways, allowing a user to develop a good road type distribution for vehicles that may be instrumented for emissions monitoring purposes.

Average Speed Distribution

This input is a set of 16 fractions that sum to 1, which represents the distribution of vehicle-**hours** traveled among 16 speed bins, as shown in Table A.5. MOVES requires this information for every combination of 13 source (vehicle) types, four road types, 24 hours of the day, and two types of days (weekdays/weekends). Therefore, it effectively asks for 2,496 distributions. Typical sources for this data include travel demand model output and possibly some observed data.

Table A.4 Example Average Speed Distribution Input

avgSpeedBinID	avgBinSpeed	avgSpeedBinDesc	avgSpeedFraction
1	2.5	speed < 2.5 mph	0.0000000
2	5	2.5 mph ≤ speed < 7.5 mph	0.0000000
3	10	7.5 mph ≤ speed < 12.5 mph	0.0000000
4	15	12.5 mph ≤ speed < 17.5 mph	0.0000000
5	20	17.5 mph ≤ speed <22.5 mph	0.0000000
6	25	22.5 mph ≤ speed < 27.5 mph	0.0000000
7	30	27.5 mph ≤ speed < 32.5 mph	0.0212651
8	35	32.5 mph ≤ speed < 37.5 mph	0.0027255
9	40	37.5 mph ≤ speed < 42.5 mph	0.0000000
10	45	42.5 mph ≤ speed < 47.5 mph	0.0000000
11	50	47.5 mph ≤ speed < 52.5 mph	0.0000000
12	55	52.5 mph ≤ speed < 57.5 mph	0.0000000
13	60	57.5 mph ≤ speed < 62.5mph	0.3890143
14	65	62.5 mph ≤ speed < 67.5 mph	0.0590208
15	70	67.5 mph ≤ speed < 72.5 mph	0.5279743
16	75	72.5 mph ≤ speed	0.0000000

[31], [34] U.S. EPA (2010c, 2012c). These guidance documents on the use of MOVES2010 for emission inventory preparation and GHG estimation note that the recommended approach for estimating average speeds is to post-process the output from a local travel demand network model. Speed results from most travel demand models must be adjusted to properly estimate actual average speeds. However, the documents do not offer any guidance on how the postprocessing can be done.

[5] Chatterjee and Miller (1994). This study identifies numerous existing data sources that can be used for developing model inputs, including speed distributions for fleets. Chapter 5 describes how travel demand models are the most common method for estimating speeds for air quality planning. It further describes how speeds developed as part of the traffic assignment step are mainly used to achieve realistic traffic flows and are really too crude to be used for air quality planning. It describes a process of using link volumes and capacities along with a standard function such as Bureau of Public Roads or Highway Capacity Manual formulas to obtain more accurate link speeds and vehicle hours traveled. This process can be applied within the travel demand model or as a post processing step. Chapter 8 discusses methods to improve speed estimation, such as improving underlying variables like traffic volume and roadway characteristics. Intelligent Transportation Systems are also mentioned as an emerging and more affordable data source for continuous speed and volume data over a wider area. Finally, modal emissions models are mentioned as a way to eliminate the need for speed inputs all together and move to what many researchers believe is a more accurate way to estimate emissions.

[13] FHWA (2006). This FHWA guidance on transportation conformity notes that since emissions estimates are extremely sensitive to vehicle speed, EPA and DOT recommend that speeds be estimated in a separate step after traffic assignment, using refined speed-volume relationships and final assigned traffic volumes. Postprocessed speeds estimated in the validation year should be compared with speeds empirically observed during the peak- and off-peak periods. These comparisons may be made for typical facilities, for example, by facility class/area type category. Based on these comparisons, speed-volume relationships used for speed postprocessing should be adjusted to obtain reasonable agreement with observed speeds. Regardless of the specific analytical technique, every effort must be made to ensure that speed estimates are credible and based on a reproducible and logical analytical procedure.

[26] TMIP (2008). This synthesis paper discusses data collection methods used to develop speed inputs to travel demand models, as well as the algorithms used within travel demand models to estimate and forecast travel speeds at a link level, based on volumes, capacity, etc. Collecting of speeds for different time periods, days of the week, and in different area types is discussed. Collection methods discussed include:

- Floating car method to collect point-to-point travel times;
- Freeway loop detector data;
- Toll transponders;

- GPS devices; and
- Video technology.

[27] TMIP (2009). This study provides a synthesis of the derivation of speed adjustments in travel demand forecasting models. The study discusses different approaches to volume-delay functions (VDF), including 1) applying a single volume-delay formulation for all facility types; 2) applying unique user specified VDF functions developed for each facility type and possibly area type in the network; and 3) developing unique user specified VDF functions to account for delay at signalized intersections. Speeds that are produced by the travel models need to be postprocessed and refined to produce more realistic network link-specific values for use in mobile source emission modeling. The information presented here is relevant to developing average speed inputs to MOVES based on travel demand model data.

[21] Miller (2002). The purpose of this study was to identify or develop a prototype postprocessor that VDOT staff could use to determine vehicle speeds for the purposes of conducting air quality conformity analysis using the MOBILE model. The postprocessor converts 24-hour link VMT to hourly volumes within each period, divides each link volume by the link's capacity, uses this ratio with a simple formula to estimate a link speed for each of the three periods, and then computes VMT and VHT for each link and for each period. The postprocessor then aggregates link-specific volumes, speeds, VMT, and VHT by period and facility type. The postprocessor reports total volume, total VMT, average speed, and total VHT by facility type and within that category by time period (AM peak, PM peak, and off-peak). The authors suggest that further validation is required. This method may hold promise for future use, but until validated, other sources of data may be preferable for developing speed distribution data for MOVES modeling.

[7] Choe, Skabardonis, and Varaiya (2001). The Freeway Performance Measurement System is a freeway performance measurement system (PeMS) for all of California that processes loop detector data. The PeMS system can help establish speed distribution data on California freeways. Similar methods could be applied to loop detector data in other areas to identify local speed distributions. However, the data are limited to freeways instrumented with loop detectors.

[3] Boriboonsomsin, Zhu, and Barth (2011). This study presents a statistical method for estimating truck traffic speed that takes advantage of existing traffic monitoring systems: the California PeMS, California weigh-in-motion stations, and the Berkeley Highway Laboratory (BHL). PeMS provides data on total flow, truck flow, and overall traffic speed, but not truck traffic speed. WIM stations provide data for truck flow and truck traffic speed, but not total flow and overall traffic speed. BHL collects data for all four required variables, but is limited to only a few miles of freeway. No single data source is sufficient for providing truck speed data for the entire state. This study developed methods to combine the data from these three sources to produce statewide truck speed estimates on freeways within California. The analysis showed that with traffic data from these systems, traffic speed can be effectively estimated on the basis of the knowledge of the overall traffic speed alone.

[1] Bar-Gera (2007). Data from GPS-equipped cell phones, if obtained for a specific geographic area and associated with network links, can be used to develop speed distributions by road type, hour of the day, and day of week.

[22] NREL (no date). The Secure Transportation Data Project is assembling detailed GPS data from household travel surveys, which contains information on trajectories of the instrumented vehicles. GPS data could be used to validate speed results from speed post processors. The dataset is currently limited to survey data from five metropolitan areas.

[2] Boriboonsomsin, Sheckler, and Barth (2012). Second-by-second data collection using GPS-equipped heavy vehicles creates a very accurate speed distribution profile for participating fleets. However, this method is limited to participating fleets which may or may not be representative of the entire heavy-duty vehicle population.

[20] Malcolm et al. (2003). Video data collection methods were tested and compared against instrumented vehicle methods for collecting speed distribution data. The instrumented vehicle method is commonly used for average speed measurement. The video method, while capturing all vehicles on a road segment, only collects speed profiles at single points on the highway network. Multiple measurement points, and calibration from instrumented vehicles, would probably be needed to capture segment or corridor-level average speeds.

[18] Lee et al. (2011). Instrumentation of vehicles with PEMS can provide a highly accurate method for collecting speed distribution data, but is limited to the vehicles with PEMS installed in them.

[24] Song and Yu (2011). This study uses large samples of second-by-second floating car data, collected from expressways in Beijing, to associate the VSP distributions with the average travel speed from 0 to 20 km/hr. While the data itself may not be relevant to U.S. conditions, second-by-second data collection, as seen in this study as well as others, is a very valuable tool in establishing activity profiles, including speed distribution.

A.3 PROJECT-LEVEL INPUTS

Project-level inputs in MOVES must be entered for each roadway link that is used to define a project. Therefore, while some of the inputs may appear to be similar to regional inputs, the difference is that at the project-level inputs can be varied for each individual link.

Project-Level Link Activity

Project-level link activity may be described using operating mode distributions, drive schedules, or average speed. A number of resources that generally address link activity are discussed first, and then sources specific to each method are discussed.

General Resources

[29] U.S. EPA (2010a). This document provides guidance on data sources and preparation methods for all MOVES inputs required for project-level hot spot analysis for carbon monoxide. Appendix A has guidance on estimating vehicle activity via three options: 1) average congested speeds, using appropriate methods based on best practices for highway analyses (for example, as described in TMIP publications and methodologies for computing intersection control delay provided in the Highway Capacity Manual); 2) link drive schedules; and 3) operating mode distributions. The guidance notes that for both free-flow highway and intersection links, users may directly enter output from traffic simulation models in the form of second-by-second individual vehicle trajectories. The U.S. EPA guidance for PM Hot Spot Analysis [30] also identifies the same three options for developing vehicle activity.

[10] Eastern Research Group (2010). This study presents a procedure for developing MOVES inputs from link-level travel demand forecasting model output (speeds and VMT). It assumes that the speeds already have been processed into MOBILE classes. The study also presents a "mapping" of travel demand forecasting model roadway types to HPMS roadway types.

[24] Song and Yu (2011). This study uses large samples of second-by-second floating car data, collected from expressways in Beijing, to associate the VSP distributions with the average travel speed from 0 to 20 km/hr. Second-by-second data collection is directly applicable to link-level data development. The data collected in this study is directed only at low-speed vehicles, and under conditions in China. However, the method used here can be used effectively to develop several inputs to MOVES on a broader application.

Operating Mode Distributions (Including Drive Schedules)

These two MOVES inputs rely on similar data, but provide it to MOVES in a different format. One or the other should be input into MOVES. If operating mode distributions are chosen the input would be a set of fractions, which represent the percent of time spent in each operating mode bin (a combination of VSP and speed). If drive schedules are chosen, the input would be a set of second-by-second speeds.

[30] U.S. EPA (2010b). This document, which provides guidance on PM hotspot analysis for conformity, contains general recommendations for the development of operating mode distributions. Operating mode distributions may be obtained from other locations with similar geometric and operational (traffic) characteristics, or output from traffic microsimulation models. For example, chase (or floating) cars, traffic cameras, and radar guns have been used previously to collect some traffic data for use in intelligent transportation systems and other applications. Users should consider the discussion in Section 4.2 when deciding on the appropriate activity input. The MOVES model is capable of using complex activity datasets with high levels of resolution to calculate link-level emissions. EPA encourages the development of validated methods for collecting verifiable vehicle operating mode distribution data at locations and in traffic conditions representative of different projects covered by this guidance. However, the user should determine the most robust activity dataset that can be reasonably collected while still achieving the goal of determining an accurate assessment of the PM air quality impacts from a given project. The decision to populate the Links table, Link Drive Schedule, or Op-Mode Distribution should be based on the data available to the user and should reflect the vehicle activity and behavior on each link.

[9] Dowling et al. (2005). This study developed a complete modeling framework for analyzing the regional impacts of traffic flow improvements. The research produced a set of relationships through microscopic simulation that determine the proportion of the time spent on a network link in a driving mode as a function of the link's type. The link type was based on typical link classifications employed in planning and operational studies (facility types) and on key design/operational characteristics (e.g., number of lanes, free-flow speed, and signal spacing). Thirty-three link types were selected. The relationships were developed through processing of simulated vehicle trajectories using the INTRAS (predecessor of FRESIM). These data could be reprocessed to produce default operating mode distributions for MOVES.

[25] Song, Yu, and Zhang (2012). This study examined the effect of using vehicle trajectories from microscopic simulation models as a basis for establishing operating mode distributions. The study concluded that the traditional approach of integrating traffic simulation models with emission models was not applicable for vehicle emission estimations – large errors were reported between the operating mode distributions of simulated versus real-world data. The study did not directly compare actual driving conditions to a simulation of those driving conditions – rather the "real world" data were collected independently, making the background traffic conditions incomparable. Even if the research findings can be validated, microscopic models may still be useful for the *relative* comparison of project impacts.

[22] NREL (no date). The Secure Transportation Data Project is assembling detailed GPS data from household travel surveys, which contains information on trajectories of the instrumented vehicles. GPS data could be a used to validate simulation model output and/or as a direct source of vehicle trajectories for specific routes for specific times of day, although there would be concerns about how representative it would be due to small number of GPS samples in most travel surveys to date.

[11] E.H. Pechan and Associates and Cambridge Systematics, Inc. (2010). This report develops MOVES operating mode distributions from microscopic simulation model outputs for various conditions of congestion, including volume to capacity (v/c) ratio and incident characteristics. It creates operating mode distributions from the trajectories of every vehicle in the simulation network for every link. The relationships could be linked to traffic demand models at either a regional or project-level scale, providing the use of trajectory-based operating mode distributions rather than average speed inputs for MOVES analysis. The linkage is provided through the estimation of v/c – each v/c level for a given link type corresponds to different operating mode distribution.

[20] Malcolm, et al. (2003). Vehicle activity and vehicle fleet data were collected in the South Coast Air Basin in southern California. Vehicle activity was characterized primarily using a large second-by-second speed and acceleration data set collected from probe vehicles operated within the flow of traffic. The average speeds represented in the data were very high, even for weekdays (57.1 mph). Although the speed-acceleration distributions are different for the three locations, the primary factor influencing the differences in distribution appears to be the level of congestion. This finding must be kept in mind if default trajectories are developed for MOVES input.

[23] Papson, Hartley, and Kuo (2012). This analysis estimates emissions using a time-in-mode (TIM) methodology, which allocates vehicle activity time to one of four modes: acceleration, deceleration, cruise, and idle. This is somewhat of an in-between methodology that is more advanced than providing only average speed, but less data-intensive than providing full operating mode distributions. The TIM was based on HCM methods – assumptions were used as to what percent of vehicles were in each TIM based largely on control delay. The method could be useful for project-level analysis of intersections where the available data allows an HCM analysis.

[6] Chamberlin, Swanson, and Sharma (2012). This paper uses a signal optimization project at an intersection as an example project to demonstrate a quantitative PM hot spot analysis using MOVES at the project level. The study describes how calculating operating mode distributions for input into MOVES centers on calculating the VSP for each vehicle at each second using second by second speed information from a VISSIM model. A separate operating mode distribution is calculated for every link in the VISSIM model, which correspond to the links provided to MOVES.

[37] Xu et al. (2012). This paper develops a model based on real world data to predict operating mode distributions based on average speed. Applicability is limited since the paper was mainly concerned with testing the average speed input approach. However, the paper is useful in describing collection of the real world data on 238 km of expressways in Beijing using 46 GPS-equipped light-duty vehicles.

Average Speed

This input simply asks for the average speed (in mph) on each link in the project. It would be used if operating modes distributions or drive schedules are not available.

Note: A number of the references for average speed distributions for regional analysis may also be relevant to project-level analysis. For example, some EPA and FHWA guidance documents (FHWA 2006, EPA 2010b and 2012) on conformity and emissions inventories address the postprocessing of link-level speed data from travel demand models, which may be used at the project level as well as the regional level.

[28] U.S. EPA (1999). This guidance for the development of facility type VMT and speed distributions is geared to MOBILE inputs, but is still a good starting point for the current NCHRP research. Speed estimation procedures are based on BPR equations and HCM methods using data from traffic counts or travel demand forecasting models.

[30] U.S. EPA (2010b). For average speeds, this guidance on PM hot spot analysis recommends that project sponsors determine average congested speeds by using appropriate methods based on best practices used for highway analysis. The document notes that resources are available through FHWA's TMIP program and that methodologies for computing intersection control delay are provided in the Highway Capacity Manual.

[21] Miller et al. (2002). This report provides a useful exploration of several methods for developing postprocessed speeds from travel demand forecasting model output.

[36] Vallamsundar and Lin (2012). This study provides insight to the process with respect to data input preparation, sensitivity testing, and MOVES model setup for PM hot spot analysis. Average speed was used as the input for vehicle activity – emission factors were developed for 5 mph increments but were reduced to 1 mph increments for some speed ranges, based on sensitivity tests (21 speed ranges in all were used). Applicability is limited, but the guidance on speed ranges is appropriate if emissions factors are to be developed in this way.

Off-Network Data

Off-network data includes start fraction, extended idle fraction, and parked fraction.

[2] Boriboonsomsin, Sheckler, and Barth (2012). The GPS-based method presented in this study offers a very accurate data collection method that already is being used in commercial fleets. The second-by-second data collection allows a user to analyze multiple variables applicable to MOVES modeling, including start fractions, extended idle fractions, and parked fractions. However, this method is limited to participating fleets and data may or may not be representative of the entire heavy-duty vehicle population.

[18] Lee et al. (2011). Second-by-second data collection using PEMS-instrumented vehicles allows a user to develop very detailed and accurate activity profiles for the instrumented fleet. Inputs can be developed at a very fine level of granularity, making it directly applicable to the development of link-level data, start and extended idle fractions, parked fractions, and off-network activity development, among others. However, a special data collection effort is required with instrumented vehicles that are representative of the fleet as a whole.

Link Characteristics

Link characteristics include traffic volume, length, and grade.

[29], [30] U.S. EPA (2010a, 2010b). These guidance documents for hot spot analysis recommend that the links specified for a project include segments with similar traffic/activity conditions and characteristics. For example, at an intersection EPA recommends defining cruise, queuing/deceleration, and acceleration links. The link length will depend on roadway geometry, how the geometry impacts activity, and the level of detail available in the activity data. Appendices D and E to [29] provide examples of determining link lengths for intersection and highway projects respectively. Traffic volumes and road grade are assumed to be available from the project sponsor and no other guidance is provided by EPA on these inputs other than to give the units for volume as vehicles/hour and for grade as percent grade.

[6] Chamberlin, Swanson, and Sharma (2012). This study describes examples of project-level MOVES analyses, which provide insights on data sources and methods for link characteristics. The links defined in simulation modeling should consider the needs in MOVES, i.e., shorter links closer to the intersection center will capture the greater emissions generated. Volumes were obtained from a simulation model of an intersection and the grade was assumed to be zero based on observation of the intersection.

[36] Vallamsundar and Lin (2012). This study conducted an analysis of a freeway interchange where the authors assumed that links are defined as individual ramps and freeway links before and after intersecting ramps. The authors obtained traffic volumes for these links from the Illinois DOT. Some ramps are described in the paper as "inclined ramps," but no information was provided on data sources or methods for determining the road grade.

Link Source Types

This input asks for a set of 13 fractions that sum to 1, which represents the percent of vehicle hours traveled by each of the 13 source (vehicle) types on a particular link.

[30] U.S. EPA (2010b). This guidance on PM hotspot analysis notes that the user needs to ensure that the source types selected in the MOVES Vehicles/ Equipment panel match the source types defined through the Link Source Type.

For projects that will have an entirely different source type distribution than that of the regional fleet, the preferred option is for the user to collect project-specific data. If the project traffic data suggests that the source type distribution for the project can be represented by the distribution of the regional fleet for a given road type, the user can provide a source type distribution consistent with the road type used in the latest regional emissions analysis.

[20] Malcolm et al. (2003). Vehicle activity and vehicle fleet data were collected in the South Coast Air Basin in southern California. Results showed significant spatial and temporal differences in vehicle activity patterns and vehicle fleet characteristics in different areas. For example, the report found that the average percentage of heavy-duty trucks in the freeway vehicle fleet varies from 2.35 percent in Riverside to 7.45 percent in Yorba Linda.

[35] University of California at Riverside (pending publication). This report describes a survey of five MPOs to identify the state of practice in data collection for mobile source inventories. One chapter describes a license plate survey in Las Vegas. For regional emissions, it shows that in-state registration data alone may not be sufficient in certain areas, such as those with high tourist activity (e.g., Las Vegas), transportation hubs, and near state borders. The report provides some details on the methods (automated versus manual) and costs involved in collecting license plate data. Other chapters will address heavy-duty truck activity and emissions data. The study recommends using the vehicle license plate survey technique in conjunction with a vehicle registration database and VIN decoder to obtain highly resolved and area-specific vehicle fleet data.

A.4 OTHER INPUTS

Meteorology Inputs

Meteorology inputs include temperature and humidity for each of the 24 hours of the day. MOVES requests a set of temperatures and humidity for each month being modeled in that particular MOVES run. For example, ozone runs would usually be for the month of July or for the summer months of June, July, and August. This input is similar to the meteorology inputs required with MOBILE6.

[32] USEPA (2012a). The MOVES User Guide describes how to use the Meteorology Data Importer to import temperature and humidity data for months, zones, counties, and hours. The MOVES model contains 30-year average temperature and humidity data for each county, month, and hour.

[33] USEPA (2012b). Local temperature and humidity data are required inputs for SIP and regional conformity analyses using MOVES. Ambient temperature affects most pollutant processes and relative humidity is important for estimating NO_x emissions. EPA has provided tools to help develop the meteorological inputs to MOVES. The guidance cites the National Climatic Data Center as a good source for meteorological data. The document provides guidance for using MOVES in emission inventory mode versus emission rate mode.

[16] Fincher et al. (2010). This study presents a road map for developing emissions inventories using MOVES. The study describes the options for developing meteorological inputs for MOVES, including using the existing template provided by MOVES. MOVES requires hourly temperature and relative humidity data. In this study, these inputs were taken from the MOBILE6 input files.

Inspection and Maintenance Programs

The I/M program input in MOVES is similar to the one found with MOBILE6 except that the information is provided in a tabular format instead of through a text input file, as shown in Table A.6. The table requests information on testing standards that impact different pollutants and emissions processes for various model years of different vehicle types. MOVES provides a default table for every county in the country, but EPA states that this should be used as a starting point only and that local information on individual programs is required for official SIP and conformity analyses.

Table A.5 IM Program Inputs

polProcessID	stateID	countyID	yearID	sourceTypeID	fuelTypeID	IMProgramID	inspectFreq	testStandardsID	begModelYearID	endModelYearID	useIMyn	complianceFactor
101	47	47065	2015	21	1	1	1	11	1975	1995	Y	98.01
102	47	47065	2015	21	1	1	1	11	1975	1995	Y	98.01
201	47	47065	2015	21	1	1	1	11	1975	1995	Y	98.01
202	47	47065	2015	21	1	1	1	11	1975	1995	Y	98.01

[32] U.S. EPA (2012a). As described in the User Guide, MOVES allows a user to specify the level of compliance and general effectiveness of an I/M program. Currently, MOVES does not include I/M emissions effects for diesel fuel or continuous I/M inspection frequency. The compliance factor reflects the program performance metrics such as waiver rates, exemptions, special training programs, and general effectiveness. The compliance factor is a function of pollutant-process, location, source type, model year range, fuel type, and specific I/M test types. MOVES allows the user to turn certain aspects of an I/M program on and off to aid in what-if analyses. Only one I/M program description record can apply to each pollutant-process, source type, fuel type, and model year combination, and program choices are restricted to applicable model years only.

[33] U.S. EPA (2012b). The guidance for using I/M programs for the purposes of SIPs and conformity analyses follows the guidance discussed in the MOVES User Guide.

[16] Fincher et al. (2010). This report discusses the methodology for formatting MOBILE6 inputs for I/M programs for use within the MOVES framework. The report reiterates EPA's recommended approach of starting with the default MOVES I/M files and making modifications as necessary. The study also discusses the challenges of mapping MOBILE6 vehicle types to MOVES source types.

Fuel Formulation and Supply

The fuel supply table defines the market share of various fuel formulations for each county and month found in the MOVES run as shown in Table A.7. Separate market share distributions should also be defined for each fuel year, which is the same as the calendar year for years 2012 and earlier, but is set equal to 2012 for all subsequent years. The market shares for all gasoline formulations should sum to one just as it should for all diesel formulations. The fuel formulation input defines all of the fuel formulations used in the fuel supply table by using 16 characteristics, such as Reid Vapor Pressure (RVP) and sulfur content. MOVES defaults for both tables are available for every county in the country, but local knowledge and/or fuel surveys should be used to verify and correct these defaults.

Table A.6 Fuel Supply

countyID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
47065	2012	4	3850	0.333333	0.5
47065	2012	4	3869	0.166667	0.5
47065	2012	4	3870	0.083333	0.5
47065	2012	4	3872	0.416667	0.5
47065	2012	4	20011	1	0.5

[32] U.S. EPA (2012a). The MOVES User Guide notes that the fuel formulation and fuel supply importers should be used together to import the appropriate fuel data. The User Guide explains that fuel formulation data contains specific fuel properties and the fuel supply data assigns fuel formulations to specific counties and defines the market share within that county. At present, a user must edit existing data and may not enter new records until a bug associated with fuels is corrected.

[33] U.S. EPA (2012b). The guidance for the fuel supply and fuel formulation MOVES inputs for the purposes of SIPs and conformity analyses follows the guidance discussed in the User Guide. The guidance outlines how the MOVES default gasoline and diesel fuel formulation and supply data was derived and cautions users that based on this approach, some fuel properties in the default database may not match actual local data. Users should take care to review the default fuel characteristics to accurately reflect real-world data for a specified modeling domain. The guidance cites sources of publicly available fuel information outside of reformulated gasoline (RFG) areas, including the National Institute for Petroleum Energy Research (NIPER) and the Alliance of Automobile Manufacturers (AAM) North American Fuel Survey. The guidance cautions users against averaging fuel properties from multiple fuel sample data to create a generic fuel profile.

[16] Fincher et al. (2010). This study discusses how the fuel formulation and supply data were developed for use within the MOVES framework using information from the MOBILE6 input files in conjunction with ozone episode modeling emissions inventories created by the appropriate state agency. The study also revealed bugs associated with MOVES when updating fuel formulation inputs. The interim solution is to simply modify existing fuel formulations instead of creating new ones. Another bug concerned the expected ethanol percentages associated with a specific fuel ID (i.e., the fuel used in the specified area is identified as E10 with an ethanol percentage of 9.38 percent; MOVES expects E10 fuel to have an ethanol percentage of 10 to 20 percent). The solution suggested by EPA was to use an alternative existing fuel ID (for E8) to accommodate the known ethanol percentage.

This section discusses three prior surveys on transitioning to the MOVES model, as follows:

- AMPO 2011 MOVES Survey;
- FHWA 2011 Survey of Five MPOs; and
- Tennessee DOT Strategic Plan for Transition to MOVES.

