On-road Mobile Source Emission Inventory Development for the Central States Regional Air Planning Association

Dana Coe Sullivan, Stephen B. Reid, Patricia S. Stiefer, Tami H. Funk, and Lyle R. Chinkin
Sonoma Technology, Inc., 1360 Redwood Way, Suite C, Petaluma, CA 94954
dana@sonomatech.com

ABSTRACT

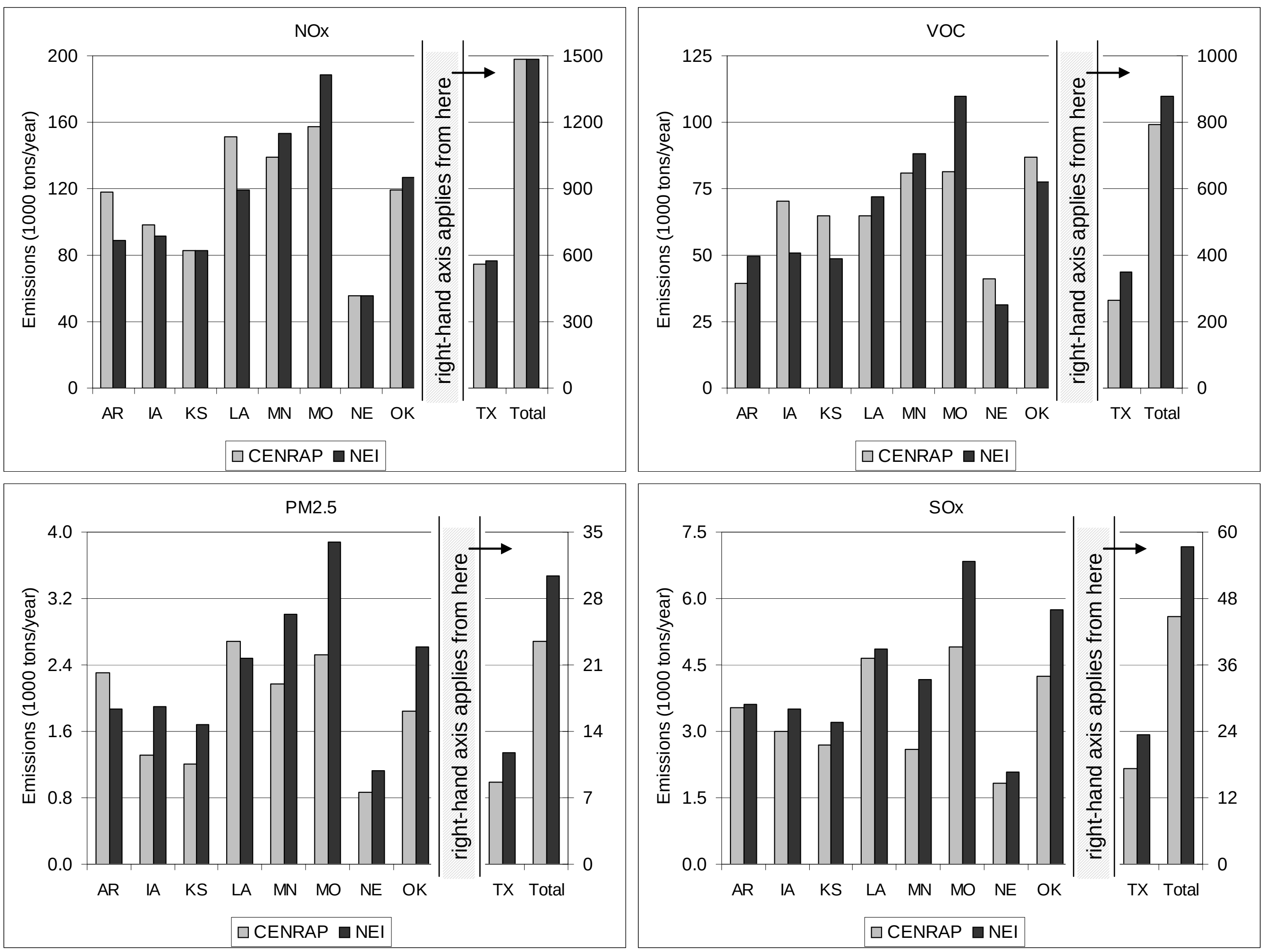
In support of the Central States Regional Air Planning Association's (CENRAP) need to develop a regional haze plan, Sonoma Technology, Inc. (STI) developed a 2002 emission inventory of on-road mobile sources for the nine-state CENRAP region, which includes Texas, Oklahoma, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Iowa, and Minnesota. The inventory was developed with MOBILE6 inputs, activity data, and other information acquired from state and local information sources. Acquired data included vehicle-miles of travel (VMT), fleet characteristics, regulatory controls, and fuels characteristics. MOBILE6-based emission inventories were generated by applying the SMOKE framework, which employs gridded, hourly temperature data to produce MOBILE6 emission factors. County-level annual average emissions were estimated by averaging the inventories for January and July. The use of extensive region-specific or local information produced significant differences and improvements over EPA's national-scale emission inventories. CENRAP-wide emissions estimates for NO_x, volatile organic compounds (VOCs), SO_2, $PM_{2.5}$, and NH_3 were up to 20% lower than those included in the preliminary 2002 National Emission Inventory (NEI) (U.S. Environmental Protection Agency, 2004). State-level emission inventories varied from the preliminary 2002 NEI by –16% to +27%.

