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Arizona-Specific Data for EPA's MOVES Model

Arizona Department of Transportation Research Center

ADOT

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16. Abstract
This report provides an implementation plan that allows the Arizona Department of Transportation and other agencies in Arizona to make optimal use, through local data inputs, of the United States (US) Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) model. MOVES is the federally approved mobile source emissions model for use in State Implementation Plan development and conformity analysis, and is recommended for other transportation air quality analysis purposes. EPA requires or recommends using local data for many of the model's inputs. This report includes an assessment of Arizona-specific data and the processing necessary to create these inputs, plus a demonstration of data-processing procedures using Yuma County as a case study. The recommendations are intended for applying the MOVES model anywhere in the state of Arizona, but are not meant to supersede work by metropolitan agencies that may use more detailed data than available in other regions of the state. This study focuses on the latest release of the model, MOVES2014.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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ACRONYMS

AADT .... annual average daily traffic
ADEQ................ Arizona Department of Environmental Quality
ADOT................ Arizona Department of Transportation
AMPO.............. Association of Metropolitan Planning Organizations
APCD .... Air Pollution Control Division
ASOS .... Automated Surface Observing System
ATDM .... Active Transportation and Demand Management Program
ATR.................. automated traffic recorder
ATV .... all-terrain vehicles
AZDWM .... Arizona Department of Weights and Measures
AZTDM .... Arizona Statewide Travel Demand Model
BPR.................. Bureau of Public Roads
CalHEAT .... California Hybrid, Efficient, and Advanced Truck Research Center
CDM .... County Data Manager
CDPHE .... Colorado Department of Public Health and Environment
CDR .... Conformity Determination Report
CSV.................. comma-separated values
CTPS .... Central Transportation Planning Staff
CYMPO............ Central Yavapai Metropolitan Planning Organization
DAQ................. Division of Air Quality
DEEP................ Department of Energy and Environmental Protection
DEP .... Department of Environmental Protection
DEQ .... Department of Environmental Quality
DMV .... Department of Motor Vehicles
DOL .... Department of Licensing
DOT .... Department of Transportation
DVMT .... daily vehicle miles of travel
DVRPC .... Delaware Valley Regional Planning Commission
ECU .... engine control unit
EPA.................. Environmental Protection Agency
ERG .... Eastern Research Group, Inc.
FHWA .... Federal Highway Administration
FMPO .... Flagstaff Metropolitan Planning Organization
FY .... fiscal year
GHG................. greenhouse gas
GPS.................. global positioning systems
GVWR.............. gross vehicle weight rating
HC.................... hydrocarbons
HCM .... Highway Capacity Manual
HDT .... heavy-duty truck
HDV .... heavy-duty vehicle
HIVIS................ highway visibility system
HPMS .... Highway Performance Monitoring System
I/M .... inspection and maintenance
LCD.................. Local Climatological Data
LDT .... light-duty truck
LDV.................. light-duty vehicle
MAG .... Maricopa Association of Governments
MOVES .... Motor Vehicle Emission Simulator
MPD .... Multimodal Planning Division
MPO .... Metropolitan Planning Organization
MVD .... Motor Vehicle Division
MY................... model year
NCDC .... National Climatic Data Center
NCHRP............. National Cooperative Highway Research Program
NEI................... National Emissions Inventory
NESCAUM .... Northeast States for Coordinated Air Use Management
NJTPA .... North Jersey Transportation Planning Authority
NO_x.................. oxides of nitrogen
NPMRDS........... National Performance Management Research Data Set

OBD .... on-board diagnostics
PAG .... Pima Association of Governments
PM .... particulate matter
RFG .... reformulated gasoline
RMV .... Registry of Motor Vehicles
RTP .... regional transportation plan
RV .... recreational vehicle
RVP .... Reid vapor pressure
SEMCOG .... Southeast Michigan Council of Governments
SIP .... state implementation plan
SJTPO .... South Jersey Transportation Planning Organization
SR .... state route
TAZ .... traffic analysis zone
TDEC .... Tennessee Department of Environment and Conservation
TDFM .... travel demand forecasting model
TDMS .... Transportation Data Management System
TIM .... time-in-mode
TIP .... Transportation Improvement Program
TVT .... travel volume trends
US .... United States
UT .... University of Tennessee
v/c .... volume to capacity
VDF .... volume-delay functions
VHT .... vehicle-hours of travel
VIN .... vehicle identification number
VMT .... vehicle-miles of travel
VOC .... volatile organic compound
VTRIS .... Vehicle Travel Information System
WIM .... weigh-in-motion
YMPO .... Yuma Metropolitan Planning Organization

EXECUTIVE SUMMARY

This research project produced an implementation plan to allow the Arizona Department of Transportation (ADOT) and other agencies in Arizona to make optimal use of the United States (US) Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) model through local data inputs. MOVES is the federally approved mobile source emissions model for use in state implementation plan (SIP) development and conformity analysis, and it is recommended for other transportation air quality analysis purposes. The EPA requires or recommends using local data for many of the model's inputs.

The research includes an assessment of Arizona-specific data and processing needs necessary to create these inputs, and a demonstration of data processing procedures using Yuma County as a case study. The assessment and recommendations are intended to provide MOVES inputs of a quality suitable for regulatory purposes. However, consultation with the EPA will be required to affirm the acceptability of these sources and the processing procedures.

The MOVES model requires data that are specific to each county of the state. Embedded or "default" values are included for many items, although in some cases local data are required. It is usually preferable to use local data, where available. The recommendations here are intended for statewide application of the model, but are not meant to supersede work by metropolitan agencies, which may make use of more detailed data than are available in other parts of the state. This study focuses on the latest release of the model, MOVES2014.

The MOVES model requires the following types of data as inputs:

- Characteristics of the vehicle fleet operating in the state, including age distribution and number of vehicles by type
- Characteristics of total vehicle activity, including vehicle-miles of travel (VMT) by vehicle type, and VMT distributions by road type and time period (hour, day of week, month)
- Vehicle speed distributions by road type and time of day
- Other data, including the state's Inspection and Maintenance (I/M) program, information on motor fuel characteristics, and meteorological data (temperature and humidity)

The primary source of **fleet inputs** is the state motor vehicle registration database, which provides information on registered vehicles by county. The ADOT Motor Vehicle Division (MVD) maintains the database. The state's vehicle registration data generally provide a good picture of the fleet operating in the state. However, the database is not structured so that all vehicles can be directly matched with their corresponding MOVES classifications. Therefore, some work is required to properly classify vehicles for the model. The MVD registration database also lacks information on school buses and transit buses.

Sources of data for **VMT and VMT-based adjustments** include statewide and Metropolitan Planning Organization (MPO) travel demand models, statewide traffic monitoring data (classification counts) from the ADOT Transportation Data Management System (TDMS), and VMT reported by ADOT to the Federal Highway Administration (FHWA). Existing sources are generally adequate for obtaining county-level estimates of VMT by road type, and statewide distributions by vehicle type/road type and time period, but not by substate- or county-specific VMT distributions.

Sources of **speed data** include statewide and MPO travel demand models and traffic monitoring data from ADOT and private sources. The statewide model is generally recommended, except in cases for which an MPO model includes peak and off-peak speed estimates. Modeled speeds should generally be used in MOVES so that forecast and base-year speeds are developed using consistent methods, but these can be improved using basic postprocessing procedures and calibration against observed speeds.

Other data embedded in MOVES2014 are generally adequate to characterize I/M programs and fuels in the state. Local meteorological data can easily be incorporated from the National Climatic Data Center (NCDC). For counties that do not have a nearby monitoring station reporting to NCDC, ADOT should investigate other options for obtaining local meteorological data, such as air quality monitors.

KEY RECOMMENDATIONS

The following actions can help enhance the utility of the agency's data for creating MOVES inputs:

- **Expand use of TDMS as a data depository** – ADOT could incorporate additional data into this tool from other agencies, such as MPOs and county/local governments, that are also collecting classification counts, ramp counts, and speed data.
- **Expand collection of speed data** – ADOT could investigate with its TDMS vendor whether it is possible to access speed information by vehicle class for the 154 classification count stations. Currently, this is only possible at the 15 weigh-in-motion (WIM) stations.
- **Expand temporal and spatial coverage of classification counts** – ADOT could increase the temporal coverage of its existing classification counters and, when replacing or adding counters, should use axle-based classification systems that can be related to MOVES inputs. ADOT should also consider adding additional permanent classification counters in strategic locations.
- **Continue to enhance the statewide model for speed estimation purposes** – Future work on the statewide model should include calibration/validation of volumes by light vs. heavy-duty vehicles, volumes by time of day, and free-flow and congested speeds by time of day.
- **Create VMT reports providing data aligned with MOVES input needs –** ADOT could ease the burden on MOVES users to analyze ADOT and FHWA data by providing reports of VMT by classifications required for MOVES (county, roadway and vehicle type, time period).
- **Add fields to the motor vehicle registration database –** ADOT's MVD could work with its contractor to add fields to the registration database that would provide additional information on bus type, truck usage, and other vehicle characteristics.
- **Update registration data every few years –** ADOT's Multimodal Planning Division air quality group should use the state registration database to prepare vehicle fleet-related MOVES inputs (age distribution and number of vehicles by type) for each county in the state at least every four to five years.

CHAPTER 1. INTRODUCTION

This research project produced an implementation plan to allow the Arizona Department of Transportation (ADOT) and other agencies in Arizona to make optimal use of the United States (US) Environmental Protection Agency's (EPA) Motor Vehicle Emissions Simulator (MOVES) model through local data inputs. MOVES is the federally approved mobile source emissions model for use in state implementation plan (SIP) development and conformity analysis, and is recommended for other transportation air quality analysis purposes. EPA requires or recommends using local data for many of the model's inputs.

This report includes an assessment of Arizona-specific data and processing needs necessary to create these inputs, and a demonstration of data processing procedures using Yuma County as a case study. The assessment and recommendations are intended to provide MOVES inputs of a quality suitable for regulatory purposes. However, EPA consultation is required to affirm the acceptability of these sources and the processing procedures.

MOVES requires data specific to each county of the state that is being modeled. Embedded or "default" values are included for many items, although in some cases local data are required. It is usually preferable to use local data, where available. The recommendations are intended for statewide application of the model, but are not meant to supersede work by metropolitan agencies, which may make use of more detailed data than available in other parts of the state. This study focused on the latest release of the model, MOVES2014.

This report includes the following chapters:

- **Chapter 2. Literature Review** – This section reviews existing literature on MOVES input sources and requirements, including national literature and Arizona-specific resources. It also presents the findings of outreach to eight other states to document their procedures for developing MOVES inputs.
- **Chapter 3. Data Needs Assessment** – This section examines existing datasets available in Arizona to produce MOVES inputs, limitations (data gaps or quality issues) with respect to the preparation of reliable inputs, options for obtaining supplemental data or enhancing existing data collection efforts, and short-term and long-term recommended data sources for developing MOVES inputs specific to Arizona.
- **Chapter 4. Processing Needs Assessment** – This section investigates options for data processing procedures to convert raw data from available sources into MOVES input format. It also tests the data sources and processing procedures through an application to Yuma County.
- **Chapter 5. Summary of Recommended Data Sources and Processing Methods** – This section summarizes key findings and recommendations for each MOVES input.

CHAPTER 2. LITERATURE REVIEW

OBJECTIVES

The literature search is a review of existing practices for developing MOVES inputs in other states and national research efforts to identify practices that may be relevant to Arizona, as well as a review of Arizona-specific issues that may affect how MOVES inputs are developed.

METHODS

The project team performed the following activities as part of this literature search:

- Reviewed results of the ADOT conformity guidelines study (ADOT 2013)
- Met with ADOT and Arizona Department of Environmental Quality (ADEQ) staff (as part of the project kickoff meeting) to understand the potential uses of MOVES, existing sources of data used for emissions modeling in the state, and other potential local data sources known to staff
- Reviewed the results of a nationwide survey of 75 agencies conducted by the project team in 2012 for National Cooperative Highway Research Program (NCHRP) Project 25-38, Input Guidelines for MOVES Model (Porter et al. 2014), to identify findings relevant to Arizona
- Reviewed recent MOVES-based National Emissions Inventory (NEI) submittals
- Reviewed other literature on the development of MOVES inputs, including research studies and EPA guidance documents
- Contacted eight states to discuss their data sources and procedures for developing key MOVES inputs
- Drew from experience preparing MOVES inputs for various state and metropolitan agencies

The literature review and subsequent analysis and recommendations are structured around the following inputs required by MOVES:

- Fleet Inputs
  - Age distribution by source type
  - Source (vehicle) type population
- Activity Inputs
  - Vehicle-miles of travel (VMT) by vehicle class
  - Road type distribution
  - Temporal adjustments (hour VMT fractions)
  - Temporal adjustments (day and month VMT fractions)
  - Ramp fraction
  - Average speed distribution
- Other Inputs
  - Meteorology data
  - Inspection and Maintenance (I/M) programs
  - Fuel formulation and supply

FINDINGS FROM THE LITERATURE

This section first discusses EPA guidance, the results of recent MOVES user surveys, and the results of MOVES sensitivity analyses. It then presents key findings from other studies.

EPA Guidance

The following EPA documents provide guidance on developing inputs for MOVES. These guidance documents typically identify recommended or acceptable practices, which are especially relevant in determining when local data are required or strongly recommended vs. when "default" data embedded in the MOVES model may be used:

- MOVES User Guide for MOVES2014 (EPA 2014a)
- Using MOVES to Prepare Emission Inventories in State Implementation Plans and Transportation Conformity: Technical Guidance for MOVES2010, 2010a, and 2010b (EPA 2012a)
- Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas (EPA 2013)
- Using MOVES in Project-Level Carbon Monoxide Analyses (EPA 2010)
- Using MOVES for Estimating State and Local Inventories of On-Road Greenhouse Gas Emissions and Energy Consumption, Final (EPA 2012b)

The first of these documents is the user guide for the MOVES model. This document provides a description of the various MOVES inputs, but does not provide detailed guidance on how to develop them.

The remaining documents provide more specific guidance on sources of input data specific to different uses, including SIP development and conformity analysis, particulate matter (PM) hot-spot analysis, carbon monoxide (CO) project-level analysis, and greenhouse gas (GHG) emissions estimation. These documents identify (1) requirements for data (including whether or not local data are required) and (2) recommended data sources for each input. Requirements for local data are generally more stringent for regulatory purposes (SIP development, conformity analysis, and hot-spot analysis) than for non-regulatory purposes (GHG emissions estimation), although the various guidance documents usually recommend the same sources of data. The PM and CO guidance documents apply to project-level inputs, while the SIP/conformity and GHG/energy documents apply to regional-level inputs (the latter being the focus of this review for ADOT).

All of these guidance documents were the current references at the time this report was developed. The documents are likely to be updated in the future as the model and guidance on its use evolve.

MOVES User Surveys

The Association of Metropolitan Planning Organizations (AMPO) conducted a 33-question survey of MOVES users in June to July 2011. The survey dealt with capacity and needs for using the MOVES model. The survey showed that the large majority of agencies (at the time of the survey) needed help developing MOVES inputs, were performing this work in-house, were not proficient with MOVES, and were at least partially dependent on national default data.

As part of NCHRP Project 25-38 (Porter et al. 2014), a survey was conducted of agencies using or transitioning to the use of MOVES. The survey was conducted in July through September 2012 to characterize how agencies are using the MOVES model, current practices in developing MOVES inputs, and needs for additional guidance or sample data inputs. About 78 responses were received representing up to 34 metropolitan planning organizations (MPOs), 14 state departments of transportation (DOTs), 22 state air agencies, and five agencies of other types. More than one-half of the respondents indicated they already had used MOVES, primarily for SIP development and regional transportation conformity.

For **fleet inputs** (age distribution and source type population), state vehicle registration databases are the most common primary source. VMT data may be used to help develop source type populations for the six Highway Performance Monitoring System (HPMS) classes. MOVES defaults are often used with local data to fill in gaps (for example, to proportion passenger vs. commercial light trucks or short-haul vs. long-haul trucks, or to obtain age distributions and source type populations for all 13 source types). Some agencies use MOVES default age distributions for heavy trucks, since these vehicles often operate across state boundaries.

Regional activity data, including VMT fractions; temporal distributions (hour, day, and month fractions); road type distributions; ramp fractions; and speed distributions, typically are derived from one or more of the following three sources:

- Observed data from automated traffic recorders (ATR), often reported as part of the HPMS
- Travel demand forecasting model (TDFM) data
- MOVES defaults

For VMT fractions, most respondents relied on either a TDFM, HPMS data, or a combination of the two (e.g., applying HPMS vehicle-type proportions to total VMT from the TDFM). For VMT-by-month fractions and day-of-week fractions, some agencies used observed data (from the HPMS system and/or other automated traffic recorders) while others used MOVES defaults. Hour fractions sometimes came entirely from observed data or MOVES defaults, but in other cases were taken from TDFM fractions by time period (e.g., a.m. peak, midday) further proportioned by observed data or MOVES defaults. Road-type fractions typically came from the TDFM or HPMS. Ramp fractions typically either were from the TDFM or were MOVES defaults. About 30 percent of the respondents that used a TDFM output to estimate speeds reported postprocessing the model results to improve the results for use with MOVES.

A much smaller number of respondents had used MOVES for **project-level analysis**. Link activity estimates were derived from a variety of sources. For operating mode and vehicle speed data, sources included the TDFM, Highway Capacity Manual (HCM), and microsimulation models. Responders had little experience with off-network activity estimates.

For **other inputs**, most respondents reported using National Climatic Data Center (NCDC) data or locally obtained data for temperature and humidity. About three-quarters of areas with an I/M program developed program-specific inputs rather than using MOVES defaults. Most respondents reported using fuel data from local and/or state sources; a few reported using MOVES defaults.

MOVES Input Sensitivity Analysis

Research conducted for NCHRP 25-38 (Porter et al. 2014) included a summary of previous sensitivity analyses on MOVES inputs and additional sensitivity testing to supplement those analyses. The results can assist in determining whether it is worthwhile to expend additional effort to gather more detailed local data for a given input. Key findings of how various inputs affect modeled mobile source emissions included:

- Age distribution has a substantial impact for passenger cars and a moderate impact for trucks. (In this report, “modest” means less than 5 percent; “moderate” means 5 to 15 percent; and “substantial” is more than 15 percent variation in overall emissions of a given pollutant.)
- For source type populations, the most critical parameter is the split of light-duty vehicles (LDVs) vs. heavy-duty vehicles (HDVs). The distinction between single-unit and combination trucks can be important for nitrogen oxides (NO_X) and PM, and short-haul vs. long-haul split has somewhat lesser, but still moderate, importance for these pollutants. Impacts of truck splits on volatile organic compounds (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.
- The impact of meteorology (temperature and humidity) varies greatly depending on the pollutant, process, source type, and temperature range.

Other Studies

A comprehensive review of the literature was conducted in 2012 in support of the NCHRP 25-38 project (Porter et al. 2014), with additional literature identified since that time. The various sources can generally be characterized as follows:

- Sources that provide guidance generally accessible to practitioners on the development of MOVES inputs. In addition to EPA guidance documents, Chatterjee and Miller (1994), while nearly two decades old now, is noteworthy for providing a comprehensive review of a number of data sources and methods that are still widely used today. Others in this group include Chamberlin et al. (2012) and Vallamsundar and Lin (2012).
- Sources describing the use of a specific advanced data collection method or study, such as global positioning systems (GPS), video, or freeway loop detectors. These include Boriboonsomsin et al. (2011); Fincher et al. (2010); and Papson et al. (2012).

- Sources discussing the preparation and use of outputs from travel demand or simulation models. These include Miller et al. (2002), FHWA (2009), and FHWA (2010).
- Data mining studies that use existing data sources in new ways. These include Lindhjem and Shepard (2007).

Some of these sources were developed prior to the release of MOVES, but still contain data or analysis relevant to developing MOVES inputs. Also, a number of the sources demonstrate experimental methods that may not be practice-ready. Relevant findings from the literature are described below, with explanations of their relevance to Arizona. The first six documents deal generally with MOVES inputs at all scales, while the last four documents deal specifically with project-level inputs.

Boriboonsomsin et al. 2011. Improving Vehicle Fleet, Activity, and Emissions Data for On-Road Mobile Sources Emissions Inventories.

This report focuses especially on methods for obtaining HDV inputs. Some of the methods in the report are potentially relevant to Arizona if the state determines there is value in collecting additional data to better characterize truck activity.

The report notes that heavy-duty trucks (HDT) are a significant source of idling emissions, especially at truck stops and terminals, as HDTs often engage in long-duration idling activities, and that an accurate characterization of HDT activity is crucial to the construction of an emissions inventory of on-road mobile sources. The state of the practice is reviewed at five MPOs (including the Maricopa Association of Governments [MAG] in Arizona); none of the five areas accounts for out-of-area vehicles in the development of vehicle class and age distributions, and none collects local data on extended truck idling.

The report evaluates a variety of alternative data sources to improve information on HDTs. The first is a license plate survey done in Las Vegas, using automated license plate recognition methods, in combination with a vehicle identification number (VIN) decoder and vehicle registration databases, to identify the origins of trucks on area freeways. It shows that in-state registration data alone may not be sufficient in certain areas, such as places with high tourist activity, near transportation hubs, and near state borders. The report provides some details on the methods (automated vs. manual) and costs involved in collecting license plate data.

The report also evaluated data from trucks' engine control units (ECU) and telematics-based vehicle tracking and monitoring to determine their potential for generating HDT activity data inputs for MOVES. The report notes that it is possible to collect a sizable amount of ECU summary downloads by contracting with truck repair shops or truck fleets that have proper software and deal with a large volume of trucks. Data from 150 trucks were processed to determine distance, hours, time at idle, and average speed. Idling time accounted for about one-quarter of total operating hours. In addition, telematics data were obtained from the Highway Visibility System (HIVIS) to identify VMT fraction by road type, day, hour, average speed distribution, and trip start location. The dataset comes from a collective fleet of more than 2,000 Class 8 HDTs traveling across the United States for the entire year of 2010, although it is heavily weighted to the Northeast and California. Finally, the report showed how data from weight-in-motion (WIM) and vehicle detector stations could be fused to generate HDT inputs for Los Angeles County freeways based on vehicle operating mode distribution.

Chatterjee and Miller. 1994. NCHRP Report 394 – Improving Transportation Data for Mobile Source Emission Estimates. NCHRP Project 25-07.

This study discusses the several transportation variables that were required at the time as inputs to emission models. While this study is somewhat dated, many of the challenges it identifies that are faced by agencies in developing emission model inputs are still challenges today. The report discusses issues such as developing average vehicle speeds, using HPMS and network-based travel demand models to develop VMT estimates, forecasting VMT in areas not covered by travel demand models, using classification counts for vehicle class distributions, and using registration and I/M data for age distributions.

Fincher et al. 2010. Final Report for Modifying Link-Level Emissions Modeling Procedures for Applications within the MOVES Framework.

This study presents a road map for developing emissions inventories using MOVES. The study also analyzes the likely impacts to emissions inventories as a result of the transition into MOVES. The study examines a specific ozone season day for a single year in the eight-county Houston nonattainment area; the results may not be applicable to other areas of the nation. Also, the data used to develop the alternative drive cycles are based on data collected in Kansas City and should be considered specific to that area. However, the study does address some common issues in development of activity data for use in MOVES from HPMS and TDFM-based sources. In addition, the information provided in the study on the use of EPA spreadsheet calculators, particularly those that are intended to transition MOBILE6-formatted data into MOVES-usable data, may be helpful.

Lindhjem and Shepard. 2007. Development Work for Improved Heavy-Duty Vehicle Modeling Capability Data Mining – FHWA Datasets.

This report demonstrates how traffic monitoring data collected from states by the Federal Highway Administration (FHWA) can be used to support MOVES input development. The report analyzes vehicle count and classification from the HPMS using automated traffic recorders used to produce the Travel Volume Trends (TVT) reports. Other datasets compile the results of data collection from WIM 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 (VTRIS). 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 vehicle types combined. Using VTRIS site information (where vehicle class counts are made and vehicle weights are measured), it is possible to aggregate vehicle class count and vehicle weight distributions by designated state and county groupings. The summary results presented in this report provide information on vehicle characteristics, weight, and class fractions of the in-use fleet. Calculations for vehicle mix distribution and temporal profiles by four road types are presented, and comparisons are made among states.

Note: As part of NCHRP 25-38 (Porter et al. 2014), the current project team has "mined" the same data source, the VTRIS, to develop updated (2012) inputs for those states with sufficient data available. Arizona did not submit information for VTRIS, but the analysis does help to illustrate the variation in temporal profiles among states. In most states, the number of classification counters is insufficient to determine road type distributions by source type, or to determine any type of input at a county or other substate level.

Miller et al. 2002. Ways to Estimate Speeds for the Purposes of Air Quality Conformity Analyses.

The purpose of this study was to identify or develop a prototype postprocessor that Virginia DOT staff could use to determine vehicle speeds for the purposes of conducting air quality conformity analyses. The postprocessor was designed for use with the MOBILE model, but concepts are still relevant to MOVES. 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 (VHT) 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.

Federal Highway Administration. 2009. Speed Adjustments Using Volume-Delay Functions.

Speed distributions are an important MOVES input, but also are challenging to develop. This document provides an overview of methods for estimating speeds based on modeled volumes and capacity. Volume-delay functions (VDF) describe the speed-flow relationships in a travel demand model network based on the available link capacity. 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. In an effort to better represent delay due to congestion, some study areas estimate alternative VDFs 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 VDF for all facility types; (2) apply unique user-specified VDFs developed for each facility type (e.g., freeway, expressway, arterials) and possibly area type in the network; and (3) develop unique user-specified VDFs to account for delay at signalized intersections.

Note: The research being conducted in support of NCHRP 25-38 investigated alternative VDFs and compared predicted travel speed distributions with distributions observed from various sources (Porter et al. 2014). The conclusions are that none of the existing estimation methods is very good at matching the speed distributions observed in the real world. If congestion in the analysis area is expected to change significantly in the future, it may be necessary to use modeled speeds, but if congestion is not expected to change significantly (for example, in less-congested rural or small metropolitan areas), using today's observed speeds may be a more accurate representation of future speeds than using modeled speeds from VDFs.

Chamberlin et al. 2012. Toward Best Practices for Conducting a MOVES Project-Level Analysis. Presented at the 91st Annual Meeting of the Transportation Research Board, January 2012.

This paper uses a signal optimization project at an intersection as an example to demonstrate a quantitative PM hot-spot analysis using MOVES at the project level. Based on this example, the paper draws conclusions on best practices, including methods of defining links and using microsimulation models to provide operating mode distribution inputs to MOVES. 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.

Federal Highway Administration. 2010. Advances in Project-Level Analyses.

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. Links are identified in relation to the bottleneck point.

Papson et al 2012. Analysis of Emissions at Congested and Uncongested Intersections Using MOVES 2010. Submitted for presentation at the 91st Annual Meeting of the Transportation Research Board, January 2012.

This analysis estimates emissions using a time-in-mode (TIM) method, which allocates vehicle activity time to one of four modes: acceleration, deceleration, cruise, and idle. This is an in-between method 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.

Vallamsundar and Lin. 2012. Using MOVES and AERMOD Models for $PM_{2.5}$ Conformity Hot Spot Air Quality Modeling. Submitted for presentation at the 91st Annual Meeting of the Transportation Research Board, January 2012.

According to the authors, this study of the Interstate 55 (I-55) and Interstate 80 (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.

STATE AGENCY PRACTICES

This section presents a snapshot of the practices of various state agencies. Information was gathered from documents obtained from the states, the experience of the project team, the NCHRP 25-38 user survey (Porter et al. 2014), and interviews with individuals from selected states.

Interviews with staff from nine states were conducted in the fall of 2013 to gather supplemental information not published or gathered in previous surveys. Interviews were conducted with state agency staff in Colorado, Connecticut, Illinois, Massachusetts, Michigan, New Jersey, North Carolina, Ohio, and Washington. Published information on Tennessee's practices was also reviewed. The states interviewed include two western states as well as states that have used statewide travel demand models for developing air quality modeling inputs. Interviews focused on a number of questions related to critical inputs, for which there are not accepted practices that fully make use of MOVES capabilities. These included the following questions:

- Source type distributions: Do you just use registration and/or HPMS data, or do you use any supplemental data sources, especially to get better information on HDVs?
- VMT by vehicle class: Do you use substate-level data, or just an average for the state? If substate-level data are used, at what scale is the data? How extensive is your classification system?
- Road type and temporal distributions – Do you use substate-level data, or just an average for the state? Do you use different distributions by source type (e.g., cars vs. trucks) or the same distribution for all source types?
- Speeds – Do you postprocess travel demand model speeds? If so, how? Do you validate model or postprocessed speeds against observed speeds? If so, what data sources and statistics do you use?

Information was requested on the level of staff effort and/or costs devoted to developing MOVES inputs. In general, the level of effort was relatively modest, with some fraction of one person's staff time dedicated to developing and using MOVES for local applications. In a few cases, agencies contracted out for specific activities (such as registration database analysis).

Colorado

The Air Pollution Control Division's (APCD) mobile source group contracts with a consultant (ERG) to develop fleet inputs from registration data (county-level), and with another consultant to do ozone modeling using SMOKE-MOVES (attainment areas) or CONCEPT-MOVES (nonattainment areas). The registration data do not represent HDVs well, so adjustments are made based on VMT data to determine HDV proportions of source types.

VMT data, including temporal distributions, are obtained from the Colorado DOT's website. The APCD works with disaggregated data (e.g., by vehicle class) as much as possible. However, classification data are not necessarily available at the county level, so they group attainment vs. nonattainment areas. Hour fractions are developed for each HPMS vehicle type. Some lower functional classes are not covered well, and they will use the next highest available functional class. (For the HPMS system, local roads are not covered and Colorado DOT assumes VMT is 10 percent of all other roads).

Age distributions were developed for as many of the MOBILE6 vehicle classes as could be determined in the 2011 Colorado registration data provided by the Colorado Department of Public Health and Environment (CDPHE). Since determining the MOBILE6 classification for each individual vehicle is time-intensive, the most consideration was placed on the LDV, light-duty truck (LDT), and HDV distributions. These distributions were calculated for each county in Colorado, as well as for the entire state. Several supplemental sources were used to help classify vehicles, including vehicle information determined from VINs decoded in the consultant's software, 2010 Colorado registration data, Colorado I/M program data, Automotive News, and manufacturer web-sites. In later processing, MOVES source type IDs were determined using the MOBILE6 category found for the vehicle, because the usage of the vehicle (personal or commercial use) was not always included in the registration data. The consultant used EPA guidance on mapping MOBILE6 vehicle types to their equivalent MOVES source types to determine the MOVES categories for the registration vehicles.

Resources:

- Dale Wells, Colorado Air Pollution Control Division, interviewed November 2013

Connecticut

The Connecticut Department of Energy and Environmental Protection (DEEP) develops MOVES inputs for the state, and some of these inputs have been borrowed by other Northeast states. Source type populations are based on state Department of Motor Vehicles (DMV) registration data using a data-driven VIN decoder/query tool, Microsoft Access postprocessors, and a spreadsheet to integrate with a VMT-based approach for Interstate highway data. The registration data or a VMT-based fraction, whichever is larger, is used to determine source type populations for trucks. Age distributions are based on state registration data except for trucks, where MOVES defaults are used.

DEEP undertook an extensive processing effort to develop VMT fractions and road type distributions using a combination of HPMS, travel demand, and older MOBILE6.2 data (using EPA converters), along with developing the adjusted source type populations. Day fractions are MOVES defaults, hour fractions are from HPMS, and month fractions are MOVES defaults adjusted with state-specific seasonal adjustments. Speed distributions are based on validated travel demand model data.

Connecticut's DEEP is one of a few agencies that did not use MOVES defaults for ramp VMT. 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 vs. expressway mileage in each county. Ramp VHT is estimated by dividing ramp VMT by the average speed for the appropriate road types set forth in MOBILE6.2 guidance.

Updates to fuel data, including Reid vapor pressure (RVP) and other parameters, were based on a local reformulated gasoline (RFG) survey. Local I/M program data from a program report were used.

Resources:

- Steve Potter, Connecticut Department of Energy and Environmental Protection, interviewed November 2013

Illinois

The Illinois Environmental Protection Agency (IEPA) uses MOVES for modeling I/M program changes and for coordinating with MPOs to set emissions budgets. Other agencies in the state have used MOVES; they have asked Illinois EPA for inputs, but they also may get inputs from other sources.

IEPA has set up and run MOVES for four areas of the state: two urban nonattainment areas (corresponding with the Chicago and St. Louis metropolitan areas) and two rural attainment areas (northern and southern Illinois, divided at 40 degrees longitude). Each area is modeled as a single county. This was originally done to reduce run time.

Source type and age distribution for LDVs are from state registration data. MOVES defaults are used for trucks and buses and are apportioned by VMT, as described in the U.S. EPA technical guidance.

VMT by vehicle class is obtained from Illinois DOT for each of the four areas. For road type, source type, and temporal distributions, they rely on U.S. EPA converter sheets (they are still working from 16 MOBILE vehicle types).

Urban area speeds are from the Chicago metropolitan area model, but have not been updated since they were developed for MOBILE6. For rural areas, MOVES defaults are used (again via the U.S. EPA spreadsheet converter). Future-year speeds are the same as for the current year.

Resources:

- Chuck Gebhardt, Illinois Environmental Protection Agency, interviewed November 2013

Massachusetts

The Massachusetts Department of Environmental Protection (DEP) is responsible for preparing most MOVES inputs. However, DEP obtains some of their inputs, including month, hour, and day VMT fractions, road type distributions, and speed distributions, from Connecticut DEEP. The northeast states work jointly on air quality issues through the Northeast States for Coordinated Air Use Management (NESCAUM). Connecticut took the lead on developing MOVES inputs a couple of years ago, and these have been reviewed by EPA.

Source type and age distributions are obtained from 2011 I/M program data, although DEP plans to use vehicle registration data from the Registry of Motor Vehicles (RMV) in the future. However, the I/M program data showed high numbers of motorcycles and low numbers of trucks, so these were adjusted based on Connecticut data. I/M program data are Massachusetts-specific. Fuel data are MOVES defaults, but adjusted for state-specific RFG formulations and RVP based on a 2007 EPA survey in Boston.

To be consistent with past practice, Central Transportation Planning Staff (CTPS), which is the staff of the Boston MPO, runs MOVES in rate mode, using VMT data from Middlesex County (from the travel demand model, adjusted for HPMS counts) to develop emission rates that are representative of the region.

Resources:

- Anne McGahan, Central Transportation Planning Staff, interviewed November 2013

Michigan

Michigan DOT uses MOVES for statewide implementation plan development, project-level analysis, and preparing NEI inputs. The Southeast Michigan Council of Governments (SEMCOG) also has used MOVES for $PM_{2.5}$ conformity.

Michigan DOT created a "master spreadsheet" tool to interface between state TDFM and MOVES inputs. The spreadsheet works tab by tab, takes model output (based on a user-specified file name), and converts the output to MOVES inputs. This process helped Michigan to be the first state to complete the NEI submittal without errors.

Fleet mix (source type population) and age distributions are obtained via a script run on an annual data dump of registration records from the Michigan Secretary of State. Processing is done using TransCAD and Microsoft Excel. Michigan DOT did not want to use a VIN decoder, because it requires annual updating. It takes at least 40 hours to run all scripts. Michigan DOT uses county-level population and age distribution data for both LDVs and HDVs, and assumes there are equal transfers of trucks in and out of other states. Transit, school bus, and postal vehicle populations are obtained directly from agencies (e.g., Department of Education for school buses; Department of Technology, Management, and Budget for transit vehicles).

VMT and road type distribution inputs are obtained from regional and statewide TDFMs. The TDFM is scaled to HPMS; local road growth rates are scaled according to collector growth in areas covered only by the statewide model. Road type distributions are by source type at the county level.

Michigan DOT uses default meteorology data (county-level EPA data is close to and better than what they could get from airports) and fuels (which they could not get from suppliers), except for some RVP corrections in conformity areas.

Resources:

- Pete Porciello, Michigan Department of Transportation, interviewed November 2013

For further reading:

- Michigan Department of Transportation (2012). "Technical Documentation for Using Moves 2010b for Transportation Conformity Analysis."
- Michigan Department of Transportation (2012). "Development of 2012 Vehicle Population Data from Secretary of State Vehicle Registration and Title Database for MOVES." Statewide and Urban Analysis Section.

New Jersey

New Jersey is a very urban state, covered by three MPOs – North Jersey Transportation Planning Authority (NJTPA), South Jersey Transportation Planning Organization (SJTPO), and Delaware Valley Regional Planning Commission (DVRPC) – and their respective travel demand models. New Jersey DOT, NJTPA, and SJTPO all currently use the AECOM/Baker product PPSUITE to produce activity-based MOVES inputs (VMT by vehicle class; average speed distribution; road type distribution; ramp fractions; month, day, and hour VMT fractions) from the travel demand model outputs (Perlman, Heller, Davies/Aleynick). PPSUITE produces the average speed distribution using a speed postprocessing method that uses hourly VMT distribution patterns to divide multihour volumes into individual hours, and then recalculates speeds based on an unknown function. The speed calculations also consider intersection delay and are done with road type and source type detail. Traffic counts are used to supplement travel demand model outputs in the calculation of some MOVES inputs, such as day and hour VMT fraction (Davies/Aleynick).

The New Jersey Department of Environment is responsible for creating the fleet inputs and other inputs for all counties in the state. Registration data are used for the age distributions and source type populations, with the exception of single-unit trucks (source types 52 and 53) and combination trucks (61 and 62), which are calculated in PPSUITE using the VMT-based method mentioned in the EPA guidance. The meteorology input is calculated using a 10-year average of local airport temperature and humidity data for each hour and each month. The I/M input is based on the characteristics of the local program, and the fuel inputs are based on a local fuel survey that identified RVP, sulfur levels, and ethanol volume (Perlman).

Resources:

- Jeffrey Perlman, NJTPA, interviewed November 2013
- David Heller, SJTPO, interviewed November 2013
- Gary Davies and Anna Aleynick, AECOM, interviewed November 2013

North Carolina

The Division of Air Quality (DAQ) runs MOVES for conformity, SIP work, statewide and county/regional inventories for submission to EPA, and occasional legislative requests.

Source types and age distribution are based on county-level registration data. The DAQ is considering some adjustments for trucks based on information from EPA training.

There is no statewide travel model. For non-MPO areas, the DAQ uses county-level HPMS for VMT; speeds are based on judgment. For MPO areas, the DAQ obtains modeled VMT by road class and speeds for up to four time periods, depending on the model.

The DAQ uses EPA converter spreadsheets, and in general uses EPA built-in distributions. Day and month distributions are from MOVES defaults. For nonattainment areas that are subsets of counties, the DAQ proportions source types based on human population at the township level.

Resources:

- Todd Pasley, North Carolina Division of Air Quality, interviewed November 2013

Ohio

Every MPO in Ohio has its own set of inputs, but primarily these are different for meteorology, road type distribution, and VMT by vehicle type. In the forecast year, only VMT changes; all other inputs are held constant.

Ohio DOT is using MOVES default speed distributions. They tried using ATR speeds, but there were not enough observations per county. They also tried using statewide average speeds from the ATRs, but the data were "all over the place." The same speeds are used in the forecast year as are used in the base year. Ohio DOT is developing a statewide model, but is not confident in the speed estimates in the beta version.