A brief description of each survey and when it was conducted is provided along with a short list of findings, if available, followed by brief interpretation applicable to the planned survey for this project. One issue that stands out in this review is that agencies that have never had to address transportation conformity or SIP development have generally not been represented. This is a critical point as these input guidelines need to help agencies that are new to tools like MOVES or its predecessor, MOBILE6. The existing knowledge base about user capabilities does not include information about these agencies.

In late 2012 and early 2013, FHWA was also undertaking a survey to help determine technical gaps/capabilities of MPOs and DOTs in using MOVES. The survey was to include an experiment that aims to sort out which factors are most important or critical to MOVES users. Results from this survey were not available at the time of this writing.

A.5 OTHER MOVES-RELATED SURVEYS

AMPO 2011 MOVES Survey

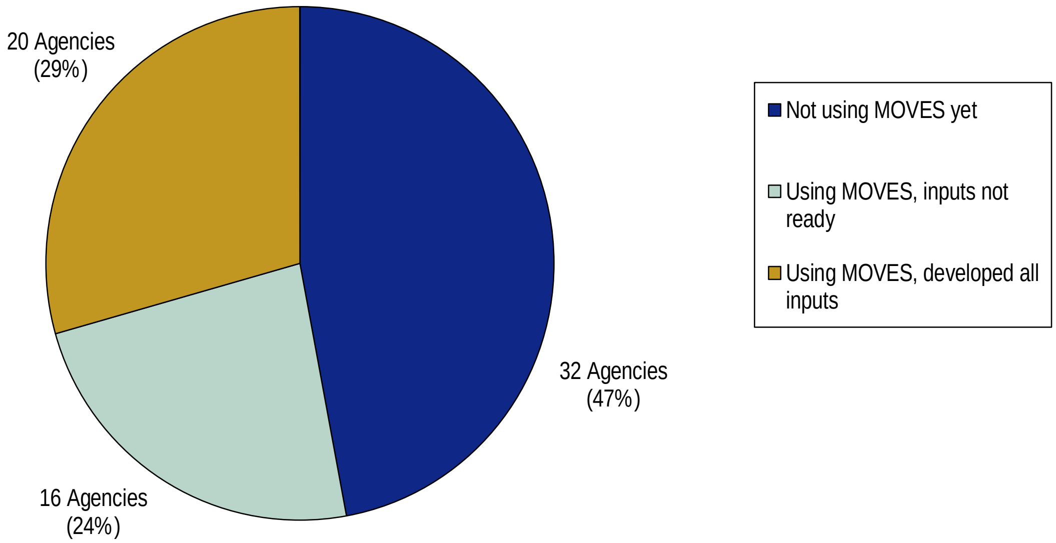
The most significant previous MOVES-related survey was conducted by the Association of Metropolitan Planning Organizations during June-July 2011.[17] This survey consisted of 33 questions compiled by AMPO with input from the FHWA, EPA, and the North Central Texas Council of Governments. The survey was sent to all state DOTs and about 90 MPOs in nonattainment and maintenance areas. Responses were received from 68 agencies, including 23 state DOTs (48 percent), 43 MPOs (46 percent), and 2 air agencies.

The survey asked 33 questions on topics, including nonattainment status, level of MOVES experience, development of MOVES data inputs, meeting MOBILE6-based budgets, and MOVES training. The questions from the AMPO survey most relevant to the NCHRP 25-38 survey are Nos. 14-16, pertaining to the level of MOVES experience, and Nos. 17-19, related to MOVES inputs. From these questions, it was found that:

- Approximately 26 percent of the DOT responses indicated that they were the lead agency for conformity; presumably this addresses rural nonattainment areas. Approximately 81 percent of the MPO responses indicated that they were the lead agency for conformity.
- Approximately 70 percent of the agencies surveyed (48 out of 69 agencies) have either not begun to use MOVES for emissions analysis or have begun, but not developed all of the inputs required to run MOVES for a SIP or conformity analysis. This is illustrated in Figure A.1.
- Approximately 67 percent of the agencies surveyed that are using MOVES (24 out of 36 agencies) perform the model runs in-house and 22 percent (8 out of 36 agencies) use some combination of in-house and contractor support. Contractors complete all portions of the MOVES runs in the remaining cases (11 percent).
- Approximately 75 percent of the agencies surveyed that are using MOVES (27 out of 36 agencies) rate themselves as being 1, 2, or 3 in terms of proficiency with MOVES when rated on a scale of 1-5, with 1 being a beginner and 5 being proficient.
- Approximately 92 percent of the agencies surveyed that are using MOVES (33 out of 36 agencies) said they are using some combination of locally derived and national default data to prepare MOVES inputs.

[17] http://www.ampo.org/assets/1480_ampomovessurveysept2011.pdf.

Figure A.1 Status of Agencies Using MOVES and Developing MOVES Inputs



In general, this AMPO survey provides the best existing snapshot of who is using MOVES and how it is being applied. It is important to note that the listed percentages in the AMPO survey are not adjusted to account for self-selection bias in the responders (i.e., nonresponders may have a tendency to be behind the responders in terms of their transition to MOVES). Keeping this in mind, it can still be concluded from these survey results that the large majority of agencies need help developing MOVES inputs, are performing this work in-house, are not proficient with MOVES, and are at least partially dependent on national default data. This confirms that the objective of NCHRP 25-38 to produce guidance on methods and procedures for obtaining and preparing input data for MOVES is in line with the needs of the MOVES user community. The AMPO survey results also indicate a large array of experience and proficiency in developing MOVES inputs and running the MOVES model. It will be important to capture responses from agencies at all of these levels during the survey conducted by this study to appropriately characterize the state of practice. The new survey also needs to consider how to address potential response bias, notably an apparent weighting towards more proficient MOVES users that is observed in the AMPO survey, for reasons discussed later in this memorandum. A sampling plan is presented later on which attempts to address this.

The survey conducted by this study needs to avoid asking the same questions as the AMPO survey. However, some of the questions to characterize the agency and their general level of MOVES experience may be necessary to include again since we are not able to obtain individual answers from the AMPO survey (AMPO is unable to release the raw data due to privacy concerns). The AMPO survey did not ask about specific MOVES inputs and their sources of data, which will be an important characteristic of the NCHRP 25-38 survey.

FHWA 2011 Survey of Five MPOs

For a project entitled "Improving Vehicle Fleet, Activity, and Emissions Data for On-Road Mobile Sources Emissions Inventories," The University of California (UC) at Riverside conducted a survey in 2011 of five MPOs on behalf of FHWA to characterize the state of practice for preparing certain MOVES inputs. MPOs were surveyed in the following areas:

- Southern California;
- The San Joaquin Valley of California;
- New York, New York;
- Maricopa County (Phoenix), Arizona; and
- Denver, Colorado.

Since the report was not published at the time of this review, the nature of the questions and results were not known.

Tennessee DOT Strategic Plan for Transition to MOVES

The Tennessee DOT completed a strategic plan for transitioning Tennessee to the MOVES model. As part of this plan, the agency conducted telephone interviews with all eight MPOs in Tennessee, as well as the Tennessee DOT and Tennessee Department of Environment and Conservation (TDEC). These interviews covered a range of MOVES-related topics, including current practices and capabilities with respect to travel demand and emissions modeling; and MOVES-specific development and data preparations underway or planned. The report provides rich details on the data sources that each MPO is using for each of the 13 MOVES inputs when running MOVES for regional conformity.

The MOVES capabilities and status of their transition to MOVES varies greatly among the eight MPOs in Tennessee. Most of the larger MPOs (Nashville, Memphis, Knoxville, Chattanooga) have begun working with MOVES at some level, although Chattanooga appears to be further along than the others. Most of the smaller MPOs had not begun working with MOVES at the time of the interviews (summer 2011) often because they were waiting to see if a new ozone standard would impact them. The report notes that several MOVES inputs, such as age distribution and source type population, are currently being prepared by the University of Tennessee (UT) using registration data. Similarly, it also notes that other MOVES inputs, such as I/M program and fuel data, are being prepared by TDEC. The MOVES inputs from both UT and TDEC are being prepared for all areas of the State and the report recommends that all MOVES users in Tennessee use these for consistency. The report recommends that MPOs enhance their travel demand models to include a time of day component and to add trucks as a vehicle type, if they have not already done so.

B. Annotated Bibliography

[1] Bar-Gera, H. (2007). "Evaluation of a Cellular Phone-Based System for Measurements of Traffic Speeds and Travel Times: A Case Study from Israel." Transportation Research Part C, Volume 15, No. 6, pages 380-391.

The purpose of this paper is to examine the performance of a new system for measuring traffic speeds and travel times based on information from a cellular phone service provider. Cellular measurements are compared with those obtained by dual magnetic loop detectors. The comparison uses data for a busy 14 km freeway with 10 interchanges, in both directions, during January-March of 2005. The dataset contains nearly 1.3 million valid loop detector speed measurements and 440,000 valid measurements from the cellular system, each measurement referring to a five-minute interval. During one week in this period, 25 floating car measurements were conducted as additional comparison observations. The analyses include visual, graphical, and statistical techniques, focusing in particular on comparisons of speed patterns in the time-space domain. The main finding is that there is a good match between the two measurement methods, indicating that the cellular phone-based system can be useful for various practical applications such as advanced traveler information systems and evaluating system performance for modeling and planning.

[2] Boriboonsomsin, K., R. Sheckler, and M. Barth (2012). "Generating Heavy-Duty Truck Activity Inputs for MOVES Based on Large-Scale Truck Telematics Data." Presented at the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2012.

A large number of fleet vehicles are now equipped with telematics-based vehicle tracking and monitoring systems which can wirelessly transmit the position information of the vehicles that is obtained from an on-board GPS device to a system server on a periodic basis. Furthermore, some systems are also connected to the vehicle's on-board diagnostic bus, allowing not only the vehicle's position but also vehicle and engine operating conditions to be monitored and reported in real-time. The objectives of this study are: 1) to examine how telematics data from heavy-duty truck (HDT) tracking and monitoring systems can be used to generate HDT activity data inputs for the MOVES model; and 2) to assess the advantages and limitations of this data source. The HDT telematics data used in this study are from the Highway Visibility System (HIVIS), a private database containing several hundred million records of commercial vehicle activity data from the telematics-based tracking and monitoring systems in the vehicles of participating fleets. The dataset comes from a collective fleet of more than 2,000 Class 8 HDTs traveling across the U.S. for the entire year of 2010. These HDTs comprise a broad cross-section of the commercial vehicle industry. The study uses map matching to assign each data point to a geographic entity based on its position relative to surrounding geographic entities and captures off-network activity. This method is able to discern road type distribution and VMT fraction by weekday/weekend and hourly distribution. Average speed distributions and vehicle starts are also available using this method.

[3] Boriboonsomsin, K., W. Zhu, and M. Barth (2011). "Statistical Approach to Estimating Truck Traffic Speed and Its Application to Emission Inventory Modeling." Presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C.

This study presents a statistical method for estimating truck traffic speed that takes advantage of existing traffic monitoring systems. With traffic data from these systems, it was found that truck traffic speed can be effectively estimated on the basis of the knowledge of the overall traffic speed alone.

[4] California Department of Transportation (Caltrans). "Data Weigh-in-Motion." http://www.dot.ca.gov/hq/traffops/trucks/datawim/.

This web site discusses the use of sensors to collect data on trucks through weigh-in-motion programs. All Caltrans WIM system sensors are either bending plates on frames embedded in concrete or piezo sensors epoxied into the pavement. Inductive loops are placed before and after the WIM sensor array to measure vehicle speed and overall length. Caltrans WIM systems are configured to calculate GVW (gross vehicle weight), individual axle weights, weight violations, vehicle speed, overall length, axle spacing, and vehicle classification (such as passenger vehicle, bus, or truck-tractor/semitrailer). WIM field systems gather and store data 24/7/365 automatically in roadside cabinets. Data collected must be screened and sorted on a historical and operational basis to validate its quality before archiving or distributing. Caltrans WIM systems are not portable; Caltrans experience with portable systems reveals shortcomings concerning accuracy and service life due to the extraordinarily high and heavy truck volumes on California highways.

[5] Chatterjee, A. and T.L. Miller (1994). *NCHRP Report 394: Improving Transportation Data For Mobile Source Emission Estimates*. TRB, National Research Council, Washington, D.C.

This study discusses the several transportation variables that are required as inputs to emission models. When developing average vehicle speeds, the typical practice is to use the 24-hour VMT and divide it by the 24-hour vehicle-hours traveled for each functional class of roadway. Spot speeds and average speeds are also used, while other methods are being researched. The study states GPS techniques may be viable for collecting data for input to emissions models. When developing VMT input data, HPMS and network-based travel demand models can be used. For establishing vehicle class distributions and VMT mix, as well as vehicle age distribution, each state performs vehicle classification counts, as well as collecting vehicle registration data and inspection and maintenance records. When developing operating modes, default MOBILE5a data may be used. Establishing trip end data, sources include census data as well as forecasting travel demand data using dynamic micro-simulation. The study discusses developing capacity as a model input and relies upon the 1985 Highway Capacity Manual, which was being revised at the time. Adjusted traffic counts and travel characteristics can be developed using transportation control measures (TCM), Clean Air Act Amendment (CAAA), and Conformity Rule reporting requirements. The study includes sensitivity and error analysis.

[6] Chamberlin, R., B. Swanson, and S. Sharma (2012). "Toward Best Practices for Conducting a MOVES Project-Level Analysis." Presented at the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2012.

This paper uses a signal optimization project at an intersection as an example project to demonstrate a quantitative PM hot spot analysis using MOVES at the project level. Based on this example project, it draws conclusions on best practices, including methods of defining links and using microsimulation models to provide input to MOVES on operating mode distributions. The study finds that the flexibility of defining links in microsimulation modeling and in MOVES suggests that air dispersion modeling considerations should determine link definition. The study also finds that greater resolution in link geometry (i.e., shorter links) closer to the intersection center will capture the greater emissions generated at this location.

[7] Choe, T.; A. Skabardonis, and P. Varaiya (2001). "Freeway Performance Measurement System (PeMS): An Operational Analysis Tool." Presented at the 81st Annual Meeting Transportation Research Board, Washington, D.C.

PeMS is a freeway performance measurement system for all of California. It processes two gigabytes per day of 30-second loop detector data in real time to produce useful information. The paper describes the use of PeMS in conducting operational analysis, planning and research studies. The advantages of PeMS over conventional study approaches are demonstrated from case studies on conducting freeway operational analyses, bottleneck identification, level of service determination, assessment of incident impacts, and evaluation of advanced control strategies.

[8] Cohen, H.S. and A. Chatterjee (2003). "Accounting For Commercial Vehicles In Urban Transportation Models: Task 3, Magnitude And Distribution." Prepared by Cambridge Systematics for Federal Highway Administration.

The purpose of this report is to use available data and information to develop an improved understanding of the magnitude and spatial/temporal distribution of different types of commercial vehicle travel. The study addresses how much traffic in a metropolitan area is attributable to commercial vehicle movements, how commercial vehicle trips are distributed geographically, temporally, and by type of transportation facility, and if commercial vehicle trips can be classified into meaningful types or categories amenable to modeling and forecasting. Research revealed: 1) there are significant discrepancies among the available data sources due primarily to differences in the purposes and uses of the various data sources, 2) there are similarities in data collected for the same purpose and use, even though they were conducted in different cities by different agencies/

firms; and 3) some data sources are useful to answer one of the above questions, but other sources were needed to answer more than one question.

[9] Dowling, R., R. Ireson, A. Skabardonis, D. Gillen, and P. Stopher (2005). *NCHRP Report 535: Predicting Air Quality Effects of Traffic-Flow Improvements: Final Report and User's Guide*. Transportation Research Board of the National Academies, Washington, D.C.

This study developed a complete modeling framework for analyzing the regional impacts of traffic flow improvements. The method includes feedback (lower travel times due to transportation improvements) to land use patterns as well as the steps in traditional travel demand forecasting. The research produced a set of relationships through microscopic simulation that determine the proportion of the time spent on a network link in a given driving mode as a function of the link's type.

[10] Eastern Research Group (2010). "Modifying Link-Level Emissions Modeling Procedures for Applications within the MOVES Framework." Prepared for Federal Highway Administration, FHWA-HEP-11-006.

This study examines a number of research questions associated with the transition from MOBILE6 to MOVES, including differences between MOBILE6 and MOVES inventory results and differences in emissions results when using MOVES default drive cycle compared to a set of real-world drive cycle collected in one particular area. Transition issues associated with creating MOVES inputs were also noted while laying out an example inventory for the Houston, Texas area using both a travel demand model and an HPMS databased approach.

[11] E.H. Pechan and Associates and Cambridge Systematics, Inc. (2010). "Advances in Project-Level Analyses." Prepared for Federal Highway Administration.

This report develops MOVES operating mode distributions from microscopic simulation model outputs for various conditions of congestion, including v/c ratio and incident characteristics. It creates operating mode distributions from the trajectories of every vehicle in the simulation network for every link. Links are identified in relation to the bottleneck point.

[12] Farzaneh, M., J.S. Lee, J. Villa, and J. Zietsman (2011). "Corridor-Level Air Quality Analysis of Freight Movement North American Case Study." Presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C.

This paper describes the use of the FHWA Freight Analysis Framework, a commodity origin-destination database, along with other sources, including vehicle registration data, to estimate the air quality impacts of freight movement in a multistate corridor. The FAF is a commodity origin-destination database. The FAF data can be assigned to highway networks to estimate truck flows by link, which can be used in conjunction with emission rates to estimate emissions from long-distance freight movement. FAF assigned network information is available as GIS data sets and contains two major data sets: commodity origin-destination data, and highway link and truck data. The highway link and truck data set contains freight and nonfreight truck volumes for each highway link along with additional information such as section length, capacity, congested speed, and estimated delay.

[13] Federal Highway Administration (FHWA) (2006). "Transportation Conformity Reference Guide." Chapter 6: Ozone and CO Nonattainment and Maintenance Areas. http://www.fhwa.dot.gov/environment/air_quality/conformity/reference/reference_guide/chap6.cfm#freeflow, accessed September 2012.

This guide was prepared by FHWA, in cooperation with FTA and EPA, as a tool to facilitate compliance by State and local agencies with the transportation conformity requirements. The guide includes a discussion of issues related to integrating network models and emission models for conformity analysis. While written before MOVES was released, some of the guidance may still be relevant to the use of MOVES.

[14] Federal Highway Administration (FHWA) (2009). "Changes in the U.S. Household Vehicle Fleet – September 2009." http://nhts.ornl.gov/briefs/Changes%20in%20the%20Vehicle%20Fleet.pdf.

This document contains a preliminary summary of vehicle fleet data from the 2008/2009 National Household Travel Survey. This document also illustrates the potential use of the NHTS as a broader data source on light-duty vehicle fleet characteristics. The NHTS collected one-day travel data from 150,000 households throughout the U.S. Twenty states and regional or metropolitan planning organizations funded add-on samples so that sample sizes in those locations would be more robust. Information was collected on vehicles owned by households, including the type of vehicle, model year, odometer reading, and annual miles driven.

[15] Federal Transit Administration (FTA). National Transit Database: Fleet Characteristics. http://www.ntdprogram.gov/ntdprogram/pubs/NTST/2007/HTML/Fleet_Characteristics.htm.

The NTD was established by Congress to be the nation's primary source for information and statistics on the transit systems of the United States. Recipients or beneficiaries of grants from the FTA are required by statute to submit data to the NTD. Over 660 transit providers in urbanized areas currently report to the NTD through the Internet-based reporting system. Annual NTD reports are submitted to Congress summarizing transit service and safety data. For each transit system, the data include number of vehicles by year of manufacture, type, length, fuel type, and annual mileage driven. The data are freely available.

[16] Fincher, S., C. Palacios, S. Kishan, D. Preusse, and H. Perez (2010). "Final Report for Modifying Link-Level Emissions Modeling Procedures for Applications within the MOVES Framework." U.S. Department of Transportation Contract DTFH61-09-C-00028.

This study presents a road map for developing emissions inventories using MOVES. The study also analyzes the likely impacts on emissions inventories as a result of the transition into MOVES. The version of MOVES used as the basis for this analysis was MOVES2010, released in December 2009. The study examines a specific ozone season day, for a single year, in the eight-county Houston nonattainment area, and the study results may not be applicable to other areas of the nation. Also, the data used to develop the alternative drive cycles is based on data collected in Kansas City and should be considered specific to that area. The study examines the impacts on CO, NO_x, and VOC emissions; other outputs from MOVES were not modeled.

[17] Hatzopoulou, M. and E.J. Miller (2010). "Linking an Activity-Based Travel Demand Model with Traffic Emission and Dispersion Models: Transport's Contribution to Air Pollution in Toronto." *Transportation Research Part D*, Volume 15, No. 6, pages 315-325.

This study describes the development of an integrated approach for assessing ambient air quality and population exposure as a result of road passenger transportation in large urban areas. A microsimulation activity-based travel demand model for the Greater Toronto Area – the Travel Activity Scheduler for Household Agents – is extended with capabilities for modeling and mapping of traffic emissions and atmospheric dispersion. Hourly link-based emissions and zone-based soak emissions were estimated. In addition, hourly roadway emissions were dispersed at a high spatial resolution and the resulting ambient air concentrations were linked with individual time-activity patterns derived from the model to assess person-level daily exposure. The method results in an explicit representation of the temporal and spatial variation in emissions, ambient air quality, and population exposure.

[18] Lee, D., J. Zietsman, M. Farzaneh, and J. Johnson (2011). "Characterization of On-Road Emissions of Compressed Natural Gas and Diesel Refuse Trucks." Presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C.

Portable Emissions Monitoring systems were used to perform on-road emissions testing of compressed natural gas and diesel refuse trucks to compare emissions and fuel consumption. PEMS provide emissions data as well as GPS location data on a second-by-second basis for in-use vehicles. Fuel consumption is determined using a carbon-balance algorithm. The data were used to develop specific duty cycles: highway driving, street driving during garbage pickup, short-distance acceleration, uphill driving, garbage collection, and compaction.

[19] Lindhjem, C.E. and S. Shepard (2007). "Development Work for Improved Heavy-Duty Vehicle Modeling Capability Data Mining – FHWA Datasets." Prepared by ENVIRON International Corporation for U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory.

This report analyzes databases collected by the FHWA, including vehicle count and classification from the HPMS using automated traffic recorders used to produce the Travel Volume Trends (TVT) reports. Other data sets compile the results of data collection from weigh-in-motion sensors, and other data sources (visual observation, weigh stations, and other special projects) maintained by the FHWA and compiled in the Vehicle Travel Information System. The primary goals of this work were to investigate the vehicle weights and mix of vehicle classes depending upon a number of regional and temporal factors by vehicle and roadway types. The report discusses how the TVT data can be used to estimate temporal variability (by month, day of week, and time of day) of total traffic volumes for all vehicles types combined. VTRIS site information (where vehicle class counts are made and vehicle weights are measured) contains the state and county FIPS codes. Using this information, it is possible to aggregate vehicle class count and vehicle weight distributions by designated state and county groupings, where the groupings could extend from one state into another. This work demonstrates that the VTRIS and TVT data can be imported into standard database programming tools that can be used to generate averages and typical temporal or regional profiles useful for emissions modeling. The summary results presented in this report provide information on vehicle characteristics, weight, and class fractions of the in-use fleet. Vehicle mix distribution calculations and temporal profiles by four road types are presented in the report.

[20] Malcolm, C., T. Younglove, M. Barth, and N. Davis (2003). "Mobile-Source Emissions Analysis of Spatial Variability in Vehicle Activity Patterns and Vehicle Fleet Distributions." *Transportation Research Record: Journal of the Transportation Research Board, No. 1842*, Transportation Research Board, Washington, D.C.

In this study, vehicle activity and vehicle fleet data were collected in the South Coast Air Basin in southern California using both instrumented vehicles and video cameras. Vehicle activity was characterized primarily using a large second-by-second speed and acceleration data set collected from probe vehicles operated within the flow of traffic. Vehicle driving patterns were collected in three cities on residential, arterial, and freeway routes. Three primary techniques were used for data collection: 1) second-by-second position and velocity data were recorded using an instrumented vehicle equipped with Doppler speed sensors, an on-board diagnostics (OBD) interface, and GPS instrumentation; 2) traffic information was collected using digital video cameras and postprocessed to obtain vehicle class distribution; and 3) average traffic speed, density, and flow rates, as well as license plate data, were captured with a digital video camera and subsequently analyzed using vehicle registration databases and VIN decoders. The results of the analysis show spatial and temporal differences in vehicle activity patterns and vehicle fleet characteristics; differences in speed and congestion affect the speed–acceleration profiles as well as associated emissions.

[21] Miller, J.S. (2002) "Ways to Estimate Speeds for the Purposes of Air Quality Conformity Analyses." Virginia Transportation Research Council, Virginia Department of Transportation.

The purpose of this study was to identify or develop a prototype postprocessor that VDOT staff could use to determine vehicle speeds for the purposes of conducting air quality conformity analyses. The postprocessor had to meet two requirements. First, speeds on the hundreds or thousands of individual links must be determined using data available from a typical long-range planning model. Second, the estimated speeds must be in a format suitable for use with the MOBILE model, meaning that the speeds need to be stratified by time period (e.g., morning peak) and facility type (e.g., rural interstate, primary arterial). This study did not seek to choose the best postprocessor and thus does not necessarily suggest that VDOT use the same method statewide. Such a recommendation would be feasible only after a longer-term validation effort, which is recommended at the end of this document. The postprocessor converts 24-hour link VMT to hourly volumes within each period, divides each link volume by the link's capacity, uses this ratio with a simple formula to estimate a link speed for each of the three periods, and then computes VMT and vehicle hours traveled for each link and for each period. The postprocessor then aggregates link-specific volumes, speeds, VMT, and VHT by period and facility type and stores this information in a file.

[22] National Renewable Energy Laboratory. "Secure Transportation Data Project." http://www.nrel.gov/vehiclesandfuels/secure_transportation data.html.

This project is assembling detailed GPS data that is collected from travel surveys for planning studies and usually discarded after processing to trip-level statistics (the primary need for planning applications). The data contains information on trajectories of the instrumented vehicles. As of July 2012, data were included from metropolitan-level travel surveys in Atlanta, Austin, Houston, San Antonio, Seattle, and southern California.

[23] Papson, A., S. Hartley, and K. Kuo (2012). "Analysis of Emissions at Congested and Uncongested Intersections Using MOVES 2010." Presented at the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2012.

This analysis estimates emissions using a time-in-mode methodology, which allocates vehicle activity time to one of four modes: acceleration, deceleration, cruise, and idle. This is somewhat of an in-between methodology that is more advanced than providing only average speed, but less data-intensive than providing full operating mode distributions. The TIM was based on HCM methods – assumptions were used as to what percent of vehicles were in each TIM based largely on control delay.

[24] Song, G. and L. Yu (2011). "Characteristics of Low-Speed Vehicle-Specific Power Distributions on Urban Restricted-Access Roadways in Beijing."