INTRODUCTION

The Central States Regional Air Planning Association (CENRAP) is responding to the U.S. Environmental Protection Agency's (EPA) mandate to protect visibility in Class I areas by researching visibility-related issues and developing a regional haze plan for the CENRAP region, which includes Texas, Oklahoma, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Iowa, and Minnesota. On-road mobile sources emit primary particulate matter (which is emitted directly to the atmosphere in particulate form) and precursors of secondary particulate matter (which is generated from chemical transformations in the atmosphere). Primary and secondary particulate matter contribute to regional haze problems in the CENRAP region. In recognition of these issues, the CENRAP sponsored the development of improved emission inventories of on-road mobile sources for each of the nine CENRAP states.

MOBILE6 emission factors were estimated and applied within the Sparse Matrix Operator Kernel Emissions (SMOKE) framework to generate the emission inventories. The inventories were based on extensive region-specific or local information, including vehicle-miles of travel (VMT), fleet characteristics, temporal distributions, and regulatory program descriptions. The inventories were further strengthened by the use of gridded, hourly temperatures. The importance of using state and county-specific data can be seen in a comparison of the CENRAP's inventory with the preliminary 2002 National Emissions Inventory (NEI) (see Figure 1). Both inventories include 1.5 million tons of NO_x from on-road mobile sources for the CENRAP region as a whole. However, significant differences exist at the state level. For example, Louisiana's NO_x emissions were 27% higher than the estimates from the NEI, while Missouri's NO_x emissions were 16% lower. Differences are apparent at the CENRAP region-wide scale for VOC emissions, which are about 10% lower than those in the NEI, while region-wide $PM_{2.5}$ and SO_2 estimates are about 20% lower. These differences seem to arise primarily from the use of more localized temperature data, fuel volatility data, and fuel sulfur contents. For example, the 2002 NEI assumes an across-the-board diesel sulfur content of 500 ppmw (the regulatory limit), whereas the state-specific data used in this inventory ranged from 330-390 ppmw for the various CENRAP states. Further improvements in data accuracy and consistency could be made by continuing to acquire and incorporate local data.

Figure 1. Comparison of CENRAP's emission inventories for on-road mobile sources to the 2002 preliminary NEI (U.S. Environmental Protection Agency, 2004).