Source type populations were determined from motor vehicle registration data, which took a long time to get because of privacy concerns. MOVES default proportions were used for source types 61 and 62 (heavy trucks) since the registration data was unavailable for Ohio. Road type and temporal distributions are the same for all source types.

Resources:

- Nino Brunello, Ohio Department of Transportation, interviewed November 2013

Tennessee

In 2011, consultants for the Tennessee DOT completed a strategic plan for transitioning Tennessee to the MOVES model (AECOM 2011). The report notes that several MOVES inputs, such as age distribution and source type population, were being prepared by the University of Tennessee (UT) using registration data. Similarly, it notes that other MOVES inputs, such as I/M program and fuel data, were being prepared by Tennessee Department of Environment and Conservation (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 provides details on the data sources that each MPO is using for each of the 13 MOVES inputs when running MOVES for regional conformity. 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.

For further reading:

- AECOM. 2011. *Strategic Plan for The Transition of Regional Emissions Technical Procedures to USEPA's MOVES Emissions Model.* Prepared for Tennessee DOT, Long-Range Planning Division.

Washington

The Department of Ecology runs MOVES in rate mode for daily inventories and inventory mode for annual county-level inventories. Washington has nonattainment areas that are subsets of a county (e.g., the Tacoma $PM_{2.5}$ area has been modeled). Rates are applied to VMT within the nonattainment area, and vehicles (source types) are proportioned based on human population. County-level inventories are factored based on the fraction of county VMT within the nonattainment area.

Age and source type distributions are from classified Department of Licensing (DOL) registration data (a VIN decoder was not used). Data were taken from the National Transit Database for transit buses, and from the Office of the Superintendent of Public Instruction for school buses. Intercity buses were factored from transit buses using the EPA default split. For trucks, source type fractions were created by county based on VMT fractions by county. Statewide average age distributions were used for trucks, and county-specific age distributions were used for most other vehicles (see Washington State Department of Ecology Air Quality Program, 2013, page 11 for details). The Department of Ecology has written Perl scripts to process registration and VMT travel fraction data into the MOVES age distribution and source population files.

County-level VMT estimates are obtained from Washington State DOT's HPMS system. However, LDV/LDT splits are based on registrations rather than VMT because of suspect ATR classification data. Temporal adjustments are statewide (the same for all vehicle classes) rather than county-specific, but are specific to road type and, therefore, vary by county depending on the mix of road types within the county. Road type distributions were developed by county using a "complicated procedure." Formulas for all of these inputs are included in the documentation.

For the SIP, congested speeds from the TDFM model are used (but are not postprocessed). For 2011 county inventories, MOVES default speed distributions were used.

The Department of Ecology used the MOVES meteorological defaults, which it examined and found to be reasonable. Fuel parameters are a combination of local fuel survey data and MOVES defaults. Local I/M program data are used.

Resources:

- Sally Otterson, Washington Department of Ecology, interviewed November 2013

For further reading:

- Washington State Department of Ecology Air Quality Program (2013). "MOVES Input Parameters and Processing."

Review of NEI Submittals

The EPA requires states to submit MOVES inputs every three years to support the NEI. Team member ERG reviewed the submittals in support of the 2011 NEI as part of quality assurance work performed for the EPA (Contract number EP-D-11-006, Work Assignment 4-01). Through this review, ERG also was able to determine the source of MOVES inputs used by the states. Table 119 of the draft NEI technical documentation (EPA 2014b) – published after this literature review was conducted – provides a summary of "best practices" and "suggested fallbacks" for each MOVES input.

The review of NEI submissions found that most states have developed inputs at a county level to support the submissions. However, many states have simply provided default inputs rather than developing inputs that are based on state-specific data. This is especially true for activity data, such as VMT temporal and road type distributions. Registration-based data are more often taken from state-specific records. EPA conducts range checks on the submitted data to ensure the data are of reasonable magnitude and has developed updated default data for some inputs where states did not supply data.

Arizona Conformity Study

Under a separate contract to ADOT, Michael Baker Jr., Inc., prepared a report on air quality conformity issues (ADOT 2013) as part of the Transportation Air Quality Conformity Guidelines study. The report provides recommendations for conformity analysis, including the data sources for MOVES. The report also cites experience in other states, including Maryland, New Jersey, and Pennsylvania. The report notes the following points relevant to this current research on MOVES inputs:

- The ADOT statewide model can provide VMT by time period, speed distribution, and disaggregation of vehicle types using link-specific truck forecasts in combination with other sources.
- VMT from the travel model needs to be adjusted for missing collector and local roads. HPMS data can be used to adjust model data for monthly and day-of-week variations, and to ensure that VMT is consistent with totals reported to FHWA.
- Speeds may need to be recalculated after VMT adjustments are made. Some states have developed postprocessing procedures to recalculate congested speeds on an hourly basis based on travel model volumes, hour fractions, roadway physical characteristics, and free-flow speed data.
- In many areas, local day and month adjustments appear reasonably consistent with the national averages contained in MOVES defaults. However, if a specific county has unique travel characteristics by season or between weekdays and weekends, then it may be desirable to use local count data.
- ADOT has developed hourly pattern files based on information from the statewide model, apportioning volumes by time period to individual hours based on MOVES defaults. A more detailed approach could be used to estimate aggregate hourly fractions based on variances by functional class or even link.
- Ramps are included in the statewide model, and the model could be used as an alternative to the default eight percent ramp fraction value, but should be evaluated for reasonableness before doing so.
- Source type population inputs should grow in future years to account for growth in households, population, and employment.
- Fuel supply data may need to be adjusted to account for local blending requirements and RVP.

MOVES-Based Conformity Determination Reports in Arizona

Research was conducted to identify any MOVES-based conformity determination reports completed so far in Arizona. This was done to determine what data sources and methods have been used to create MOVES inputs to date, so that they can be used as a starting point for Tasks 4 and 5. ADOT (2013) indicated that the three MPOs responsible for preparing initial conformity determinations are the MAG, the Pima Association of Governments (PAG), and the Yuma Metropolitan Planning Organization (YMPO). The remaining areas of the state rely on ADOT and ADEQ to prepare initial conformity determinations, which has not yet been done with MOVES. The status of MOVES input development in each MPO area is as follows:

- **MAG (Maricopa County) –** A Draft Conformity Analysis was prepared by MAG for fiscal year (FY) 2014 to 2018 Transportation Improvement Program (TIP) and the 2035 Regional Transportation Plan (RTP) (MAG 2013). This analysis includes nonattainment/maintenance areas in Maricopa County and Pinal County. The MAG planning area extends into portions of Pinal County. The Sun Corridor MPO was formed in 2013, around the same time as a conformity lapse in the West Pinal PM_{10} nonattainment area. Therefore, MAG provided assistance to the new Sun Corridor MPO by conducting the conformity analysis for the PM_{10} and $PM_{2.5}$ nonattainment areas in Pinal County that are actually covered by the two MPOs. MOVES was run in rate mode, and the MOVESLink postprocessor was used to calculate total emissions.
- **PAG (Pima County) –** PAG's most recent RTP was adopted in July 2010, when MOVES was not required yet. The conformity analysis at that time used MOBILE 6. PAG will probably do a MOVES-based conformity determination in 2014, based on typical four-year planning cycles.
- **YMPO (Yuma County) –** YMPO adopted a MOVES-based conformity analysis in July 2013. ADOT assisted with providing information on some of the inputs, and others use MOVES defaults. MOVES was run in inventory mode.

Tables 1 and 2 describe the data sources for the MOVES inputs for the Maricopa, Pinal, and Yuma County analyses, based on information from MAG (2013), PAG (2010), and YMPO (2013).

Table 1. Activity Inputs – Summary of MOVES Input Data Sources
Prepared for Conformity Determinations in Arizona
Based on information from MAG (2013), PAG (2010), and YMPO (2013)

Input	Maricopa and Pinal Counties	Yuma County
VMT by vehicle class	MAG travel demand model, which included calibrated truck model (not reconciled to HPMS).	Daily VMT from YMPO travel demand model with EPA's daily to annual VMT converter applied.
Road type distribution	Unclear from Draft Conformity Analysis.	2008 Arizona Statewide Travel Demand Model (AZTDM data were obtained from ADOT for use in this data field. Data were provided in a format appropriate for use in a MOVES data converter developed by the EPA. 2008 data were used for all analysis years.
Temporal adjustments (hour VMT fractions)	Traffic volumes for four time periods for each link are converted into hourly volumes based on traffic count data collected in Maricopa County in 2007.	2008 Arizona Statewide Model data were obtained from ADOT. Data were provided in a format appropriate for use in a MOVES data converter developed by the EPA. 2008 data were used for all analysis years.
Temporal adjustments (day and month VMT fractions)	Unclear from Draft Conformity Analysis.	Determined using EPA conversion tool for annual average weekly VMT.
Ramp fraction	Unclear from Draft Conformity Analysis.	Local data obtained from YMPO travel demand model.
Average speed distribution	MAG travel demand model validated with purchased 2011 speed data from Nokia.	Data obtained from the YMPO travel demand model. VHT split was separated into the MOVES speed bins by roadway type. Since this model does not have a time-of-day component or separate vehicle classes, the average speed distributions are the same over all hours and source types.

Table 2. Fleet and Other Inputs – Summary of MOVES Input Data Sources Prepared for Conformity Determinations in Arizona Based on Information from MAG (2013), PAG (2010), and YMPO (2013)

Category	Input	Maricopa and Pinal Counties	Yuma County
Fleet Inputs	Age distribution by source type	July 2013 vehicle registrations for respective counties obtained from ADOT.	January 2013 vehicle registration data for the Yuma area was obtained from ADOT, along with a conversion process spreadsheet to modify this data for use in the EPA converter spreadsheet. This information can be used to determine all source types.
	Source (vehicle) type population	July 2013 vehicle registrations for respective counties obtained from ADOT.	January 2013 source type population information was obtained for the Yuma area from ADOT. Conversion to MOVES source types was conducted using ADOT and EPA spreadsheets. Future-year growth was obtained by determining annual VMT growth rates, and then applying those growth rates to the 2013 source type population.
Other Inputs	Meteorology data	Unclear from Draft Conformity Analysis.	Default values (consistent with previous ADOT runs)
	Inspection and maintenance programs	Enhanced I/M program implemented in 1995; "phased-in I/M cutpoints" implemented in 2000; future years assume on-board diagnostic (OBD) tests for model year (MY) 1996 and newer vehicles, except the current plus four MYs (only for a portion of the Pinal County area).	No data were entered.
	Fuel formulation and supply	Oxygenated gasoline with an assumed market share of 100 percent ethanol. Arizona Department of Weights and Measures (AZDWM) provided fuel inspection data on gasoline volatility and average oxygen content.	Default values (consistent with previous ADOT runs).

SUMMARY OF FINDINGS

The survey previously conducted for NCHRP Project 25-38 (Porter et al. 2014), as well as additional interviews conducted for this project, confirmed that few state agencies have gone beyond basic data sources or processing methods in developing MOVES inputs.

For **fleet inputs** (age distribution and source type population), state motor vehicle registration databases are the most common source. However, source type populations for trucks are often based on observed VMT fractions (by vehicle type) and miles per vehicle from MOVES, because trucks are commonly registered in other states. Similarly, MOVES default age distributions are often used for trucks. Fleet-specific data on transit and school buses are sometimes used, if available, and these vehicles are not adequately captured in registration databases.

For **activity inputs**, travel demand models may be used to develop total VMT, road type distributions, and speed distributions for those states that have a statewide model, or for metropolitan areas within the state. Where models are not used, HPMS/traffic counter data are typically used to develop VMT and road type distribution inputs. Some MOVES users use HPMS/count data to develop temporal distributions (month, day, and/or hour fractions), but others use MOVES defaults. In areas with travel demand models, VMT by time period is usually used as a basis for hour fractions. Temporal distributions are typically developed only at the statewide level; it is more common for road type distributions to be developed at a county or other substate level, especially if a travel demand model is available.

Only a few agencies have developed different temporal or road type distributions by source type. The coverage of classification counters varies widely by state, but is usually not adequate to develop source type-specific distributions at a substate level. However, if different temporal distributions are developed by road type, the county-level distributions by source type may vary because of the different road type mix in each county.

Where nonattainment areas represent a portion of a county, the emissions inventory for the nonattainment area is typically obtained from the county-level inventory by proportioning based on the fraction of VMT occurring within the area, with source type population apportioned based on human population.

For **other inputs**, agencies have generally not found a good reason to replace the EPA default meteorological data. The default fuels information is also frequently used, although it may be supplemented by state-specific surveys, for example, in areas where RFG is required. I/M program data are almost always obtained from the local agency managing the program.

It is common practice to make use of EPA’s spreadsheet converter tools. These were originally developed with the objective of helping agencies convert MOBILE6 to MOVES inputs, but since they contain “default” proportions, they also are useful (for example) for converting data into the 13 source type categories required by MOVES.

A few noteworthy practices were identified in the research:

- Washington (Department of Ecology) has possibly the most thorough documentation and greatest attention to detail in making use of available data to develop state-specific inputs, mixing with MOVES defaults as appropriate.
- Michigan (DOT) developed a spreadsheet-based tool to convert travel demand model output and other data to MOVES input, which has allowed them to prepare quality-assured inputs for all counties in the state.

- Colorado (Air Quality Division) and Illinois (IEPA) have both developed inputs for substate areas: Colorado for attainment vs. nonattainment areas, and Illinois for two rural and two urban areas. This can be one approach for developing substate-level inputs where source data may not support different inputs at the county level.
- Most states have developed inputs at a county level to support the NEI submissions required by EPA. Where nonattainment areas represent a portion of a county, the emissions inventory for that area is typically obtained from the county-level inventory by proportioning according to the fraction of VMT occurring within the area, with source type population apportioned according to human population.
- Supplemental data collection efforts, which have thus far been primarily for research purposes, could potentially assist ADOT in creating more robust state-specific inputs. For example, license plate surveys can be used to determine proportions of out-of-state vehicles. Emerging telematics-based data sources, generally from private providers, can increasingly be used to observe actual speeds.

In addition to these findings, a sensitivity analysis and review conducted for NCHRP 25-38 provides insights into which inputs might be more or less important for refining local data (Porter et al. 2014). For example, temporal distributions (hour, day, and month VMT fractions) were found to have negligible impact on annual inventories, while age distributions, speed distributions, and car/truck splits can have a significant impact. One study in the literature review also noted the high importance of improving activity data for HDVs, and investigated alternative data sources for doing so.

Finally, the research conducted for ADOT's conformity guidebook (ADOT 2013) includes some insights into Arizona-specific data issues, as well as EPA guidance and current practices from other states.

CHAPTER 3. DATA NEEDS ASSESSMENT

OBJECTIVES

This data needs assessment addresses several crucial questions in the development of local MOVES inputs:

- What existing datasets are available in Arizona to produce the inputs?
- Are there any limitations (data gaps or quality issues) with respect to the preparation of reliable MOVES inputs?
- What options are available for obtaining supplemental data or enhancing existing data collection efforts to improve the quality of MOVES inputs?
- What are the short-term and long-term recommended data sources for developing MOVES inputs specific to Arizona?

This assessment focuses on data for county-level MOVES runs. However, some of the data, particularly the fleet data (age distributions and source type populations) and other data (meteorology, I/M programs, and fuels), may also be used for project-level runs. Other project-level data (such as link volumes, speeds, geometry, and off-network data) need to be obtained on a project-specific basis.

Ideally, county-specific inputs would be developed for each county in Arizona. However, for some inputs, it will be necessary to use regional or statewide averages due to data limitations. It also may not always be possible to provide inputs specific to each of the 13 source (vehicle) types specified by MOVES, so that MOVES default data or averages across source type may be required to support some inputs. This report addresses the spatial and source type coverage of data and the level of detail that can be obtained for each input.

METHODS

To obtain the information provided in this report, the project team reviewed websites and/or contacted staff at ADOT, ADEQ, AZDWM, MAG, and PAG.

SUMMARY OF FINDINGS

Table 3 lists the MOVES inputs that were examined and the potential local sources for these inputs. Table 3 also summarizes the potential data sources and processing methods that could be used for each MOVES input. The focus is on data sources used by states, which may cover both metropolitan and nonmetropolitan areas, rather than on data sources that may only be available within metropolitan areas. Typical or common data sources are identified, along with key issues/challenges encountered and potential supplemental sources that could be used to improve inputs in Arizona. The conclusions in Table 3 are based on the literature review findings presented in Chapter 2.

Table 3. MOVES Inputs and Data Sources for State Applications

Category	Input	Approaches to Developing Input	Issues/Challenges	Potential Alternative or Supplemental Data Sources for Arizona
Fleet Inputs	Age distribution by source type	Approach 1: State vehicle registration data, often supplemented with transit and school bus fleet data. Approach 2: State vehicle registration and fleet data, but with MOVES default distributions used for some or all truck and bus categories. Approach 3: I/M program records (light-duty) and national defaults (trucks, buses) used if vehicle registration hard to obtain or work with.	Out-of-state and unregistered vehicles not included in registration databases.	License plate surveys could be used to determine out-of-state vehicle fractions.
	Source (vehicle) type population	Approach 1: State registration data, often supplemented with transit and school bus fleet data. Approach 2: State registration data for LDV; for some or all truck and bus types, statewide VMT fractions by HPMS type (6 categories) combined with MOVES default miles/vehicle to estimate total population in 6 types and MOVES defaults used to further obtain 13-type breakout.	Out-of-state and unregistered vehicles not included in registration databases.	Investigate potential availability of commercial vehicle safety database. Investigate bus fleet data sources. License plate surveys could be used to determine out-of-state vehicle fractions.
Activity Inputs	VMT by vehicle class	Approach 1: Area-wide total VMT from traffic counts (HPMS) apportioned to 6 vehicle types by statewide VMT fractions from classification counters. Approach 2: Travel demand model, apportioned to vehicle types using similar method.	Classification counter coverage usually not enough to break out VMT fractions at a substate level.	Review classification counter coverage and sample data to determine whether substate or road type-specific apportionments can be determined.
	Road type distribution	Approach 1: Unclassified traffic counts from HPMS system, statewide average. Approach 2: Unclassified traffic counts from HPMS system, county-specific distributions. Approach 3: Travel demand model.	Typically not differentiated by source type due to limited classification count coverage.	Review classification counter data to determine whether road type-specific apportionments can be determined and combined with unclassified road type distributions.

Table 3. MOVES Inputs and Data Sources for State Applications (Continued)

Category	Input	Approaches to Developing Input	Issues/Challenges	Potential Alternative or Supplemental Data Sources for Arizona
Activity Inputs (continued)	Temporal adjustments (hour VMT fractions)	Approach 1: Unclassified traffic counts from HPMS system, statewide average. Approach 2: Model VMT fractions by time period, further broken out to hour using HPMS data or MOVES defaults.	Classification counter coverage never adequate to develop source-specific temporal distributions at a county level.	Review classification counter data to determine whether substate or road type-specific apportionments can be determined with hour of day detail.
	Temporal adjustments (day and month VMT fractions)	Approach 1: Unclassified traffic counts from HPMS system, statewide average. Approach 2: Unclassified traffic counts from HPMS system, county-specific distributions. Approach 3: Classified traffic counts from HPMS system, type-specific adjustments at statewide average or for substate areas.	Classification counter coverage never adequate to develop source-specific temporal distributions at a county level.	Review classification counter coverage to determine whether substate or road type-specific apportionments can be determined with day of week and month of year detail.
	Ramp fraction	Approach 1: MOVES default (8 percent). Approach 2: Travel demand model. Approach 3: Proportion freeway VMT data by ratio of ramp to freeway lane-mileage.	Actual ramp fraction may significantly differ from MOVES defaults in very urban and very rural areas. Travel demand model may not use ramps as a separate road type when calibrating/validating to counts.	Review ramp counts and ramp lane mileage information available.
	Average speed distribution	Approach 1: Travel demand model. Approach 2: Current year observed speeds, from ATRs or other source.	Model free-flow speeds are often lower than observed speeds. Volume-delay functions are not very good at predicting speeds.	Emerging data sources from in-vehicle monitoring (GPS, cell phones, Bluetooth).
Other Inputs	Meteorology data	Approach 1: MOVES defaults. Approach 2: NCDC from local monitoring stations (typically at airports).	Not all areas of the state have a local monitoring station.	
	I/M programs	State agency overseeing program.		
	Fuel formulation and supply	Approach 1: MOVES defaults. Approach 2: Local fuel surveys, if available.		

The project team's findings and recommendations regarding data sources for each set of MOVES inputs are described below and summarized in Table 4. *Some of the preliminary recommendations in this section may be superseded by final recommendations, as presented in later chapters and in the summary to this report. In addition, this review took place prior to the release of MOVES2014 and does not reflect updated fuels and I/M program data contained in that model release.*

Fleet Inputs

Fleet inputs include age distribution and source (vehicle) type population. Inputs are provided for 13 categories of LDVs, trucks, and buses. The primary source of fleet inputs is the state registration database, which provides information on registered vehicles by county. Data from Arizona's I/M program also could be used as a supplemental or alternative source for covered vehicle types if registration data are difficult to obtain or analyze.

The latest available Arizona registration data should be obtained and analyzed to develop both age distributions and source type populations. The primary limitation of this database is that it does not have information on vehicle use to split LDTs into passenger and commercial categories, or HDTs into short- and long-haul categories. At least in the short term, it will be necessary to use MOVES default values for these proportions. In the long term, additional research efforts may be possible to better evaluate in-state vs. out-of-state vehicles and short- vs. long-haul use.

Activity Inputs

Activity inputs include VMT by vehicle class, road type distribution, temporal adjustments (hour, day, and month VMT fractions); ramp fractions; and speed distributions. The primary sources of activity data include ADOT traffic monitoring data from the Transportation Data Management System (TDMS), and the Arizona statewide and five MPO travel demand forecasting models.

The existing data are generally adequate for preparing VMT-based MOVES inputs. Priority is given to using MPO model data for VMT and road type distributions in the five metropolitan areas, where these models are available. Outside of these areas, statewide model VMT and HPMS VMT by road type should be used. For counties that are partially in an MPO area, it may be necessary to combine MPO and statewide travel demand model outputs to obtain VMT for the entire county. Traffic monitoring data should be used to validate base-year VMT, and also to provide temporal adjustments. The existing monitoring system is not extensive enough to provide source type-specific adjustments at a county level, but it may be adequate to provide separate adjustments for major subareas of the state (e.g., north and south) if significant differences are observed. In the long term, an expanded network of classification counters could improve county-level adjustments.

Table 4. Summary of (Preliminary) Recommended MOVES Data Sources[a]

Category	Input	Short-Term Recommendations	Long-Term Recommendations
Fleet Inputs	Age distribution by source type	From Arizona motor vehicle registration database for most vehicle types. MOVES defaults for long-haul single unit and combination trucks (compare with Arizona data first).	Add fields to registration database to enhance usability for developing MOVES inputs. Consider license plate surveys to identify out-of-state vs. in-state vehicles and potentially adjust age distributions accordingly.
	Source (vehicle) type population	From Arizona motor vehicle registration database (LDVs and buses). Arizona heavy-duty VMT estimates divided by MOVES default miles per vehicle for trucks (compare with Arizona registration-based estimates first).	Add fields to registration database to enhance usability for developing MOVES inputs. Consider more extensive registration database analysis or commercial vehicle surveys to determine short vs. long-haul use for trucks.
Activity Inputs	VMT by vehicle class	Total VMT (existing and forecast) from MAG, PAG, YMPO, Central Yavapai Metropolitan Planning Organization (CYMPO), and Flagstaff Metropolitan Planning Organization (FMPO) travel demand models (metropolitan areas); Arizona travel demand model (rural areas). Statewide and MAG models have VMT for autos and two truck classes. ADOT classified traffic counts to break down total VMT into six vehicle classes (group counties into substate regions to provide enough classified data). ADOT traffic counts/HPMS reports for validation for areas outside MAG.	Expanded coverage of classification counters could provide source type-specific VMT data at the county level.
	Road type distribution	Use MPO model (where available) or statewide model (elsewhere) data to develop VMT fractions by road type. Use statewide model (except in MAG area) to develop different road type fractions by vehicle type (autos, single-unit, combination trucks) and ADOT classified counts to break down into five vehicle classes.	Expanded coverage of classification counters could provide validation of model data, or actual data, to estimate source type-specific VMT fractions by road type.

[a] Recommendations may be superseded by final recommendations provided in Chapters 4 and 5.

Table 4. Summary of (Preliminary) Recommended MOVES Data Sources (Continued)[a]

Category	Input	Short-Term Recommendations	Long-Term Recommendations
Activity Inputs (continued)	Temporal adjustments (hour, month, day VMT fractions)	Break down MAG, PAG, and statewide model (other areas) 4-period VMT fractions into 24-hour fractions using distribution from statewide traffic counter network. Apply month and day fractions from statewide traffic counter network. Either use source type-specific distributions at a statewide level, or all-source distributions at a county or substate level (evaluate data for source type and geographic differences to see which are more significant).	Expanded coverage of classification counters could provide source type-specific temporal adjustments at the county level.
	Ramp fraction	Calculate ramp fractions from MPO and statewide travel demand models. Validate model volumes with ADOT ramp traffic counts.	Expand ramp counts to additional Interstates especially in the northern portion of the state.
	Average speed distribution	Use MPO travel demand model outputs for MPO area speeds. Compare statewide model speeds against observed speed data for rural areas; use model data if distribution is close to observed data. Apply speed postprocessing methods to travel demand model outputs to develop speed distributions for each hour of the day.	Engage in additional speed data collection (procure from private providers for validation and calibration of speed prediction models, and possibly use of observed speed data in rural areas). Consider research study to evaluate differences in speeds by vehicle type at sample locations.
Other Inputs	Meteorology data	Use NCDC Local Climatological Data (LCD) summaries.	N/A
	I/M programs	Use MOVES defaults with some adjustments to more accurately reflect program details.	Monitor I/M program and incorporate any changes.
	Fuel formulation and supply	Use MOVES defaults.	If fuel sample testing is conducted in Arizona, work with sponsoring agency to obtain data suitable for validating or updating MOVES inputs.

[a] Recommendations may be superseded by final recommendations provided in Chapters 4 and 5.

Travel demand model data (from MPO models in metropolitan areas and the statewide model elsewhere) is also recommended for creating speed distributions. However, for rural areas, statewide model predictions should be compared against observed speed data from ADOT's monitoring network, and consideration should be given to using observed speed data or recalibrating statewide model parameters if significant differences are observed. Postprocessing of model data is recommended to create distributions for each hour of the day. In the long term, acquisition of additional speed data will support validation and improvement of speed estimates.

Other Inputs

Other inputs include meteorology, I/M programs, and fuel formulations. Only modest effort should be required to create or update these inputs. Meteorology data should be obtained for each county from local NCDC monitoring stations and is freely available on the Internet. The default I/M and fuels data in MOVES are reasonable representations of actual conditions in Arizona. Some tweaks should be made to the I/M data in MOVES2010 to better represent the programs active in the Phoenix and Tucson areas. Fuels data would be difficult to update without an extensive field survey, and this is considered a low priority.

FLEET INPUTS

The fleet inputs to MOVES for regional/county-scale analysis include:

- Age distribution (by source type)
- Source type population (total vehicles in modeling domain by source type)

In order to develop MOVES fleet inputs that are an alternative to national defaults, a list of the number of vehicles registered in the fleet by age and MOVES source type must be obtained or developed for each geographical area being modeled. The vehicles in each area can then be summed for each source type and geographical area to obtain the source type population. Then the age distributions can be calculated from the total source type population and ages of the vehicles in each set.

Existing Data Sources

The fleet inputs are typically obtained from the state motor vehicle registration database. In Arizona, the DOT's MVD maintains this information. The registration database contains a list of all registered vehicles in the state and the fields necessary for separating the vehicles into MOVES source types and modeling geographical areas. The registration database has information, such as vehicle type, vehicle weight, vehicle MY, vehicle fuel type, and county of registration (for geographical area). In some states, the information in the fields (especially information such as vehicle weight) is not populated for all trucks or is not reliable for a good portion of the data. In these instances, the VIN can be very helpful for filling in any missing information. The VIN can be decoded to determine the manufacturer, MY, engine type, fuel type, and weight of the vehicle. The VIN and the decoded VIN information are alternate and standardized sources of this vehicle information that can be used to check the quality of the data provided in the fields from the registration database.

Other sources, such as I/M program data from ADEQ, can be used to develop the fleet inputs. However, usually a state's I/M program does not test all vehicles in the fleet. Arizona's Vehicle Emissions Inspection Program covers only the Phoenix and Tucson metropolitan areas; the newest five MYs are exempt from the program, as are commercial vehicles registered in other states.

Additional sources of data can include traffic counters, traffic cameras, or any other sources that count the traffic on the roads in the pertinent areas. These sources can provide information on the fraction of vehicles on the road by vehicle type, which can be used to estimate source type populations, using estimates of total VMT and annual miles traveled per vehicle. Traffic counters, however, do not provide information on the age of the vehicle. The sample of roadways also may not be representative of the entire vehicle population.

Limitations of Existing Sources

The Arizona MVD vehicle registration database, like most state registration databases, has at least two key limitations:

- First, it does not include vehicles registered out of state, so these vehicles will not be reflected in age distributions or source type populations. This is a minor limitation for LDVs and certain heavy-duty types (school and transit buses, refuse trucks), which are primarily driven in-state. It is more significant for HDTs, especially long-haul trucks that are often registered in other states.
- Second, it does not contain usage information to distinguish short-haul from long-haul trucks. Single-unit and combination trucks are split into "short-haul" and "long-haul" categories, which is a characteristic of how the vehicle is used, not the vehicle itself.

Because of the second limitation, most MOVES users apply MOVES default values to split trucks into short- and long-haul categories. To address the first limitation, some MOVES users apply national age distributions, rather than state registration data, for long-haul trucks from MOVES defaults, since these trucks commonly operate across state boundaries. Estimates of source type populations for trucks also can be based on VMT by vehicle type (from models or traffic count data as described in the "activity inputs" section) and average annual mileage per vehicle (from MOVES defaults).

The limitations in geographic and vehicle MY coverage for the Arizona I/M program are such that this source is not recommended, unless MVD data cannot be obtained or are too difficult to analyze. The I/M data could be used to evaluate source type populations for the Phoenix and Tucson metropolitan areas, but are not a good source of age distribution data since they exclude the first five MYs.

Potential Supplemental Sources and Data Enhancements

In the absence of better local data, it is often necessary to split the single-unit and combination truck categories into short-haul and long-haul categories using MOVES default proportions. This can be done manually, or using a method and a tool developed by EPA to convert the old MOBILE6 categories into the MOVES source type IDs.

There are at least two possible additional methods for evaluating short-haul vs. long-haul truck use:

- Mining registration data using algorithms that estimate a vehicle's use pattern based on reported factors, such as MY and vehicle type. This was done in the 2013 California Truck Inventory and Impact Study by the California Hybrid, Efficient, and Advanced Truck Research Center (CalHEAT), which evaluated 1.5 million commercial vehicle records from Polk registration data.
- Conducting field surveys of commercial vehicles to determine origin and destination patterns. Such an effort could also provide information to assist in calibrating truck model components of the statewide and MAG travel demand models. However, such survey efforts tend to be expensive and difficult to carry out.

Another research effort that would potentially improve fleet information is a license plate survey on selected Arizona roadways. The survey would identify the proportion of in-state vs. out-of-state vehicles by vehicle type. If possible, age distribution information for out-of-state vehicles could be obtained from neighboring states and combined with in-state data to develop an overall age distribution. Alternatively, the MOVES default distribution could be used for out-of-state vehicles.

In the long term, improvements could be made to the state registration database to make it easier to translate the data into MOVES inputs. Among other things, this might include identification of the vehicle's primary use (local vs. long haul) for trucks.

Recommendations

The recommended primary source for developing fleet inputs is the Arizona MVD motor vehicle registration database. Many fields in the registration database would not be needed for this analysis. The fields that would be needed for this project are the vehicle type, vehicle weight, vehicle MY, vehicle fuel type, and county of registration (for geographical area). Also, any other information about the weight class or registered weight category would be useful. The VIN would be needed to fill in any missing information. The VIN can be decoded to determine the manufacturer, MY, engine type, fuel type, and weight of the vehicle.

Estimates of HDV source type population from this database should be compared with estimates based on VMT and mileage per vehicle (using methods described under the "Activity Inputs" section below) to evaluate the extent to which Arizona-registered trucks may be representative of the fleet on the road. Consideration should be given to using national default data for long-haul truck age distributions and to estimating truck source type populations using Arizona county-level VMT and MOVES default miles per vehicle by vehicle type.

In the long term, ADOT should consider a research effort to mine the MVD database to determine whether short- vs. long-haul truck use can be estimated from other parameters. In addition, ADOT should work with MVD to adjust the registration database to make it easier to process for developing MOVES inputs.

Recommendations for buses (transit, school, and motorcoach) are needed and will be made after a more detailed evaluation of MVD data.

ACTIVITY INPUTS: VMT AND VMT-BASED ADJUSTMENTS

VMT and VMT-based adjustments as MOVES inputs include:

- VMT by vehicle class (six classes)
- Road type distribution (VMT by MOVES road type) – can be provided by source type
- Temporal adjustments (hour, day, and month VMT fractions) – can be provided by source type and road type
- Ramp fraction (fraction of highway travel on highway entrance/exit ramps)

All of these inputs are based on traffic volumes and can be derived from travel demand model outputs and/or traffic monitoring data. Table 5 summarizes the current data sources used for VMT-based inputs based on MOVES-based conformity determinations conducted to date in Arizona. As can be seen in this table, travel demand model outputs are the main local data source, with some traffic monitoring counts used to develop temporal adjustments in the MAG area. MOVES defaults are used in a number of cases to fill in details, such as how VMT is split by vehicle types and temporal periods.

In the following subsections, existing travel demand model data are described first, followed by existing traffic count data, a discussion of the limitations of the existing data sources, and a discussion of how traffic monitoring data and HPMS reports can be used to supplement travel demand model data. Our recommendations for producing VMT-based MOVES inputs are summarized at the end of this section.

Existing Data: Travel Demand Models

Travel demand models are an important source of activity-based data for MOVES inputs, since they are able to forecast VMT for future years based on socioeconomic forecasts and based on new transportation projects that have not yet been built. Travel demand models often incorporate traffic monitoring data, or at least use it to validate the model results. For example, MAG's travel demand model uses 3,000 traffic count locations to validate total volumes estimated by the model; 550 of these locations provide vehicle classification counts used to validate medium-duty truck and HDT volumes. The MAG, PAG, and YMPO regional travel demand models have been used to create VMT-based MOVES inputs for transportation conformity purposes. Table 5 summarizes the use of these models to create VMT-based MOVES inputs.

Table 5. Current Sources for VMT-based MOVES Inputs Used in Arizona Conformity Determinations

MOVES Input	Maricopa and Pinal Counties	Pima County	Yuma County
VMT by vehicle class	MAG travel demand model, which was not reconciled to HPMS, but was calibrated/validated to 2011 traffic volumes from 3,300 count locations. Of these locations, 550 have classified counts that are used to validate medium and heavy truck volumes. MOVES defaults to split three vehicle types down to six.	PAG Travel Demand Model data – average daily VMT plus 13 percent of total VMT to account for local street travel. Default vehicle type splits found in MOVES tool used to split VMT.	Daily VMT from YMPO travel demand model with EPA's daily to annual VMT converter applied.
Road type distribution	MAG travel demand model plus MOVES defaults to get six HPMS vehicle types by road type. Same road type distribution applied to all source types within an HPMS type.	ADOT vehicle counts in Pima County for rural and urban restricted-access (2011 and 2012 combined); PAG consultant counts for urban and rural unrestricted-access (2011 and 2012 combined); Classification of rural vs. urban roadways is from ADOT classification system.	2008 Arizona Statewide Model data were obtained from ADOT for use in this data field. Data were provided in a format appropriate for use in a MOVES data converter developed by the EPA. 2008 data were used for all analysis years.
Temporal adjustments (hour VMT fractions)	Traffic volumes for four time periods for each link are converted into hourly volumes based on traffic count data collected in Maricopa County in 2007.	MOVES defaults.	2008 Arizona Statewide Model data were obtained from ADOT. Data were provided in a format appropriate for use in a MOVES data converter developed by the EPA. 2008 data were used for all analysis years.
Temporal adjustments (day and month VMT fractions)	Day-of-week and month-of-year conversion factors were derived from the traffic count data collected from permanent traffic counters in 2007.	MOVES defaults.	Determined using EPA conversion tool for annual average weekly VMT.
Ramp fraction	Travel demand model output for ramps, but no ramp counts were used to validate model outputs. MAG plans to include ramp counts in future validations.	Reviewed PAG ramp VMT data and very similar to the MOVES default; therefore, used the MOVES default.	Local data obtained from YMPO Travel Demand Model.

The research team also reviewed key characteristics of all regional travel demand models in the state and the statewide travel demand model to understand the potential for using travel demand model outputs in counties outside of those found in Table 5. Figure 1 illustrates the geographic areas covered by the regional travel demand models (this is current as of 2011; the MAG model has been expanded since then to cover Pinal County). Table 6 shows the characteristics of the different models including spatial and temporal coverage, truck modeling, and the most recent calibration and validation years. The statewide model, MAG model, and PAG model are fairly advanced models, because they provide outputs for four time periods rather than for an entire day like the remaining three regional models. The statewide model and MAG model also include a truck model to provide outputs by several vehicle types. PAG is considering adding a truck model as a future enhancement.