Presented at the 90th Annual Meeting of the Transportation Research Board, Washington, D.C.

This study uses large samples of second-by-second floating car data, collected from the expressways in Beijing, to associate the vehicle-specific power distributions with the average travel speed from 0 to 20 km/hr. A mathematical model of VSP distribution was developed on the basis of the separate analysis of VSP fractions in negative, zero and positive VSP bins. A comparative analysis between the estimated and actual fuel consumption demonstrates that the proposed VSP distribution model is reliable and accurate for the estimation of fuel consumption.

[25] Song, G., L. Yu and Y. Zhang (2012). "Applicability of Traffic Microsimulation Models in Vehicle Emission Estimates: A Case Study of VISSIM." Presented at the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2012.

This study examined the effect of using vehicle trajectories from microscopic simulation models as a basis for establishing operating mode distributions. (Vehicle trajectories were first converted to VSP, then placed into the MOVES operating mode bins.) The study concluded that the traditional approach of integrating traffic simulation models with emission models was not applicable for vehicle emission estimations – large errors were reported between the operating mode distributions of simulated versus real-world data.

[26] Travel Model Improvement Program (TMIP) (2008). "Technical Synthesis – The Derivation of Initial Speeds in Travel Demand Models." http://tmiponline.org/Clearinghouse/Items/Technical_Synthesis_-_The_Derivation_of_Initial_Speeds_in_Travel_Demand_Models.aspx**.**

This study presents a synopsis of the contributions made on the topic of speeds in travel modeling, with a specific focus on determining initial speeds and the collection of speed data that supports the derivation of initial network speeds. Speed data may be obtained from observed speeds by time-of-day, posted speed limits, and uncongested free-flow speeds representing off-peak travel speeds. Speed data can be used in a model unaltered, to derive the input network speed, or as the initial speed for deriving congested weighted speed using sequential feedback loop. Observed speed data is also used to develop speed-flow relationships that are used to create specific volume-delay equations (e.g., by facility type for different time periods) for the traffic assignment. Only a few areas have collected comprehensive speed and/or travel time data. Collection methods included collecting point-to-point travel times using a floating car method for different time periods, utilizing loop detector data on freeways to determine speed-flow relationships and travel times, using toll transponders to automatically collect travel times, acquiring speed and travel time data from vehicles installed with GPS devices (private vehicles, taxis, municipal vehicles), and using video technology to collect speed-flow relationships, volumes and travel times. Speeds may be collected at locations for different time periods and days of week for different area types.

[27] Travel Model Improvement Program (TMIP) (2009). "Technical Synthesis – Speed Adjustments Using Volume-Delay Functions." http://tmiponline.org/Clearinghouse/Items/Technical_Synthesis_-_Speed_Adjustments_Using_Volume-Delay_Functions.aspx**.**

Volume-delay functions describe the speed-flow relationships in a travel demand model network based on the available link capacity. As traffic increases on the network, the resulting travel time and delay increase. In an effort to better represent delay due to congestion, some study areas estimate alternative volume-delay functions or construct speed-flow relationships based on observed data to achieve reasonable congested weighted speeds from the trip assignment model. One of three approaches is typically applied with respect to VDF curves: 1) apply a single volume-delay formulation for all facility types; 2) apply unique user specified VDF functions developed for each facility type (e.g., freeway, expressway, arterials) and possibly area type in the network; and 3) develop unique user specified VDF functions to account for delay at signalized intersections. Because of the asymptotic nature of volume-delay curves, also described as "monotonically increasing functions" with respect to travel times, speed adjustment factors are allowed to continue infinitely until speeds reach "unrealistically low" values. Approaches for establishing the minimum allowable speed degradation are discussed. Speeds that are produced by the travel models need to be postprocessed and refined to produce more realistic network link-specific values for use in mobile source emission modeling.

[28] U.S. Environmental Protection Agency (U.S. EPA) (1999). "Guidance for the Development of Facility Type VMT and Speed Distributions."

Speed estimation procedures are based on BPR equations and HCM methods using data from traffic counts or travel demand forecasting models.

[29] U.S. Environmental Protection Agency, Office of Transportation and Air Quality (2010a). *Using MOVES in Project-Level Carbon Monoxide Analyses*, EPA-420-B-10-041.

This document provides guidance on data sources and preparation methods for all MOVES inputs required for project-level hot spot analysis for carbon monoxide.

[30] U.S. Environmental Protection Agency, Office of Transportation and Air Quality (2010b). *Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas*, EPA-420-B-10-040.

This document provides guidance on data sources and preparation methods for all MOVES inputs required for project-level hot spot analysis for particulate matter.

[31] U.S. Environmental Protection Agency, Office of Transportation and Air Quality (2010c). "Technical Guidance on the Use of MOVES2010 for Emission Inventory Preparation in State Implementation Plans and Transportation Conformity," EPA-420-B-10-023.

This document provides guidance on data sources and preparation methods for all MOVES inputs required for regional conformity analysis.

[32] U.S. Environmental Protection Agency (2012a). "Motor Vehicle Emission Simulator (MOVES) User Guide for MOVES2010b," EPA-420-B-12-001b, June 2012, http://www.epa.gov/otaq/models/moves/documents/420b12001b.pdf.

The MOVES User Guide describes the purpose of the MOVES model, gives examples of "what-if" scenarios that can be evaluated using MOVES, and explains how the MOVES model differs from previous mobile source models, the general structure of the MOVES model, and how to install and execute the MOVES model. The guide provides caution notices that must be observed to avoid errors in execution or to ensure the intended execution will occur. Notes and tips about the MOVES model are also provided throughout the guide. Each input of the model is defined and discussed, accompanied by extensive screen shots.

[33] U.S. Environmental Protection Agency (2012b). "Using MOVES to Prepare Emission Inventories in State Implementation Plans and Transportation Conformity: Technical Guidance for MOVES2010, 2010a, and 2010b," EPA-420-B-12-028, April 2012, http://www.epa.gov/otaq/models/moves/documents/420b12028.pdf.

In this document, EPA provides guidance for the use of MOVES to develop emissions inventories for State Implementation Plans and for transportation conformity determinations (excluding California). The guidance identifies appropriate inputs and how MOVES should be run to develop emissions inventories for use within SIPs and in regional conformity analyses. Using MOVES for SIP or regional conformity analysis requires the user to execute MOVES at the County scale.

[34] U.S. Environmental Protection Agency, Office of Transportation and Air Quality (2012c). *Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption*-Draft, EPA-420-D-12-001.

This document provides guidance on data sources and preparation methods for all MOVES inputs that EPA recommends using for regional greenhouse gas inventories (although there are no regulatory requirements). It is an important starting point for the guidance developed as part of NCHRP 25-38. The report states: "Selection of vehicle speeds is a complex process. The recommended approach for estimating average speeds is to post-process the output from a travel demand network model. In most transportation models, speed is estimated primarily to allocate travel across the roadway network. Speed is used as a measure of impedance to travel rather than as a prediction of accurate travel times. For this reason, speed results from most travel demand models must be adjusted to properly estimate actual average speeds."

[35] University of California at Riverside (pending publication). "Improving Vehicle Fleet, Activity, and Emissions Data or On-Road Mobile Sources Emissions Inventories." Prepared for Federal Highway Administration.

This report has a similar goal to NCHRP 25-38 to investigate methods of obtaining data for MOVES inputs. It describes a survey of five MPOs to identify the state of practice. One chapter describes a license plate survey in Las Vegas, which is applicable to both project-level and regional age distribution and vehicle type distribution inputs. For regional emissions, it shows that in-state registration data alone may not be sufficient in certain areas, such as those with high tourist activity (i.e., Las Vegas), transportation hubs, and near state borders. The report provides some details on the methods (automated versus manual) and costs involved in collecting license plate data. Other chapters will address heavy-duty truck activity and emissions data. The study recommends using the vehicle license plate survey technique in conjunction with vehicle registration database and VIN decoder to obtain highly resolved and area-specific vehicle fleet data.

[36] Vallamsundar, S. and J. Lin (2012). "Using MOVES and AERMOD Models for $PM_{2.5}$ Conformity Hot Spot Air Quality Modeling." Presented at the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2012.

According to the authors, this study (of the I-55 and I-80 interchange near Joliet, Illinois) is the first undertaking by a state DOT to implement a quantitative PM hot spot analysis under the new MOVES-based guidance. It provides insight to the process with respect to data input preparation, sensitivity testing, and MOVES model setup.

[37] Xu, Y., L. Yu, G. Song, X.C. Liu, and Y. Wang (2012). "Genetic Algorithm-Based Approach to Operating Mode Distributions via Link Average Speeds." Presented at the 91st Annual Meeting of the Transportation Research Board, Washington, D.C., January 2012.

This paper develops a model based on real world data to predict operating mode distributions based on average speed. It concludes that the model developed predicts different operating mode distributions than the default ones found in MOVES, but this is not surprising since the real world data is from Beijing, China and the MOVES model represents driving in the United States. However, the paper is also useful in describing collection of the real world data on 238 km of expressways in Beijing using 46 GPS-equipped light-duty vehicles.

C. Survey Responses

This section presents charts showing the distribution of responses to each question, along with free-response comments to each question or on each page of the survey. The free-response comments have not been edited.

C.1 SURVEY RESPONDENTS

Out of 79 responses, 59 agencies identified themselves in the survey, as listed below. In a few cases, two different people at a single agency responded.

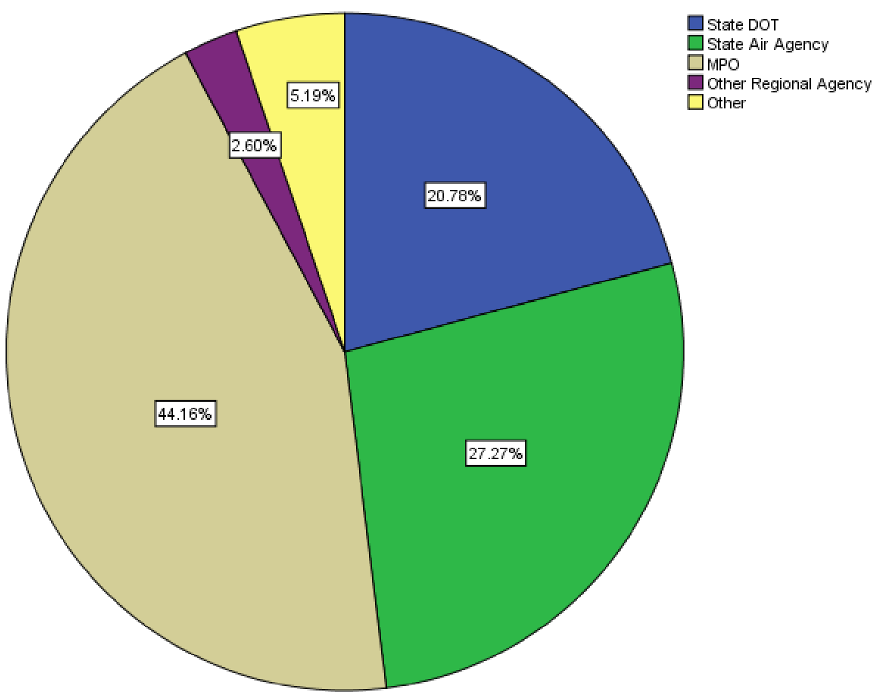
- **MPOs (up to 38 agencies represented):**
  - Anchorage Metropolitan Transportation Solutions;
  - Atlanta Regional Commission;
  - Boston Region MPO;
  - Capital District Transportation Committee (Albany, New York);
  - Chattanooga (Tennessee) Transportation Planning Organization;
  - Delaware-Muncie Metropolitan Plan Commission (Muncie, Indiana);
  - East-West Gateway Council of Governments (St. Louis, Missouri);
  - El Paso MPO;
  - Houston-Galveston Area Council;
  - Kentuckiana Regional Planning and Development Agency (Louisville, Kentucky);
  - KYOVA Interstate Planning Commission (Huntington, West Virginia);
  - Maricopa Association of Governments (Phoenix, Arizona);
  - Metropolitan Washington Council of Governments;
  - Mid Ohio Regional Planning Commission (Columbus, Ohio);
  - Mid-America Regional Council (Kansas City, Missouri);
  - Missoula (Montana) MPO;
  - Mountainland Association of Governments (Orem, Utah);
  - New York Metropolitan Transportation Council;
  - North Central Texas Council of Governments (Dallas-Fort Worth, Texas);
  - North Jersey Transportation Planning Authority;
  - Poughkeepsie-Dutchess County Transportation Council (New York);
  - Rogue Valley MPO (Medford, Oregon);

  - Southeast Michigan Council Of Governments (Detroit, Michigan);
  - Southeast Wisconsin Regional Planning Agency (Milwaukee, Wisconsin);
  - South Jersey Transportation Planning Organization;
  - Wasatch Front Regional Council (Salt Lake City, Utah);
  - Wood-Washington-Wirt Interstate Planning Commission (Parkersburg, West Virginia/Ohio); and
  - Eleven anonymous responses.
- **State DOTs (up to 14 agencies represented):**
  - Connecticut DOT (two responses);
  - Delaware DOT;
  - Georgia DOT;
  - Kentucky Transportation Cabinet;
  - New Hampshire DOT;
  - New Jersey DOT;
  - New York State DOT;
  - North Carolina DOT;
  - Pennsylvania DOT;
  - South Carolina DOT;
  - Virginia DOT;
  - Washington State DOT; and
  - Two anonymous responses.
- **State Air Agencies (up to 22 agencies represented):**
  - Alaska Department of Environmental Conservation;
  - Colorado Air Pollution Control Division;
  - Connecticut Department of Energy and Environmental Protection;
  - Georgia Department of Natural Resources – Environmental Protection Division;
  - Illinois Environmental Protection Agency;
  - Maine Department of Environmental Protection;
  - Maryland Department of the Environment;
  - Missouri Department of Natural Resources;
  - New Hampshire Department of Environmental Services;
  - New Jersey Department of Environmental Protection;
  - Pennsylvania Department of Environmental Protection;

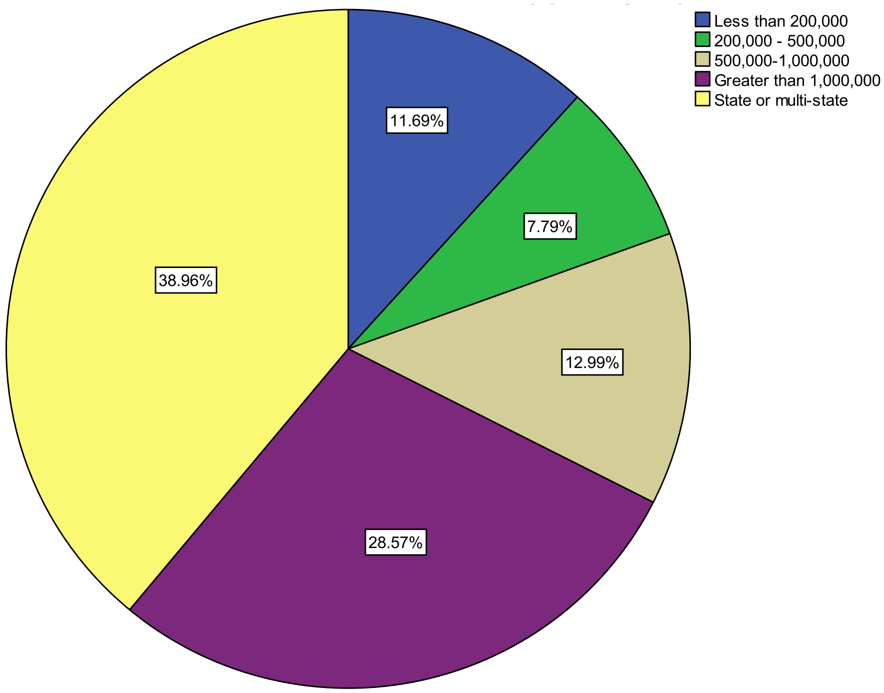
  - South Carolina Department of Health and Environmental Control;
  - Tennessee Department of Environment and Conservation;
  - Utah Division of Air Quality;
  - Washington State Department of Ecology;
  - Wyoming Department of Environmental Quality – Air Quality Division; and
  - Six anonymous responses.
- **Other (five agencies represented):**
  - Charlotte (North Carolina) Department of Transportation;
  - Louisville Metro Air Pollution Control District;
  - Mecklenburg County Air Quality;
  - Washoe County Health District, Air Quality Management Division; and
  - One anonymous response.

C.2 AGENCY CHARACTERISTICS

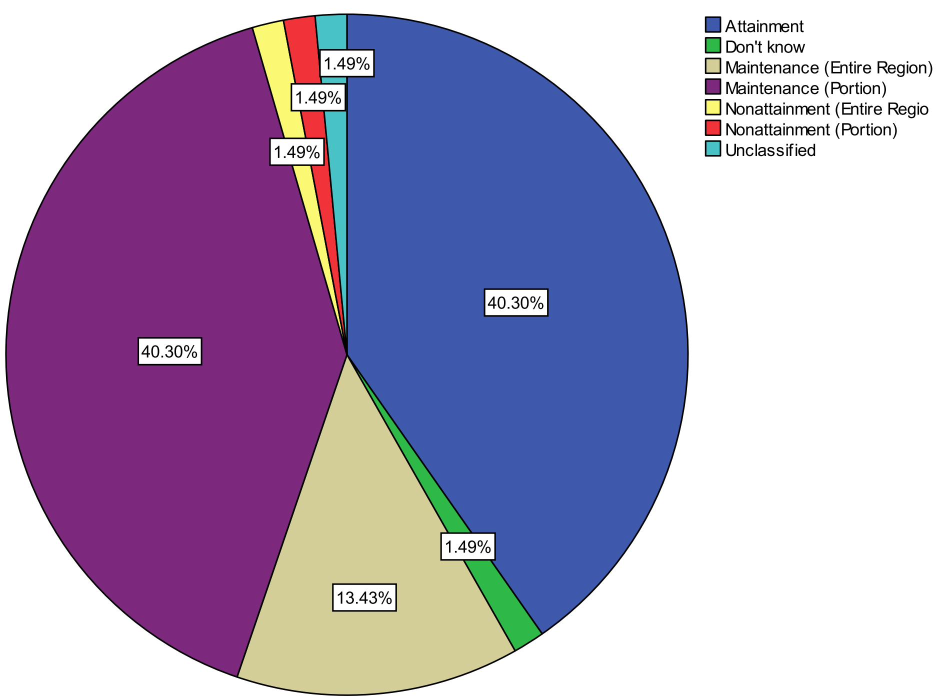
What type of agency do you represent? (N=77)



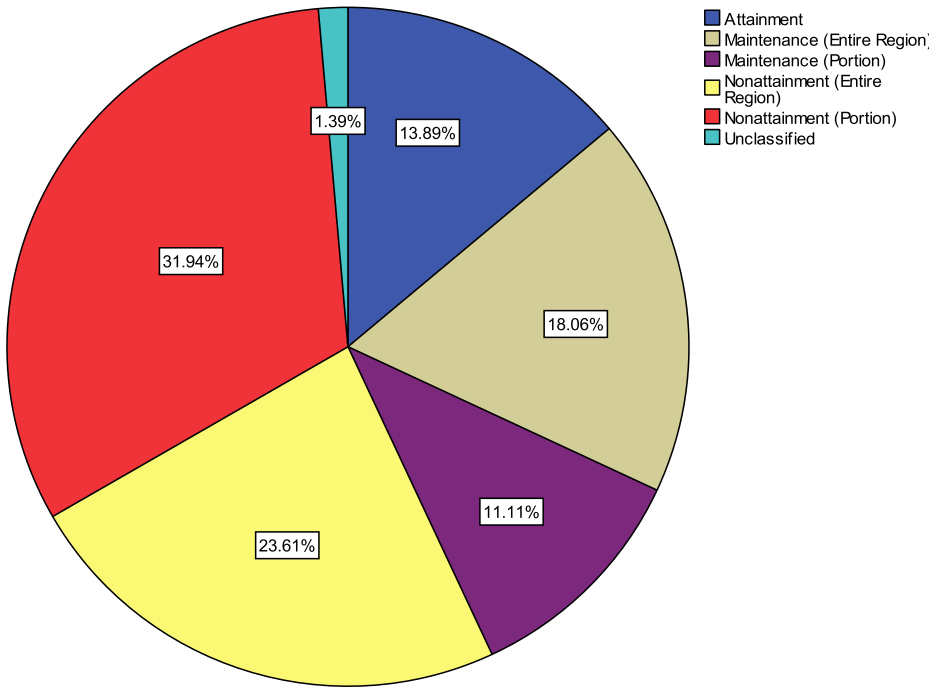
What population is served by your agency? (N=77).



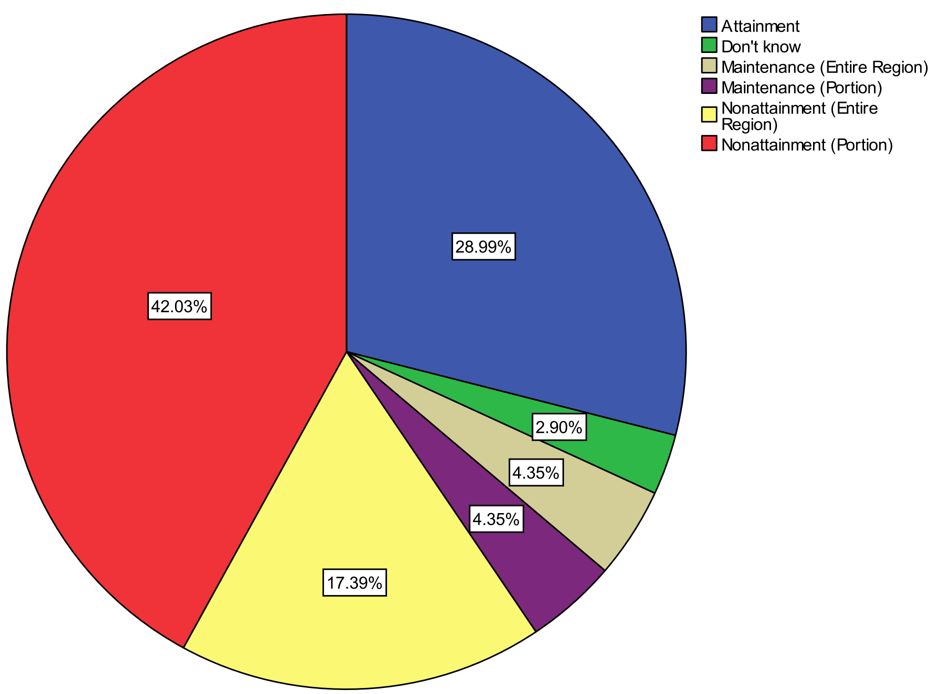
Please indicate the nonattainment status of your region for CO (N=67), Ozone (N=72), $PM_{2.5}$ (N=69), and PM_{10} (N=65).



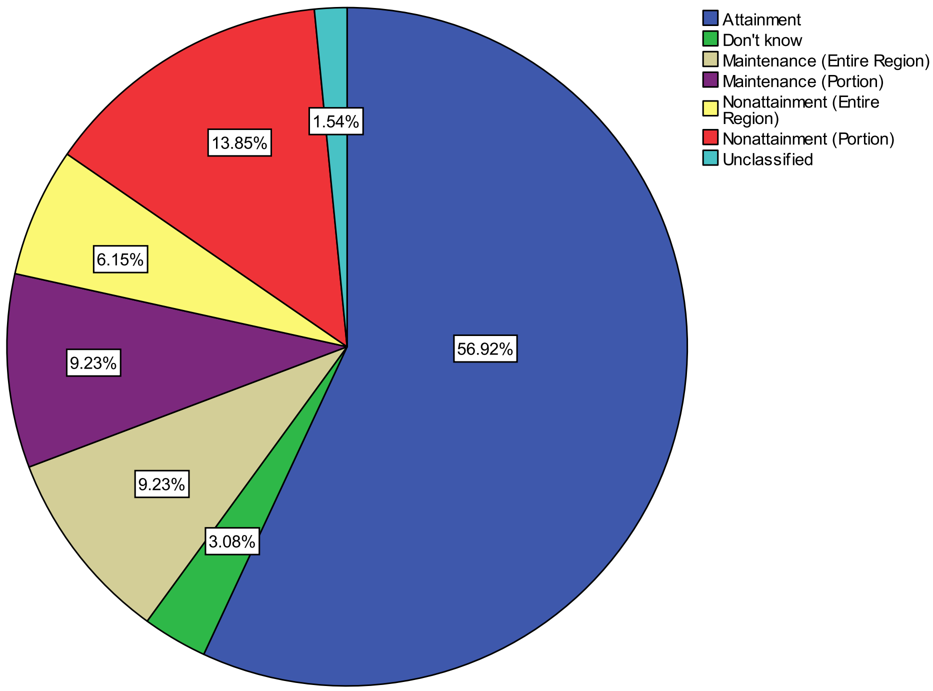
Please indicate the nonattainment status of your region for each of the following pollutants: Ozone



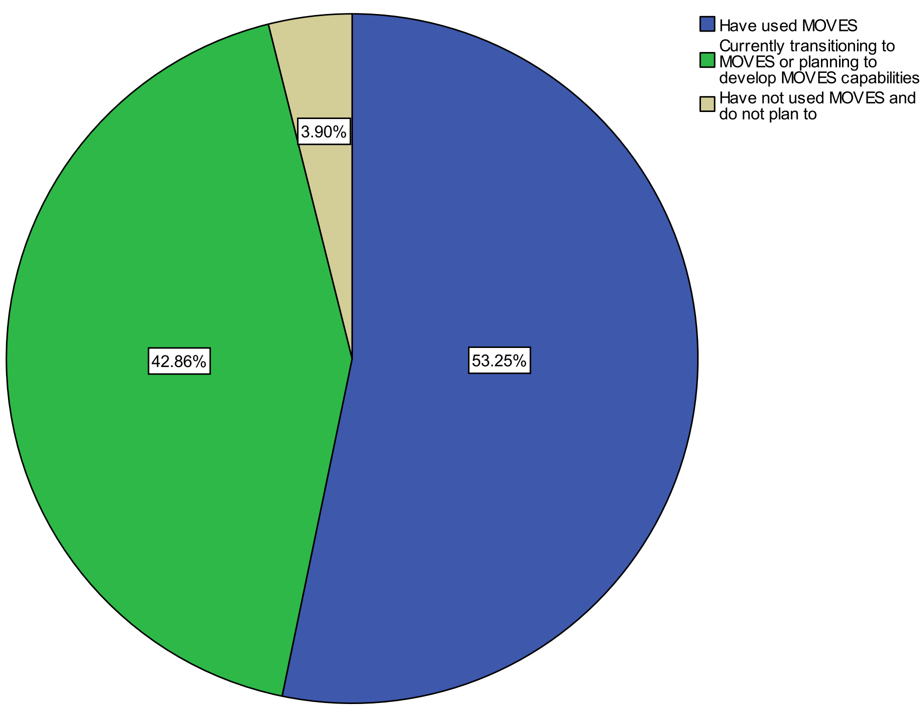
Please indicate the nonattainment status of your region for each of the following pollutants: $PM_{2.5}$



Please indicate the nonattainment status of your region for each of the following pollutants: PM_{10}

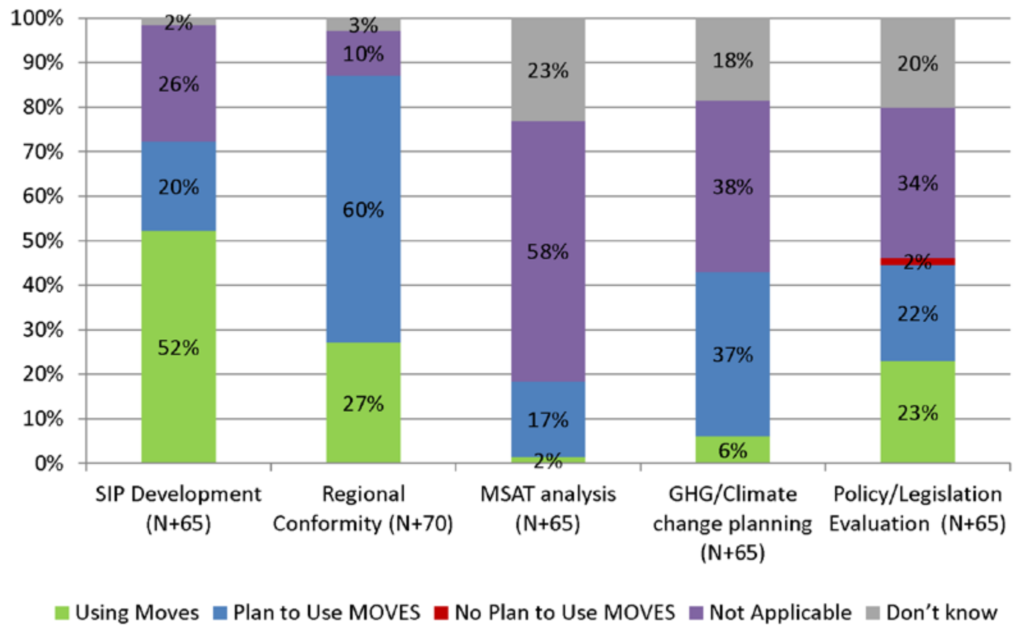


What is your agency's current status with respect to the use of MOVES? (N=77).