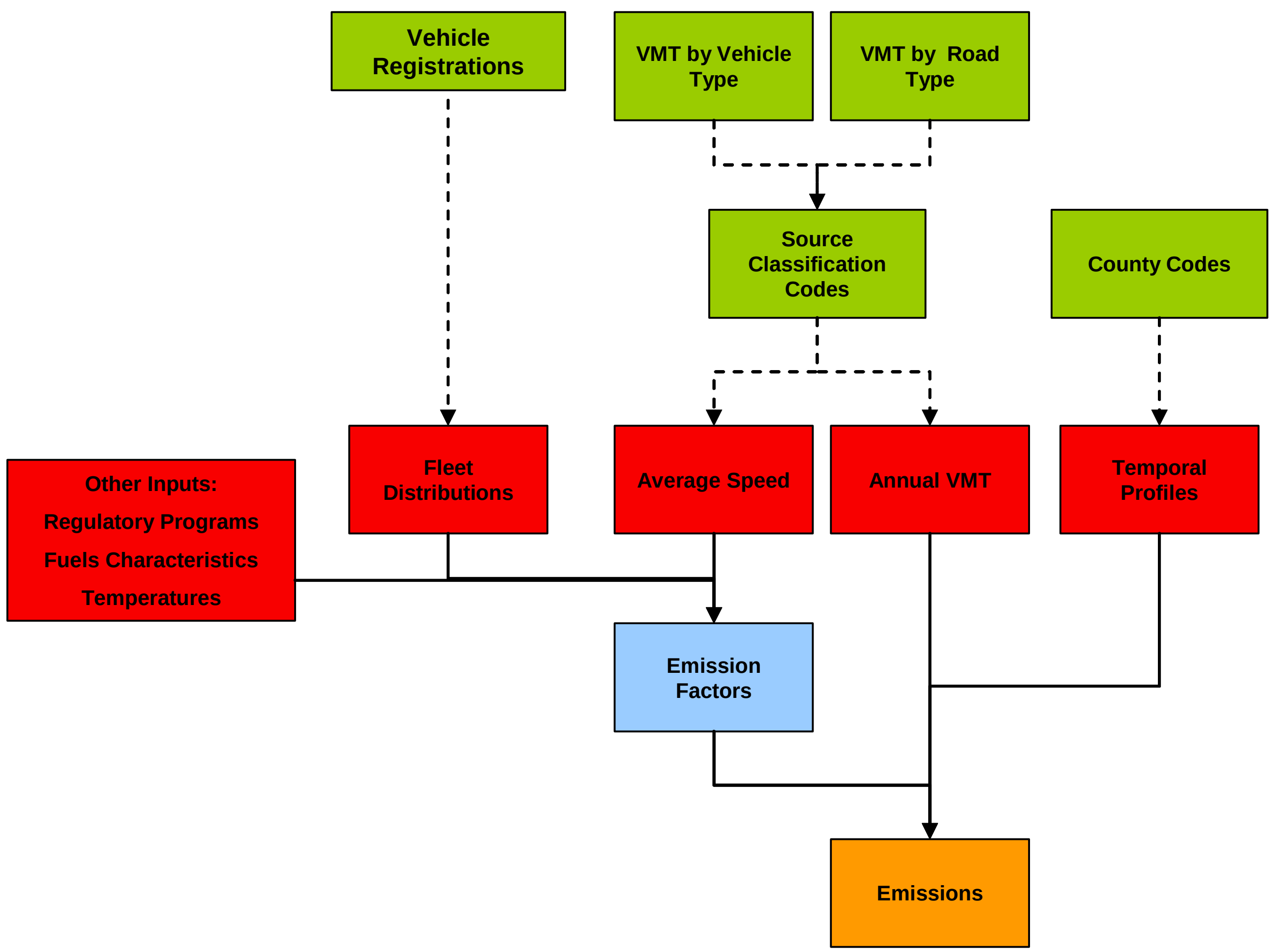


TECHNICAL APPROACH

Overview

The EPA's MOBILE6 model—an emission factor model that estimates emission factors for on-road mobile sources—and the SMOKE modeling system were used to generate and prepare emission inventories of on-road mobile sources for the CENRAP region. SMOKE processes and prepares on-road mobile source emission inventories for photochemical air quality modeling by applying temporal profiles, speciation profiles, and spatial surrogates to county-level emissions estimates. In addition, SMOKE self-contains MOBILE6. Thus, SMOKE has the added capability of generating county-level emission inventories for on-road mobile sources by (a) processing hourly, gridded temperatures and other inputs to estimate MOBILE6 emission factors, and (b) matching the emission factors to county-level activity data. MOBILE6 requires a variety of input to estimate emission factors including ambient temperatures, fleet distributions, vehicle speeds, regulatory controls settings, and fuels characteristics. Figure 2 illustrates the general processes of using MOBILE6 within SMOKE to generate on-road mobile source emission inventories.