Table 6. Comparison of Arizona Travel Demand Models

Travel Demand Model Name	Years Available	Geographic Area	Time Periods Covered	Vehicle Types Included
Arizona Statewide Travel Demand Model (AZTDM 2)	AZTDM 2 validated to 2008 conditions and has 2035. AZTDM 3 will be validated to 2010 and will have 2013, 2019, and 2035.	Statewide with enhanced traffic analysis zone (TAZ) and highway network details in MPO model areas and enhanced detail in Pinal County.	A.M. (6-9 A.M.), Midday (9 A.M.-3 P.M.), P.M. (3 P.M.-6 P.M.), Night (6 P.M.-6 A.M.)	All vehicles, single-unit trucks, multi-unit trucks
MAG	2011 Base, 2015, 2025, 2035	All of Maricopa and Pinal counties.	A.M., P.M., Midday, and Night	All vehicles, light trucks, medium trucks, heavy trucks
PAG	2010 Base, 2015 E+C, 2040 No Build, 2040 Build	Eastern 1/3 of Pima County and a small portion of Pinal County (6 TAZs).	A.M., P.M., Midday, Night, and Daily	All vehicles; truck model may be future enhancement
YMPO	2012 Base, 2014, 2016, 2024, 2034, 2037	Small portion of southwest Yuma County covering Yuma and along I-8 corridor more than halfway to Maricopa County line.	Daily only	All vehicles
CYMPO	2010 Base, 2015 E+C, 2030 E+C, 2030 Build	CYMPO planning boundary plus area of influence. This covers about 1/6 of central Yavapai County.	Daily only	All vehicles
FMPO		FMPO planning boundary, which is a very small area in central Coconino County.	Daily only	All vehicles

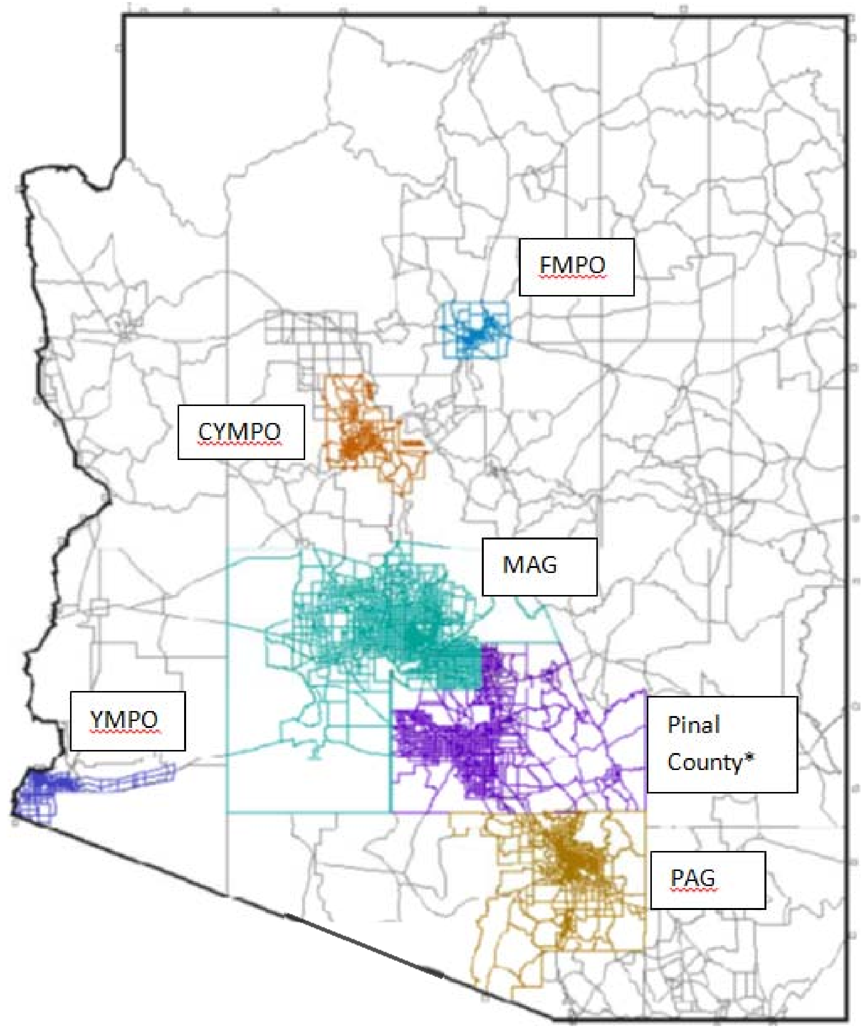


Figure 1. Regional Travel Demand Models in Arizona
Source: ADOT (2011)
Note: MAG has since expanded its model to cover all of Pinal County

Despite the fact that the statewide model includes four times of day and a truck model, regional travel demand models may still be preferred as the source of VMT information in the Yuma, Central Yavapai, and Flagstaff MPO areas. These models consider how socioeconomic growth in fine-grained TAZs impacts various parts of the roadway network, and how planned transportation projects impact traffic patterns. The statewide travel demand model does not have as fine-grained a TAZ structure and roadway network. It also focuses more on long-distance and freight trips and may not represent local trips as well as an MPO model. However, the statewide model may be a good option for VMT-based inputs in the parts of the state not covered by the five regional travel demand models, which is a large area (shown in Figure 1).

Existing Data: Traffic Monitoring Data

It appears that MAG is the only area currently using traffic monitoring data to produce VMT-based MOVES inputs (Figure 2). They use 2007 traffic count data collected in Maricopa County to produce the three temporal adjustment inputs (month VMT fraction, day VMT fraction, and hour VMT fraction). The month and day VMT fraction inputs were derived from permanent count stations that can provide data over a long period.

HPMS Arizona CY2002 — **2002 MARICOPA COUNTY ESTIMATES OF DAILY VEHICLE TRAVEL BY HIGHWAY FUNCTIONAL CLASSIFICATION & NON-ATTAINMENT AREA** — Maricopa County Request

FHWA HIGHWAY FUNCTIONAL SYSTEM

RURAL Code	Description	Estimated DVMT (In Thousands)	URBAN Code	Description	Estimated DVMT (In Thousands)
1	Principal Arterial - Interstate	2,876	11	Principal Arterial - Interstate	9,927
2	Principal Arterial - Other	1,641	12	Freeways & Expressways	13,801
6	Minor Arterial	769	14	Principal Arterial - Other	17,518
7	Major Collector	2,236	16	Minor Arterial	10,452
8	Minor Collector	255	17	Collector	6,241
9	Local	511	19	Local	7,352
	County Rural Total:	8,288		County Urban Total:	65,291

Total Estimated County DVMT: 73,579 (In Thousands)

Units for defining length and travel in this report are miles and vehicle-miles (in thousands), respectively
Figures shown originally submitted to Federal Highway Administration in October, 2003
Figures may not add up to totals due to numercial rounding

Figure 2. Example VMT by Roadway Functional Class (2002 Maricopa County)
Source: MAG (2007), page 273

Traffic monitoring data may be used indirectly to produce other VMT-based inputs, since traffic counts are often used to validate the volumes output by travel demand models. For example, MAG uses 3,300 traffic counts to validate volumes for their model.

ADOT has an online tool called the TDMS, which compiles a variety of different traffic monitoring data from both temporary and permanent count stations. This tool includes total volume counts, vehicle classification counts, and speed data. The classification counts are useful for dividing VMT by six HPMS vehicle types for the VMT by vehicle class and road type distribution inputs. Permanent counts can be used to produce the month and day VMT fraction inputs, while permanent or temporary counts can be used to produce the hour VMT fraction input. The feasibility of using this information as a supplemental data source to travel demand model outputs is discussed further below.

Limitations of Existing Sources

There are several limitations to the current approaches used for VMT-based inputs across Arizona:

- **Geographic coverage –** MOVES currently is used in Arizona mainly for transportation conformity purposes, which means that VMT-based inputs are mainly coming from regional travel demand models. As can be seen in Figure 1, these models have limited geographic coverage including mainly urban areas. If ADOT or other agencies desire to produce MOVES inputs for every county in the state for an application besides transportation conformity (such as statewide performance measures), it would be necessary to find a source of VMT data for all of the areas without a regional travel demand model. The statewide travel demand model would be a good source of VMT data for these areas. As discussed above, it is a sophisticated model that provides VMT by four times of day and three vehicle types. As discussed below, the statewide model could be combined with traffic monitoring data and HPMS reports to produce VMT-based inputs for areas without a regional travel demand model.
- **Vehicle classification –** MOVES sensitivity analyses show that the split of VMT by vehicle class has a large impact on the emissions predicted by MOVES. One study found that altering this split by the 10th to the 90th percentile of the range found in all submittals to the NEI can increase emissions by 40 to 150 percent, depending on the pollutant (Koupal et al. 2013). Since the mix of VMT by vehicle type varies substantially across the country, it is important to collect local information on this split and not rely on national default values to split the total VMT that comes out of travel demand models. The best practice for doing so is to use vehicle classification counts to estimate the percent of traffic by six HPMS vehicle classes separately for each of several different road types. This not only helps with the VMT by vehicle class input, but also provides vehicle type detail in the road type distribution input. MAG currently uses vehicle classification counts to validate the medium-duty truck and HDT volumes in their travel demand model, but they still use MOVES defaults to get down to the six HPMS vehicle types. Other areas currently use national defaults to split total VMT into the six HPMS vehicle types and do not use any local classification counts. Several sources of this information are discussed in the next section, including the FHWA's Highway Statistics Series (FHWA, 2016), which has readily available statewide information, and raw classification counts found in ADOT's TDMS online traffic monitoring data tool.
- **HPMS VMT estimates –** Every year, ADOT sends official VMT estimates to FHWA for the HPMS. These estimates are based on traffic count information that is expanded over space and time to represent VMT on all roads in the state. In some areas of the country, the EPA requires for transportation conformity purposes that travel demand model outputs be adjusted to reflect official HPMS VMT estimates. This may or may not be necessary depending on how well a travel demand model is calibrated and validated, but it has been helpful to accurately reflect VMT on lower classified roads, such as collectors and local streets. It appears that no one in Arizona reconciles travel model VMT with HPMS VMT while preparing VMT-based MOVES inputs; however, MAG does note in their conformity report that they conducted a comparison and found model and HPMS VMT to be nearly identical. PAG adds 13 percent of the model VMT to the total VMT to reflect VMT on local roads that are not included in the model. Reconciling model VMT with HPMS VMT may become a more important consideration in rural counties,

where the statewide model may not reflect lower-classified roads very well. This would require HPMS reports that contained VMT by roadway functional class for each county in the state, but this information currently is not produced by ADOT. Figure 3 shows an example of this type of information, which was included in Maricopa County's Eight-Hour Ozone Plan (MAG 2007). It appears to have been prepared by ADOT to fulfill a special request from Maricopa County, but it could theoretically be prepared every year for every county in the state and be made available on ADOT's HPMS website (ADOT 2014). The site does provide VMT by roadway functional class for "Aggregate Rural and Small Urban Areas (Table 3)" and "Individual Urbanized Areas (Table 4)," but this information is not sufficient for creating VMT-based inputs for specific counties.

- **Ramp fraction –** MOVES sensitivity analysis shows that, for most pollutants, changes to the ramp fraction input have a modest impact on emissions (less than five percent); however, it does have a greater impact (less than 15 to more than 22 percent) on PM emissions for passenger cars. All three areas that currently use MOVES for conformity either produce this input from travel demand model outputs or have compared the model outputs to MOVES defaults and found them to be close enough to use MOVES defaults. However, none of these areas currently uses ramp counts to validate the model outputs (MAG indicated they intend to in the future). As discussed below, ramp counts from the TDMS traffic monitoring data tool could be used to validate ramp volumes from both regional and statewide travel demand models.
- **Temporal adjustments –** Some areas in Arizona use local data to produce the monthly, daily, and hourly VMT fraction MOVES inputs, while others rely on MOVES defaults. MAG uses travel demand model outputs and traffic counts for all three inputs. YMPO uses information from the statewide travel demand model to split VMT over four times of day. Use of more local data in other areas may help to better reflect local seasonal travel patterns. In Arizona, the north tends to have more summertime traffic due to the cooler temperatures in the higher elevations, and the south tends to have more wintertime traffic due to the warmer conditions in the low elevations. MOVES sensitivity analyses for the hour and month VMT fraction inputs only show modest sensitivity (0 to 2 percent increase in emissions) due to changes in these inputs (Porter et al. 2014). Therefore, efforts to use more local data sources over MOVES defaults for these inputs could be assigned a lower priority than using more sensitive inputs. Despite this, the possibility of using hourly and seasonal traffic counts from ADOT's TDMS online traffic monitoring tool is discussed below.

Potential Supplemental Sources and Data Enhancements

The following bullets suggest potential supplemental data sources and enhancements to address the four limitations to the current approaches used to produce VMT-based MOVES inputs:

- **Geographic coverage –** The statewide model appears to be the best source of VMT data for areas not covered by a regional travel demand model. While official HPMS VMT estimates could be used to reconcile statewide model outputs, it is still more desirable to use the statewide outputs in combination with HPMS than to use HPMS alone, since the model can predict future VMT based on socioeconomic forecasts and reflect how future transportation projects may impact future VMT. The validation of the truck component should be reviewed in detail to determine whether vehicle classification counts should be applied to total VMT from the model or to VMT by the three vehicle types found in the model. Total volumes from the model (Figure 3) are closer to traffic counts than combination truck volumes from the statewide model (Figure 4).

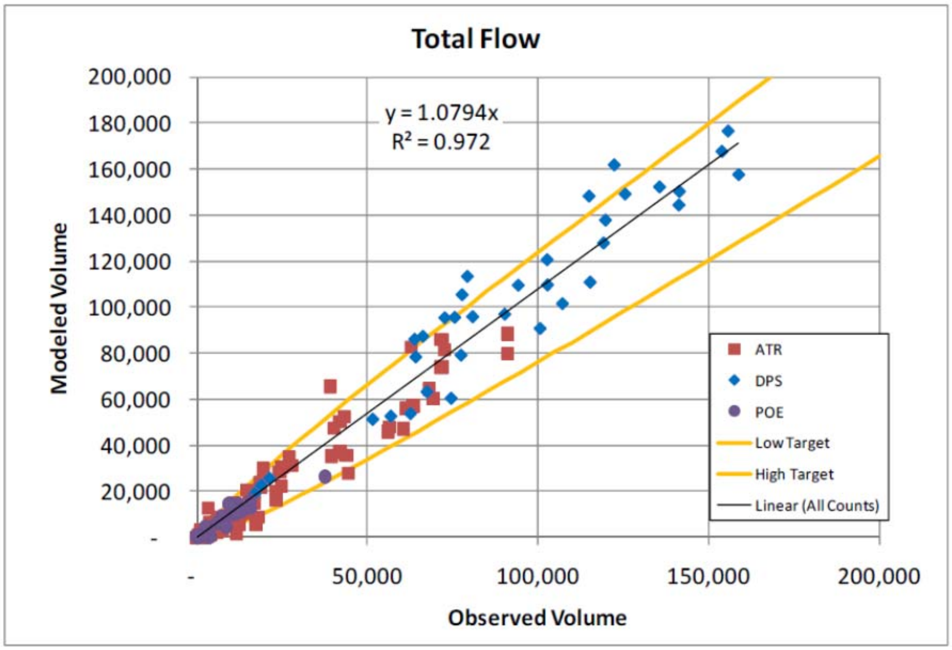


Figure 3. Statewide Model Validation Results for Total Volume
Source: ADOT (2011)

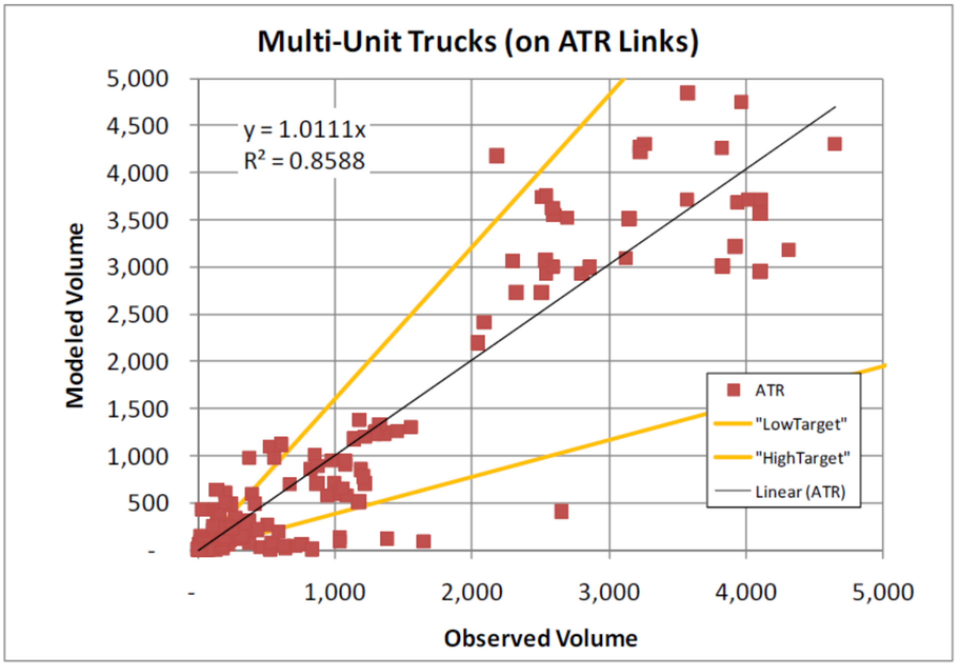


Figure 4. Statewide Model Validation Results for Combination Truck Volumes
Source: ADOT (2011)

- **Vehicle classification –** Two different sources of vehicle classification information could be used for the VMT by vehicle class and road type distribution MOVES inputs. Highway Statistics Table VM-4 (FHWA 2016) reports percentages of VMT by six HPMS vehicle types for three different road types. This information is based on HPMS reports submitted by ADOT to FHWA annually, such as the one shown in Figure 5. This information is derived from classification counts across the whole state and is presented as statewide information without any finer geographic detail. Vehicle classification information can be derived by using the underlying classification counts to produce information similar to what is available from the Highway Statistics Series but for more detailed geographies, such as individual counties or at least county groups. Raw classification counts are available in the TDMS traffic monitoring tool. Table 7 shows the number of count stations with classification data available by county and roadway type in the 2010 data. While many rural counties do not have enough stations to produce a large enough sample, it is conceivable that several counties could be grouped together to provide a large enough sample.

	Rural			Urban		
	Interstate	Other Arterial	Other Rural	Interstate	Other Arterial	Other Urban
Motorcycles	0.51 %	1.10 %	0.99 %	0.52 %	0.50 %	0.68 %
Passenger Cars	64.28 %	68.20 %	61.51 %	67.40 %	75.76 %	65.43 %
Light Trucks	18.66 %	19.36 %	23.18 %	19.67 %	17.66 %	27.65 %
Buses	0.76 %	0.64 %	0.56 %	0.54 %	0.45 %	0.35 %
Single Unit Trucks	3.50 %	3.94 %	6.00 %	3.66 %	3.34 %	3.18 %
Combination Trucks	12.29 %	6.76 %	7.76 %	8.21 %	2.29 %	2.71 %
Total	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %	100.00 %

Figure 5. Example of HPMS Report for 2012 Arizona Classification Information
Source: ADOT (2014)

Table 7. Number of Count Stations Providing Classification Counts by Hour

	HPMS Roadway Functional Class														
	Rural							**Urban**							**Grand**
County	**1**	**2**	**3**	**4**	**5**	**6**	**Total**	**1**	**2**	**3**	**4**	**5**	**6**	**Total**	**Total**
Apache				3	2		5								5
Cochise	4		2	2	1		9				1			1	10
Coconino	4		4		1	1	10	1		2				3	13
Gila			4	1			5			1				1	6
Graham					1		1			1				1	2
Greenlee						1	1								1
La Paz	2		2		2		6								6
Maricopa	7		4		3		14	2	9	1				12	26
Mohave	3		4				7	2						2	9
Navajo	1		2	1	2	1	7								8
Pima	2			2	1	1	6	1		1	1			3	9
Pinal	2			4			6								6
Santa Cruz	1				2	1	4			1				1	5
Yavapai	3		7	1			11			2				2	13
Yuma	1		1	1			3	1		1				2	5
Total	**30**	**0**	**30**	**15**	**15**	**5**	**95**	**7**	**9**	**10**	**2**	**0**	**0**	**28**	**124**

- **HPMS VMT estimates** – As explained above, HPMS reports that produce VMT by road type for every county in the state could be useful to reconcile VMT outputs from travel demand models. These currently are not available, but they should be relatively easy for ADOT to produce since

ADOT already produces similar reports for other geographies like urbanized areas. As an interim approach, the HPMS tables that currently are available on ADOT's website could be used to split the county-level VMT into road types by using the current available geographies, which are five urbanized areas plus all rural portions of the state. Adjustments could be made if it is known that some counties do not have a certain road type. For example, there may not be any restricted-access roadways in Gila, Graham, and Greenlee counties. Some counties may not have any urban areas either.

- **Ramp fraction –** The TDMS traffic monitoring tool contains 1,359 ramp count locations, although these are located only along I-10 and I-19 in southern Arizona and on many local expressways in the Phoenix metropolitan area, as shown in Figure 6. These counts could be investigated as a potential data source to validate ramp volumes in the statewide model and in some regional models, since these volumes are used to create the ramp fraction input for MOVES.

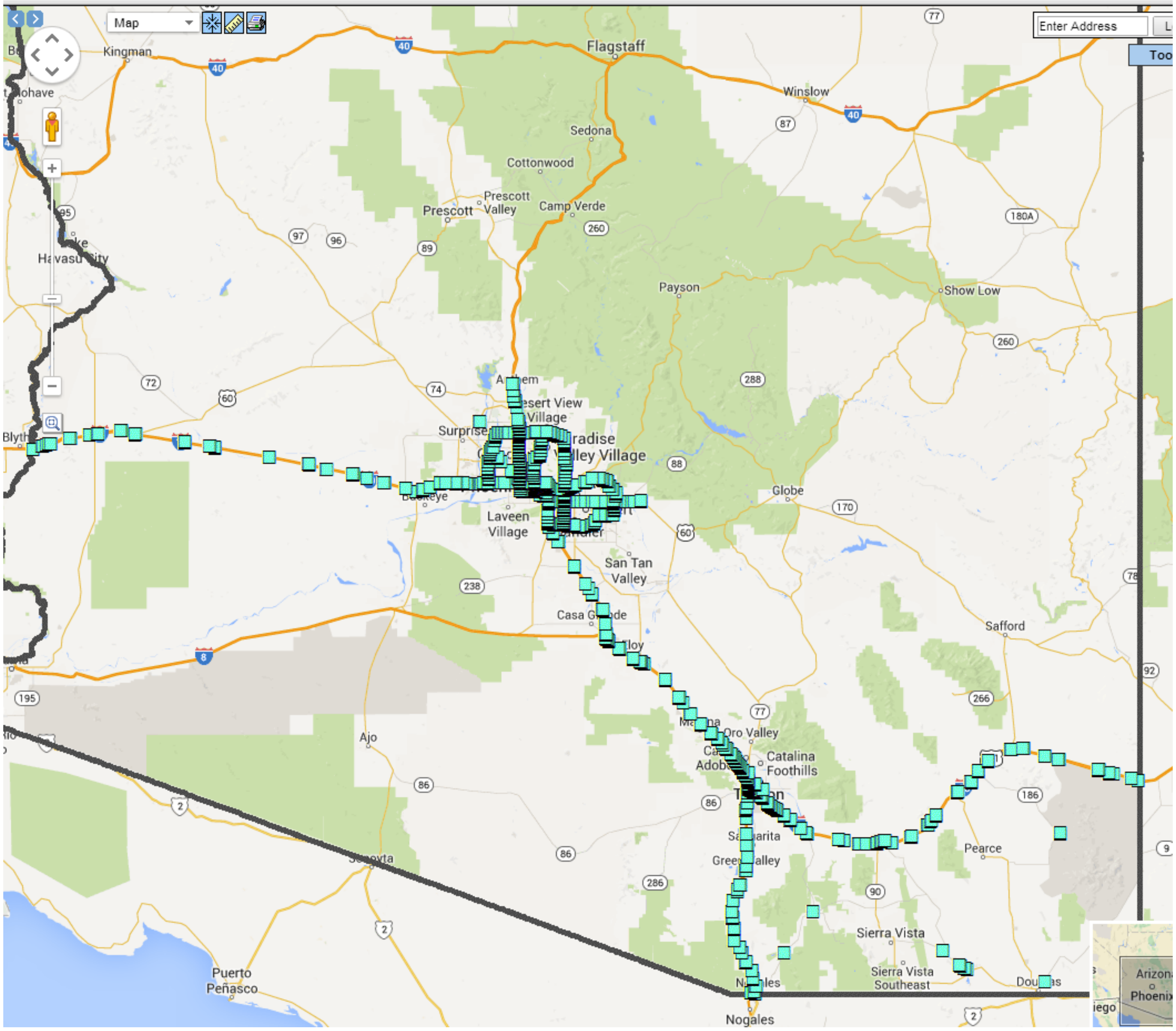


Figure 6. TDMS Ramp Count Locations
Source: ADOT (2016)

- **Temporal adjustments –** It is possible to use traffic monitoring data from the TDMS online tool to create the month, day, and hour VMT fraction MOVES inputs. The hour VMT fraction input could be created using classified count data from the 124 stations shown in Table 7, since all of these counts are available by hour of the day. If vehicle type detail is not desired for the hour VMT fraction, many more stations would be available. There are only 50 stations available in the 2010 data to produce the month VMT fraction and day VMT fraction inputs since an entire year's worth of counts are required (stations with more than 350 days of counts are considered to have a year's worth of data). Table 8 shows the breakdown of the 50 stations by county and road type. The small number of stations by county would not provide a large enough sample to produce month and day VMT fraction inputs by county, but it may be possible to group the counties into north and south, since those areas are expected to have different seasonal patterns.

Table 8. Number of Count Stations Providing More than 350 Days of Counts in 2010

HPMS Roadway Functional Class															
	Rural							**Urban**							**Grand**
County	**1**	**2**	**3**	**4**	**5**	**6**	**Total**	**1**	**2**	**3**	**4**	**5**	**6**	**Total**	**Total**
Apache				2	1		3								3
Cochise	2		1		1		4								4
Coconino	2		2			1	5			2				2	7
Gila			1	1			2								2
Graham										1				1	1
Greenlee						1	1								1
La Paz	1		1				2								2
Maricopa	1		1				2	1	1					2	4
Mohave	1		1				2	1						1	3
Navajo			2		2	1	5								5
Pima				1		1	2	1						1	3
Pinal	1			2			3								3
Santa Cruz	1				1	1	3								3
Yavapai	3		2	1			6			1				1	7
Yuma	1		1				2								2
Total	**13**	**0**	**12**	**7**	**5**	**5**	**42**	**3**	**1**	**4**	**0**	**0**	**0**	**8**	**50**

Recommendations

Assuming that the goal is to produce a separate set of county-level inputs for each county in Arizona, the study team recommends the following tiered approach for the VMT-based MOVES inputs covered in this section:

- **Local MPO travel demand models** – If available, MPO travel demand models provide the best source of VMT information for future years because they consider how socioeconomic growth in different areas impact various parts of the roadway network, and how planned transportation projects impact traffic patterns. The statewide travel demand model does this as well, but is not as fine-grained when it comes to zone structure and the roadway network. It also focuses more on long-distance and freight trips and may not represent local commuter trips as well as an MPO model does. The base year of the travel demand model should be validated against HPMS VMT and possibly adjusted, especially for roadways of lower functional classes. The travel demand model will supply total VMT by roadway type and possibly assist in breaking the VMT into times of day and LDVs vs. HDVs. The travel demand model can also provide temporal information by time of day to be used in combination with hourly counts to produce the hour VMT fraction input. It can also provide ramp volumes for the ramp VMT fraction input.

- **Statewide travel demand model** – For areas where an MPO travel demand model is not available, the statewide travel demand model can be used instead to provide total VMT by roadway type for future years and possibly the base year, if it is validated/adjusted against HPMS VMT. The statewide travel demand model has a time-of-day component and a truck model, so it can be used to assist in breaking the VMT into times of day and in producing the initial split of light-duty vs. heavy-duty VMT. It has some limitations compared to MPO models, as discussed above, but these limitations are not as critical in the rural areas where it would likely be used. As with the regional model, it can also provide ramp volumes for the ramp fraction input.
- **Traffic monitoring data** – Traffic monitoring data are important to provide further breakdown of VMT by road type from travel demand models and HPMS reports. For example, vehicle classification counts by road type can be used to break down the one or two vehicle types available from travel demand models into the six HPMS vehicle types required by the VMT by vehicle class MOVES input. Additionally, traffic monitoring data can be used to break down VMT temporally by hour of day, day of week, and month of year. Ramp counts can be used to validate ramp volumes from travel demand models.

The network of classified traffic counters is not adequate to support source type-specific temporal distributions for each individual county. The study team recommends using either source type-specific distributions at a statewide level, or all-source distributions at a county level. Data should be evaluated for source type and geographic differences to see which are more significant.

In the long term, expanded coverage of classification counters, either temporary or permanent, could provide validation of model data or be used directly to estimate VMT by vehicle class and road type for each individual county in Arizona. This information could be used to produce the VMT by vehicle class and road type distribution inputs with county-specific information. It could also be used to provide source type-specific hour VMT fraction inputs as long as each count is for at least a day. However, to provide source type-specific month and day VMT fractions, the count stations would have to be permanent to cover the whole year, which would likely require a larger investment than is needed for temporary coverage counts. Sensitivity testing by the project team suggests that further refinement of temporal inputs is likely to have a relatively minor impact on emissions. For example, temporal adjustments are observed to have generally similar distributions across states. It would be more useful to have county-specific breakdowns of VMT by vehicle type, given the important influence of vehicle type on emissions.

In the long term, ramp counts could also be expanded to additional Interstate highways, especially in the northern portion of the state, where there appears to be no coverage. However, the current network of ramp counts provides a good mix of urban and rural locations, which is expected to be the main factor influencing the ramp fraction input.

ACTIVITY INPUTS: SPEED DISTRIBUTIONS

Speed distributions describe the fraction of VHT in each of 16 speed bins. Different distributions may be provided for different source types, if data are available. Speed distributions may be obtained from travel demand models for both historical and forecast years. Observed speed data may also be used for historical year distributions, and for forecast years (assuming the same as current/historical) in situations not covered by a travel demand model.

Existing Data Sources

Currently, this input has only been developed in areas that perform transportation conformity analysis, including MAG, PAG, and YMPO. Speed distributions are obtained directly from the link-level speeds from the MPOs' travel demand models; no speed postprocessing methods are applied. The MAG and PAG models include four time periods (a.m. peak, p.m. peak, midday, and night), so speed distributions are developed for each period. The smaller MPO models are daily models, so the same speed distributions are applied over the entire day.

MAG's speed prediction is based on the Bureau of Public Roads (BPR) volume-delay formula with locally calibrated coefficients (which ADOT has borrowed for the statewide model). MAG has validated the speed results using commercial vendor data from Nokia, as well as data from ADOT detectors on freeways, demonstrating that modeled speeds are in reasonable agreement with observed speeds during both peak and off-peak time periods; see MAG (2013), pages 33-36.

ADOT's statewide travel demand model also produces speed information by time of day (four time periods). Link-level speeds are estimated using the BPR volume-delay function with MAG coefficients. Speeds have not been validated against observed speeds, and the statewide model speeds are not currently used for MOVES inputs. The statewide model could be used to provide both current and forecast year speed distributions for counties not covered by an MPO model. A separate set of speed distributions could be produced for each county.

Some data on observed speeds are also available from ADOT's network of permanent traffic count stations; this is discussed in more detail in the section on VMT inputs (see Tables 7 and 8 for the number of stations by county). These data could be used to validate modeled speeds on relevant links, or to develop speed distributions for rural road Types 2 and 3 based on observed data. The network for which speed data are available is too limited to support county-specific distributions of observed speeds. The limited number of urban stations also may be insufficient to validate speed data from MPO models.

Limitations of Existing Sources

Limitations of existing sources include:

- **Lack of temporal resolution** – MOVES requests speed distribution for each hour of the day. The MAG and PAG models and the statewide model have four time periods, and smaller MPO models are daily models only. The speeds for each time period must be assumed to represent all of the hours in the time period, unless postprocessing methods are applied.

- **Lack of source type-specific information** – Speeds from existing sources (both modeled and observed) must be assumed to be the same for all source types.
- **Limited amounts of observed data** – The network of statewide count stations that records speeds is limited enough that representative speed distributions cannot be observed at a county level.
- **Validation** – Other than for the Phoenix metropolitan area, modeled speeds have not been validated against real-world data.

These limitations are common among MOVES users. The issue of temporal resolution can be addressed through postprocessing of modeled speeds. MOVES users rarely have access to source type-specific speed data, although speeds can differ by 5 to 10 mph between light and heavy vehicles, especially in mountainous terrain. Other issues may be addressed through expanded collection of observed speed data, as described below.

Potential Supplemental Sources and Data Enhancements

Speed Postprocessing

Postprocessing the data to obtain hour-specific speed distributions is a significant, and fairly simple, way to enhance any of the speed data from travel demand models. This is done by breaking time period volumes down into hourly volumes (using the same data source as for hour VMT adjustments), recalculating the v/c ratio, and recalculating the speed on each link for each hour period using the model's VDF. This approach can be implemented using a model postprocessor that can be easily programmed using scripts or a spreadsheet. The project team's work on NCHRP 25-38 (Porter et al. 2014) showed postprocessing to significantly improve speed distributions, compared to observed distributions (Figure 7). In Jacksonville, the postprocessing of model speeds also brings emissions estimates much closer to the estimates based on observed speeds from Intelligent Transportation Systems (ITS) detectors—within 5 percent in most cases—compared to emissions that are 10 to 40 percent higher based on unpostprocessed speeds.

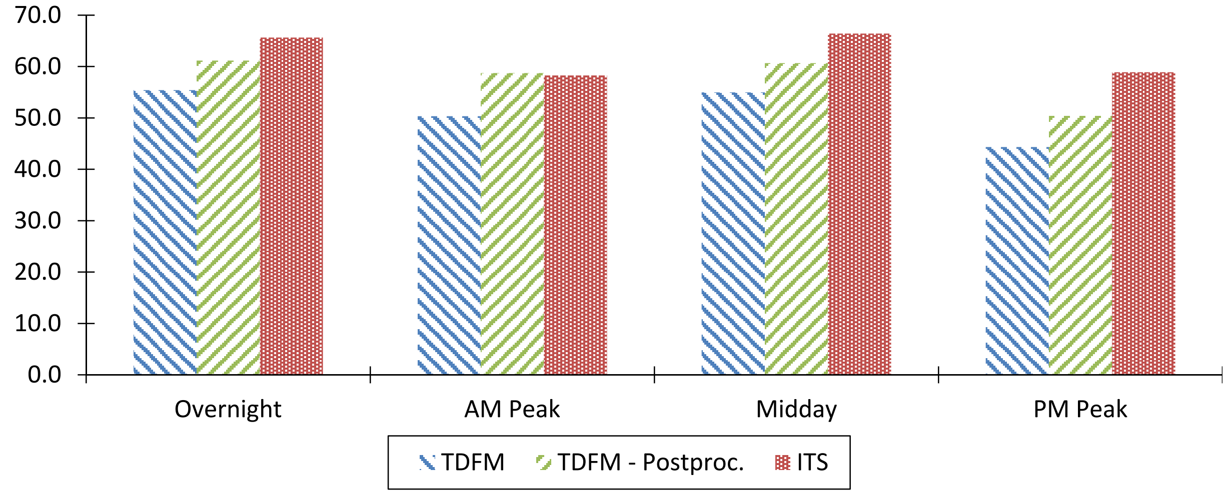


Figure 7. Average Speed on Jacksonville Freeways

Note: TDFM = travel demand forecasting model, not postprocessed; TDFM – Postproc. = travel demand forecasting model with postprocessed speeds; and ITS = observed data from ITS detector network

Validation and Calibration of Speed Distributions

Outside of the MAG area, modeled speeds have not been validated against observed data. Speed validation could be a valuable step for smaller MPO models and for the statewide model. Some existing data from ADOT's ATR network are available to compare against modeled speeds, especially for rural roads. It would be straightforward to compare modeled and observed speeds on individual road segments. If significant discrepancies are found, adjustments could be made to free-flow speeds or BPR coefficients, which predict how speed changes under congested conditions (this is most likely to be relevant in urban areas).

One option to consider in areas that are not expected to experience significant congestion is that it may be preferable to use observed speed distributions to represent both current and future conditions, rather than using modeled speed distributions. The NCHRP 25-38 work found that VDFs (such as the BPR curve) do not represent well the range of vehicle speeds at free-flow conditions, since they assume a single free-flow speed, which decreases as volume increases (Porter et al. 2014). In reality, there may be a 10- to 15-mph distribution in speeds even under uncongested conditions. This is illustrated in Figure 8, where the solid black line shows observed speeds from ITS equipment, and the dashed lines show predictions using various formulations of the BPR curve and other functions. Using observed speeds recognizes this modeling limitation and avoids the need to artificially adjust speed prediction methods.

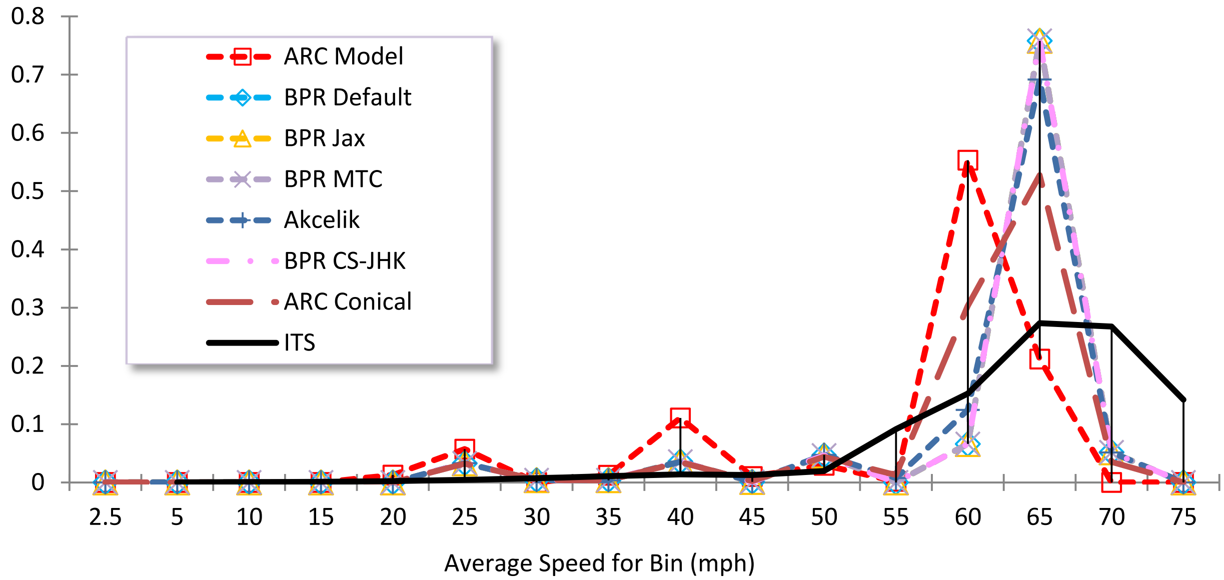


Figure 8. Speed Distributions on Atlanta Freeways, 5:00 to 6:00 a.m.

Collection of Additional Speed Data for Urban Arterials and Rural Roads

Validation against average hourly speeds from existing data would be a useful step, but it would be even more useful to compare and validate speed distributions against observed distributions of speeds. The project team's research for NCHRP 25-38 showed that using 5-minute, daily ITS data from Atlanta freeways produced a broader distribution of speeds than using annual hourly averages (Porter et al. 2014). This is because there is variation in individual vehicle speeds (and speeds of groups of vehicles), as well as daily variation that is not captured in average speeds. It might be possible to work with private vendors to obtain this type of disaggregate speed distribution data, covering freeways and arterials across the state; the cost is unknown, but is likely to be a few tens of thousands of dollars.

Speed Studies by Vehicle Type

Sampling could be conducted to determine whether there are significant differences in speeds by vehicle type on Arizona roads. This would involve roadside data collection at a few representative locations using techniques that can collect both speed and vehicle data. For example, radar, lidar, or video can be used to measure vehicle length for sorting into two or three vehicle types (with cars/light trucks vs. large trucks/buses being the distinction of primary interest). The results could be used to adjust truck speed distributions based on the relative difference. The cost of doing such a data collection effort would likely be in the tens of thousands of dollars, depending on the number of locations sampled.

Recommendations

The following short-term enhancements are recommended:

- Compare modeled speeds outside the Phoenix area with observed speed data from existing sources (ADOT traffic recorders).
- Develop a speed postprocessing procedure for the statewide model, and possibly for MPO models, to create speed distributions for 24 hours of the day. Compare the resulting distributions against observed distributions.
- Compare MPO and statewide model speed distributions for counties that are partially covered by an MPO. If the speed distributions are significantly different, they may need to be combined (weighted based on VHT), unless separate inputs are to be prepared for subcounty areas.