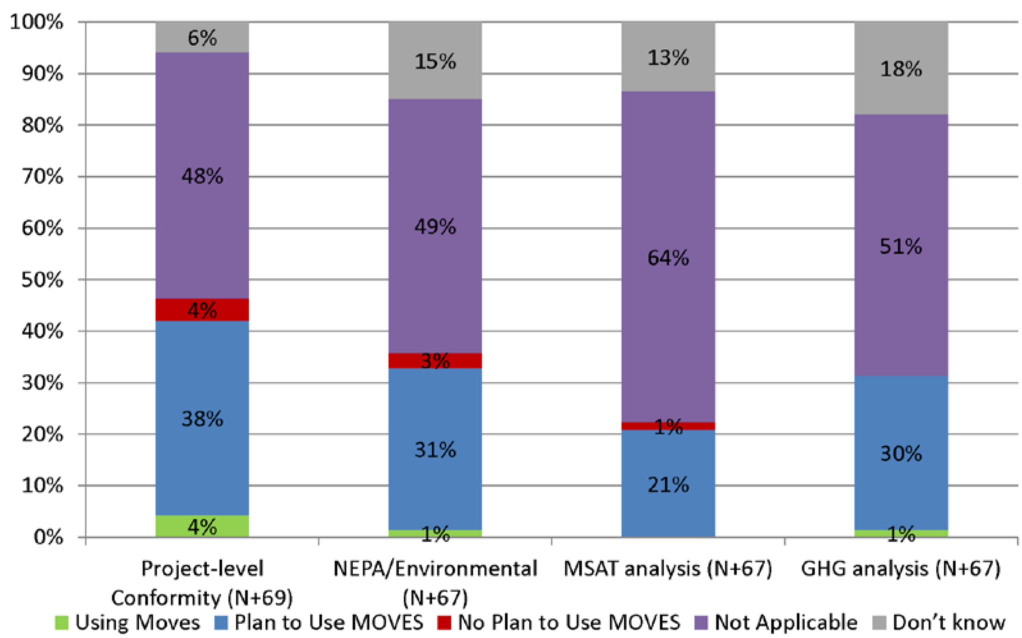


C.3 EMISSION MODELING PRIORITIES

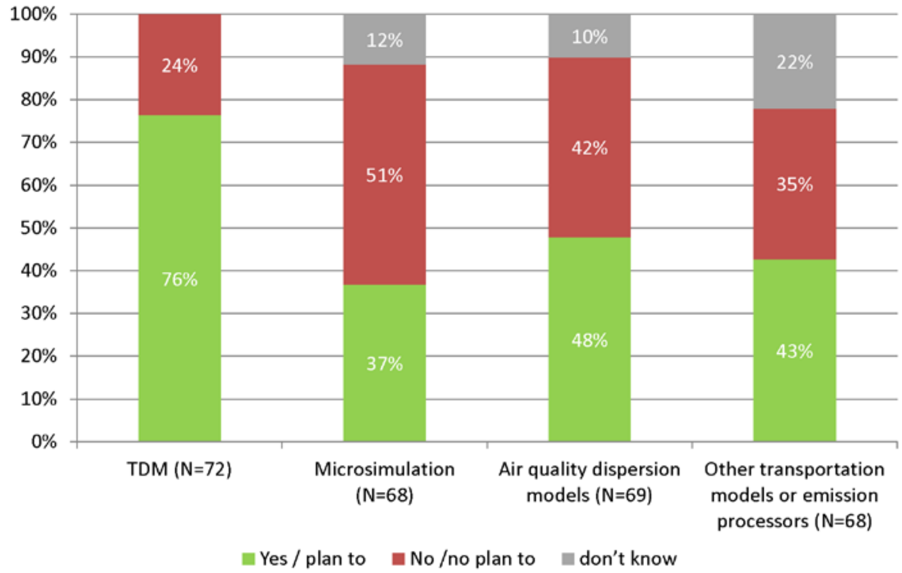
For what regional planning purposes does your agency use, or plan to use, MOVES?



For what project-level planning purposes does your agency use, or plan to use, MOVES?



Does your agency interface emissions rates, or related data, from MOVES with the following types of models?



Additional comments responses on emission modeling priorities:

- (Note that question numbers refer to those found in the Word version of the survey.) On Q8, we haven't used MOVES for an "official" conformity determination, but have used it for regional GHG analysis, for assistance with SIP development, and in work on transition from Mobile. On Q5, our agency doesn't do the SIP development, but we do support the state air agency (NJDEP) by developing activity estimates. On Q7, we use the PPSuite travel demand model postprocessor, if this qualifies as an "emission processor." PPSuite generates MOVES activity inputs based on travel model data and aggregates MOVES emission outputs for the purpose of regional air quality analysis. On Q9 (next section), we have decided to standardize on using MOVES in inventory mode for conformity analyses, but have used rate mode in GHG analyses.
- At this time we are working on developing the in-house capability to perform MOVES runs. Up until now our MOVES work has been done by an outside contractor.
- First question, this section → Items a and b are performed jointly by MPO staff and LAQA staff. Items c through e, for the most part, are performed by or will be performed by LAQA staff with MPO staff only providing input data. Responsibility for emission modeling for items f through i is not known at this time. Second question, this section → Efforts to interface MOVES w/travel demand model currently under development w/MPO staff attempting to implement postprocessor to accomplish this. Efforts to interface MOVES with traffic simulation models and other transportation models will probably be led by MPO staff to the extent that these things may occur. Efforts to interface MOVES with air quality dispersion models will be

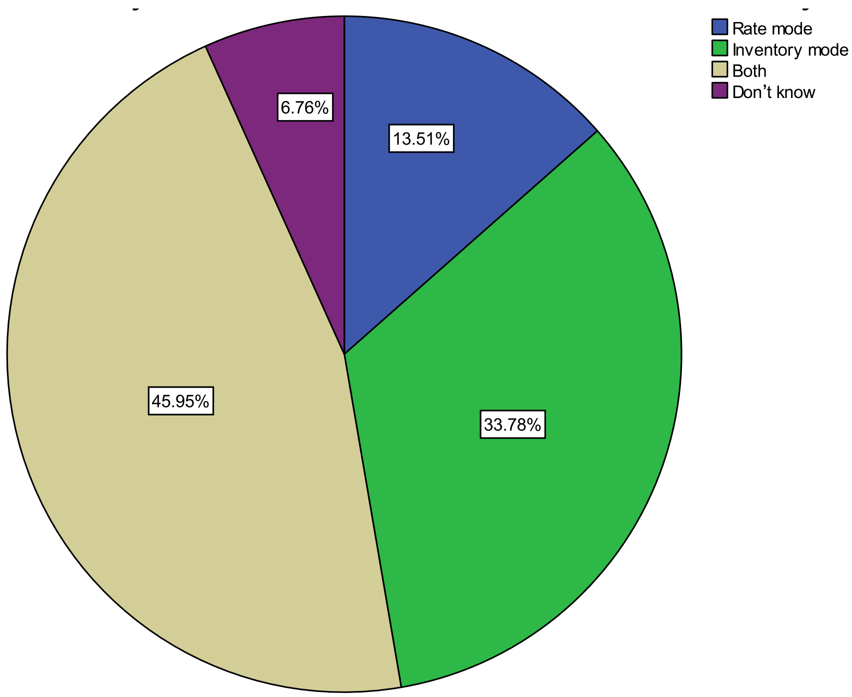
led by LAQA staff to the extent that these things may occur. Efforts to interface MOVES with emission processors may be led by either staff, if they occur.

- For the items marked "Don't know" above – We have not done this in the past, but recognize we may end up doing it at some point.
- MOVES has been integrated with MPO regional travel models and with MD_SHA-based HPMS traffic/roadway data without travel models. MOVES will be used for future project-level analysis as warranted.
- MOVES has been integrated with MPO regional travel models and with PennDOT HPMS and RMS traffic data in areas without travel models. MOVES will be used for future project-level analyses as warranted.
- Our plans are to use MOVES output to input into SMOKE, but we haven't done that ourselves yet.
- Regarding unanswered questions, we anticipate GHG analysis under state direction in the future and would probably use MOVES but guidance uncertain now.
- Responses to what portions of the area are in attainment, nonattainment, etc., are hard to answer. For example, only two out of eight counties in CT were ever in nonattainment for $PM_{2.5}$. However, are DEEP has submitted a redesignation of that area to maintenance, but has not as yet received approval. Only three areas in Ct were in nonattainment for CO but have been in maintenance for over 12 years. It might have been better to have an option for a portion of the state or a combination.
- This interface is not a direct interface but one where we put data from MOVES and put into other formats manually.
- Though we don't need emission rates for the overall emission calculations, we do need to use them for CMAQ processes and sometimes local projects assistance.

C.4 MOVES-RELATED EXPERIENCE

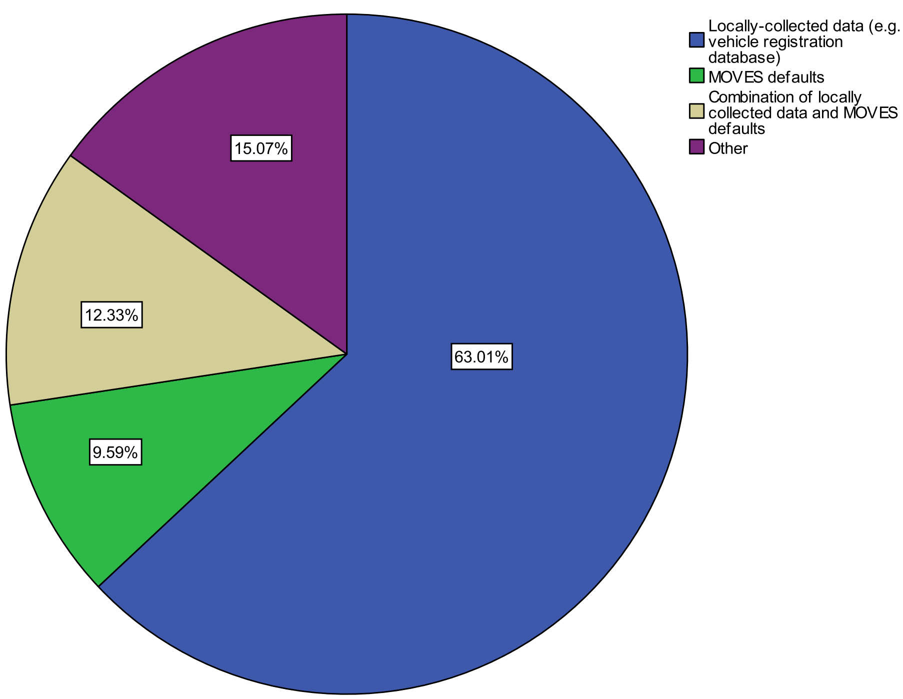
MOVES can be used in emissions inventory mode to calculate emissions entirely within MOVES, or in rate mode to output emission rates (or factors) to apply to travel activity data from a travel demand forecasting model (TDFM).

Do you use MOVES in emission rate or inventory mode? (N=74).



C.5 Experience Related to Vehicle Fleet Inputs

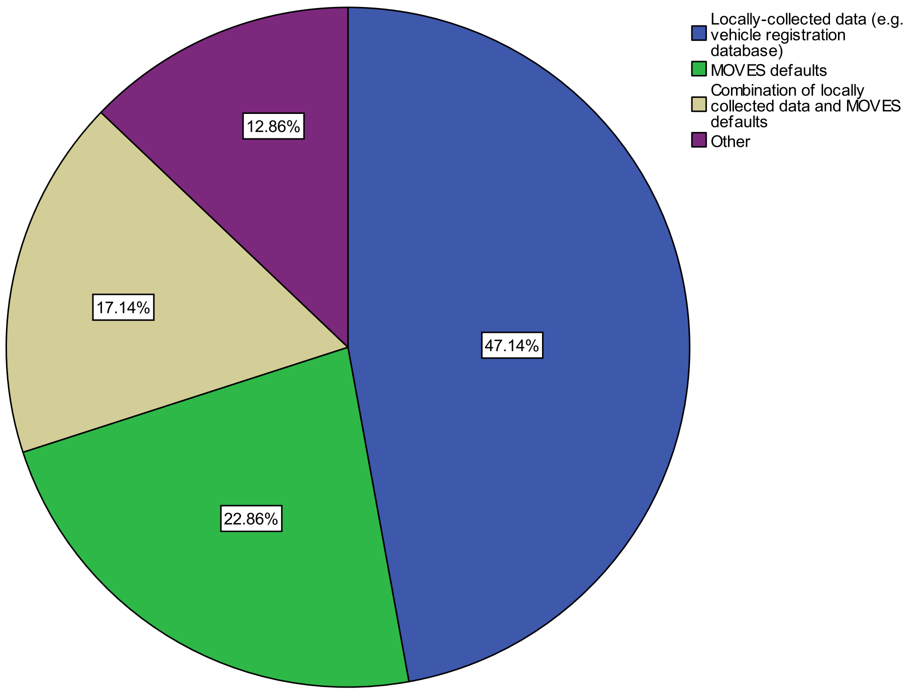
What is your agency's source of light-duty age distributions? (N=73).



Responder comments on the source of light-duty age distributions:

- Other agency provides data.
- We use local data to get totals in 3 MOVES vehicle type groups: 11, 21, 31+32. We use MOVES' technical guidance Table A.1 to split these into their individual vehicle types.
- Attempting to use registration data, but not available for HD vehicles – must use defaults for this.
- NC DMV via NC DAQ.
- DMV data disaggregated using MOVES defaults.
- CT DEEP prepares file. See their response. Based on DMV registrations.
- Not sure.
- It depends on quality of the data
- Most of the data is locally collected, but MOVES defaults are used for a few items.
- State DOT.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- We used Mobile 6 and MOVES fractions to determine light-duty fleet mix.
- DMV, DOT, IM records, and MPO data collection efforts.
- Working on this using local/state sources and MOVES data.
- Combination of vehicle registration database from State's DMV and MOVES defaults.
- Still being determined.
- R.L. Polk.

What is your agency's source of heavy-duty age distributions? (N=70).

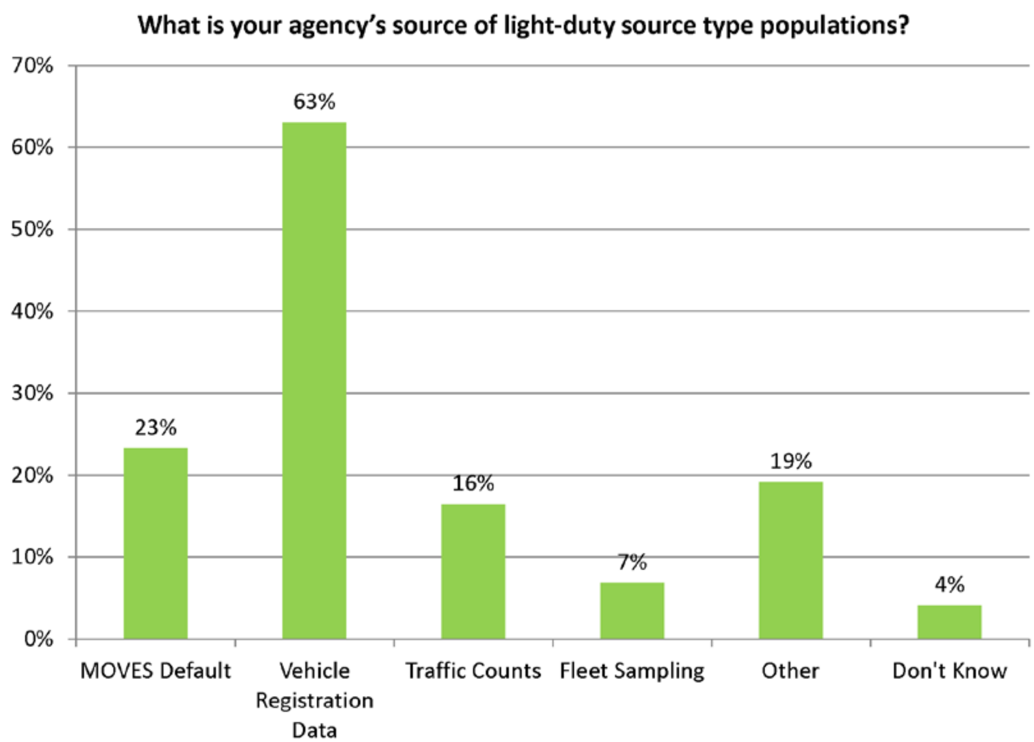


Responder comments source of heavy-duty age distributions:

- Other agency provides data.
- We use local data to get totals in 6 MOVES vehicle type groups: 41+42, 42, 51, 52+53, 54, 61+62. We use MOVES' technical guidance table A.1 to split these into their individual vehicle types.
- Fill in with MOVES proportional data where not available or complete.
- For long-haul combination trucks we use national defaults but for other heavy-duty we use local data.
- Moves default because there is no guarantee that the heavy-duty registered in the state is actually operating in the state.
- NC DMV via NC DAQ.
- CT DEEP prepares file. See their response. Based on DMV registrations.
- Not sure.
- Mostly locally collected, except for HDV8B where we use defaults.
- Most of the data is from the MOVES defaults, but locally collected data is used to the extent possible (a few items).
- State DOT.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.

- Defaults for long-haul trucks and refuse trucks.
- Source Types 11, 21, 31, 32, 41, 42, and 43 are based on local data. Others are based on MOVES defaults.
- Same as previous … working on now.
- We get available data from state DOT.
- Still being determined.
- R.L. Polk.

Source type data: sources of light-duty population data (N=73).

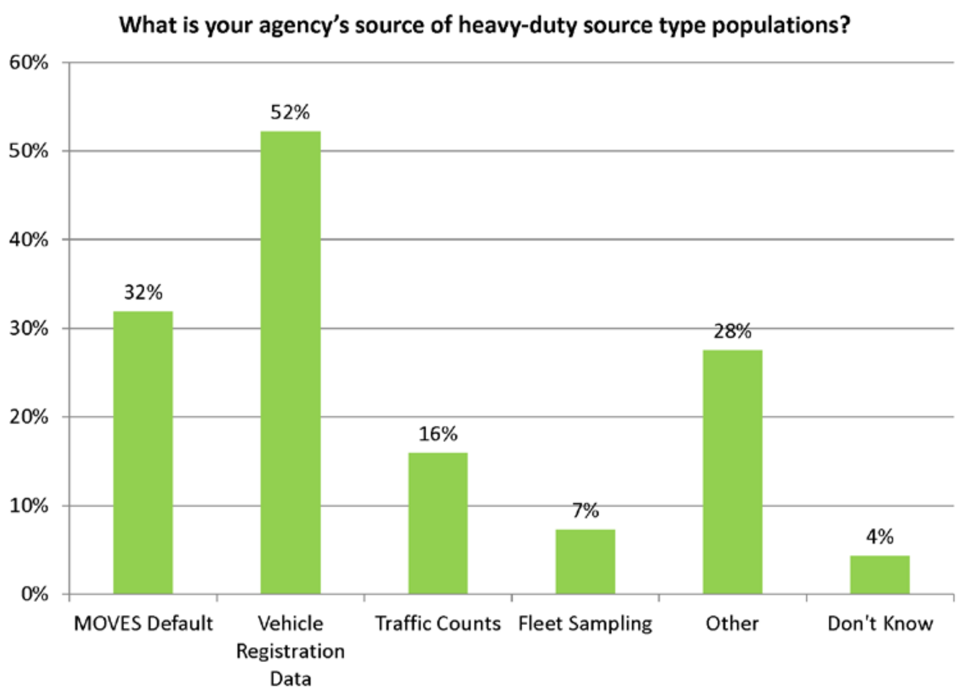


Source type data: sources of light-duty population data additional comments:

- Other agency provides data.
- Method described in section 3.3 of the technical guidance manual for MOVES 2010a.
- Right now we use a combination of SCDMV population numbers for all source types, and apply percentages from MOVES default data to split into each source type category. We are working on generating MOVES input by source type using only DMV data.

- Private company processed, QA/QC'd local vehicle registration data grown based on registration or human population trends.
- The local reg for light cars and trucks but they have mixed both categories up so we use the total vehicle count and then use moves to make the splits between vehicle types 21, 31, and 32.
- NC DMV via NC DAQ
- CT DEEP prepares file. See their response. Based on DMV registrations.
- State DOT.
- Checks against veh population calculated from VMT using MOVES default (miles/vehicle).
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- MC, PC, from MVA data – rest based on MOVES defaults.
- We used 2005 University study.
- State DMV database.
- Still being determined.
- R.L. Polk and grown to current year using census data.

Source type data: sources of heavy-duty population data (N=69).

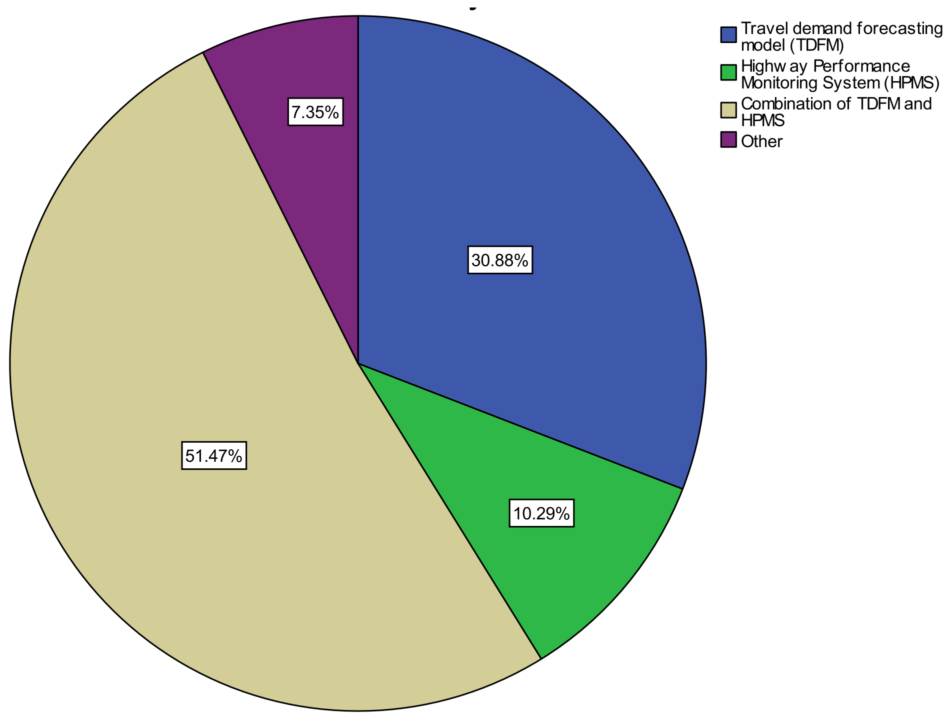


Source type data: sources of heavy-duty population data additional comments:

- Other agency provides data.
- Method described in section 3.3 of the technical guidance manual for MOVES 2010a.
- Right now we use a combination of SCDMV population numbers for all source types, and apply percentages from MOVES default data to split into each source type category. We are working on generating MOVES input by source type using only DMV data.
- Combination of what we did for light-duty plus for long-haul combination trucks we did a special calculation since they are not originating from the state but are interstate travel.
- We use a combo of local data for MOVES light-duty vehicles. Like I said above we take the total cars and truck number from DMV and then use MOVES to split it out by 21, 31, and 32 vehicle types. Then if the new local population is higher than the moves default then we use that percent difference and adjust the heavy-duty end accordingly.
- NC DMV via NC DAQ.
- CT DEEP prepares file. See their response. Based on DMV registrations.
- Some factoring with VMT and default data on source type 62 to account for more pass-through traffic. Future populations are grown based on ARC population forecasts.
- State DOT.
- Checks against veh population calculated from VMT using MOVES default (miles/vehicle).
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- Default and local when correct.
- Buses and Motor Homes from MVA data – rest based on MOVES defaults.
- Larger of local analysis of local data or a VMT-based approach for interstate HPMSVtypeIDs.
- See below.
- Not sure.
- Still being determined.
- R.L. Polk and grown to current year using census data MOVES defaults.