Figure 2. Illustration of the overall process and files used by SMOKE to generate on-road mobile source emissions output files.



Development of Activity Data and Temporal Profiles

The most critical activity data needed for this effort were county-level VMT, speed distributions, and temporal distributions for the year 2002. VMT is a measure of on-road vehicle activity and is often used as the foundation of emission inventories of on-road mobile sources including those prepared with MOBILE6. Speed distributions of VMT significantly affect emission rates, while the timing of vehicle activities by season, day, or hour significantly influences emissions due to temperature dependencies.

The availability of local- or state-level data varied geographically within the CENRAP region and depended on attainment status and level of urbanization. Urban areas often maintain state-generated or locally-generated VMT and speed or temporal distributions for the purposes of emissions assessments, air quality modeling, or transportation planning. In addition, the U.S. Federal Highway

Administration (FHWA) maintains the national Highway Performance Monitoring System (HPMS) database of VMT on major U.S. roadways. The HPMS data are reported at the county or sub-county level by road type (i.e., freeway, highway, major arterial). STI requested locally representative on-road mobile source activity data for all non-attainment areas in the CENRAP region and for urban attainment areas located near Class I areas, and used locally developed data whenever available. Alternative sources of data included local and state air quality agencies, Metropolitan Planning Organizations (MPOs), and state departments of transportation (DOTs). If locally representative data were unavailable, then state DOTs were contacted for the most up-to-date HPMS data. Table 1 summarizes the mobile source activity data acquired for each area of the CENRAP region: non-attainment areas, urban areas near Class I areas, and all other regions of the CENRAP. Following data acquisition, data were processed to prepare VMT data to meet SMOKE requirements and to calculate average speed distributions and temporal profiles. SMOKE-ready input files were prepared for use with MOBILE6 running within the SMOKE emissions processor.

Table 1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP region.

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Area	Data Acquired	Year	Source of Data
Non-Attainment Areas			
Houston/Galveston, Beaumont/Port Arthur, and El Paso, Texas	MOBILE6 input files, VMT by vehicle/road type, temporal/speed distributions	2002	Texas Transportation Institute (TTI)
Dallas/Forth Worth, Texas	VMT by vehicle/road type, temporal/speed distributions	1999	Texas Commission on Environmental Quality (TCEQ)
Baton Rouge, Louisiana	MOBILE6 input files, VMT by road type	2002	Louisiana Department of Environmental Quality (LDEQ)
Urban Attainment Areas – Within 500 km of a Class I Area			
Attainment counties, Dallas/Ft. Worth, Texas	VMT by vehicle/road type, temporal/speed distributions	1999	TCEQ
New Orleans, Louisiana	MOBILE6 input files, VMT by road type	2002	LDEQ
St. Louis, Missouri	VMT by vehicle/road type, temporal distributions	2004	East-West Gateway Coordinating Council
Kansas City, Missouri and Kansas	VMT by road type	2002	Kansas Highway Department (KHD) and Missouri Department of Transportation (MoDOT)
Topeka and Wichita, Kansas	VMT by road type	2002	KHD
Little Rock, Arkansas	VMT by road type	2002	Arkansas Highways and Transportation Department (AHTD)
Minneapolis/St. Paul, Duluth, and St. Cloud, Minnesota	VMT by road type	2002	Minnesota Department of Transportation (MnDOT)
Lincoln, Nebraska	VMT by road/vehicle type and speed	2002	Lincoln-Lancaster Metropolitan Planning Organization
Oklahoma City and Tulsa, Oklahoma	VMT by road type	2002	Oklahoma State Highway Department (OSHD)

Table 1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP region.