The following long-term enhancements are recommended for consideration:

- Work with private vendors to obtain more comprehensive observed speed data, suitable for developing MOVES distributions, for the entire state. It may be desirable to coordinate this effort with any efforts by ADOT and/or MPOs to implement travel time monitoring systems that make use of private vendor data, as economies could be achieved through data purchase. The observed speed data can be used to validate and calibrate speed prediction functions, or as a direct source of inputs to MOVES for uncongested areas. Model data should continue to be used in congested areas to ensure consistency between current- and future-year speed estimation methods.
- Conduct a sample survey to compare car and truck speeds on selected highway segments.

OTHER INPUTS: METEOROLOGY, I/M PROGRAMS, AND FUELS

Other inputs include meteorology, I/M program, and fuel inputs. Data sources for these inputs were reviewed to answer questions, such as:

- What are the best available sources for meteorological data?
- Are MOVES defaults for I/M in Arizona counties accurate? If not, are I/M program characteristics well-known or do I/M program officials need to be interviewed?
- Are MOVES defaults for fuel inputs accurate, or do other data sources need to be explored?

Each of these inputs is addressed in more detail in the subsections below.

Meteorological Inputs

Existing Data Sources

MOVES requires monthly average temperature and relative humidity values for each hour of the day to perform its calculations. While there are several different sources of meteorological data are available that meet these requirements, the two most commonly used sources are MOVES defaults and NCDC LCD summaries (NCDC 2016). Both of these sources are publicly and freely available and cover the entire United States; LCDs span multiple years, while MOVES defaults contain data for only a single calendar year. LCDs are constantly maintained and updated by NCDC, while MOVES defaults remain static unless changed with a new release of the model. The data are available at a station level; there may be multiple stations in a county, or no stations at all. The user should select an appropriate station that is representative of conditions in each county.

Limitations of Existing Sources

The default MOVES meteorological data are limited, in that only a single year of data is available. That said, this is not a substantial problem, as the meteorological data are used primarily to calculate diurnal variation effects on hydrocarbons (HC) and NO_x. As long as the data are relatively representative of the area being modeled and contain adequate diurnal variation, the emissions calculations should be acceptable.

The LCD summaries available from NCDC do require some effort from the user to process into a format usable by MOVES. The summaries contain much more information than MOVES requires, so the appropriate monthly averages must be extracted and converted to MOVES inputs.

Potential Supplemental Sources and Data Enhancements

There is no need to purchase any supplemental meteorological data for use in MOVES. For SIP modeling and other regulatory analyses, the free NCDC LCD summaries are acceptable.

Recommendations. For quick, "back-of-the-envelope" scenario evaluations, the MOVES meteorological defaults are sufficient. LCD summaries are recommended for more stringent regulatory purposes.

I/M Program Inputs

Existing Data Sources

MOVES contains default I/M program inputs, which include information such as affected source types, MY ranges, inspection frequency, type of test performed, and vehicle compliance factor. For the most part, the defaults within the model correctly describe the I/M program in place in Arizona, which covers the Phoenix and Tucson metropolitan areas. ADEQ is responsible for implementing the state's I/M program, which has been in place for many years and has remained fairly static. The I/M inputs for MOVES are created and modified by the user and must reflect the I/M program as currently implemented. No other known sources for I/M information used to create MOVES inputs exist outside of ADEQ, which has regulatory authority.

Limitations of Existing Sources

While the default I/M information within MOVES2010 is fairly accurate in its representation of the program, especially compared to such defaults for other states, there are a few items that the end user should be aware of when modeling Arizona counties. First, the defaults incorrectly reflect annual inspection for 1996 and newer OBD-compatible vehicles in the Tucson area; this should be changed to biennial. Secondly, users should check the listed compliance factors to ensure that they accurately represent the program for a given calendar year, as these factors are dependent on compliance rate, waiver rate, and regulatory class coverage (see EPA, 2014a for more information on how this value is calculated). Finally, incorrect application of annual inspections for 1996 and newer vehicles in Tucson will overestimate the effect of the I/M program on that area. Similarly, incorrect compliance factors will also affect emissions estimates.

The above review was conducted before the release of MOVES2014. Updates to default I/M program parameters in MOVES2014 have addressed these issues, and the default I/M information embedded in MOVES2014 appears to accurately reflect Arizona's I/M program characteristics.

Potential Supplemental Sources and Data Enhancements

There are no other sources of I/M data other than those described above. As mentioned, minor corrections should be made to the MOVES defaults to ensure accurate emission estimation.

Recommendations

The study team recommends using modified MOVES defaults for I/M inputs. As specified in the MOVES User's Guide, this can be easily done by exporting the default I/M values using the feature provided in the County Data Manager (CDM) into a Microsoft Excel spreadsheet, updating as appropriate, and reimporting the corrected data via the CDM. If Arizona makes substantial changes to the I/M program in the future, additional care will be needed to ensure the I/M inputs reflect those changes, and EPA should be notified so that the default data in the model are updated.

Fuels Inputs

Existing Data Sources

The MOVES model contains a number of different fuel formulations. These formulations are described by a number of different physical characteristics, including RVP, sulfur level, oxygenate volumes, aromatic/olefin/benzene content, and other parameters. In turn, these fuels are apportioned by county, calendar year, month, and market share to comprehensively describe the fuel supply for a given area's fleet.

MOVES default fuel formulations and fuel supply exist for every county in Arizona and reflect the oxygenated Arizona Clean Burning Gasoline formulations required in the Maricopa and Tucson areas (see Arizona Administrative Code Title 20, Chapter 2, Article 7).

Other laboratory data on fuels may also be available from the AZDWM, which is responsible for ensuring refiners, distributors, and fueling stations comply with state-mandated fuel blends.

Limitations of Existing Sources

The MOVES2010 defaults capture expected variation in RVP, sulfur level, and other factors on a month-to-month basis for gasoline blends. However, ethanol percentage is set to 10 percent for all gasoline formulations, regardless of month or location. Similarly, diesel sulfur levels are held constant at 11 ppm. Therefore, the defaults may not accurately represent the fuel being used in the counties of interest. Sulfur levels directly correlate with NO_x and PM emissions, and RVP has a substantial effect on evaporative HC. In addition, each county in the MOVES defaults has only a single fuel formulation associated with it in recent MYs; this may or may not accurately reflect the market share of different blends available.

This review was conducted before the release of MOVES2014. Updates to default fuel parameters in MOVES2014 have addressed the ethanol and diesel issues. If available, laboratory data from AZDWM or other agencies may provide more accurate estimation of these fuel parameters.

Potential Supplemental Sources and Data Enhancements

If fuel samples are not already available, ADOT could consider collecting fuel samples from different stations across the counties to be modeled. This is a potentially expensive endeavor, requiring many thousands of dollars in collection labor and laboratory time. The benefits of such testing would result in more accurate modeled emissions estimates, but only marginally, compared to use of MOVES model defaults.

Recommendations

If ADOT can secure results of fuel sample testing from its partner agencies for minimal cost, then updating MOVES defaults with more representative fuel formulations and market share may prove worthwhile. Conducting a new testing program to derive such information, however, is probably cost-prohibitive. In the absence of easily obtained fuels information, the default MOVES data should be sufficient for most applications.

CHAPTER 4. PROCESSING NEEDS ASSESSMENT

OBJECTIVES

This assessment investigates options for data processing procedures to convert raw data from available sources into MOVES input format. It also tests the data sources and processing procedures through an application to Yuma County. Updates to recommended data sources and processing methods, based on the Yuma County case study experience, may supersede recommendations made in the previous sections.

SUMMARY OF FINDINGS

Table 9 summarizes recommended data sources and processing procedures for all inputs. These are described in more detail in the text below.

Fleet Inputs: Age Distribution and Source Type Population

To develop age distributions and source type population fractions for Yuma County and other counties in Arizona, it is recommended that the most recent state registration data be used. For the Yuma County case study, data from June 2014 were obtained from the ADOT MVD. The initial development of source type populations involves a fair amount of work because the information provided in the registration records does not fully correspond to the MOVES source type definitions. However, once vehicles are classified into the MOVES source type IDs, it is easy to replicate the results for each county in the state. Population fractions change over time and should be updated on a regular basis. A VIN decoder is required to develop source type populations that are fully consistent with the procedures applied here, because, without the VIN decoder, the vehicle manufacturer and gross weight ratings cannot be identified. These items improve the accuracy of the classification, but are not essential. Other procedures used here to classify vehicles will expedite future updates by ADOT.

Once the population fractions are determined by MOVES source type, the MY provided in the registration data can be used to determine the age fractions for each source type. MYs were also determined by the VIN decoder and, in some cases, assumed to be more accurate than the registration database. However, this step is not essential, as most MYs matched. Using the method of classification of the vehicles into the MOVES source type IDs also makes the replication of the results for the remainder of the state very easy because the classification is done for all registered vehicles, regardless of county of registration.

The emissions impacts of out-of-state seasonal visitors are significant in some parts of Arizona, including Yuma County. The registration data used to create age distributions and source type populations for the Yuma County case study do not reflect these out-of-state vehicles. Areas that can verify large numbers of out-of-state vehicles through license plate surveys or other means could opt to use alternative approaches to these fleet-based inputs. For example, source type population could be based on national VMT and age distribution data if large numbers of out-of-state vehicles are verified for certain vehicle types.

Table 9. Summary of Recommended MOVES Data Sources and Processing Procedures

Category	Input	Data Source(s)	Processing Procedure(s)	Update Frequency
Fleet Inputs	Age distribution by source type	Arizona motor vehicle registration database.	Verify MY with VIN number.	Every 4-5 years to meet latest planning assumptions guidance, or every 1-2 years if resources permit.
	Source (vehicle) type population	Arizona motor vehicle registration database for most vehicle types. MOVES default proportions for some vehicle type suballocations.	Apply VIN decoder and use information in conjunction with registration database fields to classify vehicles by source type.	Every 4-5 years to meet latest planning assumptions guidance, or every 1-2 years if resources permit.
Activity Inputs	VMT by vehicle class	HPMS segment data. MPO travel demand model forecasts (or statewide model outside of MPO areas). ADOT TDMS classification counts.	Analyze HPMS segment data to develop annual HPMS VMT reports by county and roadway functional class. Use MPO model (or statewide model outside of MPO areas) to provide future-year VMT, which should be adjusted with HPMS adjustment factors from base year model VMT/base year HPMS VMT. Use TDMS vehicle classification counts from specific regions of the state (at least north and south) to further break down VMT by vehicle class.	HPMS VMT reports by county and roadway functional class should be prepared annually. Use the latest MPO or statewide model outputs for each conformity analysis or other MOVES application. Analyze vehicle classification counts every 4-5 years to meet latest planning assumptions guidance, or every 1-2 years if resources permit.
	Road type distribution	HPMS segment data. Arizona Statewide Travel Demand Model (AZTDM) forecasts. ADOT TDMS classification counts.	Analyze HPMS segment data to develop annual HPMS VMT reports by county and roadway functional class. Use MPO model (or statewide model outside of MPO areas) to provide future-year VMT, which should be adjusted with HPMS adjustment factors from base year model VMT/base year HPMS VMT. Use TDMS vehicle classification counts from specific regions of the state (at least north and south) to further break down VMT by vehicle class.	HPMS VMT reports by county and roadway functional class should be prepared annually. Use the latest MPO or statewide model outputs for each conformity analysis or other MOVES application. Analyze vehicle classification counts every 4-5 years to meet latest planning assumptions guidance, or more frequently if resources permit.

Table 9. Summary of Recommended MOVES Data Sources and Processing Procedures (Continued)

Category	Input	Data Source(s)	Processing Procedure(s)	Update Frequency
Activity Inputs (continued)	Temporal adjustments (hour, month, and day VMT fractions)	ADOT TDMS classification counts.	Analyze TDMS traffic volume data to develop statewide VMT fractions by vehicle type by month, day, and hour (2012 data developed for case study). Update every few years.	Every 4-5 years to meet latest planning assumptions guidance.
	Ramp fraction	MPO (or alternatively statewide) travel demand model. Ramp volume counts (if available).	Validate ramp volumes from travel demand model with ramp volume counts if available. Calculate VHT on ramps and divide by VHT on restricted-access facilities in each county. Compare with MOVES default for reasonableness.	Every 4-5 years to meet latest planning assumptions guidance, or more frequently if there are significant changes to the model or if ramp volume counts become available.
	Average speed distribution	Arizona statewide travel demand model, model links within each county. ADOT TDMS – observed speeds.	Apply speed postprocessing methods to travel demand model outputs to develop speed distributions for each hour of the day. Calibrate speed postprocessing methods (including free-flow speeds) based on observed data.	Use the latest MPO or statewide model outputs for each conformity analysis or other MOVES application. Calibrate speed postprocessing methods every 4-5 years to meet latest planning assumptions guidance.
Other Inputs	Meteorology data	NCDC LCD summaries. MOVES defaults (nonregulatory use).	Obtain LCD data for recent year(s) from closest (or most comparable) monitoring station; process using LCD_MOVES tool or manually to translate to MOVES input format.	For conformity analysis, use same meteorology data as used in the SIP, for other MOVES applications update every 4-5 years, or when MOVES defaults change if using those.
	I/M programs	MOVES2014 defaults.	Update if significant changes are made to I/M program.	Update whenever MOVES defaults change or if significant changes are made to I/M program.
	Fuel formulation and supply	MOVES2014 defaults.	Update sensitive parameters (e.g., ethanol content, diesel sulfur, RVP) as needed.	Update whenever MOVES defaults change or if significant changes are made to fuel characteristics.

Activity Inputs: VMT and VMT-Based Adjustments

VMT-based inputs include VMT by vehicle class; road type distribution; temporal adjustments (hour, day, and month VMT fractions); and ramp fractions.

Several data sources were obtained and evaluated for the case study, including 2012 YMPO travel demand model outputs, 2008 Arizona Statewide Travel Demand Model (AZTDM 2) outputs for Yuma County, 2011 and 2012 HPMS VMT for Yuma County, 2011 HPMS segment data, and 2012 statewide traffic monitoring data from the ADOT TDMS. Based on this evaluation, the following recommendations are made for the VMT-based inputs:

- **VMT by vehicle class and road type distributions** – HPMS segment data should be used to develop VMT by roadway functional class for historical years and in combination with the local MPO travel demand model results (or statewide model outside of MPO areas) to develop HPMS adjustment factors for future years. ADOT should use the HPMS segment data to develop annual HPMS VMT reports by county and roadway functional class so that it is readily available for any MOVES analysis being performed throughout the state. Vehicle classification counts (traffic monitoring data) from specific regions of the state (at least north and south) should be used to further break down VMT by the five vehicle classes required in MOVES2014. ADOT should analyze the traffic monitoring data and publish reports with vehicle distribution percentages by MOVES road type for each region on an annual basis. Further analysis should be conducted to possibly disaggregate the south region into multiple regions, with the Phoenix metropolitan area as a separate region. For the long term, installation of more permanent classification could provide classified VMT by county.
- **Ramp fraction** – If available, a local MPO travel demand model should be used to develop ramp fractions; otherwise, the statewide model should be used. All ramps/interchanges for the area of concern should be included. If available, ramp counts should be used to validate ramp volumes in the travel demand model. Results should be compared to the MOVES default eight percent ramp fraction; if travel demand model results seem unreasonable, the MOVES default is used instead. As a long-term goal, ADOT should ensure better ramp count coverage for all Interstates and freeways around the state and use these to validate ramp volumes in the statewide model.
- **Temporal distributions** – The statewide results for month, day, and hour VMT fractions developed from ADOT TDMS data should be used for all areas of the state. This research found some differences in results between regions, but research for NCHRP Project 25-38 showed that MOVES emissions results are not very sensitive to temporal distribution inputs (Porter et al. 2014). Therefore, using statewide results should be adequate, given that the north region of the state did not have enough stations available to cover all MOVES road types. ADOT should use new traffic monitoring data to update the temporal distribution results every few years. For the long term, temporal expansion of the use of permanent classification counters could allow for temporal distributions by region, and possibly even by county.

Activity Inputs: Speed Distributions

Travel demand model outputs were obtained from the 2012 YMPO model and 2008 statewide model for Yuma County. These outputs include link-level speed estimates for a daily timeframe (YMPO model) or for each of four times of day (statewide model). Traffic monitoring data were also examined to determine whether real-world speed information could be used to calibrate/validate the travel demand model results. Postprocessing procedures were also applied to the travel demand model speed estimates to disaggregate volumes and speed estimates by hour. Postprocessing has been found in NCHRP 25-38 and other research to improve the quality of speed estimates developed from travel demand models (Porter et al. 2014).

Where available, observed speed data are the most accurate source for estimating current or historical-year emissions. However, spatial coverage of observed speed data is limited, and observed data may not be representative of the entire network, especially for unrestricted-access roadways. Also, models must be used for estimating future-year speeds, unless future- and current-year speeds are assumed to be the same, as EPA guidance recommends the use of consistent methods for base- and future-year speed estimation. Therefore, the use of modeled speeds is recommended, but with adjustments to match observed speed distributions.

The speed postprocessing procedure applied in this case study appears worthwhile to implement in Yuma County and other Arizona counties, where miles traveled on congested roadways make up a significant portion of the total VMT. The postprocessing based on the statewide model seems to produce better results due to more realistic free-flow assumptions coded in the model links and the time-of-day component of that model helping to show how traffic and speeds vary over the course of the day. However, more improvements to the statewide model and the speed postprocessing procedure would help improve results further. Therefore:

- ADOT should use the statewide model results with speed postprocessing to produce speed distributions in all parts of the state, unless a more geographically detailed time-of-day model is available in certain areas (e.g., the Phoenix area).
- ADOT should use traffic monitoring data and possibly electronic travel time data to adjust free-flow speeds on statewide model links to better reflect real-world speeds, which are usually higher than modeled speeds. Alternatively, ADOT could adjust the posted speeds by roadway functional class in the speed postprocessing routine. Further analysis of traffic monitoring data would be required to come up with lookup tables of a speed increment to add to posted speed by functional class. This analysis could also come up with different speed increments to add to posted speed by time of day to account for the patterns of slower overnight driving speeds shown in this research.

Additional research should be conducted to determine whether traffic monitoring speed distributions that represent an array of different vehicle speeds can be incorporated into speed postprocessing procedures so that these procedures result in a distribution of speeds over space (e.g., all of the links in the travel demand model network) and vehicles (by incorporating the traffic monitoring distributions).

Meteorological Inputs

MOVES requires monthly average temperature and relative humidity values for each hour of the day. Two of the most commonly used sources of meteorological data needed for MOVES modeling were compared: MOVES defaults and NCDC LCD summaries. MOVES contains data for each county in the US (applying spatial averaging between meteorological stations), while LCD data are only available for weather monitoring stations, which are often located in or near major metropolitan areas. MOVES2014 data are based on a single year (2011).

For the case study, LCD data were obtained from Phoenix, which is the closest active station to Yuma. Modest differences were observed between LCD data for Phoenix and MOVES2014 defaults for Yuma County, with MOVES showing lower nighttime temperatures and higher relative humidity.

For quick, "back-of-the-envelope" scenario evaluations, the MOVES meteorological defaults are sufficient and prevent the need for processing LCD data. For more stringent regulatory purposes, including SIP and conformity analysis, EPA technical guidance recommends the use of LCD data. A case could be made that the MOVES defaults may be more reliable for locations far from the nearest monitoring station and with large changes in elevation, since the defaults take spatial averaging into account. However, some negotiation with EPA would be required to approve use of the defaults.

I/M Program Inputs

MOVES contains default I/M program inputs that include information, such as affected source types, MY ranges, inspection frequency, type of test performed, and vehicle compliance factor. The ADEQ is responsible for implementing the state's I/M program, which has been in place for many years in the Phoenix and Tucson areas and has remained fairly static. For this case study, I/M data were reviewed for Phoenix, since the program does not cover Yuma County.

As is true for the MOVES2010b defaults, incorrect application of over-broad MY exemptions will overestimate the effect of the I/M program on the area. Similarly, unduly high compliance factors will also significantly overestimate I/M benefit estimates. The MOVES2014 defaults appear to more accurately represent the benefits of the program. The use of MOVES2014 defaults is, therefore, recommended. If Arizona makes substantial changes to the I/M program in the future, the default I/M inputs will need to be updated to reflect those changes.

Fuels Inputs

The MOVES model contains default fuel formulations for every county in Arizona. These formulations are described by a number of different physical characteristics, including RVP, sulfur level, oxygenate volumes, aromatic/olefin/benzene content, and other parameters. In turn, these fuels are apportioned by county, calendar year, month, and market share.

The use of MOVES2014 defaults for fuel inputs is recommended, with periodic updates to the especially sensitive fuel variables as needed. The MOVES defaults capture expected variation in RVP, sulfur level, and other factors on a month-to-month basis for gasoline blends. However, in the future, users should be careful to ensure that the defaults accurately represent the fuel being used.

Arizona users of MOVES may wish to periodically contact AZDWM, which is responsible for ensuring refiners, distributors, and fueling stations comply with state-mandated fuel blends, to make certain that information in the model is up-to-date. This is especially important for oxygenates, diesel sulfur levels, and overall market share of fuel blends. If ADOT can secure results of fuel sample testing from its partner agencies for minimal cost, then updating MOVES defaults with more representative fuel formulations and market share may prove worthwhile.

FLEET INPUTS

Age Distribution

Age distribution shows the fraction of vehicles by age (1 to 29 years and more than 30 years). Different age distributions are provided for each vehicle (source) type.

Data Sources Used

Source type population tables were developed from a list of all vehicles registered in Arizona. These data were obtained from ADOT. A text file was obtained that contained one record per registered vehicle or trailer. The dataset included 14 data fields, including information such as the VIN, vehicle MY, make, gross vehicle weight, and county of registration. These data were provided in June 2014 and represent the vehicles registered at that time. There were 5,608,156 records in the registration data provided by ADOT.

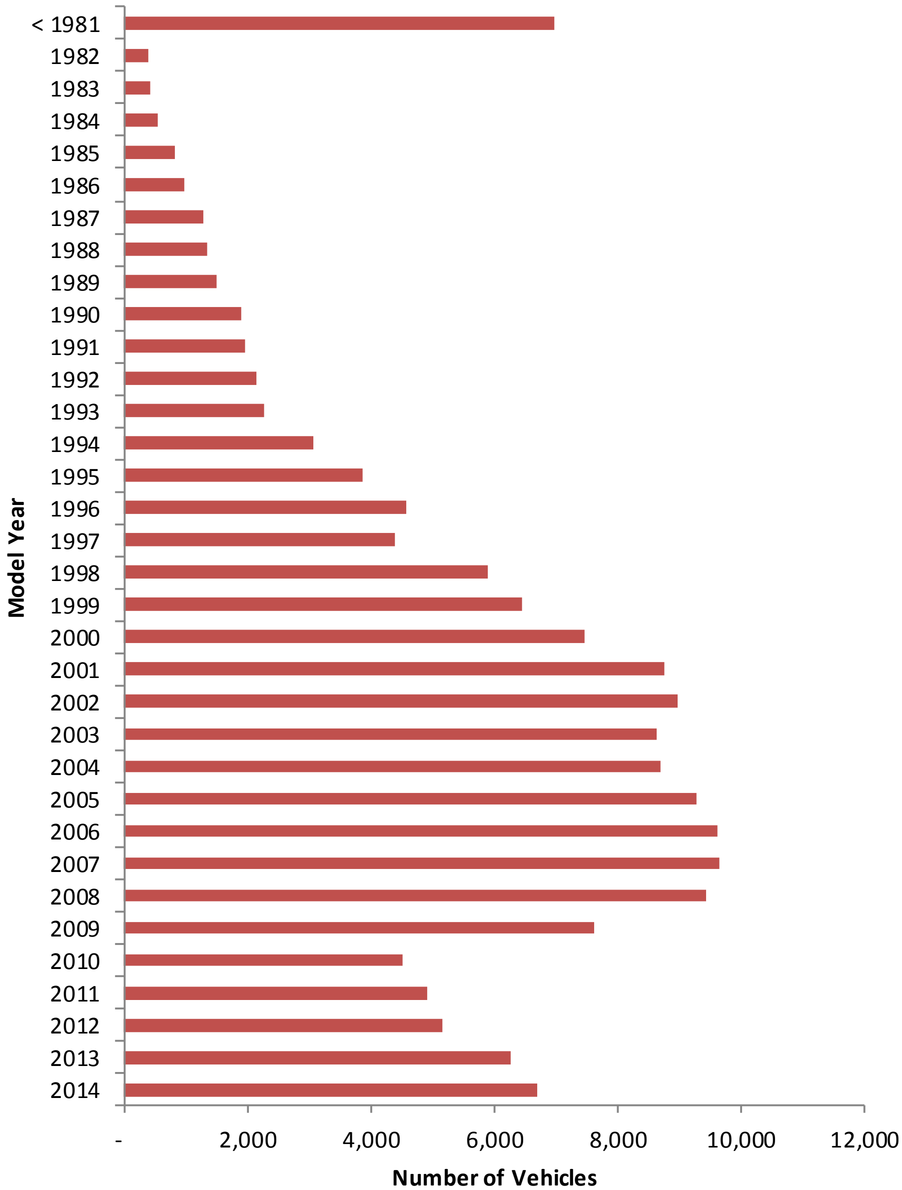
Processing Methods

The data developed for the source type population tables, as shown in the next section, were also classified into MYs using again the registration data MY in combination with the VIN-decoded MY. In many instances, the two sources of MY agreed. When they did not, if the VIN decoded without errors and was newer than 1981, the VIN-decoded MY was used as the final MY. The age of the vehicles was calculated using 2014 as the zero year, and the age distribution of the fleet was calculated for each MOVES source type ID found in the registration data in Yuma County for vehicles age zero to 30 years.

Findings

Figure 9 shows the MY distribution of the overall fleet in Yuma County for all vehicles (data is from ADOT vehicle registration records). These are the MYs for the entire county for all ages, with the MY 1981 containing all vehicles for MY 1981 and older. The age fractions were calculated separately for each MOVES source type and developed into files to use as inputs to MOVES.

The number of vehicles in MYs 2000 to 2007 is large compared to more recent years. This unusual distribution reflects the economic boom followed by recession starting in 2008. As a result, the current age distribution of Arizona vehicles is relatively old.



Model Year	Percent	Cum. %
< 1981	4.2%	4.2%
1982	0.2%	4.4%
1983	0.3%	4.7%
1984	0.3%	5.0%
1985	0.5%	5.5%
1986	0.6%	6.1%
1987	0.8%	6.9%
1988	0.8%	7.7%
1989	0.9%	8.6%
1990	1.1%	9.7%
1991	1.2%	10.9%
1992	1.3%	12.2%
1993	1.4%	13.5%
1994	1.8%	15.4%
1995	2.3%	17.7%
1996	2.8%	20.5%
1997	2.6%	23.1%
1998	3.5%	26.6%
1999	3.9%	30.5%
2000	4.5%	35.0%
2001	5.3%	40.3%
2002	5.4%	45.7%
2003	5.2%	50.8%
2004	5.2%	56.1%
2005	5.6%	61.6%
2006	5.8%	67.4%
2007	5.8%	73.2%
2008	5.7%	78.9%
2009	4.6%	83.4%
2010	2.7%	86.2%
2011	2.9%	89.1%
2012	3.1%	92.2%
2013	3.8%	96.0%
2014	4.0%	100.0%

Figure 9. Model Year Distribution of the Yuma County Fleet

Recommendations

To develop the age fractions for Yuma County, it is recommended that registration data from Arizona be used. Once the population fractions are determined by MOVES source type ID, the MY provided in the registration data can be used to easily determine the age fractions for each source type. Using this method to classify the vehicles into the MOVES source type IDs also makes the replication of the results for the remainder of the state very easy, because the classification is done for all registered vehicles, regardless of county of registration. The data should be updated on a regular basis, perhaps every two or three years or at most every four to five years, to reflect the changing nature of the vehicle fleet as economic cycles change.

Source Type Population

The source type population input shows the number of vehicles by vehicle (source) type. There are 13 source type categories in MOVES.

Data Sources Used

Source type population tables were developed from a list of all vehicles registered in Arizona. These data were obtained from the ADOT MVD. A text file was obtained that contained one record per registered vehicle or trailer. The dataset included 14 data fields, including information such as the VIN, vehicle MY, make, gross vehicle weight, and county of registration. These data were provided in June 2014 and represent the vehicles registered in 2014 at that time. There were 5,608,156 records in the registration data provided by ADOT.

Processing Methods

In order to develop the population tables, the vehicles must be classified into MOVES source type IDs. Some vehicles included in the registration database were first removed from the data, because they are not included in the MOVES model. These included off-road vehicles such as all-terrain vehicles (ATV) or dune buggies, and small electric vehicles such as golf carts. The vehicles were then categorized into MOVES source type categories using the field containing the body styles in the registration data, which contains detailed information about the body style of the vehicle, including refuse trucks, buses, auto carriers, dump trucks, cranes, and vans.

A VIN decoder was then applied to further refine the classification of vehicles. In some cases, the gross vehicle weight rating (GVWR) from the VIN-decoded information was used to classify the trucks. Any vehicle classified as a truck that weighed less than 19,501 pounds was assigned a MOVES source type ID of 30 to be a passenger or light commercial truck, based on EPA guidance and documentation of MOVES source types.

For vehicles weighing more than 19,500 pounds, the weight classification from GVWR does not completely distinguish the split between single-unit trucks (50s) and combination trucks (60s). Instead, a method was developed to split the heavier trucks, using the registration data body style and make, and the vehicle manufacturer from the VIN-decoded information. In addition, the vehicles in this category specified by the registration body style to be motor homes or recreational vehicles (RV) were put directly into the MOVES source type ID of 54 for motor homes. In addition, vehicles specified by the body style to be refuse trucks were put into the MOVES source type ID of 51 for refuse trucks.

The vehicle body style from the registration data was used to classify all buses (MOVES source type ID 40s), although not enough information was available to classify the bus type as intercity, transit, or school bus. As shown in Table 9, the default MOVES population fractions for Yuma County were used to determine the percentage of all of the buses that should be classified in MOVES source types 41, 42, and

43. A similar method was used to split all trucks (MOVES source type ID in the 30s, 50s, and 60s) into their usage categories for either personal or commercial (31/32) or short-haul or long-haul (52/53, 61/62).

Findings

Table 10 compares the results of the population counts by source type ID in Yuma County from the MOVES default data with the estimates from the ADOT registration data. There are about 16,000 more vehicles found in the registration data than estimated in the MOVES default data (11 percent higher). The registration data also show a relatively higher proportion of light trucks (31 and 32) relative to passenger cars (21) than in the MOVES data. However, there are somewhat fewer heavy trucks in the registration data than in the MOVES data. The discrepancy is not surprising, since trucks are often not registered in the same location that they are used.

Table 10. Comparison of Yuma County Source Type Population Estimates

Source Type ID	Source Type ID Description	MOVES2014 Yuma County Default Populations (2015)		Yuma County Population from June 2014 Registration Data	
		Population	Fraction	Population	Fraction
11	Motorcycle	6,848	4.5%	6,057	3.6%
21	Passenger Car	70,068	45.5%	69,681	40.9%
31	Passenger Truck	51,214	33.2%	67,196	39.4%
32	Light-Truck Commercial	17,110	11.1%	22,449	13.2%
41	Intercity Bus	105	0.1%	62	0.0%
42	Transit Bus	55	0.0%	33	0.0%
43	School Bus	706	0.5%	416	0.2%
51	Refuse Truck	44	0.0%	38	0.0%
52	Single-Unit Short-Haul Truck	3,920	2.6%	1,583	0.9%
53	Single-Unit Long-Haul Truck	574	0.4%	232	0.1%
54	Motor Home	926	0.6%	1,081	0.6%
61	Combination Short-Haul Truck	1,001	0.7%	722	0.4%
62	Combination Long-Haul Truck	1,320	0.9%	952	0.6%
Total		**153,890**	**100.0%**	**170,502**	**100.0%**

Recommendations

The latest state registration data from the ADOT MVD is the recommended data source to develop population fractions for Yuma County and other counties in Arizona. The initial classification involved a fair amount of work because the information provided in the registration records does not fully correspond to the MOVES source type definitions. However, once vehicles are classified into the MOVES source type IDs, it is easy to replicate the results for each county in the state.

Population fractions change over time and should be updated on a regular basis. To do so consistently with the procedures applied here would require a VIN decoder. Without the VIN decoder, the vehicle manufacturer and gross weight rating could not be identified. These items improve the accuracy of the classification, but are not essential. Other procedures used in this case study to classify vehicles will expedite future updates by ADOT.

ACTIVITY INPUTS

VMT and VMT-Based Adjustments

VMT and VMT-based adjustments as MOVES inputs include:

- VMT by vehicle class (six classes)
- Road type distribution (VMT by MOVES road type) – can be provided by source type
- Temporal adjustments (hour, day, and month VMT fractions) – can be provided by source type and road type
- Ramp fraction (fraction of highway travel on highway entrance/exit ramps)

Data Sources Used

A number of data sources were obtained to evaluate their utility for producing VMT-based MOVES inputs:

- **2012 YMPO travel demand model outputs** – Provides VMT by road type, but may need to be adjusted with HPMS adjustment factors. Also used to produce ramp fractions. Model data were obtained from YMPO staff.
- **2008 statewide travel demand model outputs for Yuma County** – Provides VMT by road type and three vehicle types, but may need to be adjusted with HPMS adjustment factors. Also used to produce ramp fractions. Statewide model data were obtained from ADOT staff.
- **2011 and 2012 HPMS VMT for Yuma County** – Provides official HPMS total VMT based on ATR and coverage count program for all public roads in Yuma County. Does not provide VMT by roadway functional class, so must be combined with HPMS segment data to produce HPMS adjustment factors by roadway functional class. "Daily Vehicle Miles of Travel (DVMT) by County" tables are available in ADOT (2014).
- **2011 HPMS Segment Data** – Provides official HPMS VMT by roadway functional class in Yuma County. Does not include minor collectors or local roads, so must be combined with HPMS total VMT to produce HPMS adjustment factor by roadway functional class. Cambridge Systematics, Inc., already had a copy of the national database. The ADOT HPMS coordinator should have this for Arizona.
- **2012 statewide traffic monitoring data from ADOT TDMS** – Provides classification counts to break total VMT into vehicle classes, and to help provide detailed road type distributions by source type. Also provides information for temporal distributions (month, day, and hour VMT fraction). These data were obtained from ADOT's Transportation Data Management System (ADOT 2016).

It is not necessary to use both the MPO travel demand model and statewide travel demand model, but they were both explored in this analysis to understand the advantages and disadvantages of each.

Table 11 shows the latest (post-2010) HPMS Roadway Functional Class Codes and how they relate to MOVES road types. Table 12 shows the FHWA "Scheme F" vehicle classification codes and how they relate to HPMS vehicle types (the first digit of MOVES source types). These two tables are referenced throughout this section.

Table 11. Roadway Functional Classes and MOVES Road Types

Functional Class Code	Description	MOVES Road Type Code	MOVES Road Type
N/A	N/A	1	Off-Network[a]
1R	Interstate, Rural	2	Rural restricted-access
2R	Principal Arterial – Other Freeways and Expressways		
3R	Principal Arterial – Other	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 – Other Freeways and Expressways		
3U	Principal Arterial – Other	5	Urban unrestricted-access
4U	Minor Arterial, Urban		
5U	Major Collector, Urban		
6U	Minor Collector, Urban		
7U	Local, Urban		

[a] MOVES Road Type 1 (Off-Network) is reserved for non-running emission processes (starts, extended idle, etc.) and is therefore not associated with any roadway functional classes.

Table 12. FHWA "Scheme F" Vehicle Classes and HPMS Vehicle Types

FHWA Vehicle Class	FHWA Vehicle Classification Description	MOVES HPMS Vehicle Types
Class1	Motorcycles	10 – Motorcycles
Class2	Passenger Cars	20 – Passenger Cars[a]
Class3	Other Two-Axle, Four-Tire Single-Unit Vehicles	30 – Light-Duty Trucks[a]
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	
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

[a] Note: MOVES2014 uses HPMS Vehicle Type Code 25 to denote the sum of all passenger cars (20) and light-duty trucks (30).

Processing Methods

- **Vehicle Classification Count Data Preparation –** Many of the VMT-based inputs used classification counts available in the traffic monitoring data from 2012, which was chosen to match the base year of the YMPO model. The data needs assessment described in Chapter 3 evaluated the same traffic monitoring data, but for 2010 (which is why the number of stations shown in Table 15 does not match the number shown in Table 7). Figure 10 shows the 154 stations that provide classification counts in Arizona, and Table 13 shows the distribution of stations by county and road type. Multiple queries were performed in an Access database to filter this initial set of counting stations to sets that could be used to produce various VMT-based MOVES inputs. The following filters were used:
    - **Filter #1 –** The 154 classification count stations use one of two different vehicle classification schemes. One is based on vehicle length, but is not useful since there is not a direct relationship between vehicle length and MOVES vehicle types. The second scheme is the FHWA's "Scheme F," which uses 15 vehicle classes that can be easily translated to six vehicle types useful in MOVES. A filter was applied to remove the stations that use a length-based classification, which left 97 stations, as shown in Table 14. The stations remaining after this filter can be used to create the VMT by vehicle class and road type distribution MOVES inputs.

- **Filter #2 –** The 97 remaining stations from the previous step were further filtered to remove stations that did not have a complete 24 hours of data. The purpose of this filter is to remove temporary count stations that did not collect data for 24 hours from midnight to midnight, since using a partial day count would not provide the data necessary to produce hour VMT fractions. This filter did not remove any stations, since all classification count stations appear to be permanent stations. Therefore, the same 97 stations, as shown in Table 14, remained after this filter and could be used to create the hour VMT fraction input.
- **Filter #3 –** The 97 stations remaining from the previous step were further filtered to remove stations that did not have enough days/month of data for each of the 12 months of the year to produce day and month VMT fraction inputs. The stations that were not filtered out had to have at least 15 days of counts for each of the 12 months. This filter left 26 stations remaining, as shown in Table 15. Data from these stations were used to create the month and day VMT fraction inputs.

- **VMT by Vehicle Class MOVES Input –** To create the VMT by vehicle class MOVES input (*HPMSVTypeYear* table), VMT by road type information is combined with vehicle classification counts. VMT by road type can be estimated for 2012 using a combination of HPMS segment data and ADOT HPMS VMT reports. These sources of HPMS VMT can be combined with model VMT to create HPMS adjustment factors to be used with future-year model runs to get future-year VMT.