C.6 Experience Related to Regional Activity Data

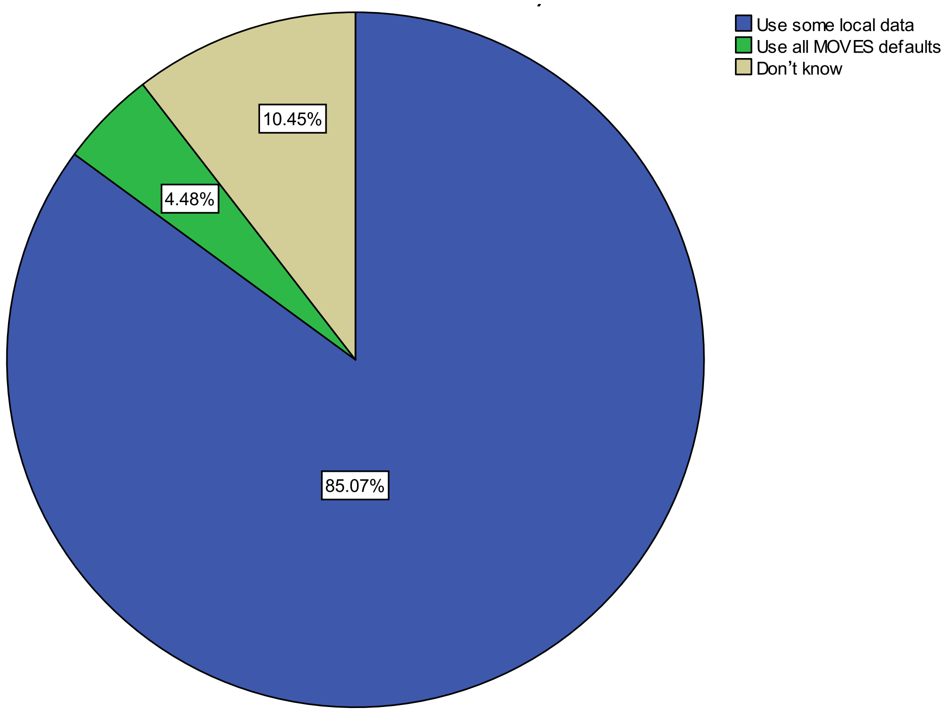
What is your agency's source of total VMT data for use in MOVES for regional analysis? (N=68).



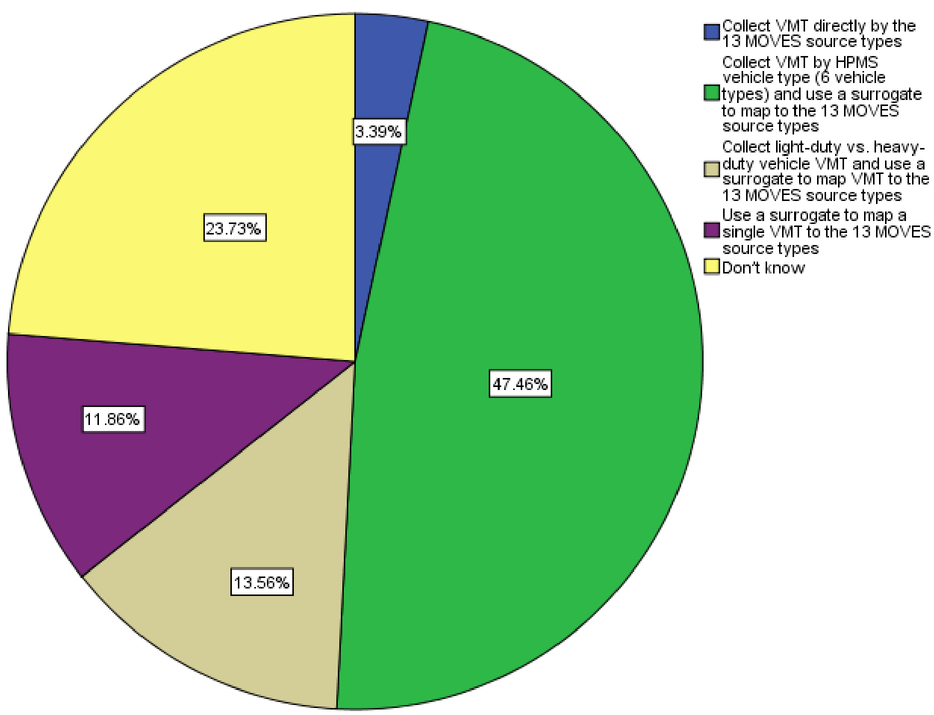
What is your agency's source of total VMT data for use in MOVES for regional analysis? (Other comments.)

- Other agency provides data.
- Local data from WY DOT.
- Illinois Department of Transportation.
- For our marginal nonattainment area we depend on travel demand model; for all other areas of the state we have county-level VMT from our DOT.
- HPMS for rural areas and TDFM for urbanized areas.

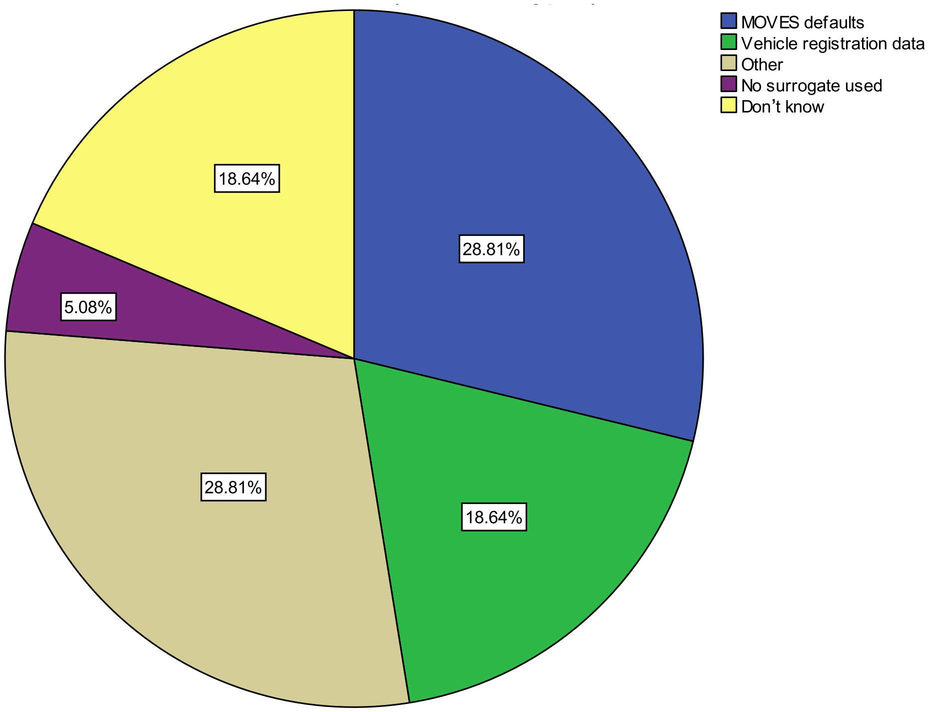
Do you use locally derived data for any of the following inputs: VMT mix by source type, annual VMT by vehicle type, month fraction VMT, day fraction VMT, hour fraction VMT, ramp fractions, road type distribution, or average speed distribution? (N=67).



How do you collect VMT data for the 13 MOVES source types? (N=59).



What is your surrogate source used to derive VMT at the MOVES source type level (13 vehicle types)? (N=59).

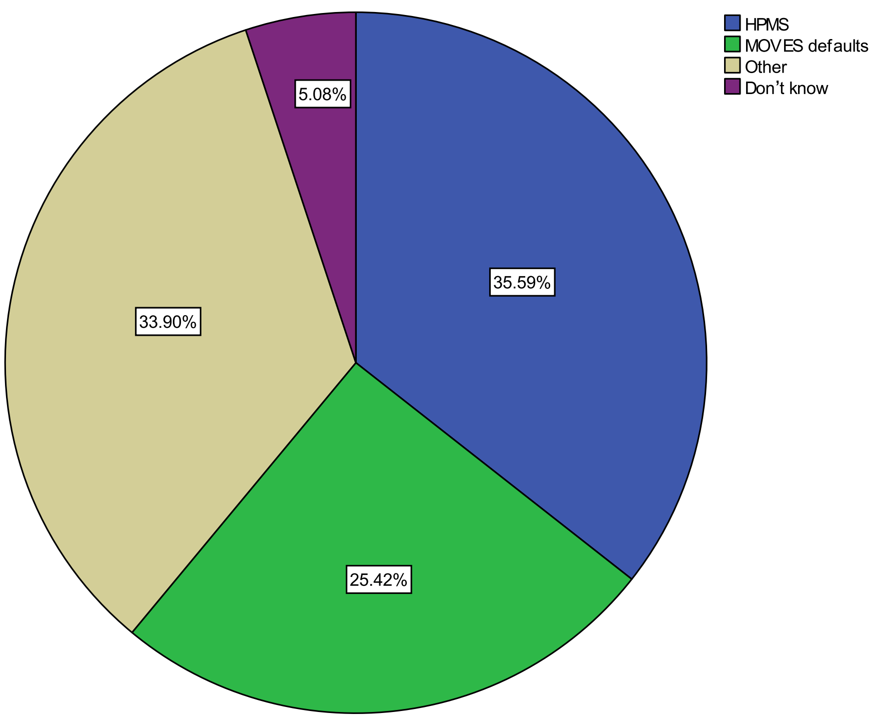


Further explanation of "Other" response:

- Based on Vehicle registration and HPMS data, the VMT is mapped to 13 MOVES vehicle type using MOVES' MOBILE6.2 to MOVES mapping tool.
- Combination.
- Combination of a) and (b).
- Combination of registration data and MOVES defaults.
- From MDOT.
- HPMS data.
- Local traffic counts, Vehicle registration data.
- MOVES source type map from 6 HPMS to 13 MOVES types was generated using combination of vehicle registration, MOVES defaults, and travel model information. Custom software was developed to produce MOVES source type map for each county and road type combination.
- MOVES source type maps from 6 to 13 types were developed using a combination of vehicle registration data, MOVES defaults, and TDFM information. Custom software was developed to generate a MOVES source type map for each county and road type combination.

- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- On street survey is used to characterize vehicle types in winter CO season.
- Permanent Traffic Counters (ATR).
- See below.
- Self made converter.
- State vehicle type counts (LD and HD based on axle spacing) and MOVES default VMT mix.
- Use State of Connecticut data.
- Vehicle count/fractions for motorcycle, HD, and LD vehicles from DOT.

What is your source of month fraction VMT data for use in MOVES for regional analysis? (N=59).

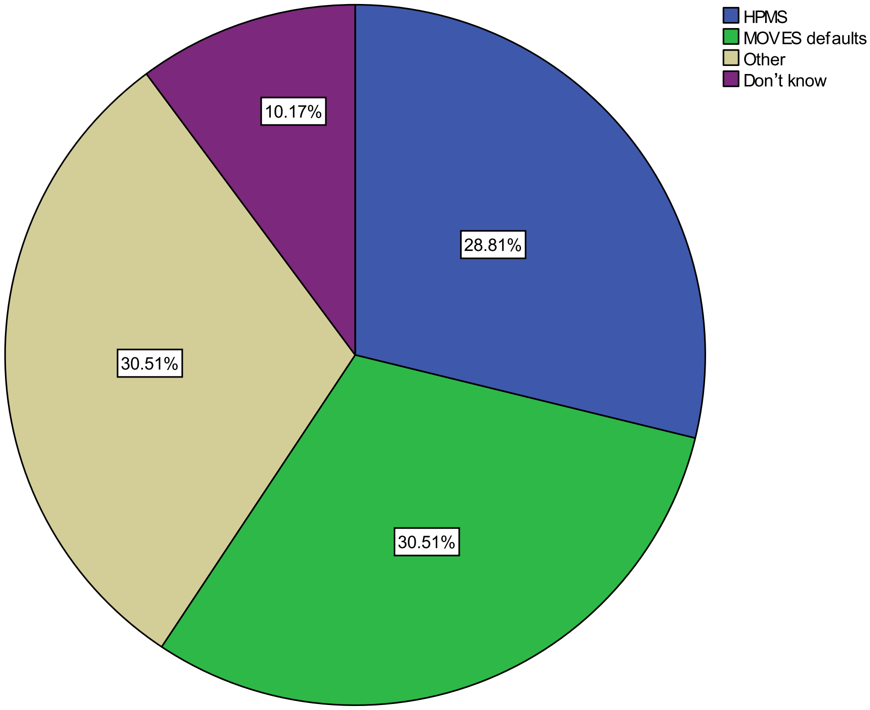


Further explanation of "Other" response:

- Actual traffic count station data broken down by month.
- Countywide ATR summaries.
- Data from New York State Department of Environmental Conservation.
- EPA Calculators with some local data.
- From MDOT.

- From TDFM.
- Local data.
- Monthly fractions are derived from Automatic Traffic Count Data and applied to VMT.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- Our state DOT compiles traffic count statistics from permanent traffic recorders as a special project for us (maybe it is HPMS-related)
- Out of the TDM.
- Permanent Traffic Counters (ATR).
- Permanent traffic recorder data – we are using traffic count fractions instead of VMT fractions because that's the best we have.
- State departments of transportation (Kansas and Missouri).
- State highway statistics (some from HPMS).
- State traffic counts (not directly from HPMS).
- Traffic study data.
- Use State of Connecticut data.
- We don't use this crap because we do daily emissions analysis for SIP and conformity purposes. We have adjusted the model to run on a daily basis and the rest of the country should do the same. We make a monthly and weekday or weekend VMT adjustment to the VMT prior to it going into the model. For example we had to model a 25-day episode in January 2009. We had specific Monday-Friday VMT and Weekend Saturday-Sunday VMT adjusted for January. So at the summary level you could see for one county that you were putting in 13 million seasonally and daily adjusted VMT and you would get 13 million VMT getting out. The only real input that changed from day to day was the 24-hour temperature profile and HVMT profile that handles starts is different from weekdays to weekends.

What is your source of day fraction VMT data for use in MOVES for regional analysis? (N=59).

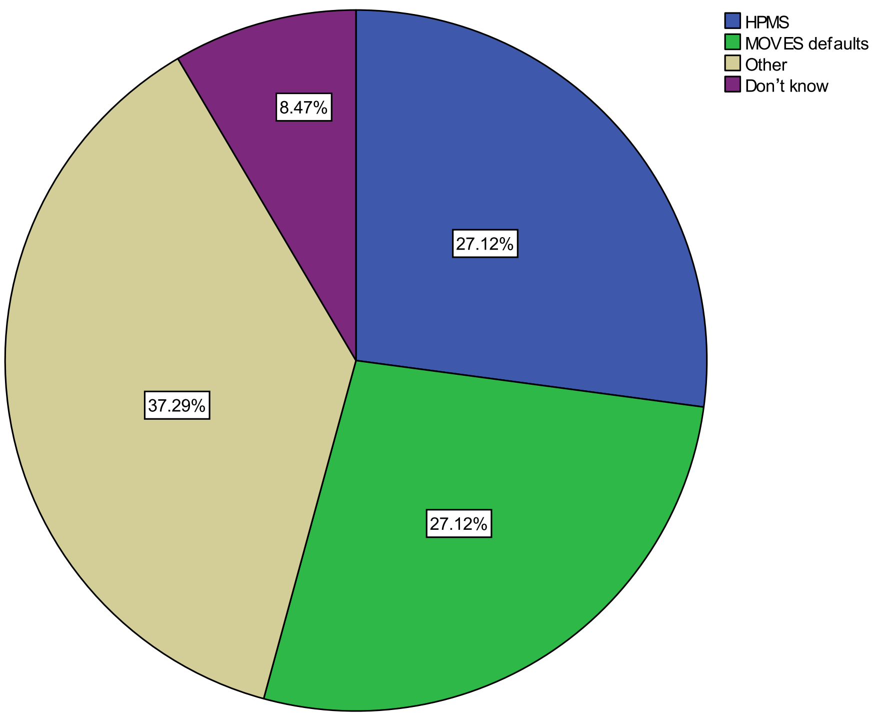


Further explanation of "Other" response:

- 2006 statewide traffic count program.
- Actual traffic count station data broken down by month.
- Again we modified the MOVES DB to allow for the daily VMT. You can use the output from this model for inventory runs or emission factors. A majority of the modelers that I work with have always used Mobile 5, 5b, and 6 in this fashion. The only time we don't is for the NEI.
- Converter.
- EPA Calculators with some local data.
- Fractions are derived from Automatic Traffic Count Data and applied to VMT.
- From MDOT.
- Local data.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- Our state DOT compiles traffic count statistics from permanent traffic recorders as a special project for us (maybe it is HPMS-related).
- Out of the TDM.

- Permanent Traffic Counters (ATR).
- Permanent traffic recorder data – we are using traffic count fractions instead of VMT fractions because that's the best we have.
- State highway statistics (some from HPMS).
- State traffic counts.
- Statewide traffic count program, data for year 2006.
- Traffic study data.
- Use State of Connecticut data.

What is your source of hour fraction VMT data for use in MOVES for regional analysis? (N=59).

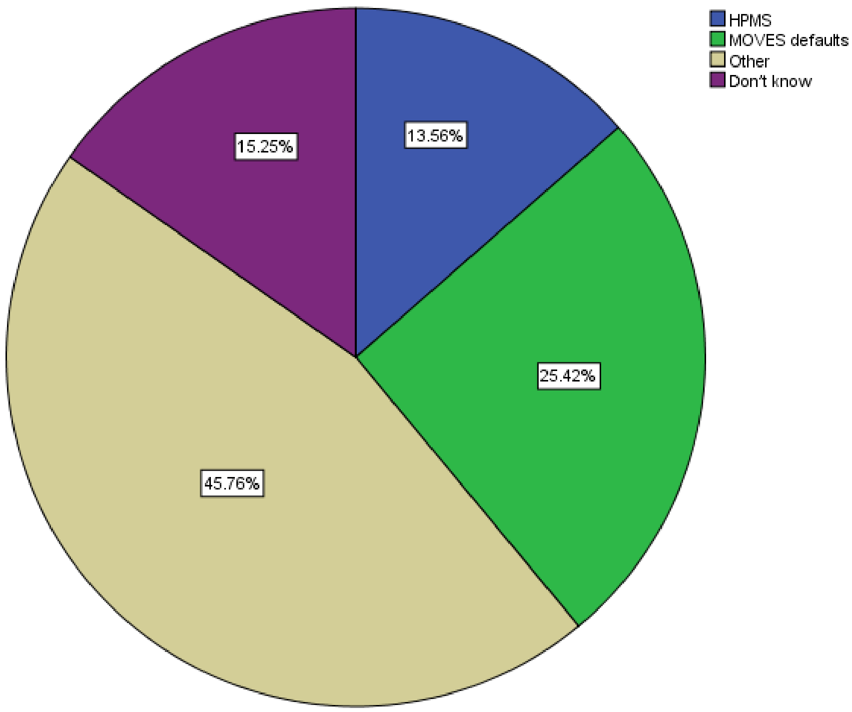


Further explanation of "Other" response:

- Actual traffic count station data broken down by month.
- EPA Calculators with some local data.
- Fractions are derived from Automatic Traffic Count Data and applied to VMT.
- Hopefully this can come from TDMs.
- Local Traffic Count Program.
- MDOT.

- MDSHA data.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- Our state DOT compiles traffic count statistics from permanent traffic recorders as a special project for us (maybe it is HPMS-related).
- Out of the TDM.
- Permanent Traffic Counters (ATR).
- Permanent traffic recorder data – we are using traffic count fractions instead of VMT fractions because that's the best we have.
- Rural areas use MOVES default and the MPOs use data from the TDM like with mobile 6.
- State highway statistics (some from HPMS).
- TDFM postprocessor using hourly VMT distribution pattern developed from traffic counts.
- Traffic study data.
- Travel demand model.
- Travel demand model.
- Travel Demand Model for networks, rest it is defaults.
- Travel Demand Model run 4 periods per day.
- Travel model link hourly VMT in conjunction with the MOVES defaults.
- Use State of Connecticut data.

What is your source of ramp fractions? (N=59).

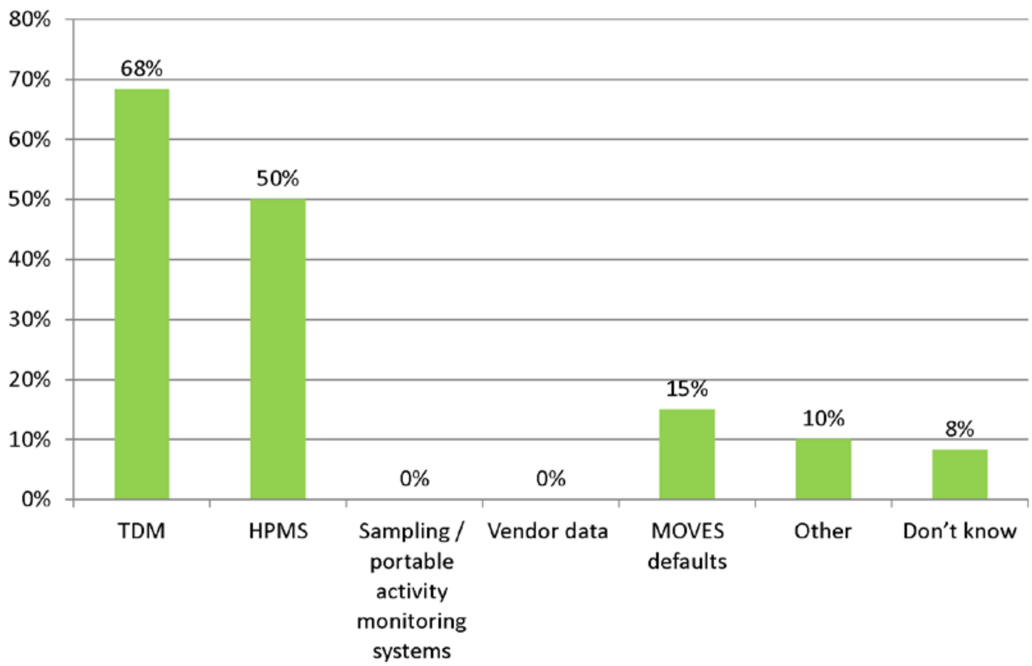


Further explanation of "Other" response:

- Adjusted VMT from Travel Demand Forecasting Model (TDFM) – See comments for explanation of VMT adjustment process.
- Ask EPA what a "ramp" is … we have ramps that can be one-half-mile to 500 feet long.
- Assume zero ramp fractions consistent with Travel Demand Model.
- Do not have Freeways.
- EPA Calculators with some local data.
- EPA needs to address errors in its converters. VMT by geographic area is tabulated by four highway classifications: expressway, arterial/collector, local, and expressway ramp. Ramp VMT is estimated as a percentage of expressways' VMT based on the ratio of ramp mileage versus expressway mileage in each county. Ramp Vehicle Hour Traveled (VHT) is estimated by dividing Ramp VMT by the average speed for the appropriate road types set forth in MOBILE6.2 guidance.
- MDOT.
- Moves Defaults and Travel Demand Model.
- MOVES Defaults unless travel demand model has ramps coded – in those cases model data used.

- MOVES Defaults unless travel model has ramps coded – in those cases model data used.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- Set to zero percent.
- TDFM.
- TDM.
- Tested local data and found it equal to MOVES defaults.
- Travel demand model.
- Travel Demand Model for networks, rest it is defaults.
- Travel Demand Model Outputs.
- Travel Demand Model ramp traffic versus overall traffic for facility type.
- Travel Demand Modeling.
- Travel Model derived based on link VMT summarized for Interstates, freeways, and ramps.

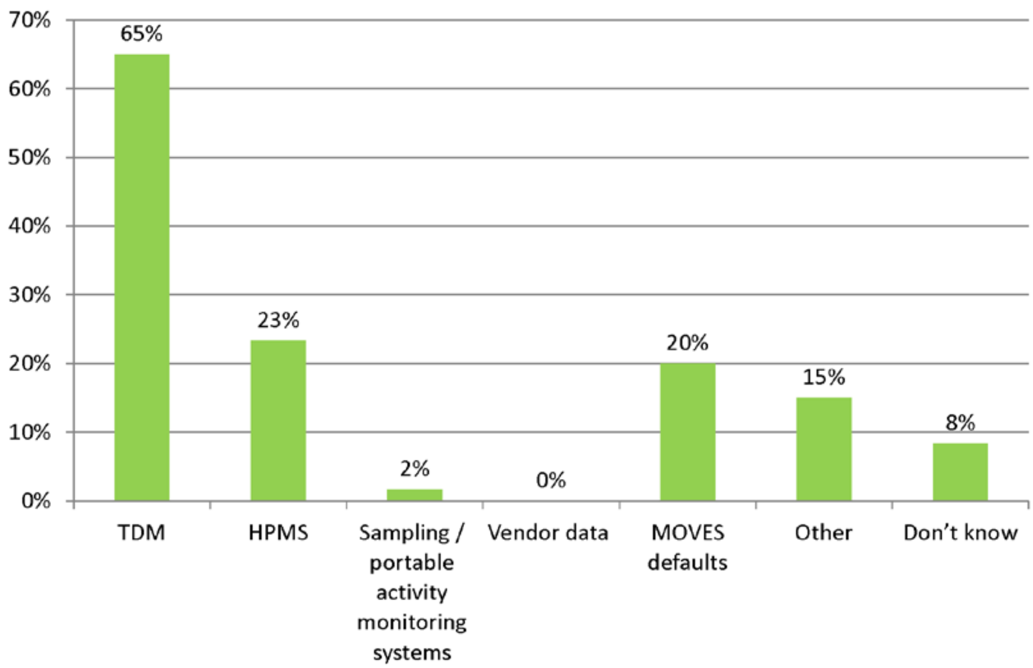
How has your agency estimated the proportion of VMT among MOVES road types?



Further explanation of "Other" response:

- EPA OTAQ MOBILE62 to MOVES Converters.
- Haven't figured this one out yet. Stay tuned.
- MDOT.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- We also modified the model to separate local roads form arterial roads. The reason we did this is because there are more heavy-duty vehicles traveling on arterials than on local roads. This allows us to model arterials and their traffic for say an average speed of 35.6 mph and then we set the local roads to 12.9 mph. This is good since it utilizes the same type of road networks we have used in the past with Mobile 6. We also adjusted the output of MOVES so that it goes directly into the SCC road type classification. SO if we are modeling an arterial there are no local roads and when I look at my SCC output for arterials it is identical to the VMT I put into this classification scheme. This is another example of where EPA takes us in the wrong direction regarding scale. They have a model that has more vehicle classes but somehow they have combined local and arterial roads. It doesn't make any sense.
- WYDOT.