Area	Data Acquired	Year	Source of Data
All Other Areas			
Texas	MOBILE6 input files, VMT by vehicle/road type, temporal/speed distributions	2002	TTI
Louisiana	MOBILE6 input files, VMT by road type	2002	LDEQ
Arkansas	VMT by road type	2002	AHTD
Iowa	VMT by road type	2002	Iowa Department of Transportation
Kansas	VMT by road type	2002	KHD
Minnesota	VMT by road type	2002	MnDOT
Missouri	VMT by road type	2002	MoDOT
Nebraska	VMT by road type	2002	Nebraska Department of Transportation
Oklahoma	VMT by road type	2002	OSHD

In addition, STI reviewed and revised the default SMOKE or EPA monthly, weekly, and diurnal temporal profiles to better represent the temporal patterns of on-road mobile emissions in the CENRAP region. For Texas and parts of Missouri, where locally developed temporal data were available, local temporal profiles were added to the SMOKE profile library. For other areas, representative temporal profiles were selected. Day-of-week temporal profiles were adopted from a recent study of traffic activity patterns (Coe et al., 2004). Monthly temporal profiles were based on the 1995 National Personal Transportation Survey (Federal Highway Administration, 1995). Diurnal profiles were based on the SMOKE/EPA default profiles for counties inside metropolitan statistical areas (MSAs) and other relatively urbanized counties. For other counties, where population densities or urban populations fell below established thresholds, diurnal profiles were based on Texas' profiles for groups of counties sharing similar population characteristics. (Population demographics were acquired from the U.S. Census Bureau.)

Preparation of MOBILE6 Inputs for Fleet Characteristics

MOBILE6 emission factors for on-road mobile sources vary with vehicle age distribution and vehicle fuel type distribution, which are derived from state transportation departments' vehicle registration records. The vehicle age distribution determines (1) the estimated proportion of the fleet that has been designed to meet certain emissions standards, and (2) the estimated average deterioration level of on-board emissions control devices. Vehicle design standard and deterioration level, in turn, are variables that govern the choice of emission factor. The fractions of the vehicle fleet powered by different fuels (e.g., gasoline or diesel) affect the choice of appropriate emission factors.

Registration distributions vary widely across regions, and Giannelli et al. (2002) indicated that registration distributions exert a major influence (i.e., potentially more than a 20% change) on MOBILE6-modeled emission factors. Therefore, the application of county-specific registration distributions is essential to the development of accurate emission inventories for on-road mobile sources.

Seven state DOTs in the CENRAP region provided extracts of their vehicle registration databases, which were decoded and processed to prepare MOBILE6-ready fleet-age distributions and fuel fractions for light-duty vehicles. The DOTs provided vehicle identification numbers (VIN) and county codes for every vehicle registered in their states on specified dates. The VIN records were decoded to yield vehicle ages and fuel types, which were used to calculate county-specific fleet characteristics.

Texas provided ready-made MOBILE6 inputs, including fleet characteristics, for use in this project. Arkansas was excluded from development of fleet characteristics because the state had a concurrent project to develop its own on-road mobile source inventory (Environ International Corporation and Eastern Research Group, 2004). Instead, MOBILE6 default fleet characteristics were used for the state of Arkansas. Fleet characteristics were developed for light-duty vehicles only because heavy-duty vehicles are often used for interstate travel; therefore, national average fleet distributions (i.e., MOBILE6 defaults) are reasonably representative.

Preparation of MOBILE6 Input for Fuels Characteristics and Regulatory Controls

Three characteristics of fuels significantly affect criteria pollutant emission predictions from the MOBILE6 model: (1) sulfur content, (2) fuel volatility, and (3) oxygenate content. Fuel sulfur content directly affects emissions of sulfates (particulate matter) and SO_2 from combustion of all fuels. In addition, sulfur's adverse effects on catalytic converters indirectly affect emissions of VOCs, CO, and NO_x from gasoline-fueled vehicles. Gasoline volatility can have a major effect on MOBILE6 estimates of VOC and CO emissions (Giannelli et al., 2002), although the influence diminishes at lower temperatures and has no effect at temperatures below 45^{o}F (Tang et al., 2003). Oxygenates for gasoline fall into two classes—alchohols and ethers—and all primarily reduce emissions of CO. Fuels characteristics were acquired for most CENRAP states from Northrop Grumman. However, for Kansas, Minnesota, and Missouri, data from state departments of agriculture were used because they were more extensive than the Northrop Grumman data.