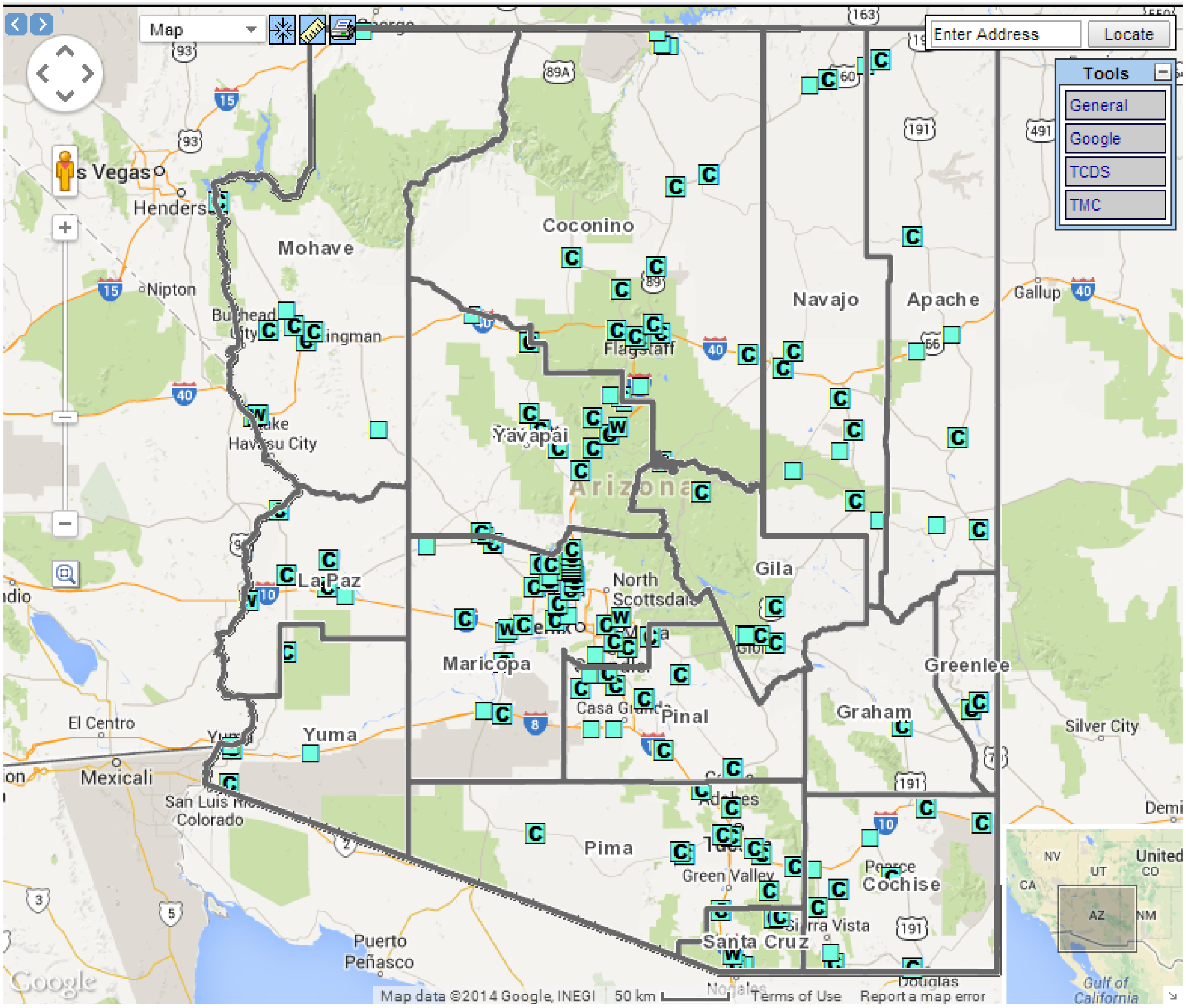


Figure 10. Stations that Provide Classification Counts in Arizona
Source: ADOT (2016)

Table 13. Stations by County and Road Type

MOVES Roadway Functional Class							
	Rural			Urban			Grand
County	2	3	Total	4	5	Total	Total
Apache	2	4	6				6
Cochise	4	5	9		1	1	10
Coconino	2	11	13	1	3	4	17
Gila		4	4		2	2	6
Graham		1	1		1	1	2
Greenlee		1	1				1
La Paz	2	5	7				7
Maricopa	12	8	20	4	15	19	39
Mohave	3	5	8	2		2	10
Navajo	1	11	12				12
Pima	4	4	8	1	2	3	11
Pinal	5	5	10				10
Santa Cruz		3	3	1	1	2	5
Yavapai	5	7	12		2	2	14
Yuma	1	1	2	1	1	2	4
Total	**41**	**75**	**116**	**10**	**28**	**38**	**154**

Table 14. Stations Available after Filters 1 and 2

	MOVES Road Type				
Region/County	2	3	4	5	Total
North	7	17	2	4	30
Apache	0	0	0	0	0
Coconino	2	7	1	2	12
Mohave	2	3	1	0	6
Navajo	1	5	0	0	6
Yavapai	2	2	0	2	6
South	20	24	12	11	67
Cochise	2	1	0	1	4
Gila	0	3	0	2	5
Graham	0	1	0	0	1
Greenlee	0	1	0	0	1
La Paz	1	4	0	0	5
Maricopa	9	7	9	5	30
Pima	4	3	1	2	10
Pinal	3	3	0	0	6
Santa Cruz	0	0	1	1	2
Yuma	1	1	1	0	3
Total	**27**	**41**	**14**	**15**	**97**

Table 15. Stations Available After Filters 1, 2, and 3

Region/County	MOVES Road Type				Total
	2	3	4	5	
North	1	1	0	2	**4**
Apache	0	0	0	0	**0**
Coconino	0	0	0	0	**0**
Mohave	0	0	0	0	**0**
Navajo	1	0	0	0	**1**
Yavapai	0	1	0	2	**3**
South	7	7	4	4	**22**
Cochise	1	0	0	0	**1**
Gila	0	2	0	1	**3**
Graham	0	0	0	0	**0**
Greenlee	0	0	0	0	**0**
La Paz	0	1	0	0	**1**
Maricopa	2	4	3	1	**10**
Pima	3	0	1	2	**6**
Pinal	1	0	0	0	**1**
Santa Cruz	0	0	0	0	**0**
Yuma	0	0	0	0	**0**
Grand Total	**8**	**8**	**4**	**6**	**26**

The latest year of HPMS segment data available is 2011. Table 16 shows annual VMT for Yuma County by FHWA functional class and area type, derived from the 2011 HPMS segment data. The HPMS segment data has a field for annual average daily traffic (AADT), beginning milepoint, and ending milepoint for each section. DVMT is calculated for each segment by calculating the length of the segment (ending milepoint minus beginning milepoint), and then multiplying by AADT. The DVMT is multiplied by 365 to obtain an annual VMT. The annual VMT is summed by FHWA functional class and area type to create Table 16.

Table 16. Yuma County 2011 Annual VMT from HPMS Segment Data

Roadway Functional Class Code	Description	Rural	Urban
1	Interstate	337,464,000	72,458,000
2	Principal Arterial - Other Freeways and Expressways	25,101,000	2,854,000
3	Principal Arterial – Other	136,464,000	202,548,000
4	Minor Arterial	114,726,000	166,136,000
5	Major Collector	166,560,000	92,279,000
Total		**780,315,000**	**536,275,000**

Since the Yuma County case study is for the year 2012, information from Table 16 was adjusted using the ratio of 2012 to 2011 HPMS VMT for Yuma County from ADOT's online tables. (Go to http://www.azdot.gov/planning/DataandAnalysis/highway-performance-monitoring-system, and under "Daily Vehicle Miles of Travel (DVMT) by County," select 2012. This pulls up a PDF table, which can also be found directly at http://www.azdot.gov/docs/default-source/planning/dvmt-2012.pdf?sfvrsn=6.) Yuma County DVMT was 4,300,000 for 2012 and 4,339,000 for 2011. Therefore, a ratio of 0.9910 was applied to the values in Table 16 to produce the values for roadway functional classes 1 to 5 in Table 17. Since HPMS segment data are not available for roadway functional classes 6 and 7, these are estimated by multiplying DVMT (4,300,000) by 365 to produce annual VMT (1,569,500,000), and subtracting the sum of rural and urban annual VMT for functional classes 1 to 5 (1,304,756,165) to produce the annual VMT for functional classes 6 and 7 (264,743,835). This amount is split between rural and urban using the ratio from functional class 5 to produce the VMT, as shown in Table 17.

Table 17. Estimated Yuma County 2012 Annual VMT

Roadway Functional Class Code	Description	Rural	Urban
1	Interstate	334,430,791	71,806,730
2	Principal Arterial – Other Freeways and Expressways	24,875,386	2,828,348
3	Principal Arterial – Other	135,237,428	200,727,449
4	Minor Arterial	113,694,814	164,642,729
5	Major Collector	165,062,918	91,449,574
6 & 7	Minor Collector and Local	170,359,695	94,384,140
Total		**943,661,032**	**625,838,970**

The VMT from Table 17 is summarized into MOVES road type (using equivalencies shown in Table 9) to produce the HPMS VMT column in Table 18. This 2012 HPMS VMT will be used directly for the next steps of this case study; however, when preparing MOVES inputs for future years, it is helpful to prepare HPMS adjustment factors that compare HPMS VMT to VMT estimated by the travel demand model. The YMPO travel demand model 2012 annual VMT is shown in the "Model VMT" column. The HPMS Adjustment Factor is calculated by taking HPMS VMT and dividing by Model VMT.

These factors can then be multiplied by model VMT results for future years to adjust the model results. An HPMS Adjustment Factor of 1.00 means the model is perfectly predicting real-world VMT, a factor of greater than 1.00 means the model is underpredicting VMT, and a factor of less than 1.00 means the model is overpredicting VMT. Sometimes urban/rural designations between HPMS and the travel demand model do not align properly for every roadway segment. For example, the high HPMS adjustment factor for rural restricted-access roads (type 2) and low HPMS adjustment factor for urban restricted-access roads (type 4) suggest that the urban/rural designations between the model and HPMS may not completely match. HPMS adjustment factors can also be calculated at other levels of aggregation. For example, in Georgia and Tennessee, it is common to calculate a separate HPMS adjustment factor for each FHWA roadway functional class. This can be helpful if classification counts are analyzed at this level of detail (they are not for this case study).

Table 18. HPMS Adjustment Factors Using 2012 Annual HPMS and Model VMT

MOVES Road Type	Model VMT	HPMS VMT	HPMS Adjustment Factor
2	244,180,548	359,306,177	1.471
3	499,482,964	584,354,855	1.170
4	163,764,423	74,635,077	0.456
5	355,491,298	551,203,891	1.551
Total	**1,262,919,233**	**1,569,500,000**	**1.243**

At this point, the VMT by MOVES road type can be broken down further into the six HPMS vehicle types by combining it with vehicle classification count data. The vehicle classification counts from the 97 stations in Table 14 were used to create percent distributions by the six HPMS vehicle types for each of the four MOVES road types following these steps:

- Vehicle type equivalencies from Table 12 were used to summarize volumes by 15 FHWA vehicle classes into six HPMS vehicle types.
- Volumes by six HPMS vehicle types were summed over all hours, day, and months for all stations within a county/MOVES road type combination (within a single cell of Table 11). This is done within Microsoft Access and exported to a Microsoft Excel table with 36 rows (60 county/MOVES road type combinations minus 24 with no stations) and six columns (for the six HPMS vehicle types).
- North/south designations were added to each of the 15 counties using the designations shown in Table 12.
- Pivot tables were used in Microsoft Excel to summarize volumes by HPMS vehicle type (rows) and MOVES road types (columns). The records were filtered by geographic area (either north/south or individual county).
- Within each MOVES road type, the volume for an individual HPMS vehicle type was divided by the volume over all vehicle types to create the percent distributions.

This process produced percent distributions by HPMS vehicle type for different geographies (statewide, north region, south region, Yuma County, etc.), which are compared in the Findings subsection below. For this case study, the southern region of Arizona (10 counties, 67 stations) was used, and the results are shown in Table 19. The 2012 HPMS VMT by road type from Table 18 is multiplied by the percentages in Table 19 to produce the more detailed VMT breakdown in Table 20. The resulting VMT for vehicle types 20 and 30 are summed and recorded under vehicle type 25 for compliance with MOVES2014, since vehicle classification counters are not reliable for differentiating between these two vehicle types. The VMT is summed across all four road types to produce the total column on the right. These five VMT numbers are used for the VMT by vehicle class (HPMSVTypeYear table) MOVES input table in MOVES2014. In older versions of MOVES (MOVES2010, MOVES2010a, or MOVES2010b), six VMT numbers must be entered (25 must be split into 20 and 30). It is recommended to use MOVES defaults to split the VMT for 25 into 20 and 30 since the vehicle classification counters are not reliable for differentiating these two vehicle types.

Table 19. Distribution of VMT by Vehicle Type from Vehicle Classification Counts in Southern Arizona

HPMS Vehicle Type	MOVES Road Type			
	2	3	4	5
10	0.53%	0.78%	0.54%	0.37%
20	66.02%	67.30%	73.11%	73.32%
30	18.95%	20.79%	18.68%	19.18%
40	0.74%	0.48%	0.51%	0.55%
50	3.43%	3.95%	3.29%	3.07%
60	10.34%	6.69%	3.86%	3.51%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 20. 2012 Yuma County VMT by Vehicle Class

HPMS Vehicle Type	MOVES Road Type				
	2	3	4	5	Total
10	1,894,731	4,554,622	405,411	2,051,430	8,906,195
25	305,276,035	514,771,643	68,507,257	509,870,295	1,398,425,229
40	2,658,381	2,824,364	382,479	3,041,432	8,906,655
50	12,320,483	23,089,848	2,456,004	16,915,397	54,781,732
60	37,156,547	39,114,378	2,883,927	19,325,337	98,480,189
Total	**359,306,177**	**584,354,855**	**74,635,077**	**551,203,891**	**1,569,500,000**

- **Road Type Distribution MOVES Input –** All of the data and calculation procedures described for the VMT by vehicle class input up to the point of Table 20 are used for the road type distribution input. The detailed VMT by MOVES road type and HPMS vehicle type in Table 20 are converted into road type distributions for each HPMS vehicle type. To do this, the VMT for a single HPMS vehicle type and MOVES road type are divided by the total VMT for that HPMS vehicle type over all MOVES road types (the number from the far right total column). This process produces the road type distributions shown in Table 21. The road type distribution input needs distributions by each of the 13 MOVES source types; therefore, the information from this table should be repeated for each of the source types that correspond to the HPMS vehicle type. Generally, the first digit of the source type indicates vehicle type, such as 41, 42, and 43 corresponding to 40; the exception is that 21, 31, and 32 all fall under 25.

Table 21. Road Type Distributions for Yuma County

HPMS Vehicle Type	MOVES Road Type				
	2	3	4	5	Total
10	0.21	0.51	0.05	0.23	1.00
25	0.22	0.37	0.05	0.36	1.00
40	0.30	0.32	0.04	0.34	1.00
50	0.22	0.42	0.04	0.31	1.00
60	0.38	0.40	0.03	0.20	1.00

- **Ramp Fraction MOVES Input –** The ramp fraction input is defined as the VHT on ramps divided by the VHT on all restricted-access roadway segments, including ramps. This is calculated as a percentage for both rural restricted-access roadways (MOVES road type 2) and urban restricted-access roadways (MOVES road type 4). This information can be calculated using travel demand model outputs in a spreadsheet format. Ideally, ramp link volumes from these outputs would be validated using ramp counts, but no ramp counts were available for Yuma County in the traffic monitoring data. Ramp counts are available for I-10, I-19, and in the Phoenix metropolitan area from the traffic monitoring data. The following procedure is used with the travel demand model outputs:
  - Ensure all links have MOVES road type codes assigned. If not, assign them using the crosswalk of roadway functional classification to MOVES road types found in Table 11.
  - Sum the VHT on all ramp links (functional class 8 in the YMPO model and 7 in the statewide model) for MOVES road types 2 and 4 (rural and urban) separately.
  - Sum the VHT on all restricted-access links for MOVES road types 2 and 4 separately.
  - Divide VHT on ramps by VHT on all restricted-access links for MOVES road types 2 and 4 separately.

This process is illustrated in Table 22 using information from the YMPO 2012 model and statewide 2008 model Yuma County results. The results show large differences between the YMPO model and statewide model. It is difficult to determine which model better represents real-world conditions, because ramp counts are not available, but they can be compared to the MOVES default value of 8 percent. Since the statewide model produces results 5 to 8 percentage points off the MOVES default value and since the YMPO model produces results less than 4 percentage points off the MOVES defaults, the YMPO model could be considered a more reliable source to produce ramp fractions. This may be due to more detailed local trip patterns picked up by the YMPO model compared to the statewide model.

Table 22. Ramp Fraction Calculation using YMPO and Statewide Models

Functional Class	VHT: YMPO Model		VHT: Statewide Model – Yuma County	
	MOVES Road Type		MOVES Road Type	
	2	4	2	4
Ramps (Step 2)	516	444	15	677
Interstates	8,036	8,893	8,201	4,433
Expressways	3,187	0	0	0
Total for restricted-access links (Step 3)	11,736	9,337	8,217	5,110
Ramp Fraction (Step 4)	4.40%	4.76%	0.19%	13.25%

- **Temporal Distributions MOVES Inputs (Month, Day, and Hour VMT Fraction) –** The classification count data go through an aggregation and calculation process to produce the month, day, and hour VMT fraction inputs. The following describes these calculation processes:
    - To produce month and day VMT fractions, data from the 26 stations, as shown in Table 15, are used. Hourly counts by vehicle type are summed up to become daily counts by vehicle type. This produces 9,149 station-days (rows) of counts (26 stations with an average of 351.9 days of counts per station). Each row has six columns for each of the six HPMS vehicle types.
        - To produce the month VMT fraction table, these data are aggregated further by summing traffic volumes over all station-days in a particular MOVES road type, month, and geographic area (north or south). The number of station-days associated with each traffic volume is also calculated. The traffic volume is divided by the number of station-days to get an average volume per day. This is done for each of the 12 months separately. Therefore, there should theoretically be 96 rows (4 road types x 2 geographic areas x 12 months), but no counts are available for road type 4 in the north, so there are only 84 rows. The lack of any stations for road type 4 in the north is likely due to the small number of urban restricted-access roadways in the north, and the few stations that are available for these roadways being filtered out for not having at least 15 days of data for each month of the year. The average volume per day for each of the 12 months is summed to produce a divisor for the month VMT fraction. The month VMT fraction is calculated as the average daily volume for each month divided by the sum of the average daily volumes over all 12 months.
        - To produce the day VMT fraction table, the data from the 9,149 row table is aggregated further by summing traffic volumes over all station-days in a particular month, MOVES road type, and day type (weekend or weekday). Therefore, there are 96 rows (12 months x 4 MOVES road types x 2 day types). The number of station-days (rows from the previous table) associated with each traffic volume is also calculated. The traffic volume is divided by the number of station-days to get an average volume per day. The average volume per day for each of the two day types is summed to produce a

divisor for the day VMT fraction. The day VMT fraction is calculated as the average daily volume for each day type divided by the sum of the average daily volumes over the two day types. Day VMT fractions can be produced for different geographic areas by first filtering the 9,149-row table to only include stations within a north/south region or particular county.

- To produce the hour VMT fraction input, data from the 97 stations shown Table 14 are used. A table with 192 rows (4 MOVES road types, 2 day types, and 24 hours) and 6 columns (six HPMS vehicle types) is created to hold the sum of volumes over multiple stations and days. This table contains the numerators for the hour VMT fractions. Another table is created that sums the volumes over 24 hours and contains the divisors for the hour VMT fraction. The numerators are divided by the divisors to create a set of 24-hour VMT fractions for each combination of road type, day type, and HPMS vehicle type. This is only done for a statewide geographic area because the geography is not believed to influence daily distribution of traffic as it does for monthly distributions.

Findings

The following subsections compare alternative data sources and methods for creating VMT-based MOVES inputs. For traffic monitoring data, different geographic areas, such as north region, south region, statewide, or individual counties, are often considered. These geographic comparisons are made to help understand the tradeoffs of using a larger sample of counting stations from a wider geographic area that may not completely represent conditions in an individual county vs. using a smaller sample of counting stations for an individual county.

- **VMT by Vehicle Class and Road Type Distribution –** Figure 11 and Table 23 compare the distributions of VMT by HPMS vehicle type produced from the traffic monitoring data for different geographic areas. These are produced from various sets of the 97 stations, as shown in Table 14. Since the south region of the state contains 67 out of the 97 stations, the statewide and south results are similar. The north shows more HDTs and fewer LDVs on restricted-access roadways when compared to the south. The differences in the distributions for unrestricted-access roadways are small when comparing north and south. Three counting stations are available from Yuma County: one on MOVES road type 2, one on MOVES road type 3, and one on MOVES road type 4. No counting station was available from Yuma County for MOVES road type 5. Even with this limited data from Yuma County, it can be seen that distributions in Yuma County are fairly different from those in both the north and south region as a whole. Since MOVES emissions results are fairly sensitive to the distribution of VMT by vehicle class, and since these limited data suggest that results can vary substantially by county, developing more reliable classification data by county should be considered as a future goal. This may require additional investment in classification counters throughout the state.

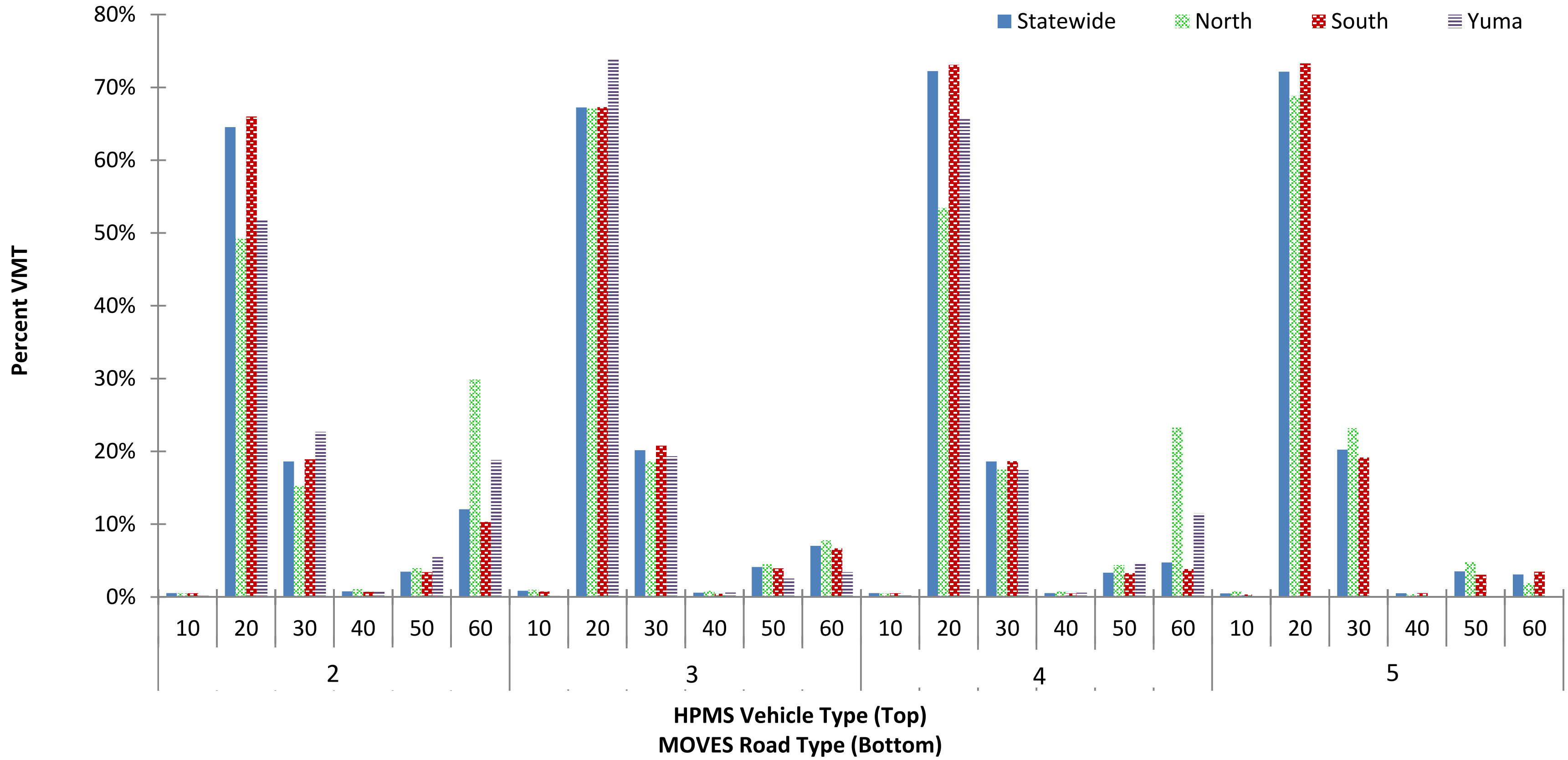


Figure 11. Comparison of Vehicle Classification Results from Different Geographic Areas

Table 23. Comparison of Vehicle Classification Results from Different Geographic Areas

MOVES Road Type	HPMS Vehicle Type	Statewide	North	South	Yuma
2	10	0.53%	0.53%	0.53%	0.19%
2	20	64.55%	49.22%	66.02%	51.94%
2	30	18.63%	15.28%	18.95%	22.70%
2	40	0.77%	1.10%	0.74%	0.82%
2	50	3.48%	3.97%	3.43%	5.50%
2	60	12.05%	29.90%	10.34%	18.84%
2	**All**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
3	10	0.85%	1.02%	0.78%	0.18%
3	20	67.24%	67.12%	67.30%	73.81%
3	30	20.16%	18.66%	20.79%	19.36%
3	40	0.60%	0.88%	0.48%	0.63%
3	50	4.12%	4.52%	3.95%	2.56%
3	60	7.02%	7.81%	6.69%	3.44%
3	**All**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
4	10	0.54%	0.51%	0.54%	0.23%
4	20	72.23%	53.46%	73.11%	65.66%
4	30	18.63%	17.52%	18.68%	17.45%
4	40	0.53%	0.82%	0.51%	0.61%
4	50	3.34%	4.41%	3.29%	4.55%
4	60	4.74%	23.28%	3.86%	11.50%
4	**All**	**100.00%**	**100.00%**	**100.00%**	**100.00%**
5	10	0.49%	0.81%	0.37%	NA
5	20	72.15%	68.85%	73.32%	NA
5	30	20.23%	23.20%	19.18%	NA
5	40	0.52%	0.42%	0.55%	NA
5	50	3.52%	4.79%	3.07%	NA
5	60	3.10%	1.94%	3.51%	NA
5	**All**	**100.00%**	**100.00%**	**100.00%**	**NA**

Figure 12 compares road type distribution results from the travel demand model without classification count information to the results from combining the classification count information with the travel demand model outputs (shown as five vehicle types). Since the light-duty cars and trucks (vehicle type 25) make up a majority of the VMT, the “without classification” results are very close to the light-duty results. However, motorcycles, buses, and trucks have fairly different results in some cases. Therefore, it is helpful to use the vehicle classification data to produce these more detailed results by vehicle type.

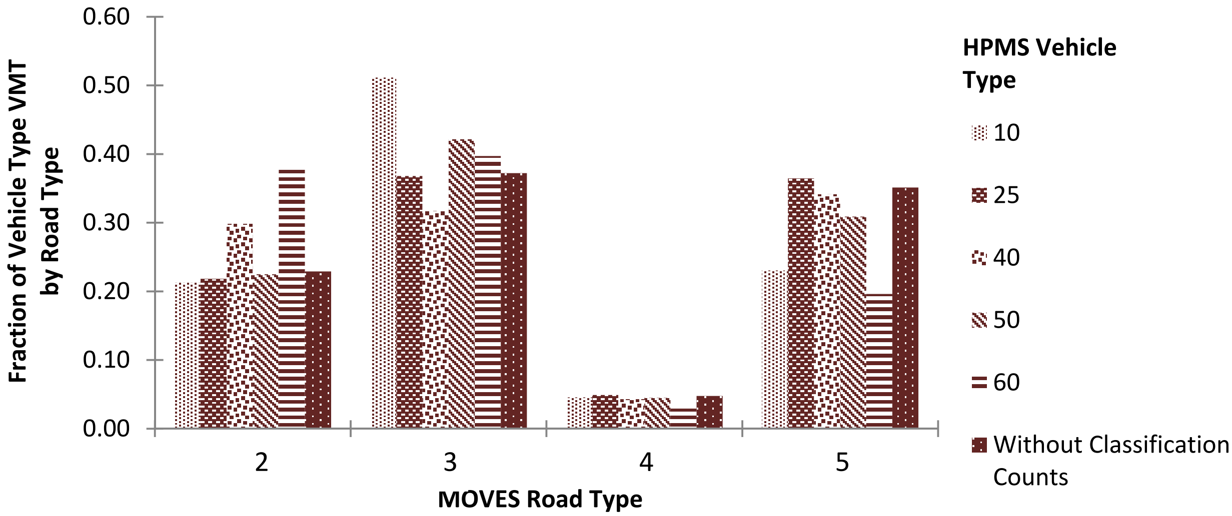


Figure 12. Road Type Distributions With and Without Classification Count Information

- **Month VMT Fraction** – Figures 13 to 17 show a variety of month VMT fraction results that could be used in different counties in Arizona. All results have a dotted line at 8.33 percent to show the month VMT fraction if traffic were evenly distributed over all 12 months. Figures 13 to 15 show results from the analysis of 2012 traffic monitoring data. Figure 13 uses data from 26 stations statewide (all stations from Table 14). Figure 14 uses data from 22 stations in the south area, and Figure 15 uses data from four stations in the north area. For comparison purposes, Figure 16 shows the MOVES2010 defaults used in the YMPO's 2013 conformity determination report. Figure 17 shows how the MOVES2014 defaults changed slightly when considering motorcycles separately from other vehicle types. These month VMT fractions for motorcycles are similar to those seen in northern Arizona from the traffic monitoring data. MOVES defaults use the same distribution for all vehicle types (except motorcycles in MOVES2014 defaults); therefore, an immediate advantage of using traffic monitoring data is that different distributions can be created for different vehicle types. This can help pick up different trends shown by HDTs.

  The statewide results from Figure 13 are very similar to the south area results in Figure 14, since 22 of 26 statewide stations are located in the south. Overall the statewide/south results show a fairly even distribution of traffic over the 12 months, with somewhat less traffic during the summer months. The results from the north area in Figure 15 show more summer traffic and less winter traffic. These trends support the theory that residents and tourists head north during the summer to escape the extreme heat experienced in the south and to visit recreational areas, such as the Grand Canyon. Local traffic counts in Yuma County from 2010 to 2012 show 29 to 33 percent higher winter traffic compared to summer traffic due to seasonal visitors. While there are not enough classified traffic counts in Yuma County to develop month VMT fractions directly from only Yuma County information, areas that have nonclassified traffic count information showing large seasonal fluctuations may want to use this information to adjust the statewide or regional distributions.

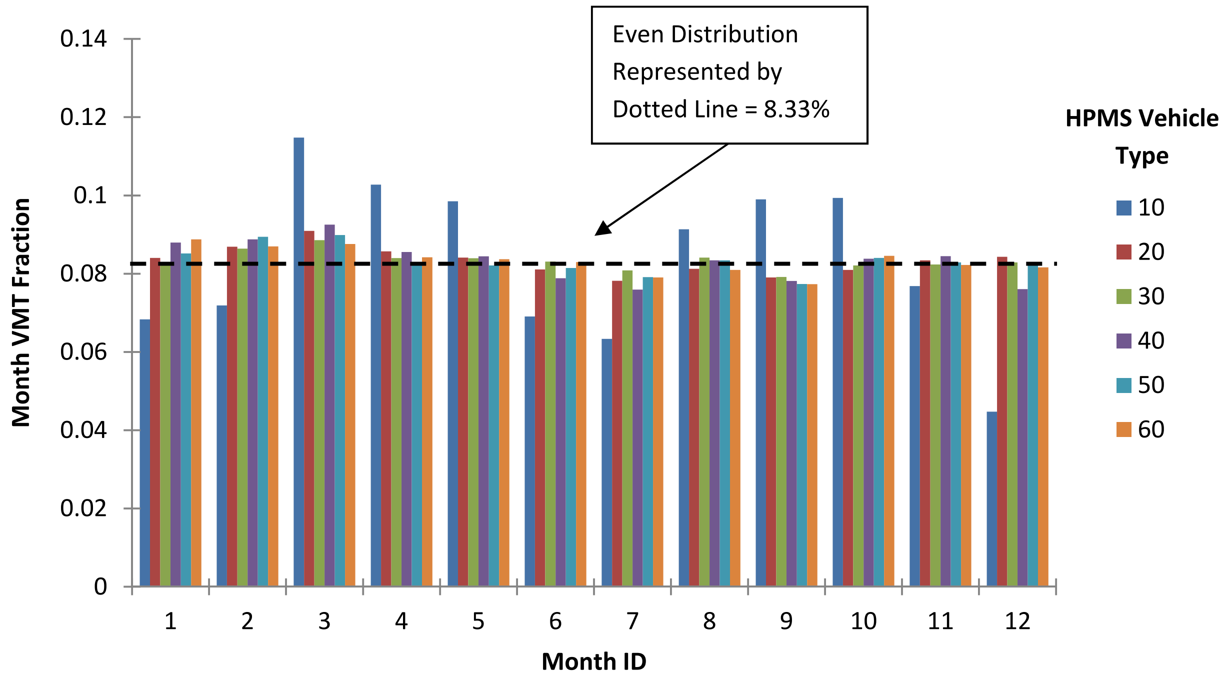


Figure 13. Month VMT Fractions Statewide

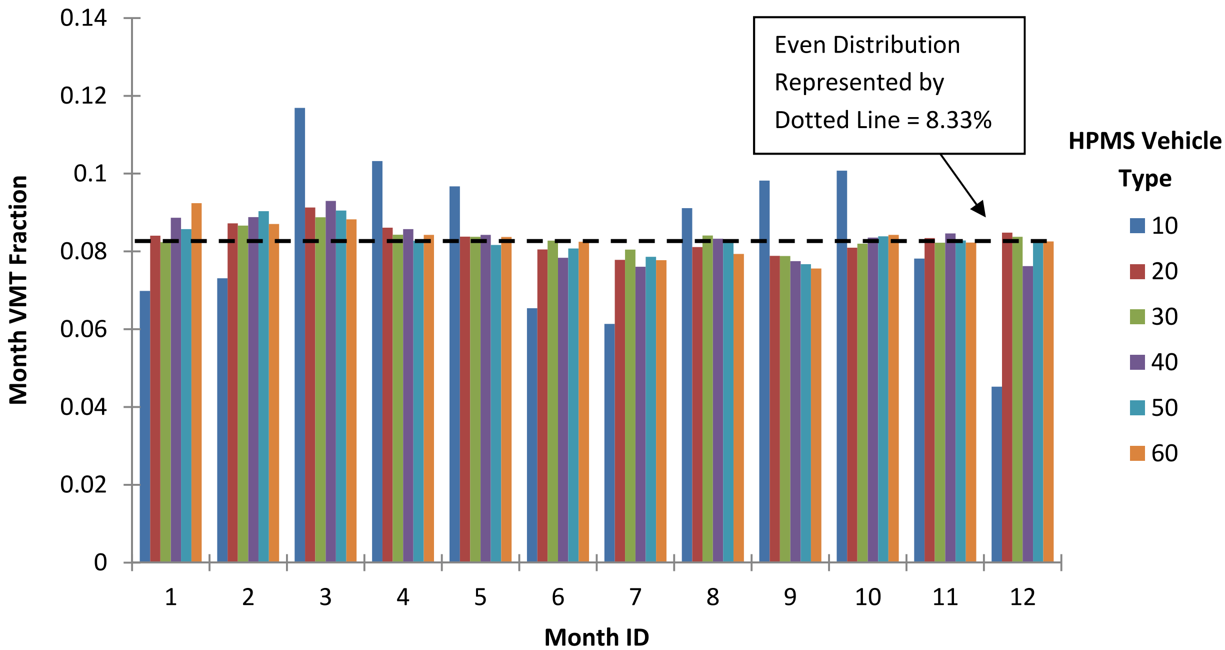


Figure 14. Month VMT Fractions for South Area

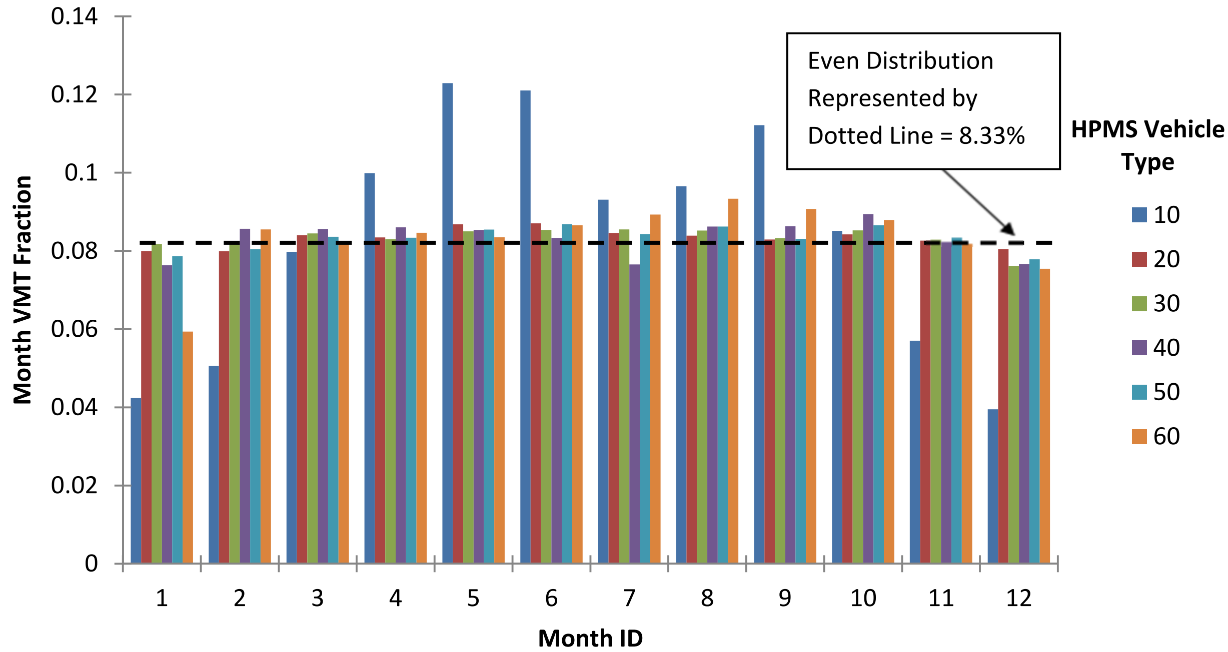


Figure 15. Month VMT Fractions for North Area

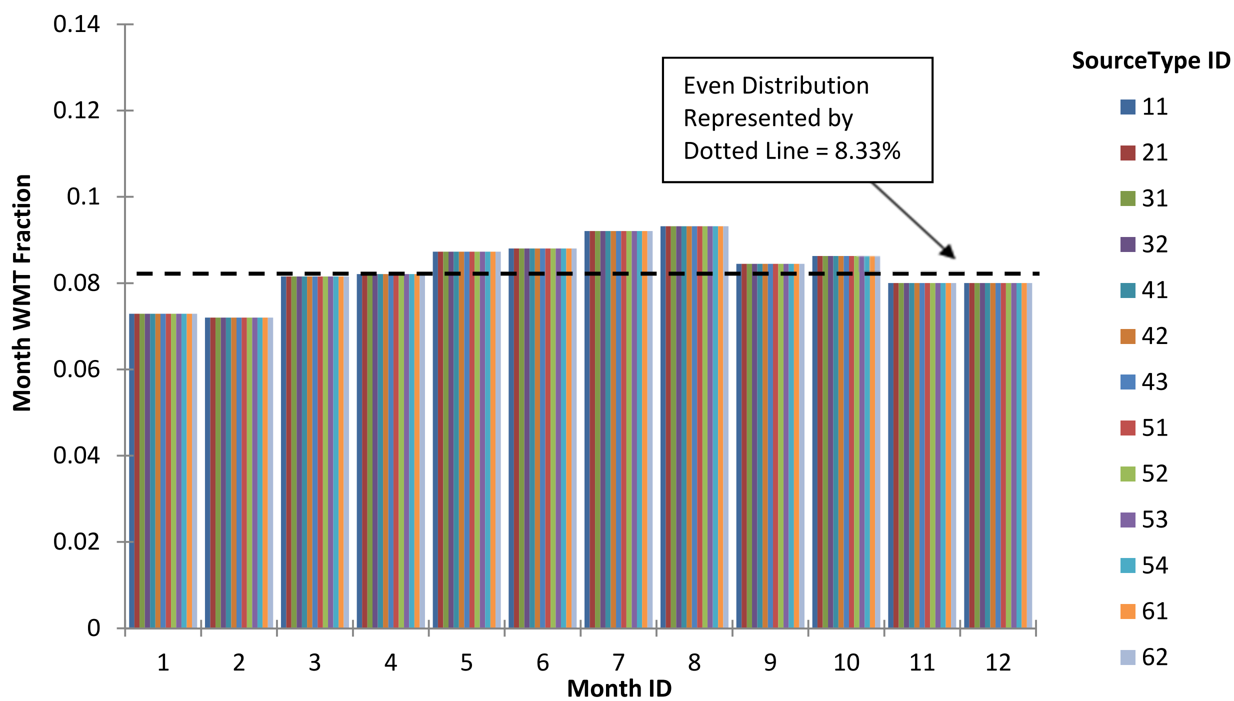


Figure 16. Month VMT Fractions from MOVES2010 Defaults

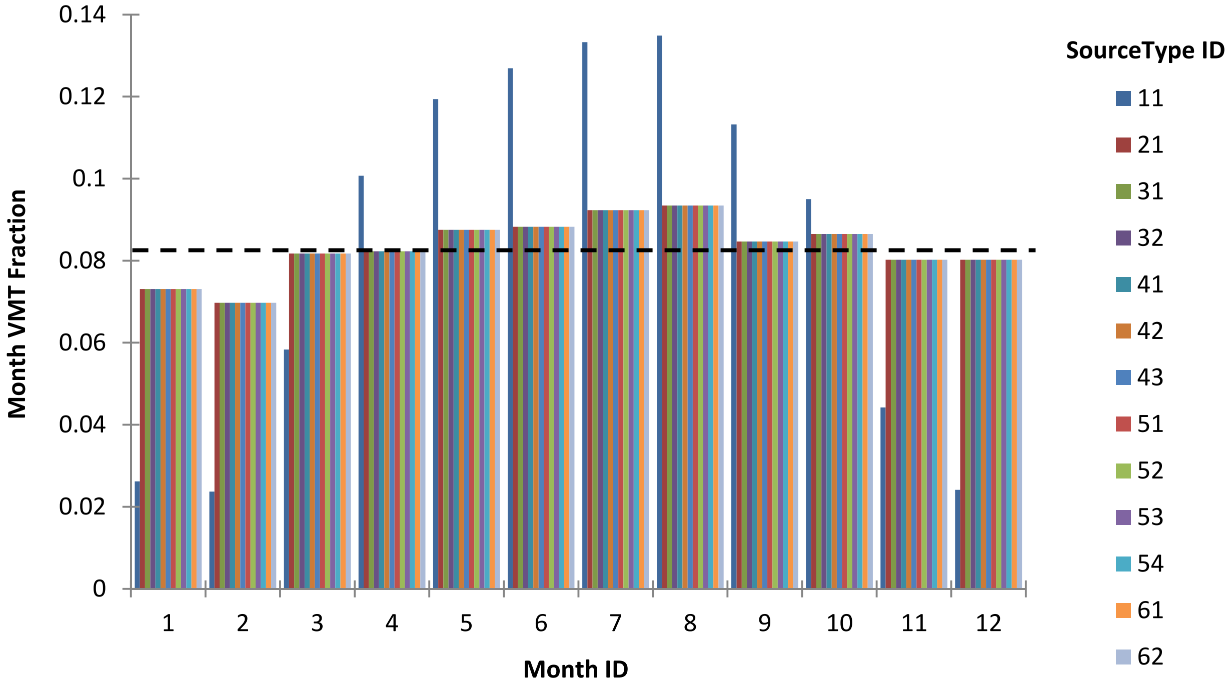


Figure 17. Month VMT Fractions from MOVES2014 Defaults

- **Day VMT Fraction –** Figures 18 to 21 compare day VMT fraction results — from traffic monitoring data for statewide, south region, and north region — to MOVES2014 defaults. Results are only shown for HPMS vehicle type 20 (passenger cars). The x-axis shows vehicle types subdivided by MOVES road type (2 to 5), and then month (1 to 12). Results from traffic monitoring data are more detailed than MOVES defaults since they vary by vehicle type and every MOVES road type (instead of just urban/rural), although the values found in the Arizona data for passenger cars are very close to the MOVES defaults. For some vehicle types and road types, which are not shown on these graphs, weekend traffic shown by traffic monitoring data can be greater than 40 percent or less than 10 percent of all traffic; whereas, MOVES defaults always show weekend traffic between 20 percent and 30 percent of all traffic. Statewide and south region results are very similar since 22 out of 26 stations used to produce day VMT fractions are in the south. The north region results are fairly different from the statewide results in some cases, with differences between the fractions as high as 15 percent. However, the north region results are only based on four stations, and no station was available to represent MOVES road type 4. Overall, the traffic monitoring data provides useful local information for day VMT fractions that differs from MOVES defaults, but there are currently only enough stations to produce reliable results for a statewide region.