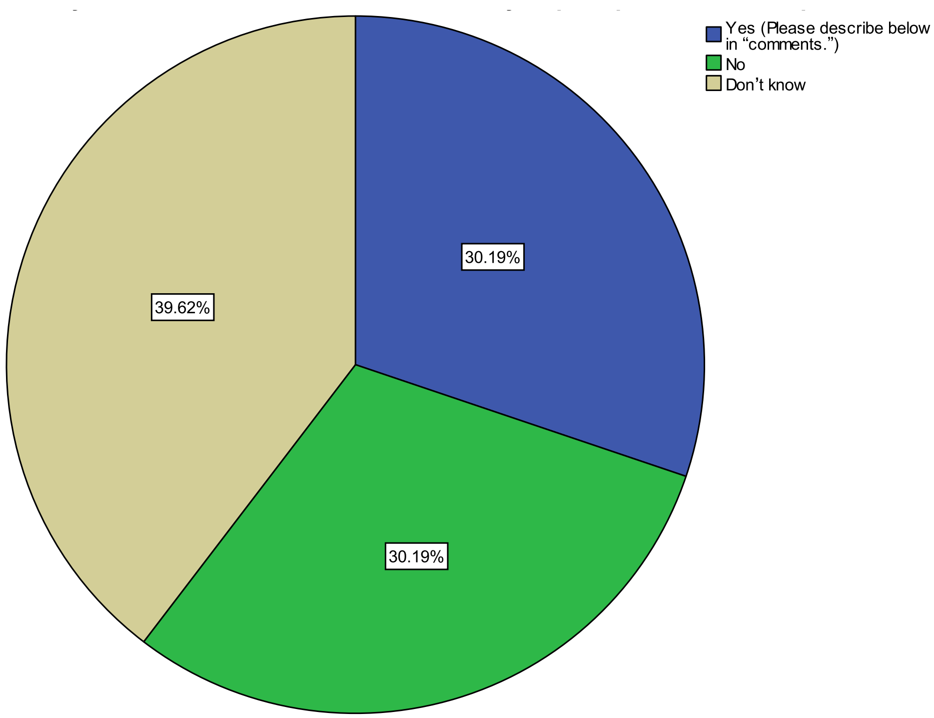
How has your agency estimated the proportion of VMT among speed bins for the average speed distribution?



Further explanation of "Other" response:

- EPA methodology to estimate speed distribution from an average speed.
- For rural areas we use the FHWA EMIT model which uses a HCM method and HMPS and capacity inputs to generate speeds. The MPOs generate speed profiles for urban freeways and arterials and urban local roads are set to 12.9.
- In addition to TDFM and HPMS, Highway Economic Reporting System (HERS) methodology and Bureau of Public Roads formula were used. See comments for explanation of the procedure.
- Local data.
- MDOT.
- MOVES converter tool.
- Ohio DOT takes the lead in developing this data for consistency statewide in conjunction with Ohio BMV and Ohio EPA.
- State has consultant help for this, provides results to MPOs
- Used the USEPA spreadsheet converter with urban speed data the same as MOBILE6.2 data and MOVES default rural speed data.
- WYDOT.

If you indicated in the previous question that you use a travel demand forecasting model, have you postprocessed the speeds to account for impedance?



Please identify any key data sources, pre- or postprocessing steps, or provide other explanation:

- [The MPO] appears to use impedances, but I do not know how they do it. We do not post-process the speeds to account for impedance.
- Basically, we use the TDFM's total VMT but it is adjusted by HPMS data in county and road type level. We did not post-process the speeds to account for impedance since our TDFM uses the modified BPR function already.
- Custom postprocessing software (PPSUITE) is used to disaggregate daily traffic volumes and recalculate hourly speeds for each roadway segment. The post processing software includes assumptions for intersection delay and the effects of congestion. The software aggregates VHT by each speed bin across all links within each hour, road type group.
- Custom postprocessing software (PPSuite) is used to disintegrate daily traffic volumes and recalculate hourly speeds for each roadway segment. The postprocessing software includes assumptions for intersection delay and the effects of congestion. The software aggregates VHT by each speed bin across all links within each hour, road type group.
- Discussion below concerning adjustment of VMT and speeds used as inputs to MOVES is related to questions concerning: a) ramp fractions, b) VMT proportions among speed bins, and c) last question above. Adjustment of VMT 1) Adjustment factors for base year developed by comparing HPMS VMT to model output VMT for each county and functional class → Ramps combined w/ interstates and other freeways and expressways in

developing factors /2) Factors applied to future year model results based on county and functional class of model link / /Adjustment of Speeds /1) Estimates of base year free-flow speeds determined using Highway Economic Reporting System (HERS) methodology and HPMS data (e.g., horizontal curvature, and surface roughness) /2) Adjustment factors for base year developed by comparing HERS speeds to model output average speeds for each functional class → Ramps NOT combined w/interstates and other freeways and expressways in developing factors; ramp speeds not adjusted /3) Factors applied to future year model results based on functional class of model link / / Calculation of VMT by speed bin / – For each link, / 1) Adjust volume of each link based on county and functional class. /2) Adjust free-flow speed of each link based on functional class. /3) Disaggregate adjusted link volume into 24 hourly volumes based on information from continuous counting stations (in the region) for the same functional class. / – For each hourly volume, /4) Calculate congested speed using the Bureau of Public Roads formula (a=0.15, b=4) with the volume from step 3), and the free-flow speed from step 2). / 5) Calculate the hourly VMT for the link using volume from step 3) and the length of the link from the TDFM and assign it to the appropriate speed bin based on the congested speed from step 4).

- Done by MPOs.
- For the Anchorage MOVES runs for conformity, speeds were adjusted. I don't know the details of how and why.
- I think so. The speeds are described as "congested speed." However, these are only single link speeds by 5 time periods. They are NOT speed distributions, so they are not ideal for MOVES.
- No need, Model already is calibrated to account for that.
- Please check with TTI on the above questions. For these first MOVES runs, TCEQ (state environmental agency) contracted with TTI to run the models. H-GAC did run the travel demand model.
- PPSuite travel model postprocessor to generate MOVES input speeds by source type and by road type. Using hourly VMT distribution patterns, PPSuite estimates hourly speeds on each road link and aggregates data onto MOVES input format.
- Q15: Total VMT is derived from the TDFM, adjusted by HPMS counts as required by regulation. Q25: We use the PPSuite postprocessor to generate MOVES input speeds by source type and by road type based on our TDFM. Using hourly VMT distribution patterns, PPSuite estimates hourly speeds on each roadway link and aggregates data into MOVES input format.
- Speed from Travel demand Model was Post Processed using formulas from the Highway capacity Manual.

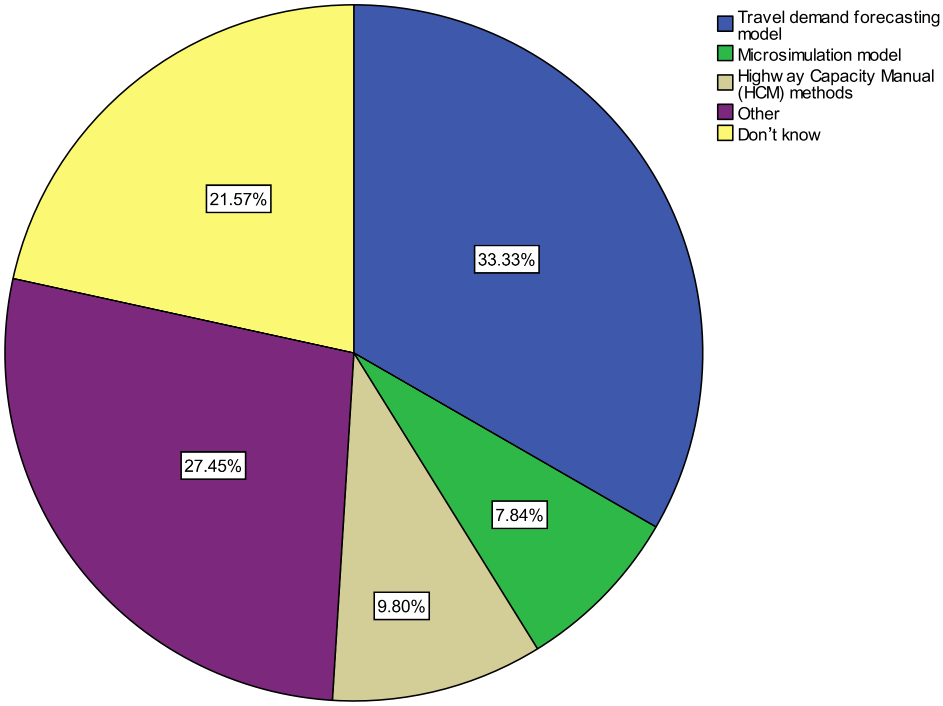
- Takes average speed by road type.
- The outputs of the travel demand model are compared to estimates of speed based on: 1) the equations of the Highway Economic Reporting System (HERS) and 2) the use of data from Automatic Continuous Traffic Recorders (ATR).
- The State DOT had postprocessing software and procedure for use by its MPOs developed using consultants.
- The travel demand model forecast volumes. The speed model is a post process model to estimate a more accurate speed according to Highway Capacity Manual using volumes from the TDM.
- To meet EPA's requirements, link volumes within the PERFORM model were stratified by HPMS functional class based on link location and facility type code. All highway network links in the model are individually coded for HPMS functional class. All HPMS functional classes are represented in the highway network. Intra-Zonal trips (those too short to get on the model network – less than 2 percent of the total VMT) are assigned an average trip length based on the size of the traffic analysis zone and were considered local road trips. The PERFORM model was adjusted in this manner to produce data for these road classifications. / CT DOT calibrated the 2009 model year VMT to 2009 HPMS VMT. These adjustments are carried throughout the forecasted years and are reflected in the 2017 and 2025 VMT estimates. / Connecticut had an average of 86.0 million VMT per day in 2009. / Validations of the PERFORM model were accomplished by comparing model output to known base data. In particular, HPMS VMT was an important basis of model validation and calibration. / I – 4 / A link by link assignment versus Average Daily Traffic (ADT) tabulation was made to examine expressway assignments. Graphic plots were used as a visual review of model output of the highway network, with assignments and ADTs posted on a link basis. / CT DOT also used a self-consistent equilibrium assignment process in that the state of equilibrium within the PERFORM model was determined by the closure ratio criterion. This is the ratio of the summation of the loaded network travel time to the projected summation of loaded travel time after capacity-restrained adjustment for the current iteration. The suggested default of 0.10 was retained for all assignment runs. This closure ratio was always attained at a point before the maximum number of iterations specified. The equilibrium assignment module uses volume-to-capacity ratios to adjust link speeds between iterations so that links are not over assigned. / VMT by geographic area is tabulated by four highway classifications: expressway, arterial/collector, local, and expressway ramp. Ramp VMT is estimated as a percentage of expressways' VMT based on the ratio of ramp mileage versus expressway mileage in each county. Ramp Vehicle Hour Traveled (VHT) is estimated by dividing Ramp VMT by the average speed for the appropriate road types set forth in MOBILE6.2 guidance.8 / Connecticut used "Travel Activity by

Vehicle Type and Functional System" data reported by CT DOT to the Federal Highway Authority for the HPMS program (see Table I.1.1-4a and Table I.1.1-4b). This report lists 13 HPMS vehicle type percentages on the 12 road types outlined previously. These data don't categorize vehicle types in the same manner as MOBILE6.2. / HPMS vehicle fractions were converted to MOBILE6 vehicle fractions for input into a MOVES VMT Preprocessor by doing the following: / The HPMS vehicle count percentages were summed into light-duty and heavy-duty totals multiplied by the MOBILE6.2 vehicle mix for each HPMS road type. This generated a VMT fraction for each of the 14 HPMS facility type by vehicle type for each MOBILE6.2 16 vehicle type on each road. / The 13 vehicle groups associated with HPMS observations were summed into three groups, i.e., Light-Duty Vehicle observations (LDVo), Heavy-Duty Vehicles observations (HDVo) and Motorcycle observations (MCo) for each of the 14 HPMS road types. "Passenger Car" and "Other 2-Axle, 4-Tire Vehicles" vehicle count fraction observations were summed to get LDVo count fraction observations. "Motorcycle" count fraction observations were summed for count fraction observations and the remaining vehicle categories were summed for the HDVo count fraction observations group. All of the sums were done by the 14 HPMS road types. / A Connecticut vehicle VMT fraction augmented default group totals of LDVt, HDVt, and MCt per road were calculated from the augmented MOBILE6 default vehicle fractions. LDVt was a summation of VMT mix fractions for the MOBILE6.2 LDV and LDT1, LDT2, LDT3, and LDT4 vehicle classes. HDVt was a summation of the VMT mix fractions for the MOBILE6.2 HDV2B, HDV3, HDV4, HDV5, HDV6, HDV7, HDV8A, and HDV8B vehicle classes. MCt was the MC / I – 5 / default. / EPA national default values from Table 4.1.2 (National Average Vehicle Miles Traveled Fractions by Vehicle Class Using MOBILE6.2) found in Section 4.1.4 of Reference 8 were augmented using an additional step to adjust the mix percentages. The LDV, LDT1, LDT2, LDT3, LDT4, HDV2B, HDV3, HDV4, and HDV5 vehicle class EPA national default mix values were localized using DMV registration data by age and national default mileage accumulation. This adjustment was based on the vehicle counts by vehicle class and by age from the vehicle age distribution analyses and EPA's Reference 15 annual mileage accumulation by vehicle class and by age, which was normalized to replace the existing LDV through HDV5 values. The Connecticut fleet is comprised of more cars (LDV's) and heavier trucks than the national default and the adjustment of the national default values better aligns the MOVES VMT to the appropriate MOVES Source Types. It also better aligns the VMT apportionment to the appropriate vehicle age distribution. The localization of LDV through HDV5 was based on the MOBILE6.2 to MOVES Source Type mapping and consideration of how the vehicles would operate within the state and be appropriately represented by local data. VMT mix calculations were normalized to the fractional value of the default values being replaced. The complete set of augmented default MOBILE6.2 VMT mix values includes a composite of original default values that were not modified from their original values (MC, HDV6, HDV7, HDBS, HDBT, HDV8A, and HDV8B) and localized default values that were modified as described in this paragraph (LDV, LDT1, LDT2, LDT3, LDT4, HDV2B, HDV3, HDV4, and HDV5). / The net result of the additional localization of the data includes an emission reduction due to a greater percentage of vehicle VMT being assigned to passenger cars (MOVES Source Type 21) and an emission increase due to a greater percentage of vehicle VMT being assigned to commercial trucks (MOVES Source Type 32). The VMT contribution from lighter trucks (MOVES Source Type 31) is reduced proportionally to the VMT contribution increases. / The preprocessing of the MOVES VMT converter HPMS input table used the methodology outlined in the MOBILE6.2 Technical Guidance8 section 4.1.4: "Disaggregation of Local Information." Following the calculation of the complete set of augmented default VMT mix values and calculation of the VMT fraction augmented default group totals. A Connecticut-specific table with MOBILE6.2 VMT mix values for each of the 14 HPMS road types was developed. This table was developed by multiplying the HPMS fractional observation count (LDVo, HDVo, MCo) times the augmented MOBILE6.2 default value divided by the MOBILE6.2 VMT fraction augmented default group totals (LDVt, HDVt, and MCt) for each of the 16 MOBILE6.2 vehicle classes and each of the 14 HPMS road types. This table was formatted to obtain a Connecticut localized input table for the MOVES VMT converter. Table I.1.1-4.c presents the results of the above calculation in the form of the Connecticut MOVES converter input for fraction of VMT on HPMS Road Type by MOBILE6.2 16 Vehicle Type. / The state-specific vehicle mix data was entered into the MOBILE6 to MOVES converter for each road class, together with county-level VMT (see Tables I.1.1-6a and 6b) for each of the 14 2010+ FHWA HPMS road types discussed above, the MOBILE6.2 VMT by hour data shown in Table I.1.1-7, the percent of Vehicle Hours Traveled on Ramps and the MOBILE6.2 Registration / I – 6 / Age Distribution so that appropriate MOVES inputs could be obtained. The CT DOT's updated EPA 16 vehicle type/14 road type converter supplied the following: A daily VMT value (HPMSvTypeYear) that was input to the EPA's average annual weekday vehicle miles traveled (aadvmtcalculator_hpms.xls) converter to generate annual VMT by MOVES HPMSVTypeID; An hourly fraction (HourVMTFraction) for each MOVES Source Type for each hour and day type (weekday and weekend); A road type VMT fraction (RoadTypeDistribution) which indicates the fraction VMT that a MOVES Source Type travels on each MOVES road type. The sum of all road type fractions will be a value of one for each MOVES source type and a value for road type 1 is required, but it will always be zero; An hourly fraction (VHT fraction aka RoadType) of the time spent on ramps relative to the total time spent on each restricted MOVES road type ramp (restricted road types are also called limited access road types); And a SourceTypeAgeDistribution that could be used or compared to a more accurate directly calculated age distribution obtained directly from registration data. / In addition to producing annual VMT by MOVES HPMSVTypeID mentioned above, EPA's average annual weekday vehicle miles traveled (aadvmtcalculator_hpms.xls) converter also produced the dayVMTFraction and monthVMTFraction inputs for input to the MOVES Model. In addition to inputting a daily VMT value, Connecticut entered seasonal VMT adjustments based on winter, summer and annual VMT estimates to localize monthly adjustment factors. Weekday versus weekend factors were not altered from the EPA default values provided. Tables I.1.1-8a and I.1.1-8b show the total annual VMT by MOVES HPMSVTypeID.

- To more fully answer the first couple of questions, we use VIN-decoded data to determine source type populations, although some EPA mapping is required primarily because we have no way of distinguishing between short- or long-haul use. Additional research in this areas would be helpful. / / As for the last question on speed impedance, we get link volumes, capacities, and posted speeds from the travel demand model and use HCM equations to calculate the congested speed for each link.
- Travel Demand Model speeds are calibrated to observed speeds, but not separately postprocessed.
- VMT from TDM is performed by our MPO, we just receive the end results.
- We adjust model speeds using travel time survey data, a single adjustment factor is applied to restricted access roadways (all freeways and expressways) and a separate, single adjustment factor is applied to unrestricted access roads.

C.7 Experience Related to Project-Level Data

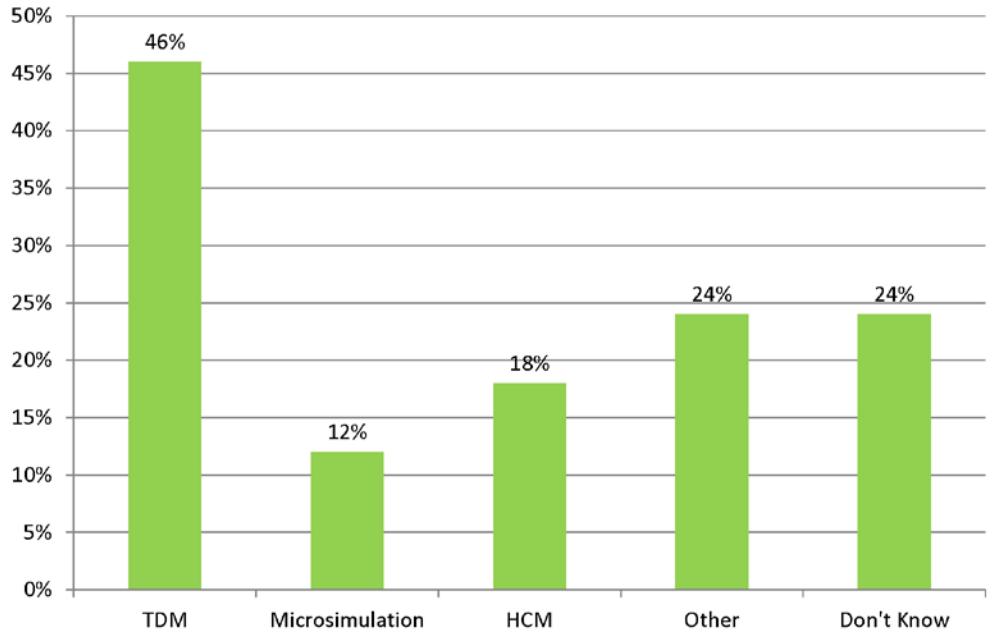
What sources of project-level vehicle volume information has your agency used? (N=51).



Further explanation of "Other" response:

- Actual traffic counts and travel demand model.
- Agency does not do project-level analysis.
- Have not performed project-level analysis to date.
- Haven't done project-level analysis.
- HPMS.
- MOVES ready input data sets provided to us by the project managers and their contractors.
- No MOVES project-level analyses conducted yet; have used combinations of all above sources for past analyses.
- No MOVES-based project-level analysis conducted yet. The scope of work would be restricted to review of MDE-based MOVES inputs such a age distributions, fuel, I&M, VPOP, and met data.
- None.
- Other agency addresses this.
- Travel Demand Forecasting Model, HPMS, and Traffic Counts.
- We do not do "project-level" analyses; only "county-level" analyses.
- We don't have a source.

What sources of project-level vehicle speed information has your agency used? (N=50).

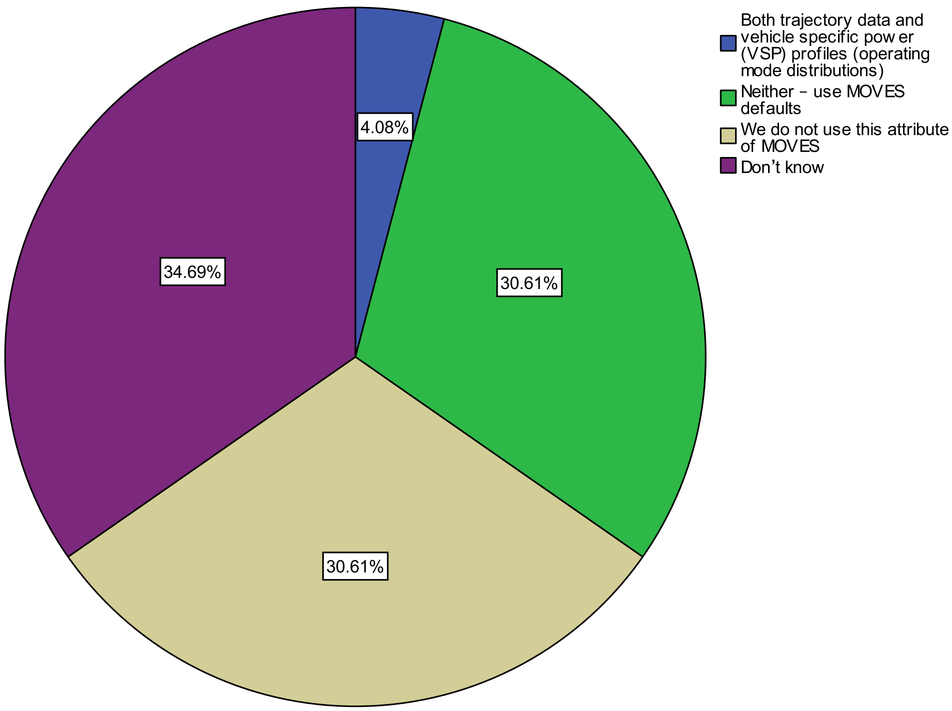


Further explanation of "Other" response:

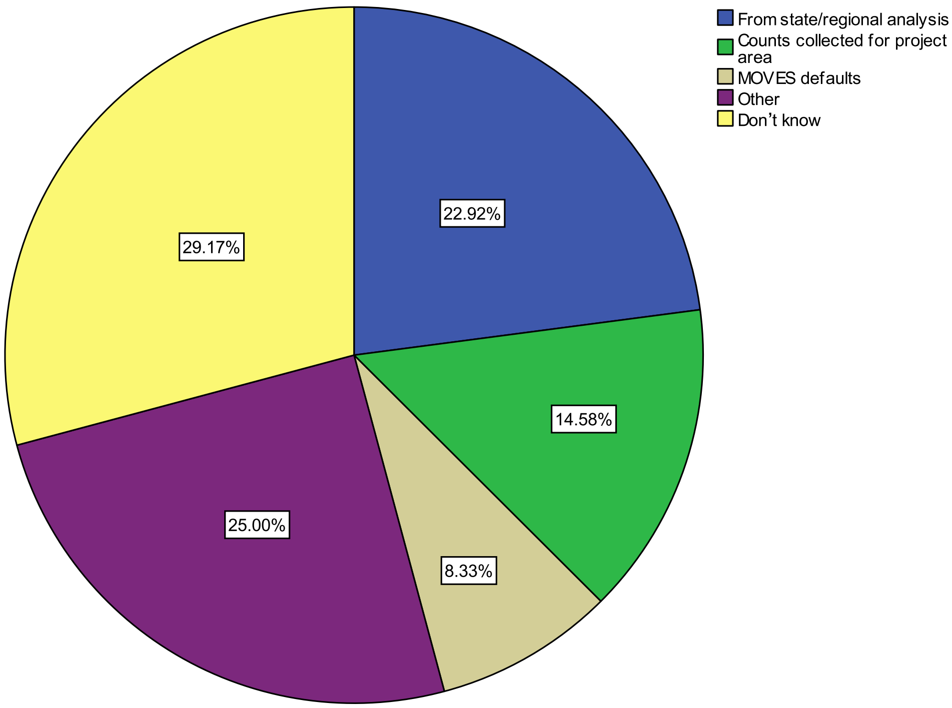
- Agency does not do project-level analysis.
- Have not performed project-level analysis to date.
- Haven't done project-level analysis.
- LOS of roadway link.
- No MOVES project-level analyses conducted yet; Have used combinations of all above sources for past analyses.
- No MOVES-based project-level analysis conducted yet. The scope of work would be restricted to review of MDE-based MOVES inputs such a age distributions, fuel, I&M, VPOP, and met data.
- None.
- Note: Speed information from TDFM may be postprocessed as described in previous section.
- Other agency addresses this.
- We do not do "project-level" analyses; only "county-level" analyses.
- We do not do project-level AQ analysis with MOVES, still using MOBILE for this.

- We don't have a source.

Has your agency developed vehicle trajectory data or MOVES vehicle-specific power profiles (operating mode distributions) for link-level vehicle activity? (N=49).



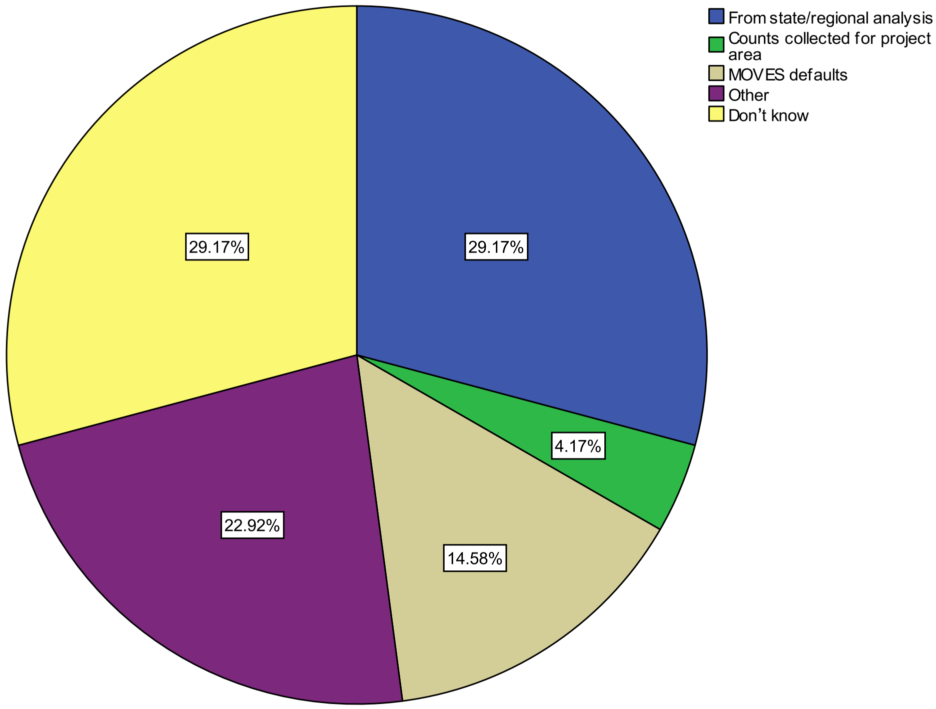
How has your agency determined project-level fleet mix (link source type) information? (N=48).