Regulatory controls that affect engine emissions and are modeled by MOBILE6 and/or NONROAD include (1) anti-tampering programs (ATPs), (2) inspection and maintenance (I/M) programs, and (3) Stage II refueling controls. Environmental regulatory agencies in each of the CENRAP states were contacted for information regarding ATPs, I/M programs, and Stage II controls. These agencies provided the relevant information in the form of MOBILE6 input files. Stage II refueling emissions are typically excluded from mobile source emission inventories developed using MOBILE6 because they are considered to be stationary area source emissions. Thus, refueling emissions were excluded from the CENRAP emission inventory of on-road mobile sources, and associated MOBILE6 settings were not prepared.

MOBILE6/SMOKE Processing

In addition to the activity data described above, gridded, hourly temperature data produced by the Mesoscale Model (MM5) for each day in January and July 2002 were averaged and used as inputs to the MOBILE6 model. This step was performed so that MOBILE6 outputs would represent an entire month rather than a specific episode date. These outputs were matched with county-level VMT estimates within SMOKE to estimate average January and July emissions for each county in the

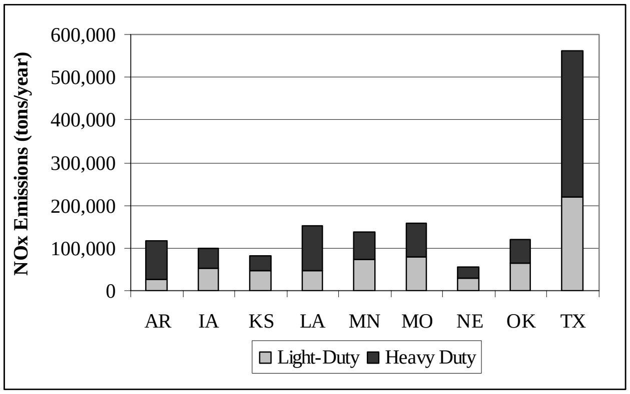
CENRAP region. An annualized on-road mobile source inventory was then assembled as an average of the runs performed for January and July—a necessary simplification due to the availability of gridded temperatures prepared with MM5. The inventory could be improved by performing runs for all 12 months of the year as new meteorological inputs become available. However, this would likely produce only minor or insignificant changes in total annual emissions. (As a test, spring and summer runs were performed using representative minimum and maximum monthly temperatures for each CENRAP state. The resulting annual averages of seasonal emissions varied only slightly from the January and July averages.)

RESULTS AND DISCUSSION

Over 525 billion VMT were estimated to have occurred in 2002 in the CENRAP region, with consequent emissions illustrated in Figures 1 and 3 and Table 2. Figure 4 illustrates the geographic distribution of on-road mobile source emissions for a selected date, and Figures 5 through 7 show the temporal variations in on-road mobile source activity by vehicle type. The CENRAP emissions estimates are within 30% of those from the preliminary 2002 NEI (U.S. Environmental Protection Agency, 2004), with exceptions as follows. Except as noted, differences between the CENRAP inventory and preliminary 2002 NEI seem to arise primarily from the use of more localized temperature data, fuel volatility data, and fuel sulfur contents.