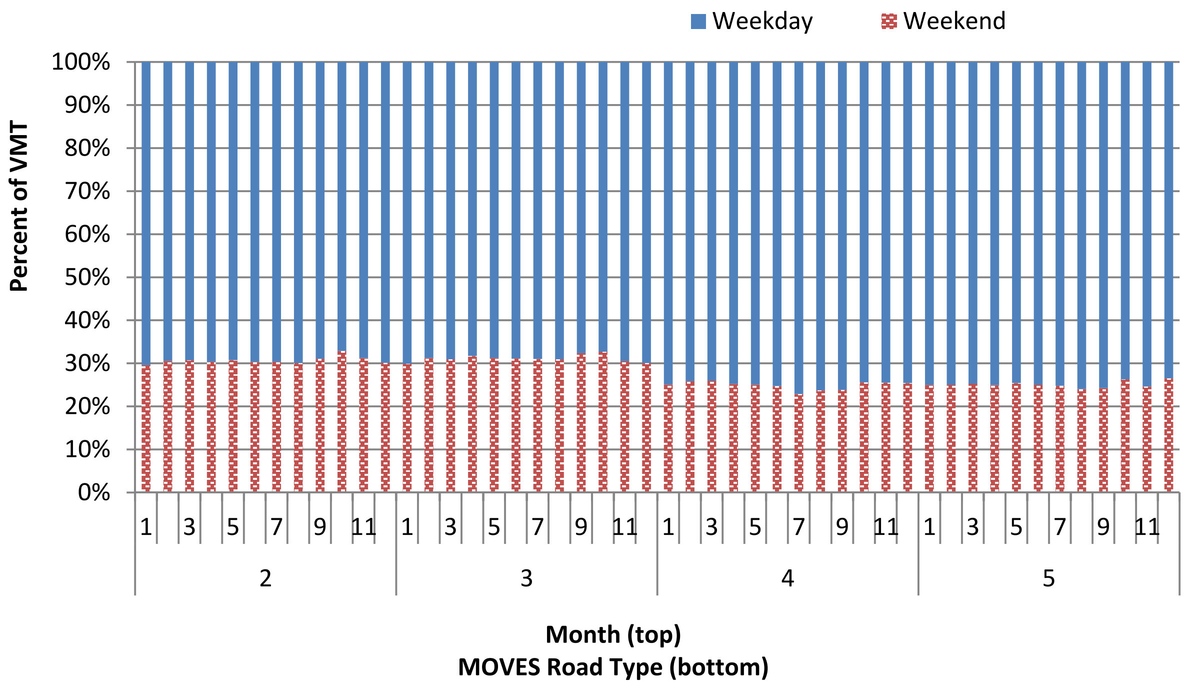


Figure 18. Day VMT Fractions from Statewide Traffic Monitoring Data for Vehicle Type 20

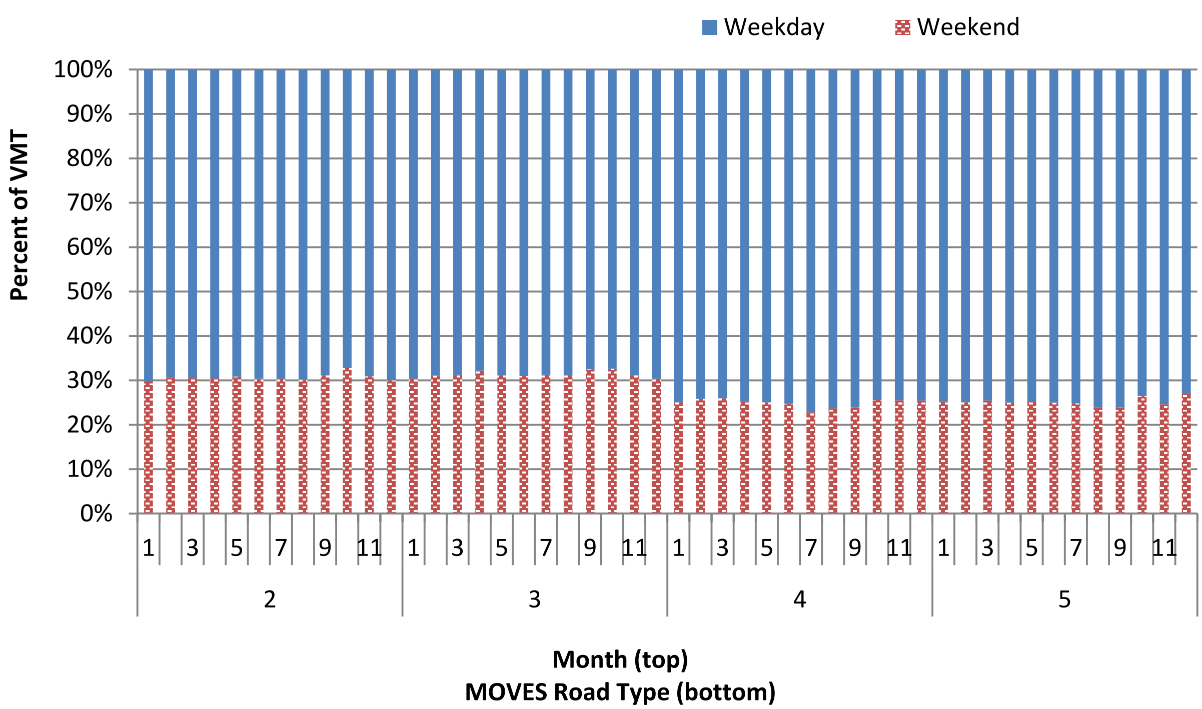


Figure 19. Day VMT Fractions from South Region Traffic Monitoring Data for Vehicle Type 20

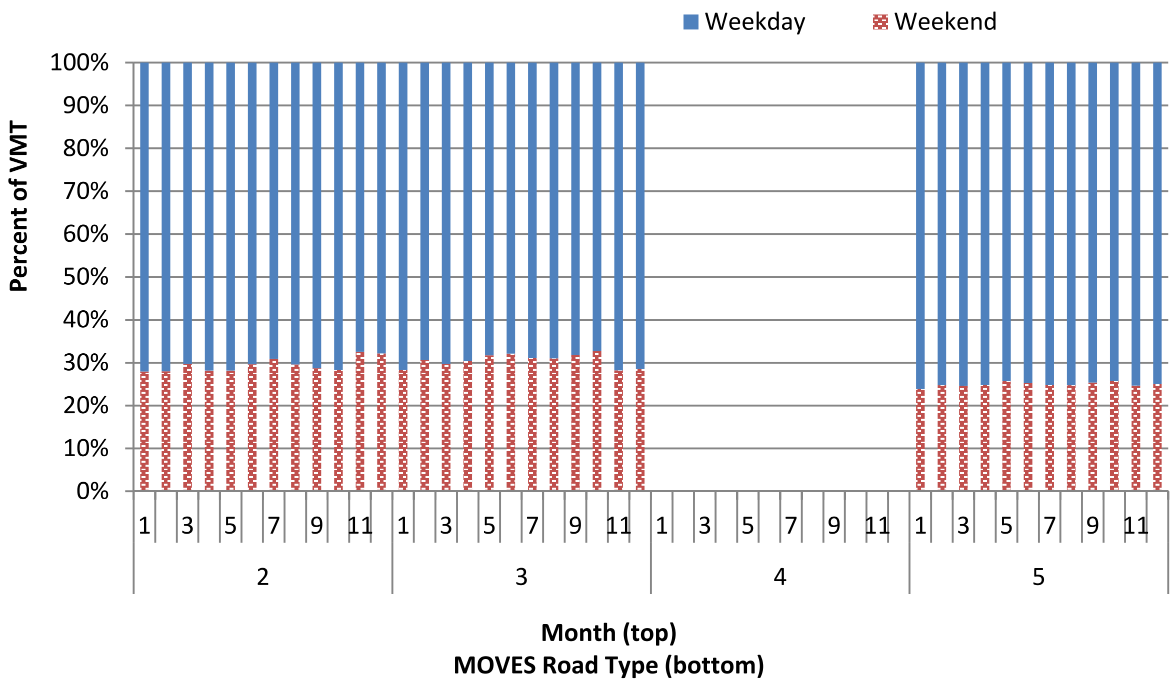


Figure 20. Day VMT Fractions from North Region for Vehicle Type 20

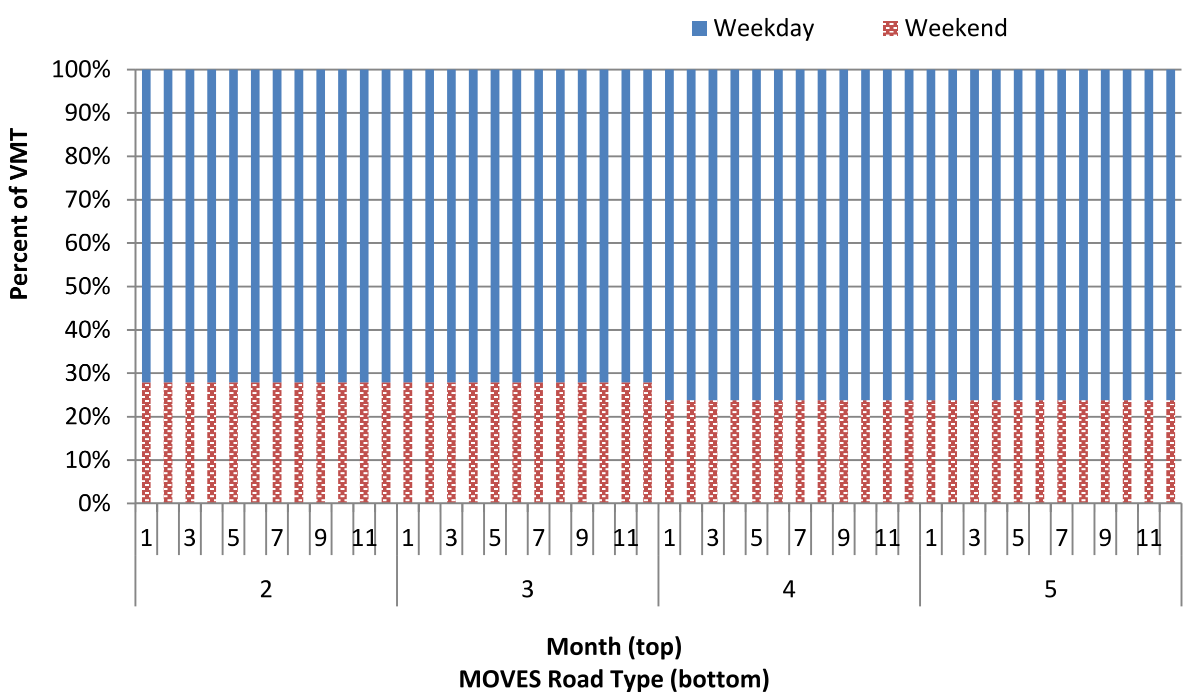


Figure 21. MOVES 2014 Defaults for Day VMT Fraction for Vehicle Type 20

- **Hour VMT Fraction –** Figures 22 to 25 compare hour VMT fraction results from traffic monitoring data, MOVES defaults, and the YMPO's MOVES-based conformity determination report (YMPO, 2013), which used the 2008 Arizona statewide model as the data source for hour VMT fractions. There are four sets of MOVES defaults that correspond to the four figures: rural-weekend, rural-weekday, urban-weekend, and urban-weekday. The YMPO report used the same single hour VMT fraction set for all days, road types, and source types. The traffic monitoring data provide the most detailed hour VMT fractions, with separate sets provided for each road type, day type, and HPMS vehicle type, thus providing 48 sets (12 are shown on each of the four figures).

  In general, MOVES defaults are better than the statewide model data used in the YMPO CDR, since different sets of fractions are available for different area types and day types. The statewide model data best resembles weekday urban traffic, which was probably the type of data used to calibrate the statewide model. The MOVES defaults generally follow the local Arizona data for each of the four cases and would be good to use in the absence of better local data. However, since the traffic monitoring data have now been analyzed for the whole state and provide an even greater level of detail, they should be used as much as possible. These data do show some differences between vehicle types, such as more overnight HDT traffic and a single peak for HDT traffic in the middle of the day instead of morning and evening peaks on weekdays for light-duty traffic.

Legend notes for Figures 22 to 25: "TM" = traffic monitoring data; "Rd2" and "Rd3" = MOVES road types 2 and 3, respectively; "Vehxx" = HPMS vehicle type xx; YMPO CDR = data from statewide model used in YMPO Conformity Determination Report

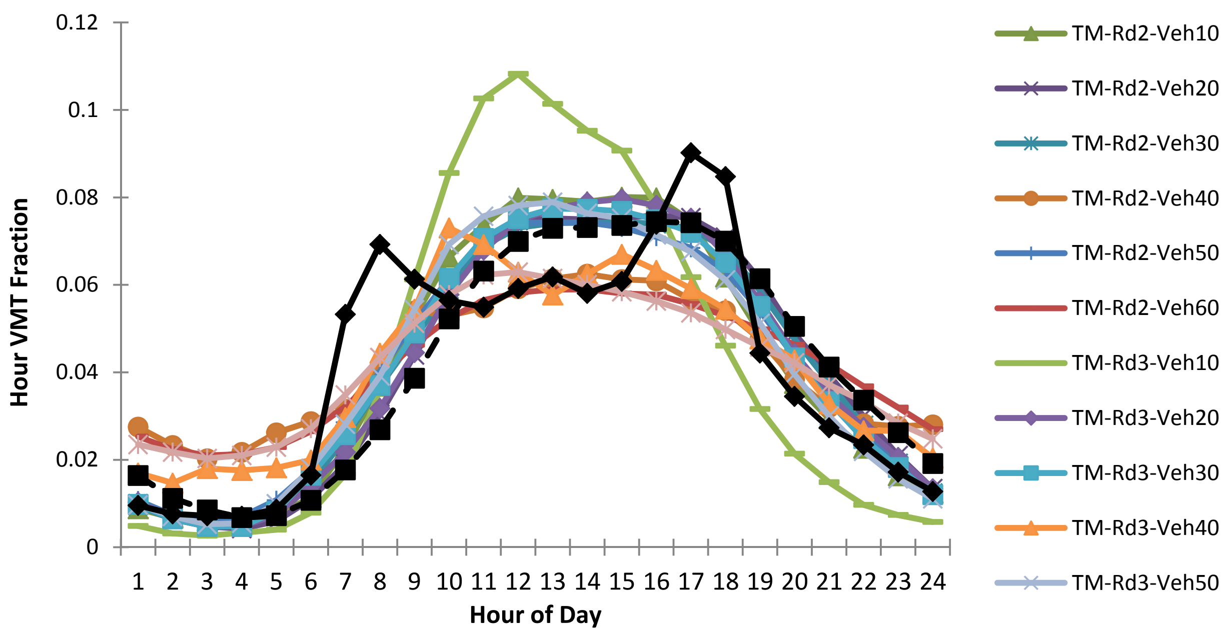


Figure 22. Hour VMT Fractions for Rural Road Types on Weekends

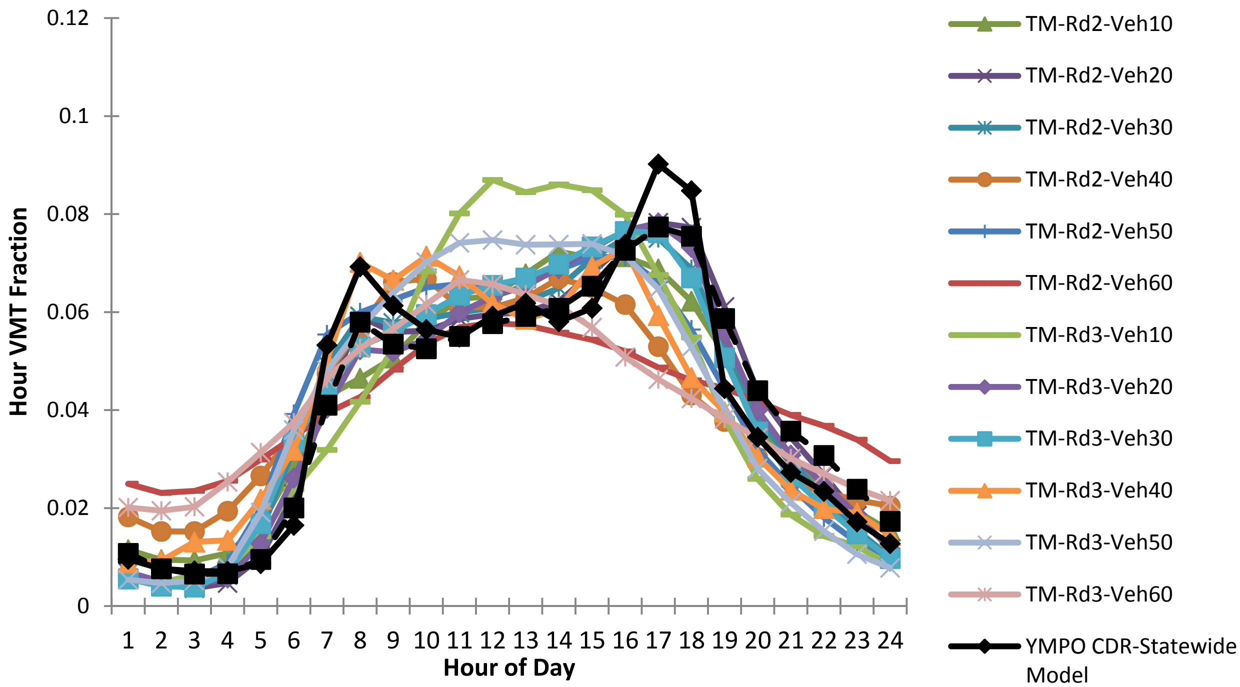


Figure 23. Hour VMT Fractions for Rural Road Types on Weekdays

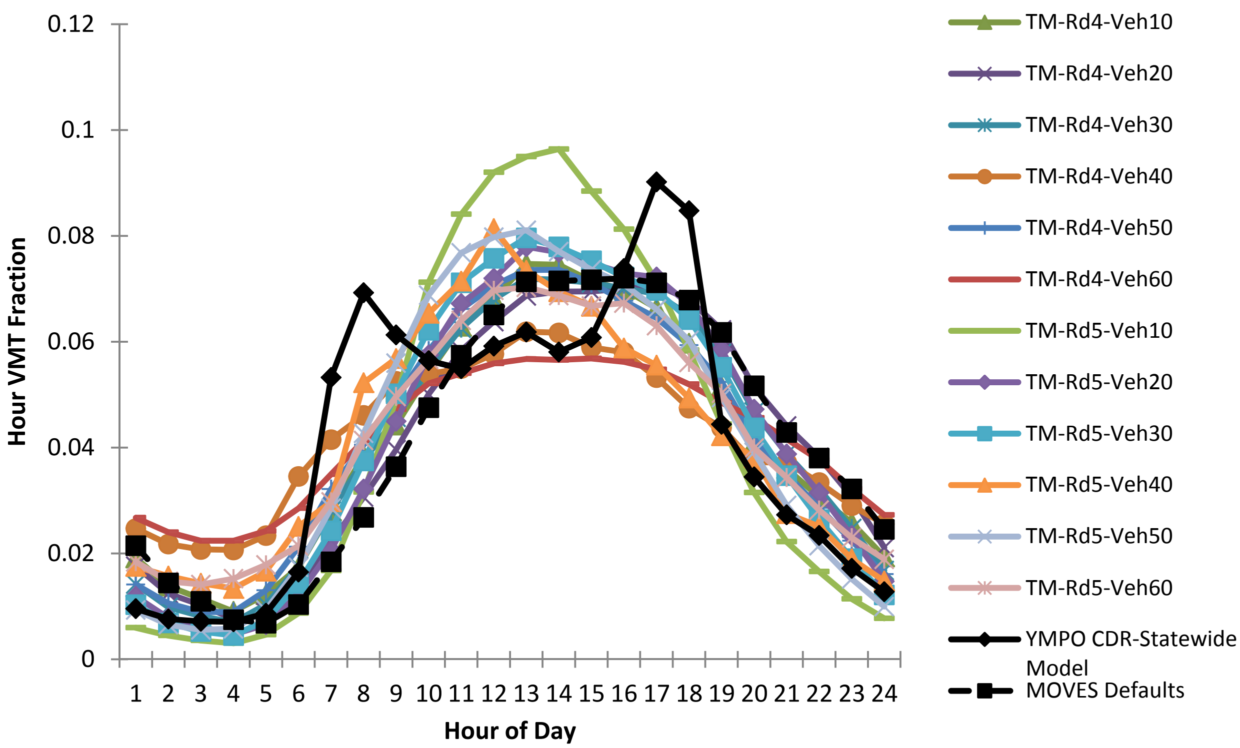


Figure 24. Hour VMT Fractions for Urban Road Types on Weekends

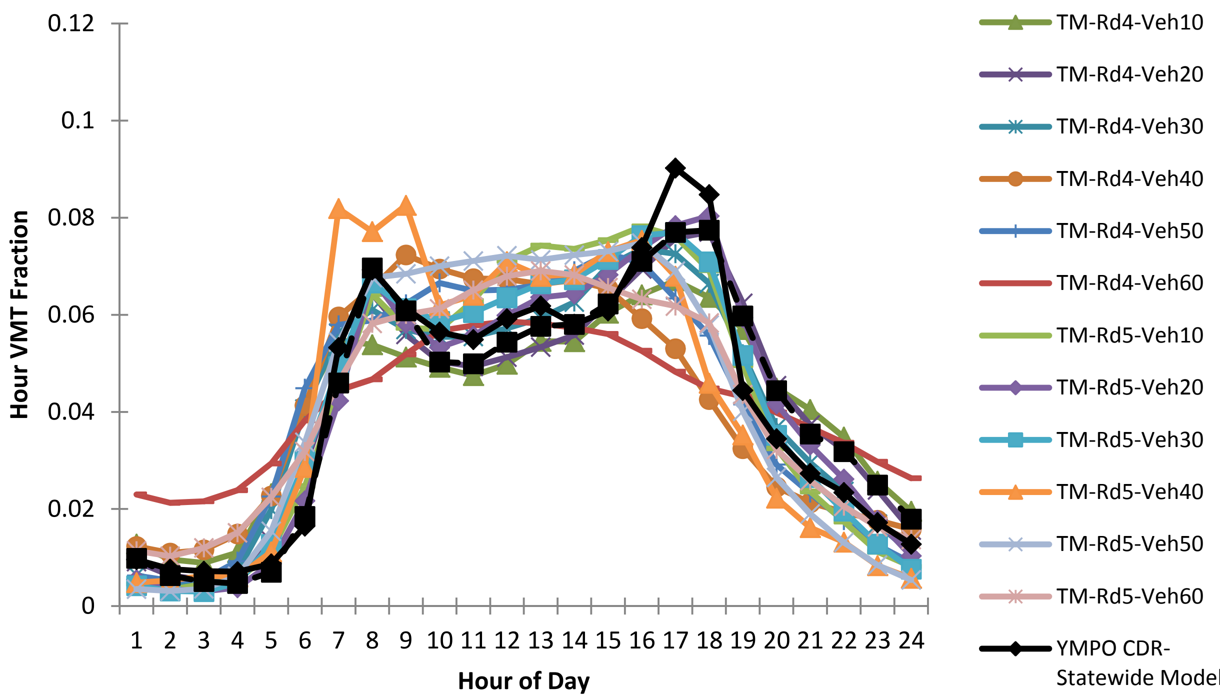


Figure 25. Hour VMT Fractions for Urban Road Types on Weekdays

Recommendations

The following recommendations are made for the VMT-based inputs:

- **VMT by vehicle class and road type distributions** – HPMS segment data should be used to develop VMT by roadway functional class for historical years and in combination with the local MPO travel demand model results (or statewide model outside of MPO areas) to develop HPMS adjustment factors for future years. ADOT should use the HPMS segment data to develop annual HPMS VMT reports by county and roadway functional class, so that the reports are readily available for any MOVES analysis being performed throughout the state. Vehicle classification counts (traffic monitoring data) from specific regions of the state (at least north and south) should be used to further break down VMT by vehicle class. ADOT should routinely analyze the traffic monitoring data and publish reports with vehicle distribution percentages by MOVES road type for each region. Further analysis should be conducted to possibly break down the south region into multiple regions, possibly with the Phoenix metropolitan area being removed from the south region because it may exhibit different trends. In the long term, more permanent classification counters should be installed, if possible, to allow results by county.
- **Ramp fraction** – If available, a local MPO travel demand model should be used to develop ramp fractions; otherwise, the statewide model should be used. All ramps and interchanges for the area of concern should be included. If available, ramp counts should be used to validate ramp volumes in the travel demand model. Results should be compared to the MOVES default 8 percent ramp fraction, and if travel demand model results seem unreasonable, the MOVES defaults should be

used instead. As a long-term goal, ADOT should ensure better ramp count coverage for all Interstates and freeways around the state and use these to validate ramp volumes in the statewide model.

- **Temporal distributions** – The statewide results for month, day, and hour VMT fraction developed from ADOT TDMS data should be made available for all areas of the state to use for MOVES runs. The research found some differences in results between regions, but NCHRP 25-38 research showed MOVES emissions results are not very sensitive to temporal distribution inputs (Porter et al. 2014). Therefore, use of statewide results should be adequate, given that the north region of the state did not have enough stations available to cover all MOVES road types. ADOT should use new traffic monitoring data to update the temporal distribution results every one to four years and make them available for MOVES users throughout Arizona. For the long term, more permanent classification counters should be installed to allow for results by region and possibly even by county.
- **ADOT published traffic data reports** – To support the above activities, ADOT's HPMS coordinator should create an annual report to be posted on the ADOT website for MOVES users statewide of average annual DVMT by the 15 counties, seven roadway functional classifications, and urban/rural designations. Reports for temporal distributions should also be created. Other states (such as Tennessee and Georgia) produce such reports, which eliminate data processing steps for MOVES users.

Speed Distributions

Speed distributions show the fraction of vehicle travel by speed range in 16 bins. Separate speed distributions are provided for each of four MOVES road types (rural and urban, restricted, and unrestricted-access). Separate speed distributions can also be provided for each of the 13 MOVES source (vehicle) types, although data are rarely available on speeds by vehicle type.

Data Sources Used

Travel demand model outputs were obtained from the 2012 YMPO model and 2008 statewide model for Yuma County. These outputs include link-level speed estimates for a daily timeframe (YMPO model) or for each of four times of day (statewide model).

In addition to travel demand model outputs, traffic monitoring data were also examined to determine whether real-world speed information could be used to calibrate/validate the travel demand model results. The free-flow speed used in the travel demand model represents most of the speed outputs for uncongested roadway links; therefore, it is important to understand whether the free-flow speeds used reflect real-world conditions. Arizona’s TDMS collects speed data at a limited number of permanent classification counting stations. There are four such stations in Yuma County, one covering each of the four MOVES road types. These are shown as small green boxes, as indicated by red arrows, on the map in Figure 26.

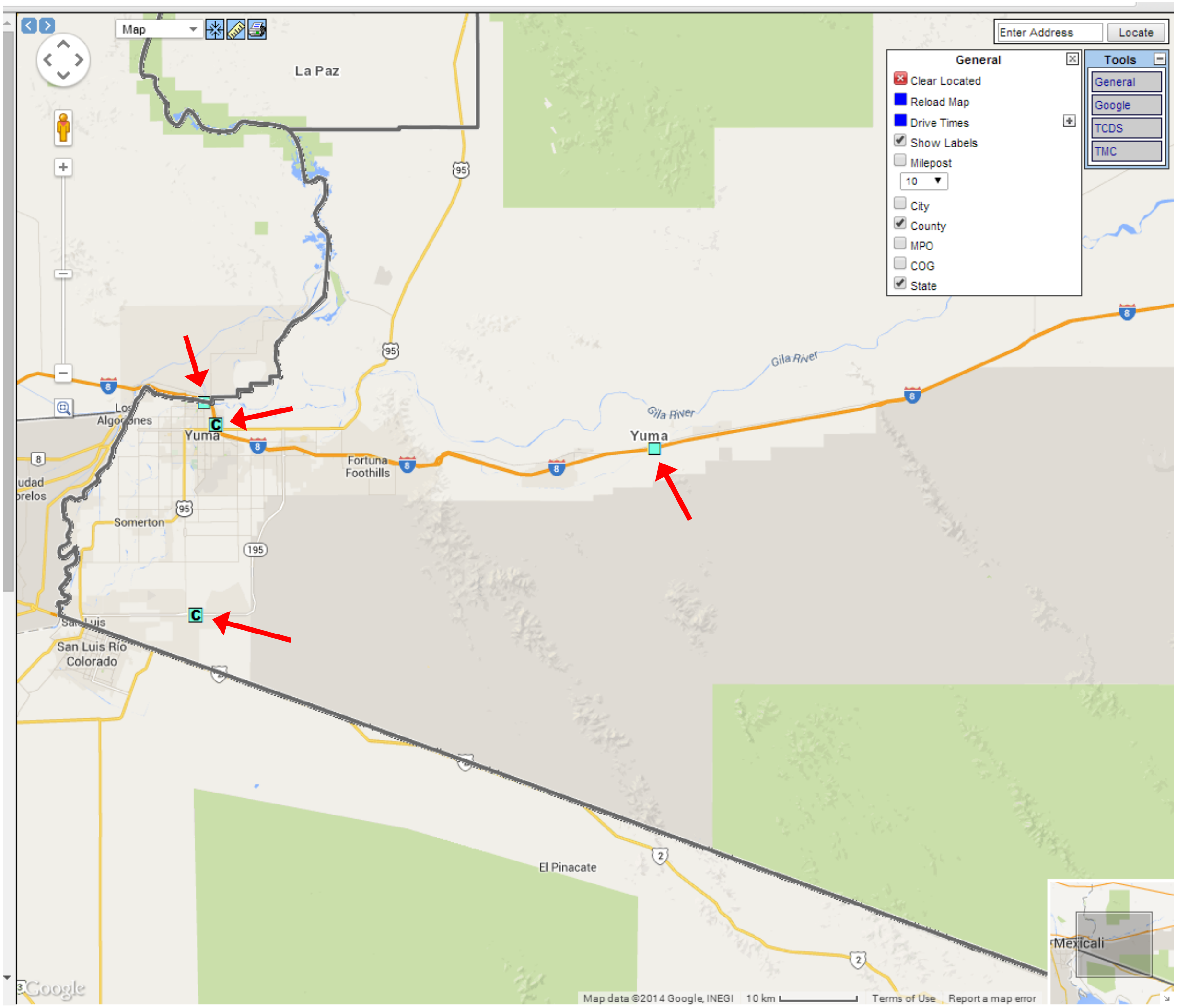


Figure 26. Stations with Speed Data in Yuma County
Source: ADOT (2016)

Processing Methods

The travel demand model link-level speed estimates were postprocessed in a spreadsheet format to allow ADOT to follow the step-by-step procedure shown below. The postprocessing breaks down daily or time-of-day volumes into 24 hourly volumes to calculate v/c ratios for each of the 24 hours of the day. These v/c ratios are input into the BPR formula to calculate new speeds for each of the 24 hours of the day in both the A to B and B to A directions on each link. In the spreadsheet, each link is represented by a separate row, and there are 48 columns (24 hours x 2 directions) for most of the processing steps below (volumes, v/c ratios, predicted speeds, etc.).

Processing Steps:

1. MOVES default hour VMT fractions are used to break down directional volumes on each link into 24 different volumes for each hour of the day. These are reported in 48 different columns (24 hours x 2 directions). Local hour VMT fractions developed from traffic monitoring data could also be used.
2. Each of the 48 different volumes is divided by the directional capacity of the link to calculate 48 different v/c ratios shown in 48 more columns.
3. Each of the 48 v/c ratios is used in the BPR equation, along with the appropriate alpha and beta coefficients to calculate 48 different speeds shown in 48 more columns. The BPR equation is:

   $$S = S_f/[1 + \alpha(V/C)^{\beta}] \qquad \text{(Eq. 1)}$$

   Where:

   S = Predicted mean speed
   S_f = Free-flow speed (calculated using length and free-flow travel time from model)
   α = Alpha value (look up by facility type and area type using Table 24)
   β = Beta value (look up by facility type and area type using Table 25)
   V = Volume (from model outputs)
   C = Capacity (look up by facility type and area type using Table 26. The YMPO model has local roads, which are not included; therefore, 1/10 of the daily capacity coded in the YMPO model network is assumed)
4. The speed bin for each of the 48 speeds is determined using a nested IF function in Excel. The speed bins are recorded in 48 more columns.
5. A lookup value is created by concatenating the MOVES road type, speed bin from Step 4, and the hour. This is recorded in 48 more columns.
6. The VMT for each hour and direction is calculated by multiplying the hourly volumes from Step 1 by the link length. These are recorded in 48 more columns.
7. All VMT are summed by MOVES road type, speed bin, and hour, using the lookup values from Step 5.
8. VMT is converted to VHT by dividing by the average speed for the speed bin.
9. VHT is summed by MOVES road type and hour to provide the denominator for the average speed distribution.
10. The average speed distribution values are calculated by taking the VHT associated with a particular MOVES road type, speed bin, and hour combination and dividing by the VHT associated with the corresponding MOVES road type, and hour combination.

Table 24. Alpha Values from Arizona Statewide Model Documentation

Facility Type	Area Type					
	CBC	Urban	Suburban	Rural	SmTownCBD	OutofState
HOV	0.87	0.71	0.71	0.71	0.71	0.10
Freeway	0.87	0.71	0.71	0.71	0.71	0.10
Major Arterial	0.96	0.73	0.33	0.16	0.33	0.10
Minor Arterial	0.96	0.73	0.33	0.16	0.33	0.10
Major Collector	0.96	0.73	0.33	0.16	0.33	0.10
Minor Collector	0.96	0.73	0.33	0.16	0.33	0.10
Ramp	0.96	0.73	0.33	0.16	0.33	0.10
Metered Ramp	0.96	0.73	0.33	0.16	0.33	0.10
Centroid Connector	0.10	0.10	0.10	0.10	0.10	0.10

Source: ADOT (2011), Table 73.