Further explanation of "Other" response:

- Agency does not do project-level analysis.
- From county-level processed registration data with MOVES defaults for 'fill-in' data.
- Have not performed project-level analysis to date.
- Have not yet applied MOVES to project level.
- Local vehicle registration and MOVES defaults.
- Never.
- No.
- Other agency addresses this.
- Project-level analysis not used so far.
- We do not do "project-level" analyses; only "county-level" analyses.
- We have not done this.

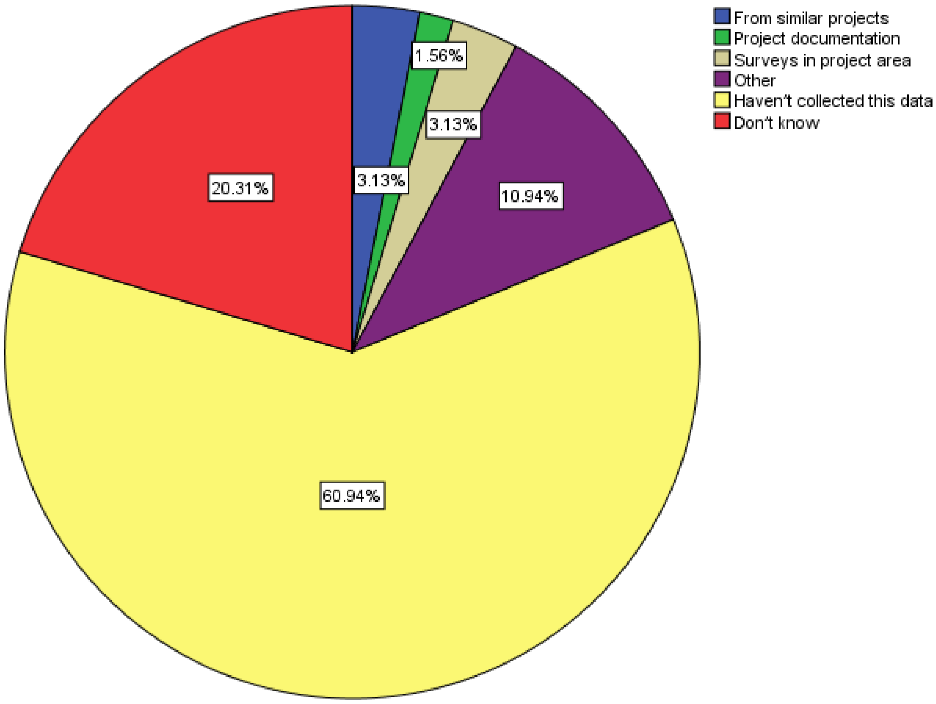
How has your agency determined project-level age distribution information? (N=48).



Further explanation of "Other" response:

- How has your agency determined project-level age/distribution information?-TEXT.
- Agency does not do project-level analysis.
- From county-level processed registration data with MOVES defaults for 'fill-in' data.
- Have not performed project-level analysis to date.
- Have not yet applied MOVES to project level.
- How would this be different than the county level we already have?
- Local vehicle registration and MOVES defaults.
- Other agency addresses this.
- Project-level analysis not used so far.
- We do not do "project-level" analyses; only "county-level" analyses.
- We have not done this.

How has your agency collected project-level "off-network" MOVES data, such as estimates of vehicle starts or extended idle fractions? (N=64).



Further explanation of "Other" response:

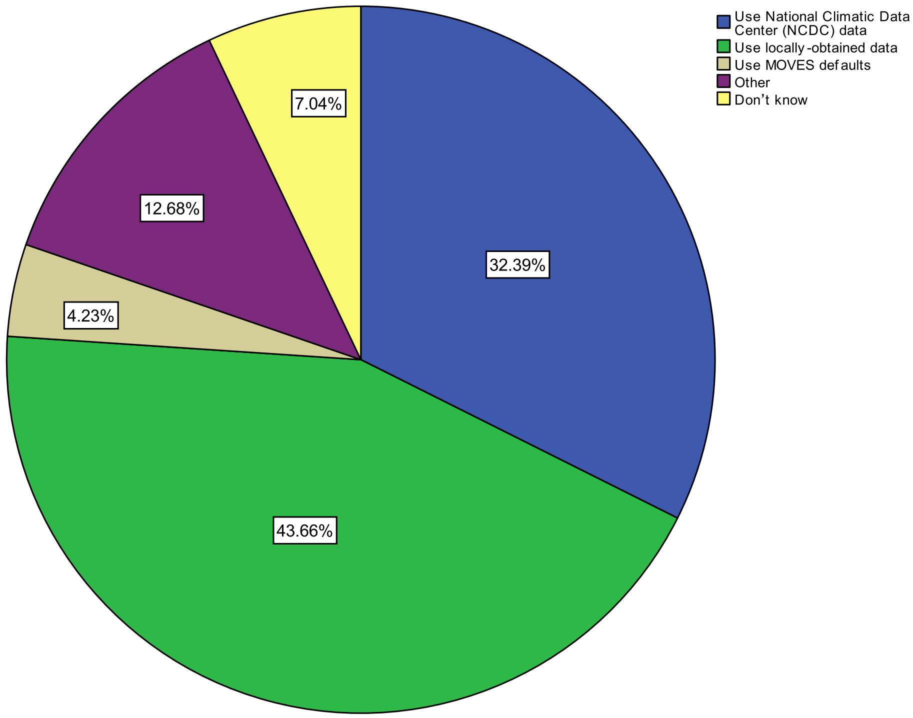
- How has your agency collected project-level "off-network" MOVES data, such as / estimates of vehicle s.– TEXT.
- Have not performed project-level analysis to date.
- Have not yet applied MOVES to project level.
- Local data showed large differences in starts comparatively to MOVES defaults; since EPA requires use of MOVES defaults for starts, we use default values.
- No.
- Project-level analysis not used so far.
- Who has money for this study.

Please identify any key data sources, pre- or postprocessing steps, or provide other explanation:

- Again TTI has used a combination of travel demand model data from H-GAC, HPMS, vehicle registration data, and in the future we intend to build in drayage truck inventory, speed and emissions data gained from study with EPA and TCEQ.
- Have not done a project-level analysis.
- Have not sorted this data element out yet.
- Haven't done any project-level analyses yet.
- No MOVES-based project-level analysis conducted yet. The scope of work would be restricted to review of MDE-based MOVES inputs such a age distributions, fuel, I&M, VPOP, and met data. MD-SHA is responsible for hotspot analyses. However methods and procedures will be agreed upon through the interagency consultation process.
- Note: No MOVES hotspot analyses completed to date. When one is completed an evaluation will be made of available data sources. Methods and procedures will be agreed on through the interagency consultation process.
- Our agency doesn't do project-level runs.
- Project-level analysis is not conduct by MPO.

C.8 EXPERIENCE WITH OTHER MOVES INPUTS

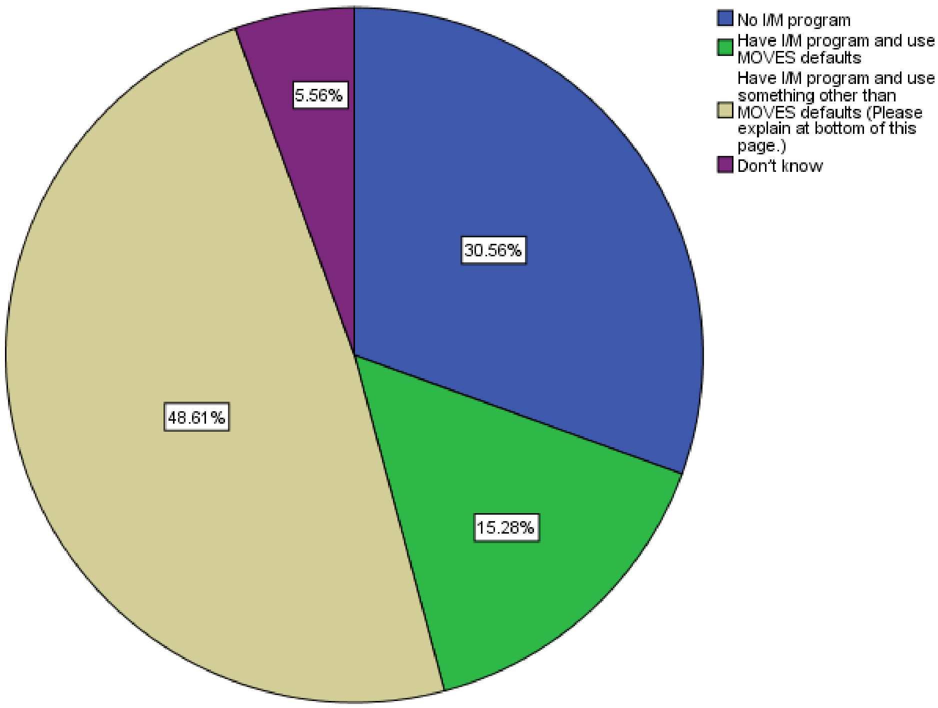
How do you derive your temperature and humidity inputs to MOVES? (N=71).



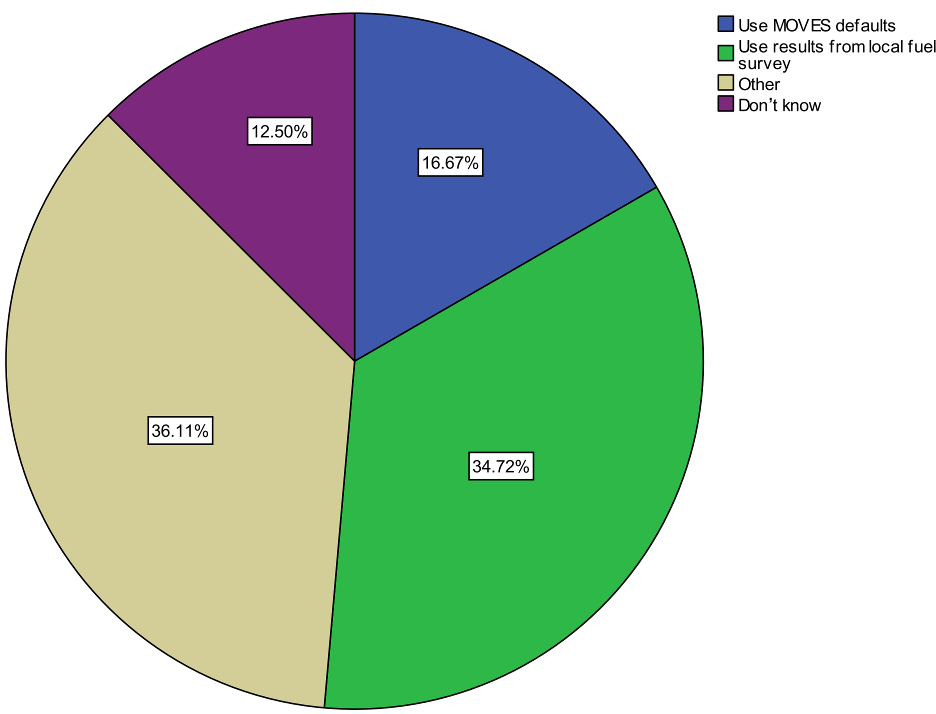
Further explanation of "Other" response:

- 2008 NEI inventory tables.
- data from department of energy and environmental protection.
- Division of Air Quality responsibility.
- From State DEEP.
- Have use MOVES Defaults and output of MM5 met model.
- MESO West.
- NMIM defaults.
- Typically set design temperatures per EPA guidance for SIP/conformity analyses. Local evaluations allowed for alternative look see analyses not requiring EPA approval.
- We have used both b) and c) depending on the end use of the data.

Does your area have an Inspection and Maintenance (I/M) program and, if so, what is your source of inputs? (N=72).



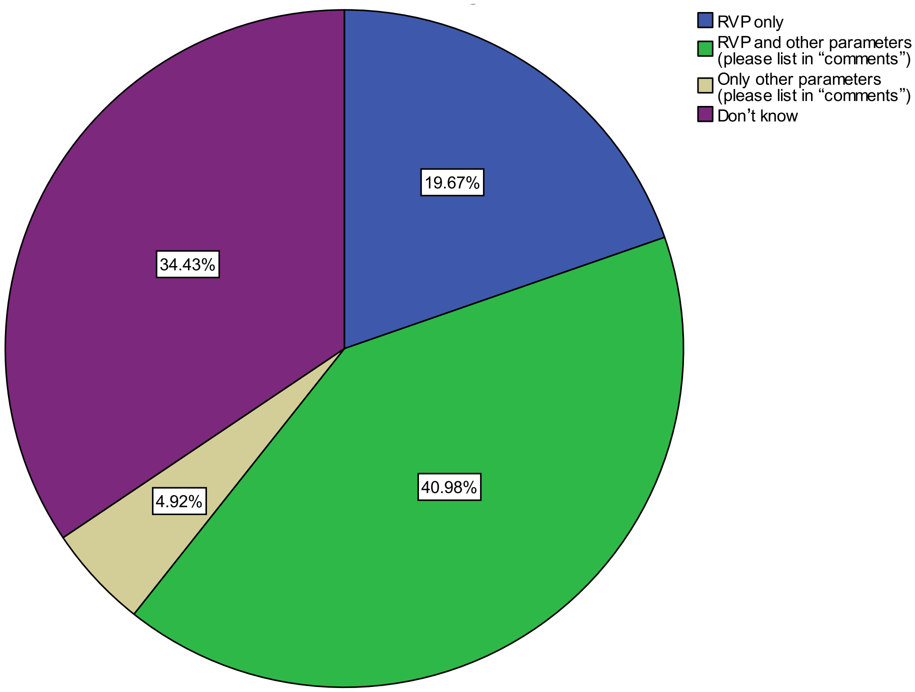
What source of information does your agency use as inputs for fuel parameters such as Reid Vapor Pressure (RVP)? (N=72).



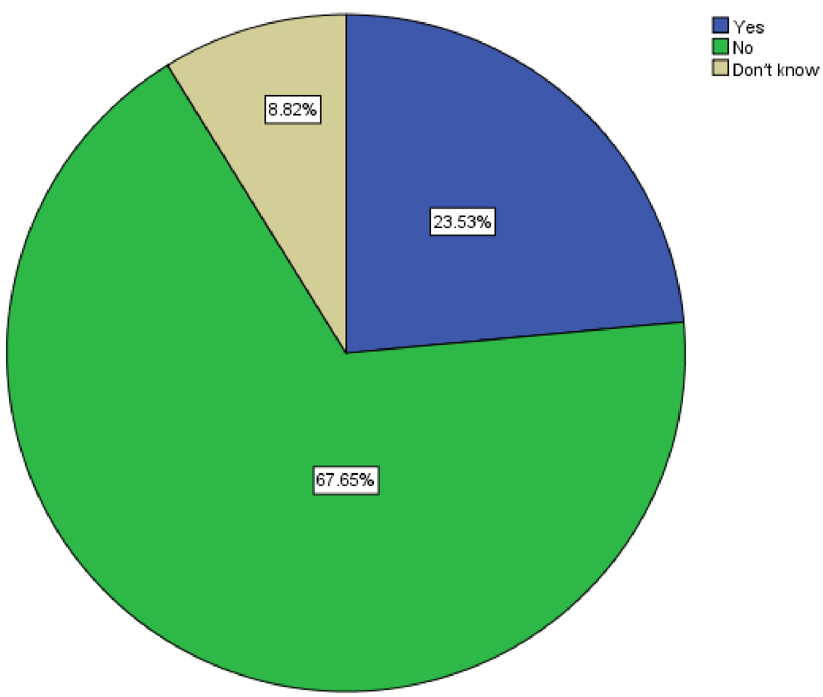
Further explanation of "Other" response:

- Data from department of energy and environmental protection.
- DEQ.
- Division of Air Quality responsibility.
- EPA field test data from EPA web site.
- EPA RFG survey data and MOVES defaults.
- From EPA-collected field data on Internet web data.
- From State DEEP.
- MDOT.
- Modify defaults based on local knowledge (ethanol waiver).
- Provided by state air agency.
- Results for analysis of RFG survey data.
- State agency experts.
- State air agency is developing this.
- This information is provided by State DOT.
- Use defaults modified with local data.
- Use parameters per program regulations/EPA guidance/Past SIP parameters.
- Use results from local fuel testing.
- Use survey data and MOVES defaults.
- Using what has been used in the past. Not sure of the root source …
- Utah Refinery Association.
- We are currently working with the fuel industry and they have given us a weighted average fuel inputs to deal with E10. We have E10 in every county in Utah beginning in 2010 and the EPA default does not reflect that and we are dealing with a winter time 24-hour $PM_{2.5}$ issue centered on VOC.
- We have statutory limitations on our RVP.
- We sometimes use MOVES defaults and sometimes our regulatory RVP levels, depending on the purpose of the run.
- We used the default profiles and county assignments as a starting point. We used local fuel data/regs to adjust Default RVP and E10 use, and also to assign counties to fuel profiles.

If you do not use MOVES defaults for fuels, which fuel parameters do you change? (N=61).



Has your agency performed any sensitivity testing on the use of alternative MOVES inputs (including fleet data, regional activity data, project-level activity data, or other inputs)? (N=68).



Please identify any key data sources, pre- or postprocessing steps, or provide other explanation:

- Comments:
  - Define IM program following MOVES guidelines. Each county program is described in a large Excel workbook with a separate tab for each year. All gasoline LD vehicle types are addressed, HD and diesel is ignored.
  - Other fuel parameters changed are sulfur content.
- Comments:
  - As indicated above I/M and Fuel Parameter have been determined using a combination of sources, including local data surveys, I/M feedback, regulations, inputs from EPA, and parameters assumed in past SIP analyses.
  - MD updates much of the data on triennial basis. At the time of updates the sensitivity of key inputs have been evaluated. Typically vehicle age data has the largest impact on emissions. The fleet age in MD has been steadily aging since 2005, producing much higher emissions.
- Comments:
  - As indicated above I/M and Fuel Parameters have been determined using a combination of sources, including local data surveys, regulations, input from EPA, and parameters assumed from past SIP analyses.
  - Pennsylvania updates much of their data inputs on a triennial basis. At time of updates the sensitivity of key inputs have been evaluated. Typically, vehicle age data has the largest impact on emissions. The fleet age in Pennsylvania has been steadily aging since 2005, producing much higher emissions results.
- Comments
  - Fuel parameters changes are gasoline: sulfur, RVP, benzene, aromatic, olefin, E200, E300, ETOH, ETBE, MTBE, and TAME.
  - Sensitivity Testing: Fleet Mix changes, meteorological changes, 12-month run versus 1-month runs → Data available upon request by contacting Craig Butler of the Louisville Metro Air Pollution Control District at ___.
  - Due to lack of staffing, no sensitivity analysis is able to be performed. “Modeling” is seen as a black box where you just push a button. hard to convince of need for analysis.
  - Ethanol content.

- Comments:
  - For our NEI tables we had to modify the IM defaults provided to us by EPA; they were incorrect.
  - For our NEI fuel tables – we will likely use MOVES defaults because EPA was unable to provide defaults. We may modify the tables based on local knowledge – we have a waiver for ethanol.
  - Fuel data are provided by New York State Department of Environmental Conservation.
  - Fuel formulations obtained from Utah Division of Air Quality.
  - Fuel parameters from EPA field test data: RVP, Ethanol, E200, E300, Benzene, etc. Did some sensitivity testing with earliest version of MOVES, including 12 mo. versus 1 repr. mo. runs, meteorology changes, and fleet age distribution changes (with MOVES2010). Results available upon request from Louisville Metro Air Pollution Control District, craig.butler@louisvilleky.gov.
  - Have local program; working with state air agency to develop MOVES inputs.
- Comments:
  - I&M data extracted from I&M report. HDV I&M not credited due to considerations associated with VMT mix approach and inability of MOVES to directly model regulatory vehicle classes (i.e., Source Types would have undesirable bias if HDV I&M were included).
  - If you do not use MOVES defaults for fuels, which fuel parameters do you change? All. /
  - Sensitivity analyses – Speed, Ramp Fraction, VMT Mix and I&M. Analyses not saved, but some sent to MOBILE@EPA.GOV when results not as expected.
  - I/M inputs (percent compliance) as provided by NC DAQ. / NC DAQ defined local RVP input for Mecklenburg County only.
- Comments:
  - I/M inputs developed using data supplied by agency I/M program office, such as compliance rate and waiver rate.
  - Fuel RVP and other parameters available at http://www.epa.gov/otaq/fuels/rfgsurvey.htm.
  - I/M program inputs are taken from state air agency.
- Comments:
  - I/M program is run by our agency and the information regarding the I/M processes at our emission testing sites are provided by our Mobile

and Area Source Program through William Cook, Manager of the Engine and Fuels Unit.

- As for sensitivity tests, we have done emissions inventory test runs varying the fuel blend (all 10 percent ethanol versus no ethanol), RVP (varying it by 1 psi), and fuel type (CNG versus Diesel/Gasoline). The results of these tests are not finalized and are informal. If you are interested in our work in this regard, please contact me at gil.grodzinsky@dnr.state.ga.us
- Met data typical comes from nearby airports. Our state air agency develops the fuel inputs for our use.
- Our I/M program data comes from our state air agency. It differs from the MOVES defaults in our region. Feel free to contact about sensitivity testing. We mostly did some tests on VMT variations, age distributions, other simple things).
- Oxygenated fuels
- Q33: All I/M MOVES inputs are based on local data. Q34 and Q35: Fuel input was generated to include local data for RVP, sulfur level, and ethanol volume. Q36: Sensitivity testing was done for various VPOP inputs, VMT growth factors, and comparisons with MOVES default estimates.
- Fuel input was generated to include local data from RVP, Sulfur Level, and Ethanol Volume.
- Sensitivity testing was done for various source type population inputs. /
- RVP and oxygen content.

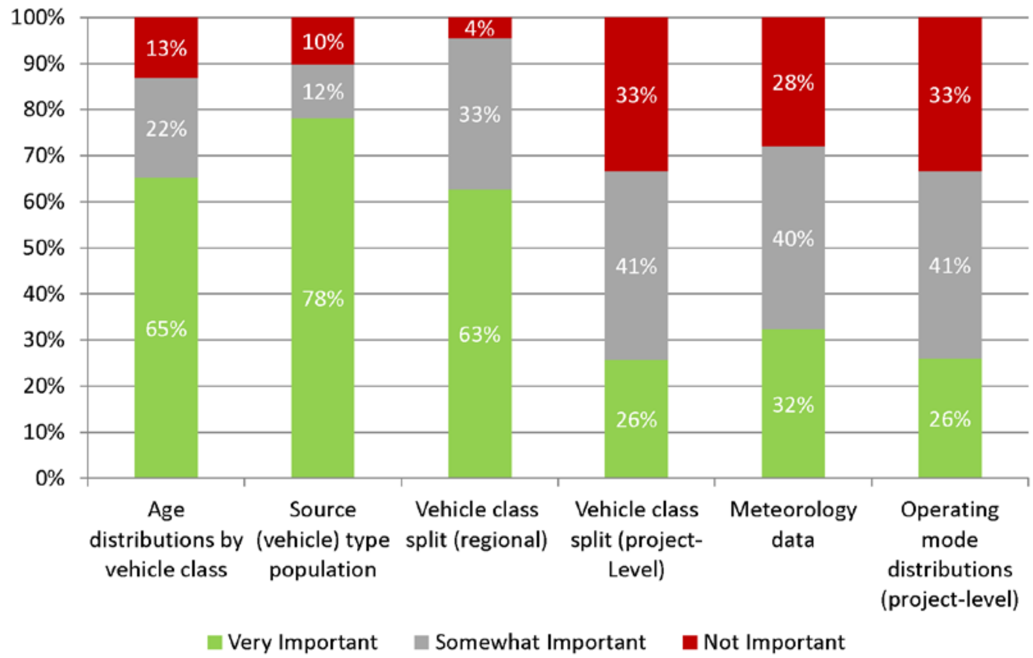
- Comments:
  - SEMCOG also changed the MarketShare in FuelSupply table based on local fuel survey data.
  - SEMCOG tested alternative inputs of vehicle population, age distribution, and VHT speed data during the processes of the local data development.
  - State develops IM data. For fuel, State is working on fuel formulations – has data to modify rvp and E200, E300.
  - The state provides the parameters for fuel and for I/M Program. TTI would have input this info into model
  - Use a combination of MOVES defaults and local factors
  - Use our I/M program’s vehicle coverage (different than defaults).
  - we are transitioning to MOVES
  - We create our own IM input table based on our regulations for the area.

- We have done multiple statewide inventory runs for both SIP and sensitivity to determine possible impacts of I/M program changes. We are also working on off model credit for I/M programs.
- We have found the MOVES default I/M coverage data does not accurately describe the Illinois program. For example, the ending model year is off by on year. In addition, MOVES does not allow modeling of the OBD and idle tests to be modeled for the same model year, but different GVWRs. In Illinois light-duty cars and trucks were required to use an OBD test while heavy-duty trucks (>8,500 lbs. GVWR) required an idle test.
- We have updated RVP, Ethanol percent, and percent sulfur.

- Comments:
  - We use our I/M program data to develop the inputs for the IMCoverage file.
  - For fuels, we changed RVP and the market share of E10. We also changed some county to profile assignments.
  - Sensitivity testing – compared each of the County Data Manager inputs for which we had local data to the default data for a single county. Some of the comparison will need to be redone, since some of the local data derivation processes have changed.
  - You cannot just change the RVP and expect a reduction in VOC emissions. We asked the refineries for their fuel and they gave us a fuel that had a lower RVP and guess what the VOC emissions are higher. I have too much data to give a link so contact me [contact information deleted]

C.9 INPUT ON NCHRP 25-38 PROJECT OUTCOMES

One objective of this NCHRP project is to provide methods and guidance for developing MOVES input data, and/or additional datasets that can be used. What datasets or methods/guidance would be the most important to your agency?

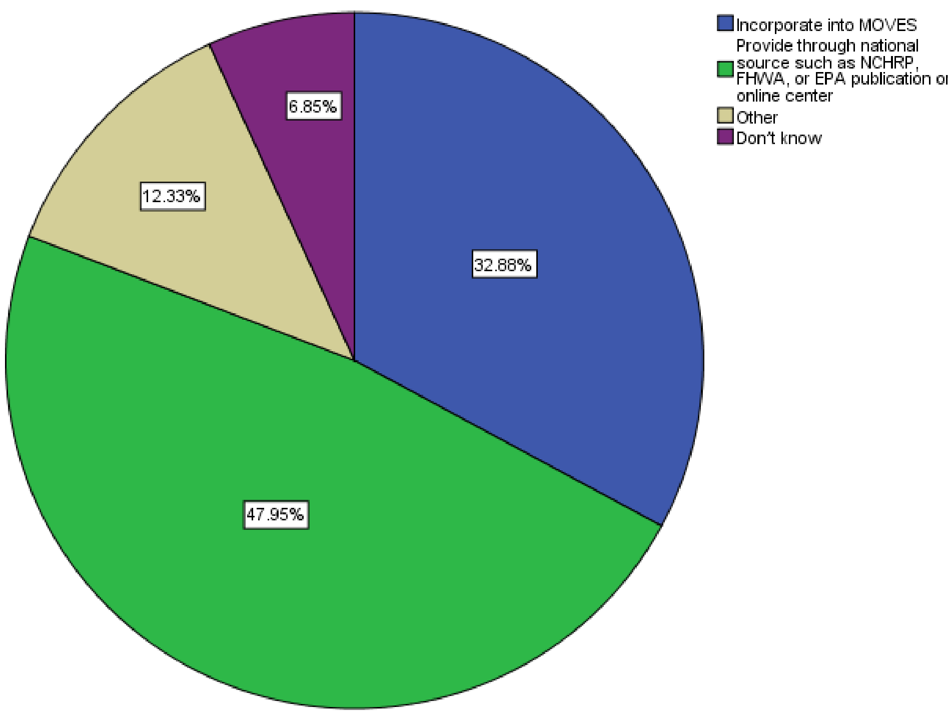


Write-in responses:

- VMT Fraction by Day/Month/Hour (Somewhat Important).
- Alternative Fuel Vehicles (Somewhat Important).
- Local fuel data, including actual RVP, etc. (Somewhat Important).
- Accounting for latest engine technologies (Somewhat Important).
- VMT Road Type split (Somewhat Important).
- VMT (Very Important).
- speed distribution (Very Important).
- speed by source type (Very Important).
- Source Type VMT Mix (Very Important).
- Number of starts (Very Important).
- default off-network inputs for various project types (Very Important).

- MOVES Fleet Projections and Regulatory Class Distributions within MOVES Source Types 31 and 32 (Very Important).
- Vehicle Starts (Very Important).
- sourcetype by roadtype (not constant across roadtype) (Very Important).
- Avg speed distribution by veh type (Very Important).
- Alternative Fuel Emission Factors (i.e., CNG) (Somewhat Important).
- Idle Fractions (Very Important).
- While not really guidance – EPA had compiled a MOBILE62 Sensitivity Document that facilitated understanding both by the regulated community and regulators, by providing context and significance to Guidance. A MOVES Sensitivity Document could fill a similar role. (Somewhat Important).

For any datasets developed as part of this project, how would you prefer they be made available? (N=73).



Further explanation of “Other” response:

- Both a and b.
- Depends on the dataset. I would only put universally accepted and used datasets in MOVES. While others that are not so universally used, should be outside of MOVES. MySQL is not MOVES!
- Incorporate into MOVES if this can be done in a timely manner; otherwise, make datasets available through organizations such as those listed in b.
- Incorporate into MOVES, with the flexibility of minor editing for better local data if available.
- Keep all the MOVES files distributed through one source – the EPA MOVES site. They don’t need to be built into MOVES, but it would be nice to only have one clearinghouse for MOVES info.
- Option B when option A is not possible.
- Please Be careful if you are going to be making additions to MOVES. We have created a MYSQL DB that holds all of the relevant data sets for VMT, vehicle population, age distribution, I/M programs files, and temperature profiles. Right now it is very easy to make a change in one of those data sets and do a sensitivity analysis. I only have to run a couple of scripts. If any of the CDM inputs change then I need to reformat my DB and that can be a pain.
- Supplied by State DOT using local data.
- Whatever method would provide most current and timely input data.

What additional guidance for obtaining and preparing MOVES input data, at either the regional or project level, would you find helpful that is not already available in existing EPA guidance:

- Comments:
  - 1. We have a method we use to determine long-haul combination truck VMT and population. It works for us but if you have additional guidance for vehicles traveling through a region (not originating there) it would be useful.
  - 2. We would like a way to better analyze the benefits of CNG emissions other than using just transit buses. We have fleets with CNG for other vehicle types. Any good way to deal with this other than AP-42, etc.?
  - A reference guide with examples from other areas/jurisdictions would be helpful in setting the model up.
  - Additional or updated guidance on mapping of 13 MOVES source types from 6 types of HPMS vehicle classification data.
  - Additional or updated guidance on mapping of 13 MOVES vehicle types from HPMS classification data (6 or 13 types).
- Comments:
  - Descriptions and references for all the default data.
  - An on-line data/idea sharing forum for the MOVES community (maybe you already have this).
  - Once you get the results of this survey, publish some of the user methods for developing local data and using national data to refine local data.
  - Do not know.
  - Guidance on generating speed distribution from the Travel Demand Model.
  - How do we use MOVES emission rates in other processors such as CMAQ program?
  - I would personally like to be able to show people how to modify MOVES to accept Daily VMT and Local roads. Since I have made these changes it has been very easy to get some of my older Modeling colleagues to buy into the MOVES model. It is also very satisfying and rewarding to be able to see an input like VMT and see it go into and out of the model and have some reassurances that the model is working. I might add that since we have the Daily and local road setup that we have been able to identify input errors in minutes that could trip up users of the default model for days. Missing days matters for MOVES. I have setup batch runs that go on for a week and I can do that because I

have the confidence that the model is going to work with my inputs. My method gives the modeler confidence in MOVES. I think that once you get a modeler use to running MOVES on the inventory side with daily inputs and local roads that the project-level side would be pretty easy … My method is about building confidence in the model because it allows the user to utilize their own inputs. The way that the model is setup now it is hard for the user to take ownership.

- In addition of all the above, EPA needs to do a better job on documenting from where the Emission Factors for air toxics and HONO are coming from.
- Methods for estimating vehicle population for regions with high levels of "through" traffic.
- Methods for estimating vehicle populations for regions with high levels of 'through' or inter-county traffic.
- More detailed guidance on development of I/M program inputs
- MOVES is sensitive to the number of starts, which is sensitive to the vehicle population which is a very elusive number (interstate vehicles, registered vehicle that are inactive, etc.). We need better vehicle population data or a better surrogate for vehicle starts. I suggest the latter – and the Travel Demand Model may be the solution by estimating vehicle trips and relating that to vehicle starts. This would give credit to reducing vehicle starts by increasing transit usage – something the current MOVES model does NOT do.
- N/A
- Provide more details on how to develop and locate data for each of the MOVES model inputs.
- Sample project-level analyses for a few different project types (intersection, interchange, a couple with off-network inputs, etc.) that lead you step-by-step through the preparation of the MOVES input file and Project Data Manager inputs that can be easily followed when preparing hotspot analyses.

- Comments:
  - Since EPA does fuel surveys, the MOVES defaults should reflect the most recent EPA survey data available and not require states to alter it.
  - The one area that we believe many states struggle with the most is characterizing the fleet. MOVES requires a registration age distribution AND total vehicle counts (source type population) by newly defined MOVES vehicle classes. I know it would be a big effort, but it would be great if states could submit a list of active VINs by county and a VIN decoder could be used to create these default MOVES inputs. The big advantage to doing this is that there would be standardization of the

data and it would hopefully be more accurate than what states are able to cobble together from their registration databases.

- The current guidance has a degree of flexibility to accommodate unique circumstances and situations, where EPA regions provide input based on applicable data. This allows a more intelligent approach based on the model sensitivity and significance. Areas where some additional standardization could aid the process could include:
  - We would be interested in EPA information and guidance on the speciation of regulatory classes within MOVES source types. For example, a project-scale analysis of a fleet of Honda CRVs versus GMC Hummers was supported by MOBILE62, but is not directly supported by MOVES. The closest approximation that can be made based on my understanding is that one could model the CRVs with the regulatory class distribution of MOVES Source Type 31 and the Hummers with the regulatory class distribution of MOVES Source Type 32. The project scale provides the best example of this issue, but I am actually more interested in being able to adjust the regulatory class distribution within the source types within the county scale, because we have a heavier distribution than what is assumed in MOVES (because many LDT's are LDV's in Connecticut).
  - Additional fleet data (beyond that stated in item 1) is embedded in portions of the MOVES model. This data is often from 1990 era studies. This data should be updated to allow MOVES to accurately calculate emissions.
  - Ramp fraction plays a more significant role in emissions, than was expected. EPA should fix the converters to indicate Vehicle Hours Traveled (VHT) rather than the current incorrect entry of Vehicle Miles Traveled (VMT).
  - Current MOBILE62 to MOVES converters are aligned with the old FHWA format. We supplied an updated converter consistent with the FHWA 2010+ HPMS Classes. This CT FHWA 2010+ based converter used nonstandard numbering for new FHWA classes, because SCC codes do not yet exist for the new FHWA classes.
  - Many states have asked for additional source type population guidance and tools to support implementation of that guidance. We have developed a series of tools, including a VIN decoder/analysis tool that could support regional analyses. There is enough guidance in place to develop source type population estimates, however additional sensitivity analyses and guidelines for EPA regions would be helpful, since many of minor details are left to either the state or the EPA region. Many of the decisions critical to the analysis center not on what is right, but rather what is consistent with the prior analyses, such that

comparisons are apples-to-apples. Sensitivity analyses could help EPA regions reviewing analyses focus on what is important.

   – Compromises in Speed-VMT were needed in regional analyses, because MOVES can only support one speed-VHT input for a run and because of limitations imposed by the SMOKE MOVES interface. This may be something that could be worth addressing.

   – We have not had the chance to use MOVES to estimate refueling emissions and have stuck with the MOVES defaults in the inventory mode for estimating these emissions. The old method of producing a controlled (Stage II) and an uncontrolled composite gram per gallon emission factor from MOBILE62 appeared to make good sense and work well. Is there any way that MOVES could support this type of approach, so that we could better estimate area source refueling emissions?

   – Additional SCCs are needed to properly reflect the FHWA 2010+ HPMS road types. Ideally the MOBILE62 to MOVES VMT Converter would use HPMS numbering consistent with the SCCs. EPA maintains the SCC list and controls the MOVES internal classifications to SCC associations. This is not critical to states because this issue is a matter of presentation based on road type and regulations are more focused on regulated vehicle classification and associated emission regulation and reductions that what type of road the vehicle is traveling.

- The most helpful guidance would be how to develop local inputs. What kinds of data should we be asking for? What it the first choice isn't available? What are options for putting together the various local data sets?

- VMT for Maine registered vehicles to use as growth factors.

- We are told that MOVES is very useful and provides detailed information, but yet we are having to resort to using defaults since the input information is just not there. We are not given any assistance or funding for collecting the input data either. How or why would anyone develop a model claimed to provide detailed information, where the input data is not available and approximations are used. The whole accuracy is thrown out the window. How was it envisioned that agencies would collect data such as: VMT by 13 vehicle types by 4 road types by month-hour by 16 speed bins, for input? / /

- We would like to be able to use MOVES for credible forecasts of GHG, and fleet age distribution would be very helpful, especially with new CAFE standards coming on line.

D. Survey Instrument

MOVES Data Sources and Guidance Needs

If your agency uses MOVES, or is developing MOVES capabilities, your response to this survey is requested. The purpose of the survey is to identify the sources of data that users of EPA's MOVES model are using as input to the model, as well as needs for additional datasets or guidance on data inputs for using MOVES. The survey is being conducted as part of National Cooperative Highway Research Program (NCHRP) *Project 25-38, Input Guidelines for Motor Vehicle Emissions Simulator Model (MOVES)*. This project will result in the development of guidance, datasets, and other resources to support use of the MOVES model – your input is very important.

The survey should take between 10 and 30 minutes to complete, depending upon how many questions are relevant to your agency. You can partially complete the survey and return to it later by clicking on the link in the email again. Your response is requested no later than **Friday, August 24th.** If you encounter any problems with the survey, have questions about the research effort, or would prefer to take the survey by telephone, contact David Kall (dkall@camsys.com, 404-460-2608) or Chris Porter (cporter@camsys.com, 617-354-0167).

Section 1: Agency Characteristics

What type of agency do you represent?

◉ a. State DOT
○ b. State air agency
○ c. MPO
○ d. Other regional agency
○ e. Multi-state air agency
○ f. Other [ ]

(Optional) What is the name of your agency?

[Survey completed on Behalf of PennDOT and PaDEP]

What population is served by your agency?

○ a. Less than 200,000
○ b. 200,000 - 500,000
○ c. 500,000-1,000,000
○ d. Greater than 1,000,000
◉ e. State or multi-state

Please indicate the nonattainment status of your region for each of the following pollutants:

	Attainment	Unclassified	Nonattainment (Entire Region)	Nonattainment (Portion)	Maintenance (Entire Region)	Maintenance (Portion)	Don't know
CO	◉	○	○	○	○	○	○
Ozone	○	○	○	○	○	◉	○
PM2.5	○	○	○	◉	○	○	○
PM10	◉	○	○	○	○	○	○

What is your agency's current status with respect to the use of MOVES?

◉ a. Have used MOVES
○ b. Currently transitioning to MOVES or planning to develop MOVES capabilities
○ c. Have not used MOVES and do not plan to
○ d. Don't know

MOVES Data Sources and Guidance Needs

Section 2: Emission Modeling Priorities

For what purposes does your agency use, or plan to use, MOVES?

	My agency has used MOVES for this purpose	My agency does this and plans to use MOVES	My agency does this but does not plan to use MOVES	My agency does not do this	Don't know
Regional (County-Level) Analysis a. State Implementation Plan development	●	○	○	○	○
b. Regional conformity analysis	○	●	○	○	○
c. Regional Mobile source air toxics (MSAT) analysis	○	●	○	○	○
d. GHG analysis/climate change planning	○	●	○	○	○
e. Evaluation of policy and/or legislation	○	●	○	○	○
Project-Level Analysis f. Project-level conformity analysis (hot-spot analysis)	○	●	○	○	○
g. NEPA analysis/ environmental documentation	○	●	○	○	○
h. Hot-Spot Mobile source air toxics (MSAT) analysis	○	●	○	○	○
i. GHG analysis	○	●	○	○	○

Does your agency interface emissions rates, or related data, from MOVES with the following types of models?

	Yes, we have done this	No, but we plan to	No, and we do not have plans to	Don't know
Travel demand models	●	○	○	○
Traffic simulation models	○	●	○	○
Air quality dispersion models	○	●	○	○
Other transportation models or emission processors	●	○	○	○

Comments

MOVES has been integrated with MPO regional travel models and with PennDOT HPMS and RMS traffic data in areas without travel models.

MOVES will be used for future project-level analyses as warranted.

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MOVES Data Sources and Guidance Needs

Section 3: MOVES-Related Experience

MOVES can be used in emissions inventory mode to calculate emissions entirely within MOVES, or in rate mode to output emission rates (or factors) to apply to travel activity data from a travel demand forecasting model (TDFM). Do you use MOVES in emission rate or inventory mode?

- ○ a. Rate mode
- ◉ b. Inventory mode
- ○ c. Both
- ○ d. Don't know

Fleet Data

MOVES requires information about the age and mix of vehicles that are on the road. This section of the survey focuses on your agency's experience working with these data.

What is your agency's source of light-duty age distributions?

- ◉ a. Locally-collected data (e.g. vehicle registration database)
- ○ b. MOVES defaults
- ○ c. Combination of locally collected data and MOVES defaults -- Please explain.
- ○ d. Other

What is your agency's source of heavy-duty age distributions?

- ○ a. Locally-collected data (e.g. vehicle registration database)
- ◉ b. MOVES defaults
- ○ c. Combination of locally collected data and MOVES defaults (Please explain.)
- ○ d. Other

What is your agency's source of light-duty source type populations? (Check all that apply.)

- ☐ a. MOVES defaults
- ☑ b. Local vehicle registration data
- ☐ c. Local traffic counts
- ☐ d. Local fleet sampling
- ☑ e. Other
  Checks against veh population calculated from VMT using MOVES default
- ☐ f. Don't know

What is your agency's source of heavy-duty source type populations? (Check all that apply.)

- ☐ a. MOVES defaults
- ☑ b. Local vehicle registration data
- ☐ c. Local traffic counts
- ☐ d. Local fleet sampling
- ☑ e. Other
  Checks against veh popultation calculated from VMT using MOVES defau
- ☐ f. Don't know

Please identify any key data sources, pre- or post-processing steps, or provide other explanation:

MOVES has been linked to models and RMS using both inventory and rate methods. Inventory methods have been used for SIP submissions and is expected for furture conformity analyses. Rate method is available for other testing and control strategy analyses as needed.

Truck source type population method for SIPs has been based on VMT as more conservative approach; Further studies may be required to identify what additional data sources may be used to update these estimates.

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MOVES Data Sources and Guidance Needs

Regional Activity Data

What is your agency's source of total VMT data for use in MOVES for regional analysis?

- ○ a. Travel demand forecasting model (TDFM)
- ○ b. Highway Performance Monitoring System (HPMS)
- ◉ c. Combination of TDFM and HPMS
- ○ d. MOVES defaults
- ○ e. Other
- ○ f. Don't know

Do you use locally-derived data for any of the following inputs: VMT mix by source type, annual VMT by vehicle type, month fraction VMT, day fraction VMT, hour fraction VMT, ramp fractions, road type distribution, or average speed distribution?

- ◉ a. Use some local data
- ○ b. Use all MOVES defaults
- ○ c. Don't know

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MOVES Data Sources and Guidance Needs

How do you collect VMT data for the 13 MOVES source types?

- ( ) a. Collect VMT directly by the 13 MOVES source types
- ( ) b. Collect VMT by HPMS vehicle type (6 vehicle types) and use a surrogate to map to the 13 MOVES source types
- (•) c. Collect light-duty vs. heavy-duty vehicle VMT and use a surrogate to map VMT to the 13 MOVES source types
- ( ) d. Use a surrogate to map a single VMT to the 13 MOVES source types
- ( ) e. Don't know

What is your surrogate source used to derive VMT at the MOVES source type level (13 vehicle types)?

- (•) a. MOVES defaults
- ( ) b. Vehicle registration data
- ( ) c. Other
- ( ) d. No surrogate used
- ( ) e. Don't know

What is your source of month fraction VMT data for use in MOVES for regional analysis?

- (•) a. HPMS
- ( ) b. MOVES defaults
- ( ) c. Other
- ( ) d. Don't know

What is your source of day fraction VMT data for use in MOVES for regional analysis?

- (•) a. HPMS
- ( ) b. MOVES defaults
- ( ) c. Other
- ( ) d. Don't know

What is your source of hour fraction VMT data for use in MOVES for regional analysis?

- (•) a. HPMS
- ( ) b. MOVES defaults
- ( ) c. Other
- ( ) d. Don't know

What is your source of ramp fractions?

- ( ) a. HPMS
- ( ) b. MOVES defaults
- (•) c. Other
  MOVES Defaults unless travel model has ramps coded - in those cases model data used
- ( ) d. Don't know

How has your agency estimated the proportion of VMT among MOVES road types? (Check all that apply.)

- [x] a. Travel demand forecasting model
- [x] b. HPMS
- [ ] c. Vehicle sampling and portable activity monitoring systems (PAMS) instrumentation
- [ ] d. Publicly available vendor data (e.g., cell phone and GPS providers)
- [ ] e. MOVES defaults
- [ ] f. Other
- [ ] g. Don't know

How has your agency estimated the proportion of VMT among speed bins for the average speed distribution? (Check all that apply.)

- [x] a. Travel demand forecasting model
- [x] b. HPMS
- [ ] c. Vehicle sampling and portable activity monitoring systems (PAMS) instrumentation
- [ ] d. Publicly available vendor data (e.g., cell phone and GPS providers)
- [ ] e. MOVES defaults
- [ ] f. Other
- [ ] g. Don't know

If you indicated in the previous question that you use a travel demand forecasting model, have you post-processed the speeds to account for impedance?

- (•) a. Yes (Please describe below in "comments.")
- ( ) b. No
- ( ) c. Don't know

Please identify any key data sources, pre- or post-processing steps, or provide other explanation:

Custom post processing software (PPSUITE) is used to disaggregate daily traffic volumes and re-calculate hourly speeds for each roadway segment. The post processing software includes assumptions for intersection delay and the effects of congestion. The software aggregates VHT by each speed bin across all links within each hour, road type group.

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MOVES Data Sources and Guidance Needs

Project-Level Data

What sources of project-level vehicle volume information has your agency used?

- ○ a. Travel demand forecasting model
- ○ b. Microsimulation model
- ○ c. Highway Capacity Manual (HCM) methods
- ◉ d. Other
  - No MOVES project level analyses conducted yet; Have used combinations of all
- ○ e. Don't know

What sources of project-level vehicle speed information has your agency used? (Check all that apply.)

- ☐ a. Travel demand forecasting model
- ☐ b. Microsimulation model
- ☐ c. Highway Capacity Manual (HCM) methods
- ☑ d. Other
  - No MOVES project level analyses conducted yet; Have used combinations of all
- ☐ e. Don't know

Has your agency developed vehicle trajectory data or MOVES vehicle-specific power profiles (operating mode distributions) for link-level vehicle activity?

- ○ a. Trajectory data
- ○ b. Vehicle specific power (VSP) profiles (operating mode distributions)
- ○ c. Both
- ○ d. Neither – use MOVES defaults
- ○ e. We do not use this attribute of MOVES
- ◉ f. Don't know

How has your agency determined project-level fleet mix (link source type) information?

- ◉ a. From state/regional analysis
- ○ b. Counts collected for project area
- ○ c. MOVES defaults
- ○ d. Other
  - [ ]
- ○ e. Don't know

How has your agency determined project-level age distribution information?

- ◉ a. From state/regional analysis
- ○ b. Counts collected for project area
- ○ c. MOVES defaults
- ○ d. Other
  - [ ]
- ○ e. Don't know

How has your agency collected project-level "off-network" MOVES data, such as estimates of vehicle starts or extended idle fractions?

- ○ a. From similar projects
- ○ b. Project documentation
- ○ c. Surveys in project area
- ○ d. Institute of Transportation Engineers (ITE) trip generation data
- ○ e. Other
- ○ f. Haven't collected this data
- ◉ g. Don't know

Please identify any key data sources, pre- or post-processing steps, or provide other explanation:

Note: No MOVES hotspot analyses completed to date. When one is completed an evaluation will be made of available data sources. Methods and procedures will be agreed on through the interangency consultation process.

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MOVES Data Sources and Guidance Needs

Other MOVES Inputs

How do you derive your temperature and humidity inputs to MOVES?

- ○ a. Use National Climatic Data Center (NCDC) data
- ◉ b. Use locally-obtained data
- ○ c. Use MOVES defaults
- ○ d. Other [ ]
- ○ e. Don't know

Does your area have an Inspection and Maintenance (I/M) program and, if so, what is your source of inputs?

- ○ a. No I/M program
- ○ b. Have I/M program and use MOVES defaults
- ◉ c. Have I/M program and use something other than MOVES defaults (Please explain at bottom of this page.)
- ○ d. Don't know

What source of information does your agency use as inputs for fuel parameters such as Reid Vapor Pressure (RVP)?

- ○ a. Use MOVES defaults
- ○ b. Use results from local fuel survey
- ◉ c. Other [Use parameters per program regulations / EPA guidance / Past SIP parameters]
- ○ d. Don't know

If you do not use MOVES defaults for fuels, which fuel parameters do you change?

- ○ a. RVP only
- ◉ b. RVP and other parameters (please list in "comments")
- ○ c. Only other parameters (please list in "comments")
- ○ d. Don't know

Has your agency performed any sensitivity testing on the use of alternative MOVES inputs (including fleet data, regional activity data, project level activity data, or other inputs)? (Please share copies of, or links to, relevant data sets through the comments section at the bottom of the page).

- ◉ a. Yes
- ○ b. No
- ○ c. Don't know

Please identify any key data sources, pre- or post-processing steps, or provide other explanation:

As indicated above I/M and Fuel Parameters have been determined using a combination of sources including local data surveys, regulations, input from EPA, and parameters assumed from past SIP analyses.

Pennsyvania updates much of their data inputs on a triennial basis. At time of updates the sensitivity of key inputs have been evaluated. Typically, vehicle age data has the largest impact on emisisons. The fleet age in PA has been steadily aging since 2005, producing much higher emissions results.

[<<] [>>]

MOVES Data Sources and Guidance Needs

Section 4: Input on NCHRP 25-38 Project Outcomes

One objective of this NCHRP project is to provide methods and guidance for developing MOVES input data, and/or additional datasets that can be used. What datasets or methods/guidance would be the most important to your agency?

	Very Important	Somewhat Important	Not Important
Age distributions by vehicle class	◉	○	○
Source (vehicle) type population	◉	○	○
Vehicle class split for regional VMT	○	◉	○
Vehicle class split for project-level link activity	○	○	◉
Meteorology data	○	○	◉
Project-level link activity (operating mode distributions)	○	◉	○
Other 1 (fill in blank) Alternative Fuel Vehicl	○	◉	○
Other 2 (fill in blank)	○	○	○
Other 3 (fill in blank)	○	○	○

For any datasets developed as part of this project, how would you prefer they be made available?

- ○ a. Incorporate into MOVES
- ◉ b. Provide through national source such as NCHRP, FHWA, or EPA publication or online center
- ○ c. Other
- ○ d. Don't know

What additional guidance for obtaining and preparing MOVES input data, at either the regional or project level, would you find helpful that is not already available in existing EPA guidance?

Methods for estimating vehicle population for regions with high levels of "through" traffic.

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MOVES Data Sources and Guidance Needs

Section 5: Follow Up

Can we contact you for a follow-up interview if we need additional information regarding any of your responses? If so, please provide your contact information here.

Name

Agency

Telephone

Email

Do you know of others with MOVES experience whom we could contact for an interview? If so, please provide contact information here.

Name:

Agency:

Telephone:

E –mail:

Has your agency developed literature (guides, analyses, sensitivity test results, etc.) that the research team could look at as part of their literature review?

- (selected) a. Yes (Please identify and provide web links if available.)
  You can contact us if you are looking for certain items. We don't have a consolidated guide but have completed var
- b. No
- c. Don't know

If you encountered any problems with the survey or have questions about the research effort please contact David Kall (dkall@camsys.com, 404-460-2608) or Chris Porter (cporter@camsys.com, 617-354-0167).

<< Submit