Table 25. Beta Values from Arizona Statewide Model Documentation

Facility Type	Area Type					
	CBC	Urban	Suburban	Rural	SmTownCBD	OutofState
HOV	5.0	3.47	3.47	3.47	3.5	2.0
Freeway	5.0	3.47	3.47	3.47	3.5	2.0
Major Arterial	2.3	2.36	3.0	3.8	3.0	2.0
Minor Arterial	2.3	2.36	3.0	3.8	3.0	2.0
Major Collector	2.3	2.36	3.0	3.8	3.0	2.0
Minor Collector	2.3	2.36	3.0	3.8	3.0	2.0
Ramp	2.3	2.36	3.0	3.8	3.0	2.0
Metered Ramp	2.3	2.36	3.0	3.8	3.8	2.0
Centroid Connector	2.0	2.0	2.0	2.0	2.0	2.0

Source: ADOT (2011), Table 74.

Table 26. Capacity per Lane per Hour from Arizona Statewide Model Documentation

Facility Type	Area Type					
	CBC	Urban	Suburban	Rural	SmTownCBD	OutofState
HOV	1,800	2,000	2,100	2,100	2,100	99,999
Freeway	1,800	2,000	2,100	2,100	2,100	99,999
Major Arterial	700	800	900	1,000	900	99,999
Minor Arterial	550	625	700	800	700	99,999
Major Collector	400	450	500	600	500	99,999
Minor Collector	300	350	400	500	400	99,999
Rap	1,000	1,100	1,200	1,200	1,200	99,999
Metered Ramp	1,000	1,100	1,200	1,200	1,200	99,999
Centroid Connector	99,999	99,999	99,999	99,999	99,999	99,999

Source: ADOT (2011), Table 71. The value for "centroid connector" of 99,999 is provided so that capacity on the connectors is not constrained.

To process the traffic monitoring data to produce speed distributions that correspond to MOVES speed bins, use the following steps:

1. Query the Access database downloaded from the Arizona TDMS system to find stations in Yuma County with counts by speed classifications. Four stations were found in this analysis.
2. Assign weekday/weekend designations to every day of counts with speed classifications.
3. For each station, sum volumes by speed bin, weekend/weekday, and the 24 hours of the day for all days of the year that fall into the appropriate categories.
4. Convert count station speed bins to MOVES speed bins using the following substeps. These steps are necessary since the two sets of speed bins do not align (as shown in Table 27).
5. Assign zero to MOVES speed bins 1 to 4.
6. Assign all volume from the 0 to 20 mph count speed bin plus 0.5 of the volume from the 20 to 25 mph count speed bin to the 17.5 to 22.5 mph MOVES speed bin (bin 5).
7. Assign the other 0.5 of the 20 to 25 mph count speed bin plus 0.5 of the 25 to 30 mph count speed bin to the MOVES 22.5 to 27.5 mph speed bin (bin 6).
8. Follow the same procedure with 0.5 of the preceding and 0.5 of the next speed bin to assign volumes to MOVES speed bins 7 to 15.
9. Assign 0.5 of the 70 to 75 mph count speed bins plus all of the 75 to 80, 80 to 85, and more than 85 mph count speed bins to the more than 72.5 mph MOVES speed bin (bin 16).
10. Assume stations represent conditions for 1 mile. Multiply volumes by 1 mile to get VMT. Divide VMT by the midpoint of each speed bin (in mph) to convert to VHT.
11. Divide VHT in each speed bin by the sum of VHT over all speed bins to get a MOVES speed distribution.

Table 27. Speed Bins for Count Stations and MOVES

Count Station Speed Bins		MOVES Speed Bins		
		1	2.5	Speed < 2.5 mph
		2	5	2.5 mph <= speed < 7.5 mph
		3	10	7.5 mph <= speed < 12.5 mph
		4	15	12.5 mph <= speed < 17.5 mph
SP01	<=20 mph	5	20	17.5 mph <= speed <22.5 mph
SP02	20-25 mph	6	25	22.5 mph <= speed < 27.5 mph
SP03	25-30 mph	7	30	27.5 mph <= speed < 32.5 mph
SP04	30-35 mph	8	35	32.5 mph <= speed < 37.5 mph
SP05	35-40 mph	9	40	37.5 mph <= speed < 42.5 mph
SP06	40-45 mph	10	45	42.5 mph <= speed < 47.5 mph
SP07	45-50 mph	11	50	47.5 mph <= speed < 52.5 mph
SP08	50-55 mph	12	55	52.5 mph <= speed < 57.5 mph
SP09	55-60 mph	13	60	57.5 mph <= speed < 62.5 mph
SP10	60-65 mph	14	65	62.5 mph <= speed < 67.5 mph
SP11	65-70 mph	15	70	67.5 mph <= speed < 72.5 mph
SP12	70-75 mph	16	75	72.5 mph <= speed
SP13	75-80 mph			
SP14	80-85 mph			
SP15	>=85 mph			

Findings

Travel Demand Model Outputs – Figures 27 and 28 compare the results of the speed postprocessing procedure from the YMPO model and Arizona statewide model in Yuma County. These figures have 24 bars within each speed bin, one for each of the 24 hours of the day produced by the postprocessing.

Using the YMPO model, speed postprocessing only made a difference for MOVES road type 5 (Figure 28), urban unrestricted-access roadways, since variation can be seen across the 24 hours of the day. Speed postprocessing did not make a difference in speed distributions (i.e., the same result would have been obtained without the postprocessing procedure) for the other three road types—rural restricted-access roadways (road type 2), rural unrestricted-access roadways (road type 3), and urban restricted-access roadways (road type 4). This is likely due to the lack of congestion on these road types, which led to low v/c ratios over all 24 hours of the day. When using the BPR equation in postprocessing, low v/c ratios result in speeds close to or at the free-flow speed provided from the model. In contrast, the urban unrestricted-access roadway (road type 5) does show how congestion during morning and evening peak periods leads to different speed distributions during those times. These peak periods have lower speeds than the rest of the day, as illustrated by speed bins 7, 8, and 9 having a higher daily average, and speed bins 10, 12, and 13 having a lower daily average.

Using the Arizona statewide model in Yuma County, speed postprocessing produces different speed distributions for all road types than would have been obtained without the postprocessing procedure. The results vary for each of the 24 hours of the day, but the most variation can be seen for road type 5, likely due to congested conditions, as explained above for the YMPO model. The reason that speed postprocessing makes a difference in more cases when using the statewide model compared to when using the YMPO model is likely related to the fact that the statewide model has four times of day built into it before it is subdivided into individual hours of the day during the postprocessing procedure.

Besides the differences in the speed postprocessing impacts, the YMPO model and statewide model also produce slightly different overall speed distributions. For example, for MOVES road type 2, the YMPO model would show a lower average speed than the statewide model, since VHT is distributed among speed bins 8, 12, and 14, as opposed to speed bins 14 and 16 for the statewide model. The other three road types show similar trends, with the YMPO model always predicting lower speeds. This is likely due to the free-flow speed assumptions, which are somewhat different between the two models. The Arizona statewide model documentation states that link free-flow speeds are coded directly onto the network to allow “the speeds to be related directly to operating conditions and posted speed limits specific to those links.” It appears that the YMPO model follows the same approach to coding free-flow speeds by individual link, instead of applying some general rules related to area type and roadway type. However, the judgment used by the YMPO and statewide travel demand modelers appears to be slightly different based on some manual inspection of the assumed free-flow speeds by link. For example, on a segment of I-8 east of downtown Yuma, the YMPO model had a free-flow speed of 50 mph and the statewide model had a free-flow speed of 65 mph.

Notes for Figures 27 and 28: X-axis = speed bin (1-16); Y-axis = percent of speed in hour in speed bin (sum = 100 percent across all speed bins for each hour); series = hour of day

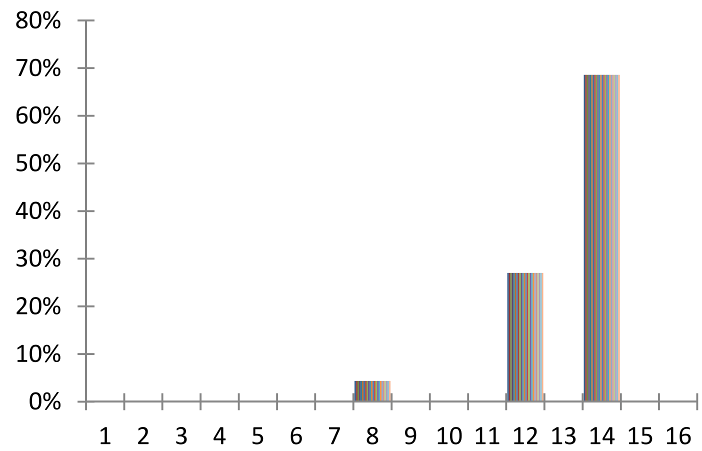
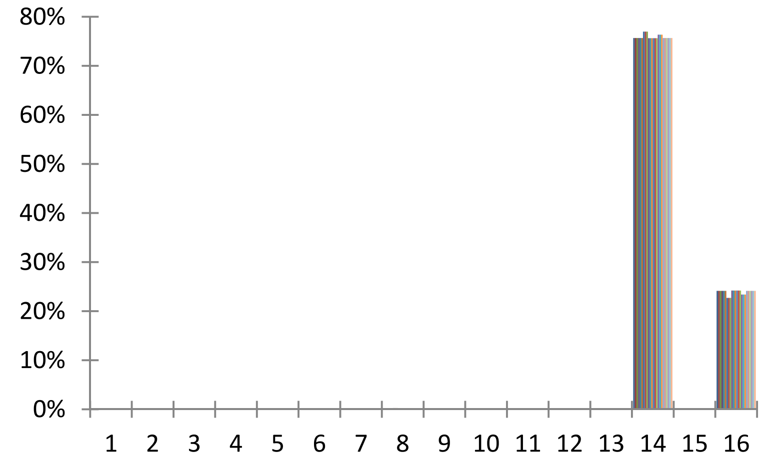
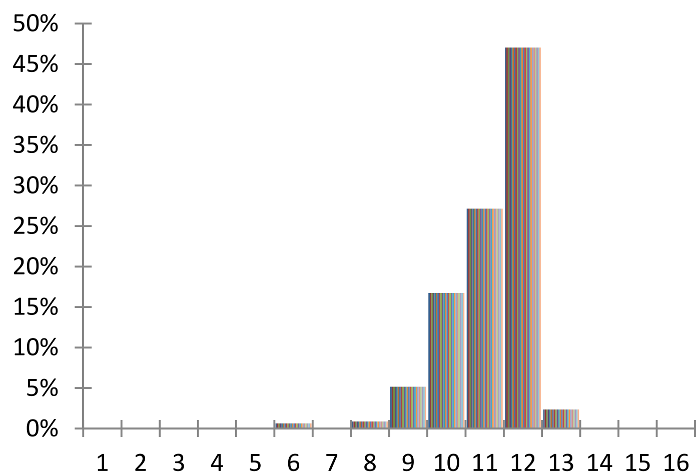
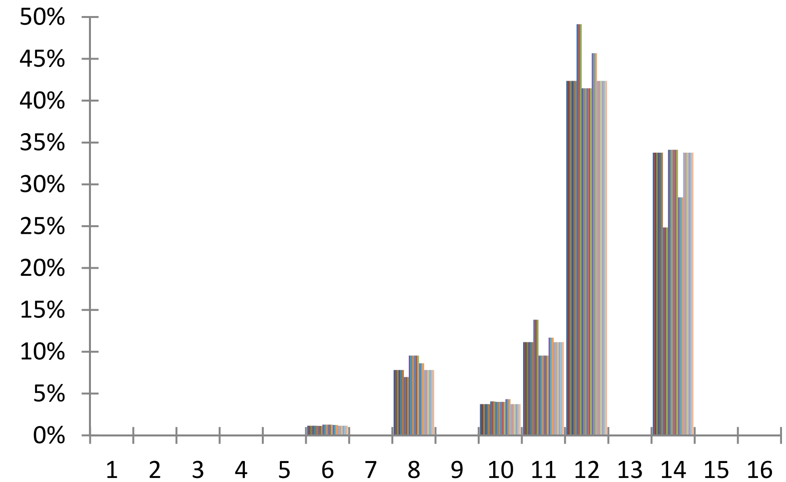
Road Type	YMPO Model	Arizona Statewide Model in Yuma County
2 – Rural Restricted Access		
3 – Rural Unrestricted Access		
Hour of day: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24		

Figure 27. Speed Distribution Results from Speed Postprocessing Procedures: Road Types 2 and 3

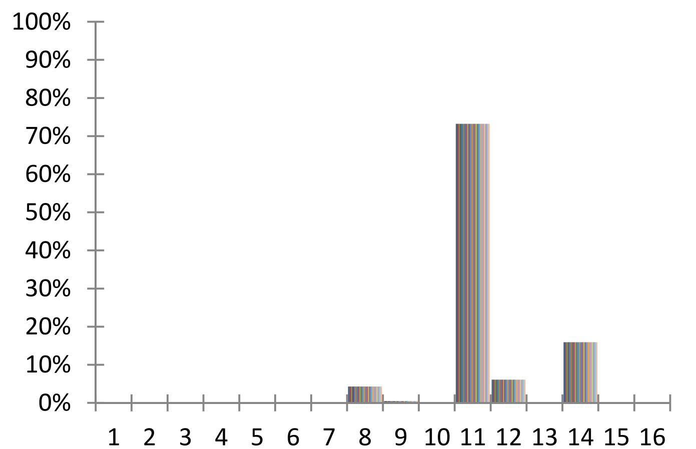
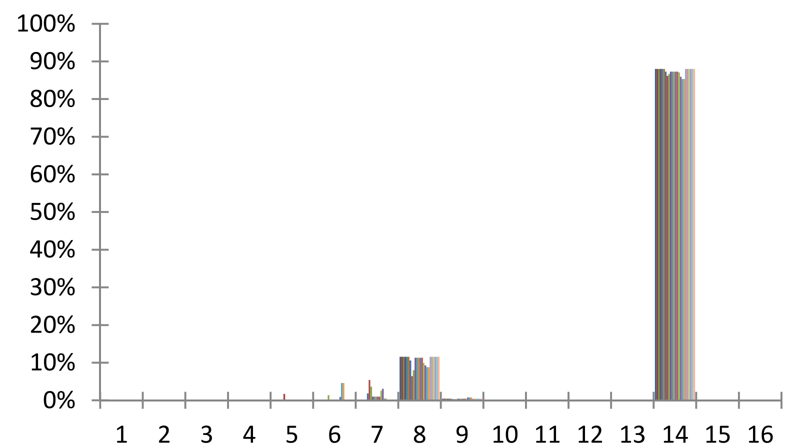
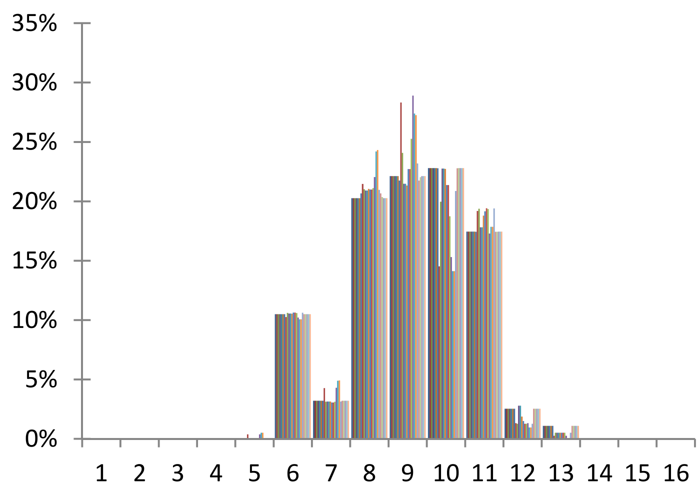
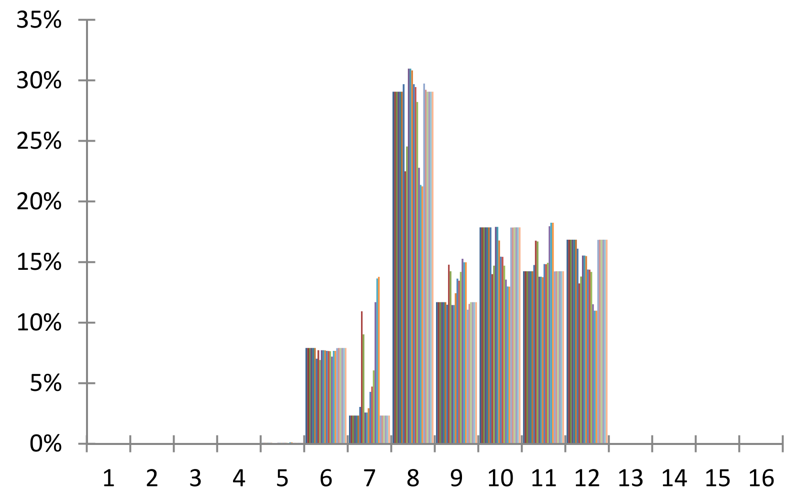
Road Type	YMPO Model	Arizona Statewide Model in Yuma County
4 – Urban Restricted Access		
5 – Urban Unrestricted Access		
Hour of day: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24		

Figure 28. Speed Distribution Results from Speed Postprocessing Procedures: Road Types 4 and 5

Traffic Monitoring Data – Figures 29 to 32 show distributions of observed speeds at the four traffic monitoring locations using a year's worth of data from 2012. The distribution represents the array of speeds for each vehicle that passes the counting station location. This is different from the distributions in Figures 27 and 28, which represent an array of link-level speed estimates predicted for every link in the travel demand model, and are therefore not directly comparable. Ideally, the travel demand model speed postprocessing procedures would take a single speed prediction from the BPR equation and the VHT over a distribution around that predicted speed to represent an array of vehicles traveling at different speeds, as shown in these traffic monitoring data results. The I-8 rural location does show more variation by time of day than the other locations. The hours with a lower percent of the very high speeds are during the overnight period when it is dark. This may reflect a lower free-flow speed during nighttime conditions.

The traffic monitoring data results show little variation in speed over the 24 hours of the day; therefore, the assumption could be made that this speed information represents free-flow conditions, and it can be used to check the free-flow assumptions in the travel demand model. Figure 33 shows the result of comparing the traffic monitoring data weighted average speeds to the travel demand model speed postprocessing results for the four links that correspond to the four traffic monitoring stations that provided speed data. The distributions in Figures 29 to 32 are collapsed to a single speed per hour by taking a weighted average of the speed bin midpoints using the distributions as a weighting factor. The YMPO model and statewide model speeds are taken directly from the speed postprocessing procedure described above. The results show that:

- Both models underpredict speeds at the rural I-8 location by 5 to 8 mph
- Both models underpredict speeds at the rural State Route (SR) 195 location by 8 to 11 mph
- The YMPO model underpredicts speeds at the I-8 urban location by 6 to 9 mph, but the statewide model overpredicts speeds at this location by 0.5 to 4 mph
- The YMPO model overpredicts speeds at the SR 8B urban location by 10 to 13 mph, but the statewide model only overpredicts at this location by 0.5 to 4 mph

These results show that the assignment of free-flow speeds to links in the travel demand model is very important, and that traffic monitoring data should be used to decide how much above or below the posted speed the free-flow speed should be. Alternatively, if travel demand modelers routinely set the free-flow speed equal to posted speed, a certain number of miles per hour could be added to the posted speed during the speed postprocessing procedures. These certain amounts of additional speed could be determined by roadway functional class during a more extensive examination of traffic monitoring speed data throughout the state compared to the statewide model. If the number of traffic monitoring sites that have speed information is too limited, then electronic travel time data from vehicle probes (available from the FHWA National Performance Management Research Data Set (NPMRDS) dataset or from vendors like INRIX and HERE) could also be used to conduct this additional research.

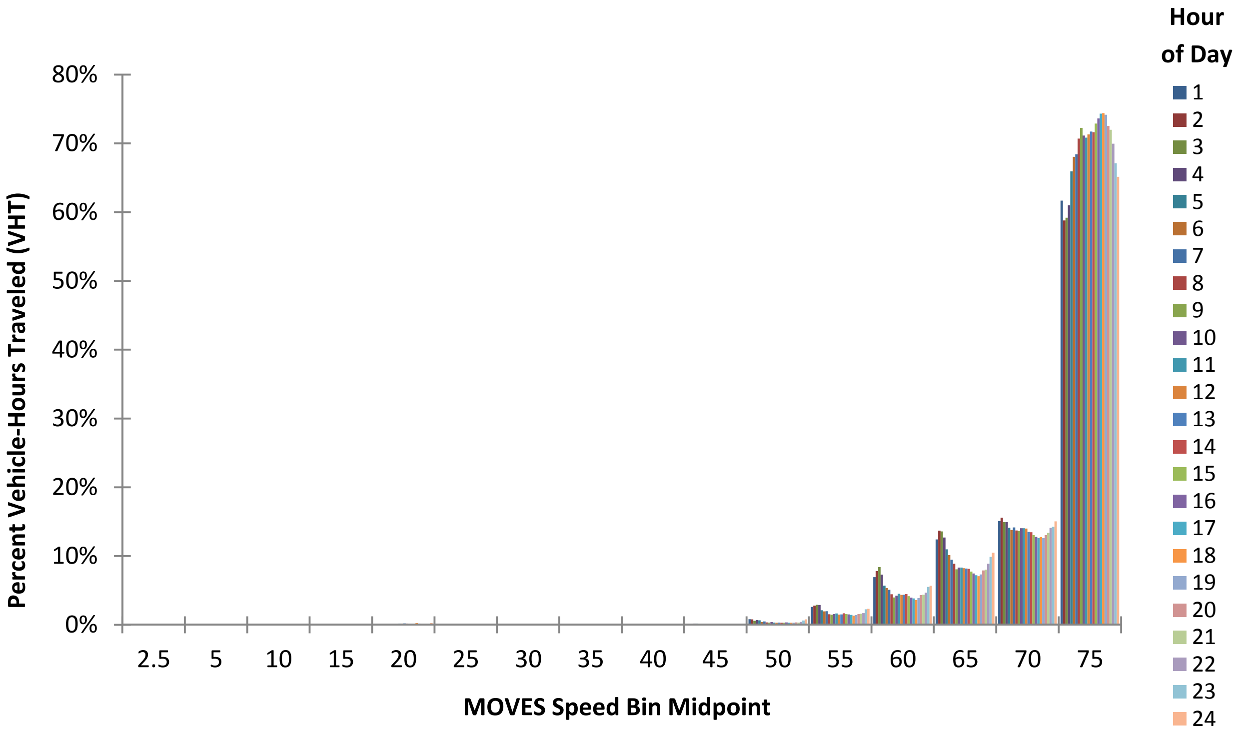


Figure 29. Speeds at the I-8 Rural Location

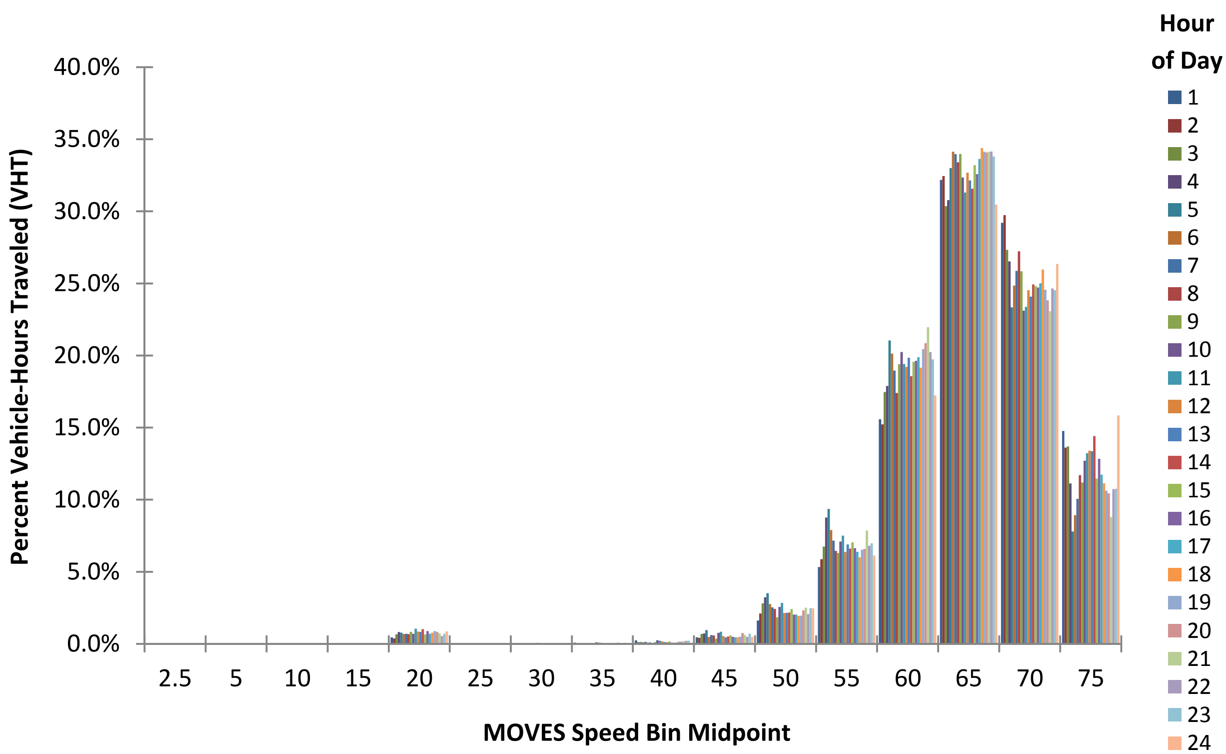


Figure 30. Speeds at the SR 195 Rural Location

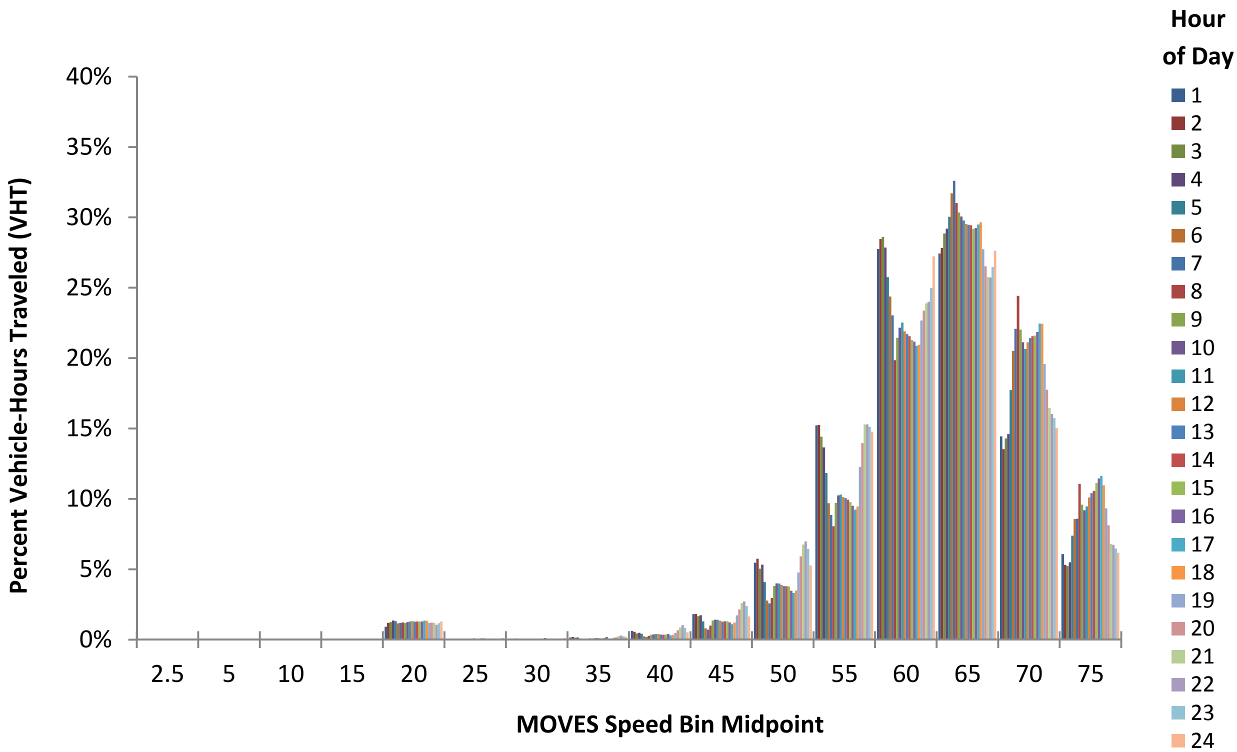


Figure 31. Speeds at the I-8 Urban Location

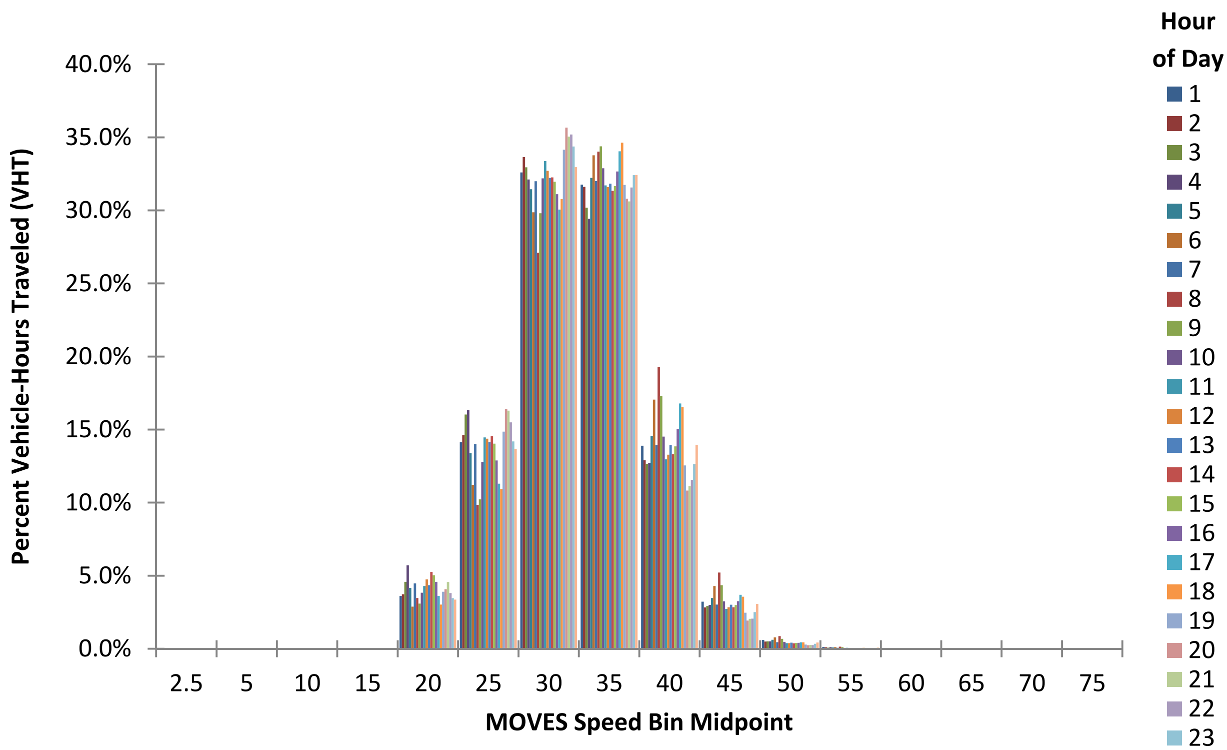


Figure 32. Speeds at the SR 8B Urban Location

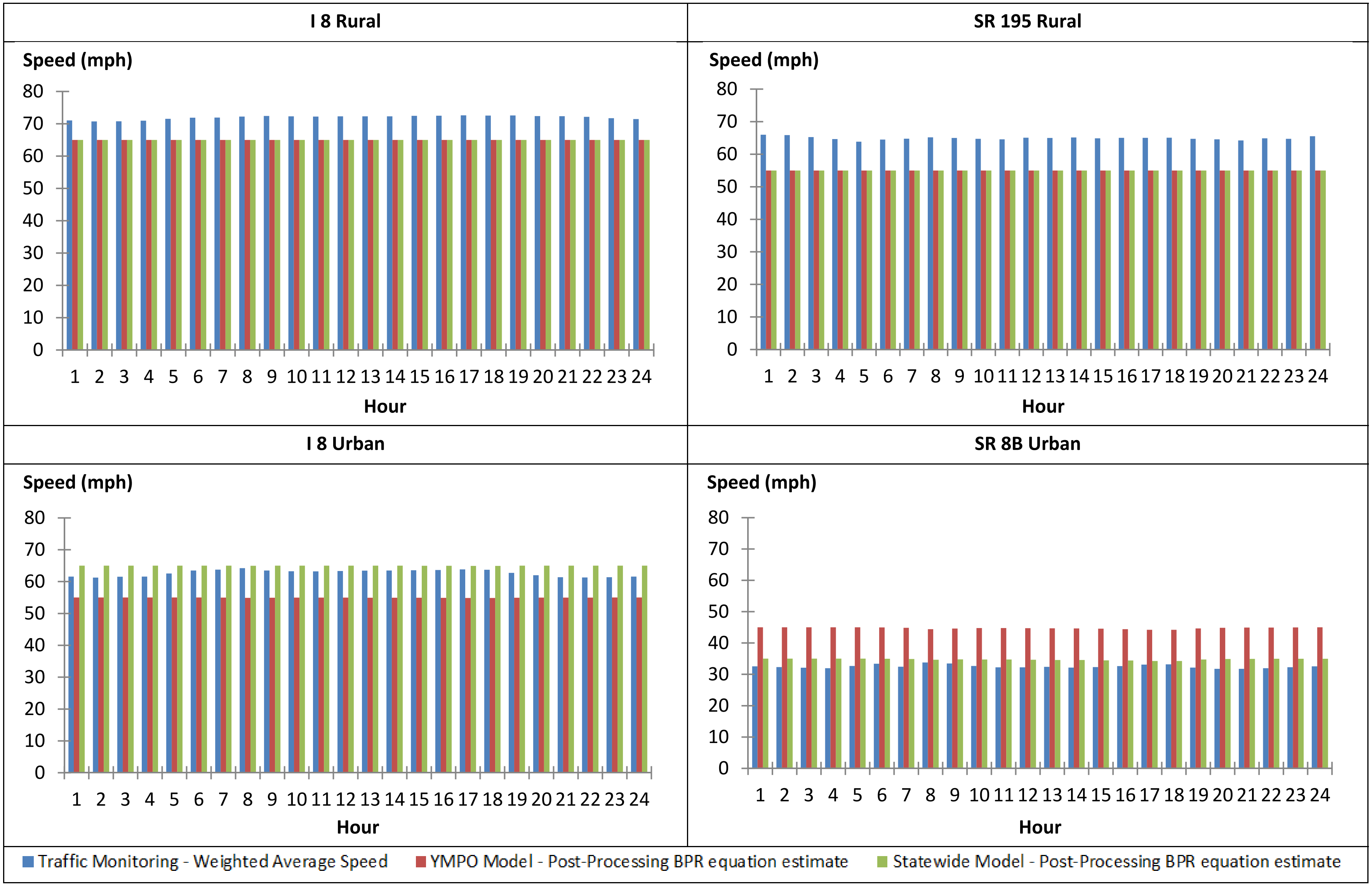


Figure 33. Comparison of Speed Postprocessing Results to Traffic Monitoring Data for Four Selected Locations

Speed differences by vehicle type were also investigated using sample data from four WIM stations on I-10 and SR 87 in Maricopa County, I-17 in Yavapai County, and I-19 in Santa Cruz County. In Figure 34, the data show an over 10-mph speed differential between LDVs (WIM vehicle classes 1 – 3) and HDVs (WIM vehicle classes 4 – 6) with a light-duty speed of 73 to 74 mph and a heavy-duty speed of 62 to 63 mph. The time-of-day effect at this location, if any, is quite modest.

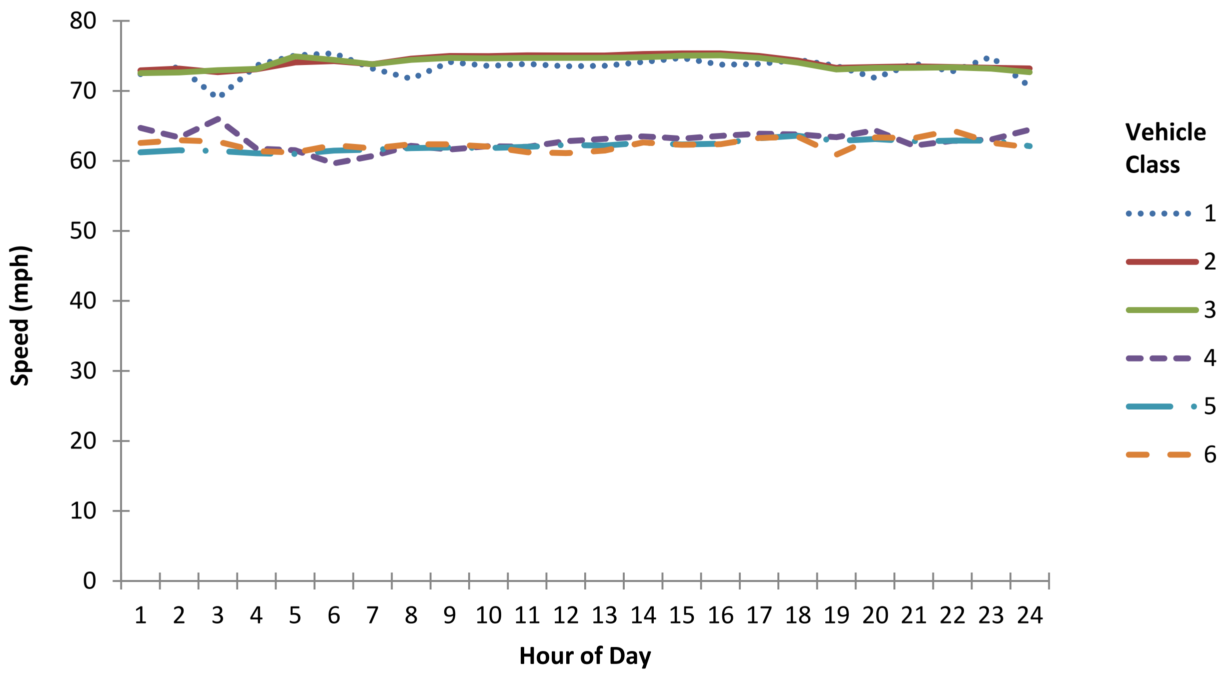


Figure 34. Speed by Hour of Day and by Vehicle Type, Four WIM Stations

Recommendations

Observed speed data—where available—are the most accurate source for estimating current or historical-year emissions. However, spatial coverage from the Active Transportation and Demand Management Program (ATDM) system is limited and observed data may not be representative, especially for unrestricted-access roadways. Also, for estimating future-year emissions, model estimates must be used (unless future- and current-year speeds are assumed to be the same), and EPA guidance recommends the use of consistent methods for base- and future-year speed estimation. Therefore, the use of modeled speeds is recommended, but with adjustments to match observed speed distributions.

The demonstrated speed postprocessing procedure does seem to be a worthwhile procedure to implement in Yuma County and other Arizona counties, where congested roadways make up a significant portion of the total VMT. (In Yuma County, urban unrestricted-access roadways, which exhibited the most congestion impacts, make up about 28 percent of total VMT.) The postprocessing based on the statewide model seems to produce better results because of more realistic free-flow assumptions coded in the model links, and the time-of-day component of that model helping to show

how traffic and speeds vary over the course of the day. However, more improvements to the statewide model and the speed postprocessing procedure would help improve results further. Therefore, the following recommendations are made:

- Use the statewide model results with speed postprocessing to produce speed distributions in all parts of the state, unless a more geographically detailed time-of-day model is available in certain areas (e.g., the Phoenix area).
- ADOT should use traffic monitoring data and possibly electronic travel time data to adjust free-flow speeds on statewide model links to better reflect real-world speeds. Alternatively, ADOT could adjust the posted speeds by roadway functional class in the speed postprocessing routine. Further analysis of traffic monitoring data would be required to come up with lookup tables of amount of speed to add to posted speed by functional class. This analysis could also come up with different amounts of speed to add to posted speed by time of day to account for the patterns of slower overnight driving speeds shown in this research.
- Additional research should be conducted to determine whether traffic monitoring speed distributions that represent an array of different vehicle speeds on every link, not just an average speed by link, can be incorporated into speed postprocessing procedures. The goal is for these procedures to result in a distribution of speeds over space (all of the links in the roadway network) and time (hour-to-hour and day-to-day variation across the year).
- MOVES allows for input of different speed distributions by source type. Sample data from a WIM on a rural freeway show a significant speed difference between cars and trucks. Speed data by source type should be further evaluated to determine whether this difference is consistent across locations, and if so, adjustments should be made to HDV speeds at least for this road type. If data can be gathered to evaluate speeds by source type on other road types (e.g., from ATR stations included in the TDMS), ADOT should evaluate whether adjustments to speed distributions should also be made on these road types.

OTHER INPUTS

Meteorological Inputs

Data Sources Used

MOVES requires monthly average temperature and relative humidity values for each hour of the day to perform its calculations. For this exercise, two of the most commonly used sources of meteorological data needed for MOVES modeling were compared: MOVES defaults and NCDC LCD summaries. Both of these sources are publicly and freely available and cover the entire United States; LCDs span multiple years, while MOVES defaults contain data for only a single calendar year. LCDs are constantly maintained and updated by NCDC, while MOVES defaults remain static for each release of the model. The MOVES defaults presented here are from the new MOVES2014 release, which includes data from a single year (2011).

MOVES contains data for each county in the United States, while LCD data are often only available in or around major metropolitan areas, often stations in place at large airports. Some of the MOVES county data may be interpolated from readings at these stations. With respect to LCD, there may be multiple stations or no stations available in a county. With these issues in mind, the user must select a station that is representative of conditions in each county.

Coverage of NCDC stations in Arizona is sparse in some areas. Table 28 lists the available NCDC data stations throughout the state, along with the most recent year of data available.

Table 28. Available NCDC Station Data in Arizona

Location	ID	Most Recent Year
Flagstaff	FLG	2014
Phoenix	PHX	2014
Tucson	TUS	2014
Winslow	INW	2014
Prescott	PRC	1999
Yuma	YUM	1995

Central and southeast Arizona, which contain most of the urban areas of the state, are well covered by currently collected data, but other regions of the state are not. For the southwestern portion of Arizona, Yuma data are available up until 1995—still within the 30-year climatic normal, but not ideal. Las Vegas data could be used for the northwestern portion of Arizona in some cases, but there are no NCDC stations covering the northeastern portion of Arizona at all. In such regions, use of MOVES meteorological defaults is advised.

MOVES2014 default data were obtained by exporting default *zonemonthhour* data for Yuma County in 2015 from the CDM. LCD data were obtained from the NCDC website (NCDC 2016); one LCD text file was downloaded for each month in 2013 for the Phoenix airport. Only four stations with current data are available in all of Arizona from the NCDC site, as Yuma data are only available through 1995. Since Phoenix was the closest site to Yuma, it was selected for the purpose of representing southwestern Arizona for this exercise.

Processing Methods

To process the downloaded LCD files, the study team used an internally developed tool (LCD_to_MOVES) to parse the text files and extract average monthly temperature and relative humidity by hour. This tool is being made publicly available as part of the final products of NCHRP 25-38 and can be provided to ADOT. However, the meteorological data extraction can be done manually without too much difficulty, if the user begins with the meteorological template provided in the MOVES CDM.

Findings

Default Yuma data and 2013 LCD Phoenix data are shown in Figure 35. The graph shows the temperature and relative humidity variation over an average 24-hour period in each of 12 months.

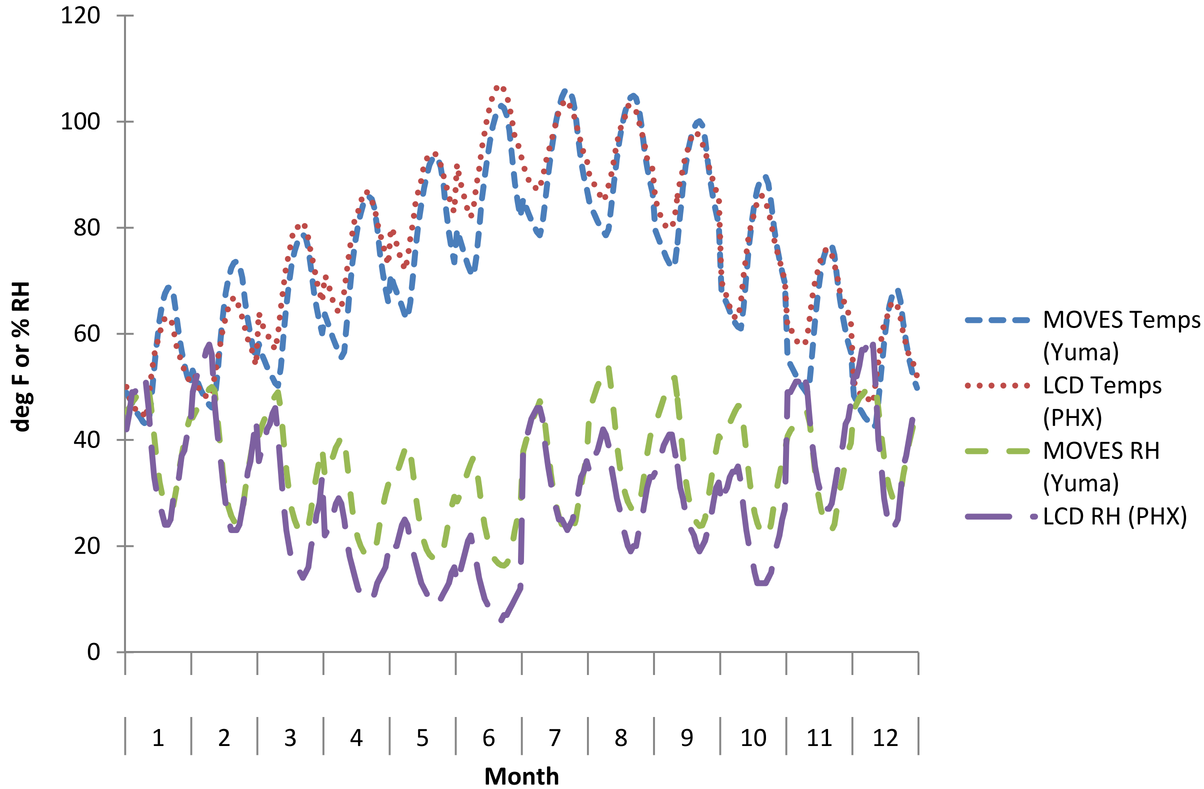


Figure 35. Example Meteorological Data: Yuma and Phoenix

As shown in Figure 35, the diurnal temperatures follow similar trends, although the Yuma nighttime temperatures tend to be slightly lower than Phoenix nighttime temperatures most of the year; Yuma humidity levels are generally somewhat higher.

The data provided to the MOVES CDM, as with most MOVES inputs, are in tabular comma-separated value (CSV) format. An example of January meteorological data is shown in Table 29.

Table 29. Example of Meteorological Data for MOVES Input

monthID	zoneID	hourID	temperature	relHumidity
1	40270	1	48.9	45.3
1	40270	2	47.9	46.1
1	40270	3	47.0	47.1
1	40270	4	46.0	47.7
1	40270	5	45.0	48.6
1	40270	6	44.2	49.3
1	40270	7	43.4	50
1	40270	8	43.0	49.9
1	40270	9	43.3	49.9
1	40270	10	47.5	46.0
1	40270	11	53.4	40.8
1	40270	12	58.4	36.0
1	40270	13	62.7	32.1
1	40270	14	65.7	29.6
1	40270	15	67.6	28.0
1	40270	16	68.7	27.2
1	40270	17	68.8	26.9
1	40270	18	67.6	27.7
1	40270	19	64.0	30.5
1	40270	20	59.8	34.3
1	40270	21	56.8	37.1
1	40270	22	54.2	39.8
1	40270	23	52.1	42.3
1	40270	24	50.4	44.1

Recommendations

The default MOVES meteorological data are somewhat limited, in that only a single year of data is available. That said, this is not a substantial problem, as the meteorological data are used primarily to calculate diurnal variation effects on HC and NO_x. As long as the data are representative of the area being modeled and contain adequate diurnal variation, the emissions calculations should be acceptable.

The LCD summaries available from NCDC do require some effort to process into a format usable by MOVES. The summaries contain much more information than MOVES requires, so the appropriate monthly averages must be extracted and converted to MOVES inputs. However, since the LCDs do contain data for several calendar years, they may be used to capture the effects of significant meteorological events on emissions. For example, it may be desirable to use LCD data for episodic modeling of a particularly hot summer where increased emissions of evaporative HC might be a concern. This is not an issue for SIP or conformity analysis, where average information is desired.

The methods for acquiring and using meteorological data for other areas in the state will be the same for either LCD or MOVES defaults. In some cases, judgment may be required to determine the most representative LCD station to use for a rural county without any data available.

For quick, "back-of-the-envelope" scenario evaluations, the MOVES meteorological defaults are sufficient. For more stringent regulatory purposes, including SIP and conformity analysis, EPA technical guidance recommends the use of LCD data. A case could be made that the MOVES defaults may be more reliable for locations far from the nearest Automated Surface Observing System (ASOS) station and with large changes in elevation, since the defaults take spatial averaging into account. However, some negotiation would be required for EPA to approve use of the defaults.

I/M Program Inputs

Data Sources Used

MOVES contains default I/M program inputs that include information, such as affected source types, MY ranges, inspection frequency, type of test performed, and vehicle compliance factor. For the most part, the defaults within the model correctly describe the I/M program in place in Arizona, which covers the Phoenix and Tucson metropolitan areas. The ADEQ is responsible for implementation of the state's I/M program, which has been in place for many years and has remained fairly static. The I/M inputs for MOVES are created and modified by the user and must reflect the I/M program as currently implemented. No other known sources for I/M information used to create MOVES inputs exist outside of ADEQ, which has regulatory authority.

MOVES default I/M data for Yuma County do not exist, since an I/M program is not currently in place there. For this exercise, I/M data were obtained for the Phoenix area by exporting default *imcoverage* data from the CDM in both MOVES2010b and the recently released MOVES2014.

Processing Methods

Minimal processing is required for use of default MOVES I/M data in Arizona. In this case, the MOVES2010b defaults were exported and compared to the known I/M program in Maricopa County to determine whether there were any errors in the exported information. The study team noted that the defaults incorrectly reflect the exemption in place for the newest five MYs for vehicles in the Phoenix area. Secondly, a compliance factor of 95.9 percent was in place for all vehicles, regardless of MY, source type, or test type. This seemed unreasonable, as the factor depends on compliance rate, waiver rate, and regulatory class coverage and should not be static.

Next, the study team similarly compared the MOVES2014 default I/M information for Maricopa County to the Arizona standards. The newly updated MOVES2014 I/M data seemed much more reasonable, in that MY exemptions were accounted for and more representative compliance factors were in place.

Findings

As currently present in the MOVES2010b defaults, incorrect application of over-broad MY exemptions will overestimate the effect of the I/M program on the area. Similarly, unduly high compliance factors will also significantly overestimate I/M benefit estimates. The MOVES2014 defaults appear to more accurately represent the benefits of the program.

The I/M data provided to the MOVES CDM is in tabular CSV format. An example of NO_x exhaust I/M data from MOVES2014 is shown in Table 30.

Table 30. Example of NO_x Exhaust I/M Data

Pol Process ID	State ID	County ID	Year ID	Source Type ID	Fuel Type ID	IM Program ID	Inspect Freq	Test Standards ID	Beg Model Year ID	End Model Year ID	Use IM YN	Compliance Factor
301	4	4013	2015	21	1	103	1967	1980	1	13	Y	57.6164
301	4	4013	2015	32	1	103	1967	1980	1	13	Y	57.6164
301	4	4013	2015	52	1	103	1967	2011	1	13	Y	87.2032
301	4	4013	2015	31	1	103	1967	1980	1	13	Y	57.6164
301	4	4013	2015	31	1	106	1981	1995	2	31	Y	64.12
301	4	4013	2015	21	1	106	1981	1995	2	31	Y	64.12
301	4	4013	2015	32	1	106	1981	1995	2	31	Y	64.12
301	4	4013	2015	21	1	110	1996	2011	2	51	Y	90.0428
301	4	4013	2015	32	1	110	1996	2011	2	51	Y	90.0428
301	4	4013	2015	31	1	110	1996	2011	2	51	Y	90.0428

Recommendations

The study team recommends using MOVES2014 (**not** MOVES2010b) defaults for I/M inputs. As specified in the MOVES User's Guide, this can be most easily done by exporting the default I/M values using the feature provided in the CDM into a Microsoft Excel spreadsheet, updating as appropriate, and reimporting the corrected data via the CDM. If Arizona makes substantial changes to the I/M program in the future, additional care will be needed to ensure the I/M inputs reflect those changes, and EPA should be notified so that the default data in the model are updated. The methods for acquiring and using I/M data for other areas in the state should be the same regardless of county.

Fuels Inputs

Data Sources Used

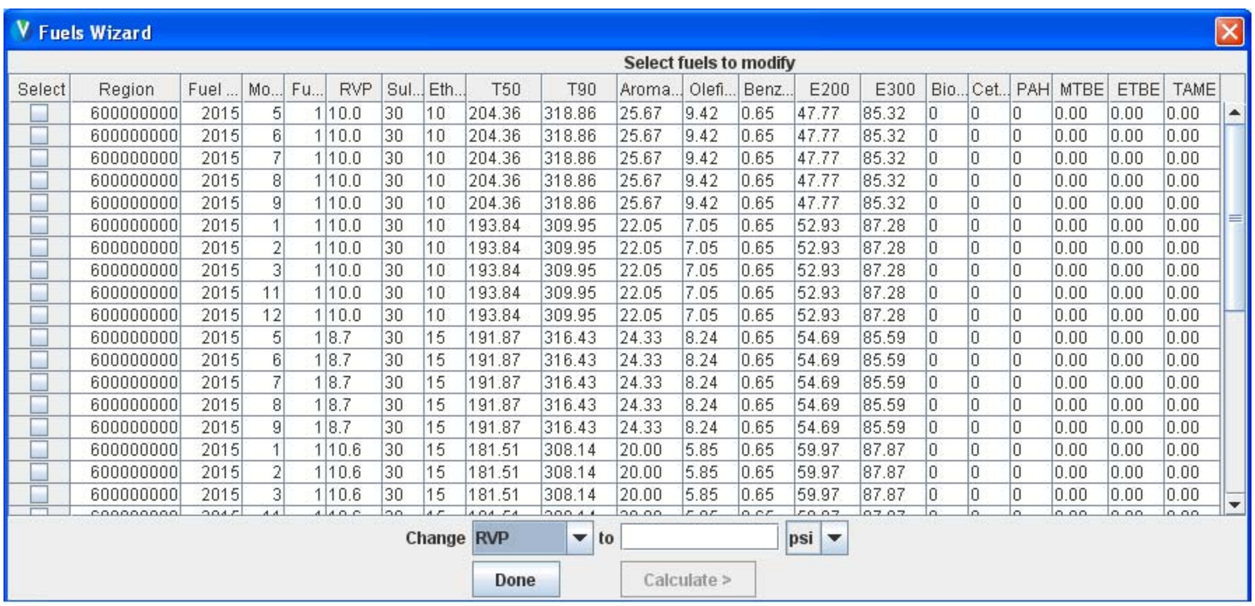
The MOVES model contains a number of different fuel formulations. These formulations are described by a number of different physical characteristics, including RVP, sulfur level, oxygenate volumes, aromatic/olefin/benzene content, and other parameters. In turn, these fuels are apportioned by county, calendar year, month, and market share to comprehensively describe the fuel supply for a given area's fleet. MOVES default fuel formulations and fuel supply defaults exist for every county in Arizona.

In contrast to previous versions of the model, MOVES2014 also includes as part of its fuel data two additional tables: *fuelusagefraction* (new) and *avft* (previously a separate input). MOVES2014 default data were obtained by exporting these two tables, along with the default fuel supply and fuel formulation data for Yuma County in 2015, from the CDM.

Processing Methods

Minimal processing is required for use of default MOVES fuel data in Arizona. As discussed above, this can be most easily done by exporting the default fuel values using the feature provided in the CDM into a Microsoft Excel spreadsheet, updating as appropriate, and reimporting the corrected data via the CDM.

A new feature to MOVES2014 is the Fuels Wizard, which allows for automatic adjustment of fuel formulation parameters. If only simple adjustments to a single parameter are necessary—for example, changing the RVP of a particular formulation—this wizard will accept a single updated value from the user and alter other parameters for consistency, as shown in Figure 36.



Select	Region	Fuel ...	Mo...	Fu...	RVP	Sul...	Eth...	T50	T90	Aroma...	Olefi...	Benz...	E200	E300	Bio...	Cet...	PAH	MTBE	ETBE	TAME
	600000000	2015	5	1	10.0	30	10	204.36	318.86	25.67	9.42	0.65	47.77	85.32	0	0	0	0.00	0.00	0.00
	600000000	2015	6	1	10.0	30	10	204.36	318.86	25.67	9.42	0.65	47.77	85.32	0	0	0	0.00	0.00	0.00
	600000000	2015	7	1	10.0	30	10	204.36	318.86	25.67	9.42	0.65	47.77	85.32	0	0	0	0.00	0.00	0.00
	600000000	2015	8	1	10.0	30	10	204.36	318.86	25.67	9.42	0.65	47.77	85.32	0	0	0	0.00	0.00	0.00
	600000000	2015	9	1	10.0	30	10	204.36	318.86	25.67	9.42	0.65	47.77	85.32	0	0	0	0.00	0.00	0.00
	600000000	2015	1	1	10.0	30	10	193.84	309.95	22.05	7.05	0.65	52.93	87.28	0	0	0	0.00	0.00	0.00
	600000000	2015	2	1	10.0	30	10	193.84	309.95	22.05	7.05	0.65	52.93	87.28	0	0	0	0.00	0.00	0.00
	600000000	2015	3	1	10.0	30	10	193.84	309.95	22.05	7.05	0.65	52.93	87.28	0	0	0	0.00	0.00	0.00
	600000000	2015	11	1	10.0	30	10	193.84	309.95	22.05	7.05	0.65	52.93	87.28	0	0	0	0.00	0.00	0.00
	600000000	2015	12	1	10.0	30	10	193.84	309.95	22.05	7.05	0.65	52.93	87.28	0	0	0	0.00	0.00	0.00
	600000000	2015	5	1	8.7	30	15	191.87	316.43	24.33	8.24	0.65	54.69	85.59	0	0	0	0.00	0.00	0.00
	600000000	2015	6	1	8.7	30	15	191.87	316.43	24.33	8.24	0.65	54.69	85.59	0	0	0	0.00	0.00	0.00
	600000000	2015	7	1	8.7	30	15	191.87	316.43	24.33	8.24	0.65	54.69	85.59	0	0	0	0.00	0.00	0.00
	600000000	2015	8	1	8.7	30	15	191.87	316.43	24.33	8.24	0.65	54.69	85.59	0	0	0	0.00	0.00	0.00
	600000000	2015	9	1	8.7	30	15	191.87	316.43	24.33	8.24	0.65	54.69	85.59	0	0	0	0.00	0.00	0.00
	600000000	2015	1	1	10.6	30	15	181.51	308.14	20.00	5.85	0.65	59.97	87.87	0	0	0	0.00	0.00	0.00
	600000000	2015	2	1	10.6	30	15	181.51	308.14	20.00	5.85	0.65	59.97	87.87	0	0	0	0.00	0.00	0.00
	600000000	2015	3	1	10.6	30	15	181.51	308.14	20.00	5.85	0.65	59.97	87.87	0	0	0	0.00	0.00	0.00

Figure 36. MOVES2014 Fuels Wizard

Findings

The MOVES2010 defaults capture expected variations in RVP, sulfur level, and other factors on a month-to-month basis for gasoline blends. However, ethanol percentage is set to 10 percent for 97.4 percent of gasoline sold in the Yuma area (15 percent for the remaining 2.6 percent) for all gasoline formulations, regardless of month or location, in the *fuelformulation* table. Similarly, diesel sulfur levels are held constant at 15 ppm. In the future, users should be careful to ensure that the defaults accurately represent the fuel being used, as sulfur levels directly correlate with NO_x and PM emissions, and RVP has a substantial effect on evaporative HC.

Arizona users of MOVES may wish to periodically contact AZDWM, which is responsible for ensuring that refiners, distributors, and fueling stations are using state-mandated fuel blends, to make certain that information in the model is up-to-date. This is especially important for oxygenates, diesel sulfur levels, and overall market share of fuels blends.

The fuel supply data provided to the MOVES CDM are in tabular CSV format. An example of these data for Yuma County from January through June is shown in Table 31.

Table 31. Example of Fuels Data Inputs

Fuel RegionID	Fuel YearID	Month GroupID	Fuel FormulationID	Market Share	Market ShareCV
600000000	2015	1	3281	0.974276	0.5
600000000	2015	1	3283	0.0257235	0.5
600000000	2015	1	25005	1	0.5
600000000	2015	2	3281	0.974276	0.5
600000000	2015	2	3283	0.0257235	0.5
600000000	2015	2	25005	1	0.5
600000000	2015	3	3281	0.974276	0.5
600000000	2015	3	3283	0.0257235	0.5
600000000	2015	3	25005	1	0.5
600000000	2015	4	3293	0.974276	0.5
600000000	2015	4	3294	0.0257235	0.5
600000000	2015	4	25005	1	0.5
600000000	2015	5	3280	0.974276	0.5
600000000	2015	5	3282	0.0257235	0.5
600000000	2015	5	25005	1	0.5
600000000	2015	6	3280	0.974276	0.5
600000000	2015	6	3282	0.0257235	0.5
600000000	2015	6	25005	1	0.5

Recommendations

The study team recommends using MOVES2014 defaults for fuel inputs in the near term, with periodic updates to the especially sensitive fuel variables, as needed. If ADOT can secure results of fuel sample testing from its partner agencies at a minimal cost, then updating MOVES defaults with more representative fuel formulations and market share may prove worthwhile.

In the future, ADOT could consider collecting fuel samples from different stations across counties of interest to provide a more accurate estimation of fuel characteristics. Conducting a new testing program to derive such information, however, is probably cost-prohibitive and likely only marginally beneficial compared to use of MOVES model defaults. In the absence of easily obtained fuels information, the default MOVES data should be sufficient for most applications.

The methods for acquiring and using fuels data for other areas in the state should be the same regardless of county.

CHAPTER 5. SUMMARY OF FINDINGS AND RECOMMENDATIONS

This section summarizes the following information for each MOVES input:

- A definition of the input
- Existing data sources
- Recommended methods for processing the data
- Limitations of existing data
- Data enhancements—recommendations to support the creation of better MOVES inputs
- Value of enhancements—the priority for each suggested enhancement considering both the sensitivity of MOVES to the referenced inputs and the cost of getting better data

FLEET INPUTS: AGE DISTRIBUTION AND SOURCE TYPE POPULATION

Definition. Fleet inputs include age distribution and source (vehicle) type population. Inputs are provided for 13 categories of LDVs, trucks, and buses.

Data sources. The primary source of fleet inputs is the state motor vehicle registration database, which provides information on registered vehicles by county. This database is maintained by the ADOT MVD. Updated data should be obtained at least every four to five years to meet latest planning assumptions guidance, or more frequently if resources permit.

Processing methods. The initial analysis of registration data involves a fair amount of work because the information provided in the registration records does not fully correspond to the MOVES source type definitions. A VIN decoder maintained by the project consultant was used in the case study to assist in classifying vehicles. The procedures used in this case study can be applied in the future to expedite the analysis of updated registration data. A modest level of outside assistance may be required to apply a VIN decoder, although classification could also be performed (with less accuracy) internally by ADOT.

Data limitations. The MVD database does not provide information to split LDTs into passenger and commercial categories, or HDTs into short- and long-haul categories. MOVES default values were used for these proportions. Use of the state registration database also does not account for differences in age distribution or source type population for out-of-state vehicles; in Arizona, this is mostly a concern for long-haul truck traffic and some areas with seasonal visitors. Finally, the bus information in the database is limited; school buses are identified, but transit and intercity buses are not distinguished.

Data enhancements. Adding or revising certain fields in the MVD registration database would reduce the effort required and enhance the accuracy of vehicle categorization for MOVES inputs. Examples of data that would be useful include vehicle manufacturer, gross weight rating, vehicle fuel type, and a geographic identifier for an area smaller than a county (e.g., ZIP code). Transit and intercity buses should be distinguished. Primary usage information would also be helpful, including passenger vs. commercial use for light trucks, and short-haul vs. long-haul use for heavy trucks.

Additional data collection activities, such as license plate surveys and/or commercial vehicle use surveys, could be undertaken to better characterize the fleet of all vehicles operating in Arizona (regardless of registration) and to identify short-haul vs. long-haul truck traffic.

Value of enhancements. Both age and source type distributions can have a significant effect on emissions. Therefore, the accurate classification of vehicles is important. Enhancements to the registration database would make it easier for ADOT to create regular updates of these data. Additional survey-based data collection activities could be costly, but might be worth the effort if they also produced data that could be used for other purposes. For example, commercial vehicle surveys would assist in improving modeled estimates of truck traffic.

ACTIVITY INPUTS: VMT AND VMT-BASED ADJUSTMENTS

Definition. VMT-based inputs include VMT by vehicle class (motorcycle, passenger car and light truck, single-unit truck, combination truck, and bus); road type distribution (fractions of VMT on rural and urban restricted-access and unrestricted-access roads); temporal adjustments (fractions of VMT by hour, day, and month); and fraction of VMT on highway ramps. Different road type and temporal fractions may be provided for the 13 MOVES source (vehicle) types.

Data sources. A number of data sources were obtained and evaluated for the Yuma County case study, including YMPO travel demand model outputs, Arizona Statewide Travel Demand Model (AZTDM) outputs, VMT reported by ADOT for the FHWA HPMS, HPMS segment-level data, and statewide traffic monitoring data from the ADOT TDMS. Based on this evaluation, the following recommendations are made for the VMT-based inputs:

- **VMT by vehicle class and road type distributions** – HPMS segment data should be used to develop VMT by roadway functional class for historical years, and to adjust forecast VMT from MPO travel demand models (or the statewide model outside of MPO areas). Vehicle classification counts from specific regions of the state (at least north and south) should be used to further break down VMT by the five vehicle classes required.
- **Ramp fraction** – If available, a local MPO travel demand model should be used to develop ramp fractions; otherwise, the statewide model should be used.
- **Temporal distributions** – Statewide month, day, and hour VMT fractions developed from ADOT TDMS data should be used for all areas of the state.

Processing methods. ADOT can assist MOVES users by regularly analyzing its traffic monitoring data and publishing reports with vehicle type distribution percentages by MOVES road type for each region of the state (at a minimum, south and north). The reports should be updated at least every four to five years to meet latest planning assumptions guidance, or more often if resources permit. Travel demand model outputs can be combined with HPMS and TDMS data to create MOVES inputs using the procedures described in Chapter 4 of this report.

Data limitations. A very limited number of classification counters with enough temporal coverage in some areas of the state makes it difficult to develop reliable region-specific temporal and road type distributions. Furthermore, many counters use a length-based classification system that cannot be directly related to

MOVES vehicle classes. The available data suggest that some factors (such as weekday vs. weekend and volumes by month) vary regionally, especially for the northern vs. southern parts of the state.

Data enhancements. Expanded temporal coverage of permanent classification counters and use of axle-based classification systems when replacing or adding counters could provide classified VMT by county or for subareas of the state. The addition of permanent classification counters in strategic locations could help ensure that each county has at least two or three counters for each MOVES road type. This would allow the development of temporal distributions and vehicle class distributions by region (e.g., north vs. south) and possibly even by county. In addition, better ramp count coverage for certain limited-access highways (I-8, I-17, and I-40), which are currently not available in TDMS, could be used to validate ramp volumes in the statewide model.

Value of enhancements. Expanded coverage of classification traffic counters would provide better information on VMT by vehicle type by region of the state, which could have a significant impact on emissions locally. The highest priority would be to have at least two or three classification counters on each MOVES road type in each county, so that county-specific VMT and road type distributions could be developed. A lower priority would be to expand the temporal coverage of existing stations to allow for vehicle type-specific temporal distributions at a substate level. This is considered a lower priority because the MOVES model shows limited sensitivity to temporal inputs for annual inventory development and regional conformity analysis. However, hourly and monthly VMT fractions are important for project-level or episodic modeling used as input to air quality models. Expanded ramp count coverage would also be considered a second-priority item.

ACTIVITY INPUTS: SPEED DISTRIBUTIONS

Definition. Speed distributions indicate the fraction of vehicle-hours of travel in 16 speed bins. Separate speed distributions may be provided by road type, source (vehicle) type, and time of day (hour).

Data sources. Current and future-year speed distributions can be obtained from travel demand model outputs, including the statewide model and MPO models in MPO areas. Speed information could also be obtained from ADOT's traffic monitoring stations and private sources that use cellphone and GPS data. Because EPA requires the source of historical and forecast-year speed data to be consistent, model data should be used for regulatory purposes; however, observed speed data can be used to better calibrate the models' speed estimates. Because the smaller MPOs' models typically do not include a time-of-day component, use of the statewide model speed data is recommended in all parts of the state, unless a more geographically detailed time-of-day model is available in certain areas (e.g., Phoenix).

Processing methods. Postprocessing of travel demand model speed estimates is recommended to disaggregate speed estimates from aggregate estimates (daily or peak/off-peak) to hour of the day, as required for MOVES inputs. Other research and the Yuma County case study found that postprocessing improves the quality of speed estimates developed from travel demand models. Adjustments to speed distributions for heavy trucks on restricted-access roads should be considered after further examination of WIM speed data and classification counter speed data, if it can be reported by vehicle type.

Data limitations. Travel demand models provide limited speed data—only for up to four time periods of the day, and only for all vehicles collectively. MOVES can accept different speed distributions by hour and vehicle type, as well as by road type. ADOT's traffic counters in some cases have the capability to record speeds, but this capability is not always used in a manner that allows for reporting speed by vehicle type. Currently, speed data by vehicle type are reported only for 15 WIM stations.

Data enhancements. ADOT should consider using its own traffic monitors and/or purchasing privately gathered travel time data to adjust free-flow speeds on statewide model links to better reflect real-world speeds, which are usually higher than modeled speeds. ADOT should investigate with its TDMS vendor whether speed data (ideally classified by vehicle type) could be obtained from other classification count stations. Additional speed analysis could also consider differences in speeds by time of day (slower nighttime speeds were observed in this research). Speed monitoring sources such as WIM stations can also be used to evaluate speed differentials between cars and trucks.

Value of enhancements. Speed has a significant influence on emissions, and accurate estimates of speed distributions are therefore important. Since the speed-emissions relationships differ by vehicle type, it could also be important to look at differences in speed distributions for light vs. heavy vehicles, although few agencies have done this in practice.

METEOROLOGICAL INPUTS

Definition. MOVES requires monthly average temperature and relative humidity values for each hour of the day.

Data sources. Meteorological data are available from the NCDC LCD summaries, as well as embedded MOVES default values. MOVES contains data for each county in the United States, applying spatial averaging between meteorological stations, while LCD data are available only for weather monitoring stations, which are often located in or near major metropolitan areas. EPA recommends the use of local data rather than MOVES defaults, where possible. The nearest available meteorological station with complete data to each county should be used.

Processing methods. LCD data can be processed into MOVES input format using spreadsheet methods, or using a free tool distributed with the products of NCHRP Project 25-38.

Data limitations. Not every county contains an LCD meteorological station. For example, in the Yuma County case study, the nearest information was from Sky Harbor International Airport in Phoenix. Because of elevation and other climatological differences in Arizona, the nearest station may not accurately represent the conditions in the county being analyzed.

Data enhancements. Data from other meteorological stations, such as those associated with air quality monitors, could potentially be used if available locally where LCD data are not available. The most appropriate data source will need to be determined on a county-by-county basis.

Value of enhancements. The benefit of identifying a local meteorological data source will be greatest in areas where climate differs substantially from the climate of the nearest stations reported in the LCD.

I/M PROGRAM INPUTS

Definition. I/M program inputs include information such as affected source types, MY ranges, inspection frequency, type of test performed, and vehicle compliance factor.

Data sources. MOVES contains default I/M program inputs. The ADEQ is responsible for implementation of the state's I/M program, which has been in place for many years in the Phoenix and Tucson areas and has remained fairly static. The MOVES2014 defaults appear to accurately represent the characteristics of the program.

Processing methods. No processing is needed for the default inputs. If Arizona makes substantial changes to the I/M program in the future, the default I/M inputs will need to be updated to reflect those changes.

FUELS INPUTS

Definition. Fuels are described by physical characteristics, including RVP, sulfur level, oxygenate volumes, aromatic/olefin/benzene content, and other parameters. Market shares of different fuel blends are provided by county, calendar year, and month.

Data sources. The MOVES model contains default fuel formulations for every county in Arizona, and these defaults are recommended as a starting point. Updated data may be obtained from the AZDWM if fuel formulations change.

Processing methods. No processing is needed for the default inputs.

Data limitations. If fuel formulations change between updates of MOVES, the latest fuel characteristics will not be reflected in the defaults.

Data enhancements. The AZDWM should be contacted periodically to determine whether fuel formulations have changed. If ADOT can secure results of fuel sample testing for minimal cost, MOVES defaults may be updated with more representative fuel formulations and market shares.

Value of enhancements. Some fuel parameters can have a significant effect on emissions, especially oxygenates, diesel sulfur levels, and overall market share of fuels blends. Major changes in these fuel characteristics should be monitored.

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APPENDIX: LIST OF DATA FILES

The files listed in the table below were provided to ADOT as part of this project.

File Name	Description	Relevant MOVES Inputs
TCDS_adot_smw_PIVOT_20140728.mdb	An Access database of classified traffic counts for 2012 downloaded from the ADOT TDMS. Queries were added summarize the volume data for export to Excel where pivot tables could be used. Hour VMT fraction values were created directly in this file.	VMT by vehicle Class, Road Type Distribution, Temporal Adjustments (Month, Day, and Hour VMT Fraction)
TCDS_adot_smw_SPEED_20140724.mdb	An Access database of classified traffic counts for 2012 downloaded from the ADOT TDMS. Queries were added summarize the speed data for export to Microsoft Excel.	Average Speed Distribution
TCDS_adot_smw_WIM_20140731.mdb	A Microsoft Access database of classified traffic counts for 2012 downloaded from the ADOT TDMS. Queries were added summarize the WIM data for export to Microsoft Excel.	Average Speed Distribution
AZ2012_TotalVMT_Matrix.xlsx	A Microsoft Excel file with a summary of volumes by six vehicle types, four MOVES road types, and county. This file is used to create the VMT by vehicle class and road type distribution input.	VMT by Vehicle Class, Road Type Distribution
Pivot_MonthVMT_ExcelSteps_20140804.xlsx	A Microsoft Excel file with a summary of volumes by six vehicle types, station, and individual days. It starts with output from the Microsoft Access database as 9,149 station-days (rows) of counts (26 stations with an average of 352 days of counts per station). The days are summarized by month and stations translated into road types and geographic areas to produce month VMT fractions.	Month VMT Fraction
monthVMTFraction-MOVESDefaults-YumaCountyCDR.xls	Values from YMPO CDR based on MOVES2010 defaults provided by ADOT. Microsoft Excel file used to create graph to compare results for month VMT fraction from different data sources.	Month VMT Fraction
monthVMTfraction-MOVES2014defaults.xlsx	Values obtained from MOVES2014 default database. Microsoft Excel file used to create graph to compare results for month VMT fraction from different data sources.	Month VMT Fraction

File Name	Description	Relevant MOVES Inputs
Pivot_DayVMT_ExcelSteps_20140731.xlsx	Microsoft Excel file with summary of volumes by six vehicle types, station, and individual days. It starts with output from the Microsoft Access database as 9,149 station-days (rows) of counts (26 stations with an average of 352 days of counts per station). Days are summarized by weekend/weekday and month. Stations are translated into road types and geographic areas to produce day VMT fractions.	Day VMT Fraction
dayVMTfraction-MOVES2014defaults.xlsx	Values obtained from MOVES2014 default database. Microsoft Excel file used to create graph to compare results for day VMT fraction from different data sources.	Day VMT Fraction
AZ2012_HourVMTFraction_Draft1.xlsx	Hour VMT fraction values were created directly in the Microsoft Access database (TCDS_adot_smw_PIVOT_20140728.mdb) and graphed using this Microsoft Excel file.	Hour VMT Fraction
Speed Process VMT Avg Spd Dist YMPO.xlsm	A Microsoft Excel file that postprocesses outputs from the YMPO travel demand model to produce average speed distributions for MOVES.	Average Speed Distribution
Speed Process VMT Avg Spd Dist AZTDM_v3.xlsm	A Microsoft Excel file that postprocesses outputs from the Arizona Statewide Travel Demand Model for Yuma County to produce average speed distributions for MOVES.	Average Speed Distribution
Yuma Speed Distribution_Weekdayend_20140725.xlsx	Microsoft Excel file to create graphs of speed distributions from four traffic monitoring stations in Yuma County that represent the four MOVES road types. Most processing performed in Access and exported to "original-counts" tab in this file.	Average Speed Distribution
SpeedValidation.xlsx	A Microsoft Excel file to compare speed estimates from real-world traffic monitoring stations to modeled speeds from postprocessing procedures using the YMPO model and ADOT statewide model.	Average Speed Distribution
YumaCaseStudy.zip	A .zip file with all Yuma County inputs for MOVES2014 resulting from the Task 5 case study.	All
SAS_program_AZmapvehicles.docx	A SAS program to map vehicle records in Arizona DMV registration database to MOVES vehicle classes, based on the VIN and other data contained in the DMV records.	Age Distribution, Source Type Population
AZDOTdata_reg_vindcd.txt	Decoded VIN data from DMV registration database.	Age Distribution, Source Type Population
AZDOTdata_reg_vindcd_meta.txt	Metadata for the decoded VIN data file.	