- $PM_{2.5}$ emissions for the states of Iowa, Missouri, and Oklahoma were 30% to 35% less than those from the preliminary 2002 NEI.
- SO_2 emissions for the state of Minnesota were 38% less than those from the preliminary 2002 NEI.
- VOC and CO emissions for the states of Iowa, Kansas, and Nebraska were 30% to 40% greater than those from the preliminary 2002 NEI. Light-duty vehicle registration databases acquired for these states indicated that the vehicle fleets comprise relatively large proportions of old vehicles, which MOBILE6 associates with high VOC and CO emission factors.
- NO_x emissions for heavy-duty vehicles in the states of Arkansas and Louisiana were 83% and 61% greater than those from the preliminary 2002 NEI. The AHDT and LDEQ provided vehicle type-specific VMT fractions, which attributed relatively large proportions of VMT to heavy-duty vehicles. AHDT and LDEQ assigned 38% and 26% of statewide VMT to heavy-duty vehicles. Other than Arkansas, Louisisana, and Texas, no other CENRAP state had available vehicle type-specific VMT fractions, which necessitated the use of MOBILE6 default values in lieu of region-specific data. MOBILE6 defaults attribute only 14% of VMT to heavy-duty vehicles. TTI and TCEQ provided VMT fractions for Texas that were vehicle type- and county-specific; however, they generally differed from MOBILE6 default values to a lesser degree than those provided by AHDT and LDEQ. (The inner quartiles of county-specific VMT fractions assigned to heavy-duty vehicles in Texas ranged from approximately 15% to 25%.) As shown in Figure 3, relatively large proportions—61% to 77%—of total NO_x emissions from on-road sources are attributed to heavy-duty vehicles in the 3 states that provided region-specific VMT fractions: Texas, Louisiana, and Arkansas.

Figure 3. 2002 on-road mobile source emissions of NO_x and VOC by state for the CENRAP region.



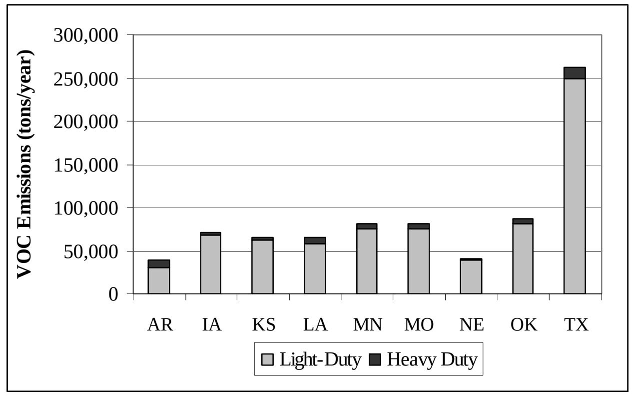


Table 2. 2002 VMT and emissions (tons) for on-road mobile sources in CENRAP states.

State	Annual VMT (10^6 miles)	$PM_{2.5}$	CO	NO_x	SO_2	NH_3	VOC
Arkansas							
Light-Duty	19,224	235	502,991	27,137	1,383	1,971	29,752
Heavy-Duty	9,955	2,076	102,247	90,833	2,163	313	9,786
Iowa							
Light-Duty	27,664	381	973,854	53,702	2,113	2,755	67,501
Heavy-Duty	3,701	931	30,853	44,607	884	107	2,993
Kansas							
Light-Duty	25,424	345	930,039	47,210	1,938	2,528	61,867
Heavy-Duty	3,401	855	29,686	35,520	758	98	2,979
Louisiana							
Light-Duty	34,246	416	824,585	45,929	2,396	3,485	57,283
Heavy-Duty	9,049	2,272	74,770	105,449	2,257	263	7,361
Minnesota							
Light-Duty	46,880	595	1,285,076	73,656	1,274	4,771	75,663
Heavy-Duty	6,271	1,577	43,160	65,290	1,314	182	5,255
Missouri							
Light-Duty	53,030	680	1,375,126	77,916	3,120	5,356	76,004
Heavy-Duty	7,238	1,841	52,065	79,607	1,787	209	5,491
Nebraska							
Light-Duty	15,957	246	581,402	30,649	1,229	1,581	38,788
Heavy-Duty	2,449	624	18,626	25,037	589	71	2,115
Oklahoma							
Light-Duty	39,569	509	1,194,649	64,504	2,989	3,968	81,676
Heavy-Duty	5,293	1,331	48,382	54,812	1,265	154	5,062
Texas							
Light-Duty	190,132	2,339	3,653,523	220,819	10,555	19,365	248,680
Heavy-Duty	25,989	6,276	113,949	340,992	6,667	692	14,057
Total	525,473	23,529	11,834,984	1,483,668	44,678	47,870	792,310

Figure 4. Geographic distribution of on-road mobile source emissions of NO_x in the CENRAP states on July 10, 2002.

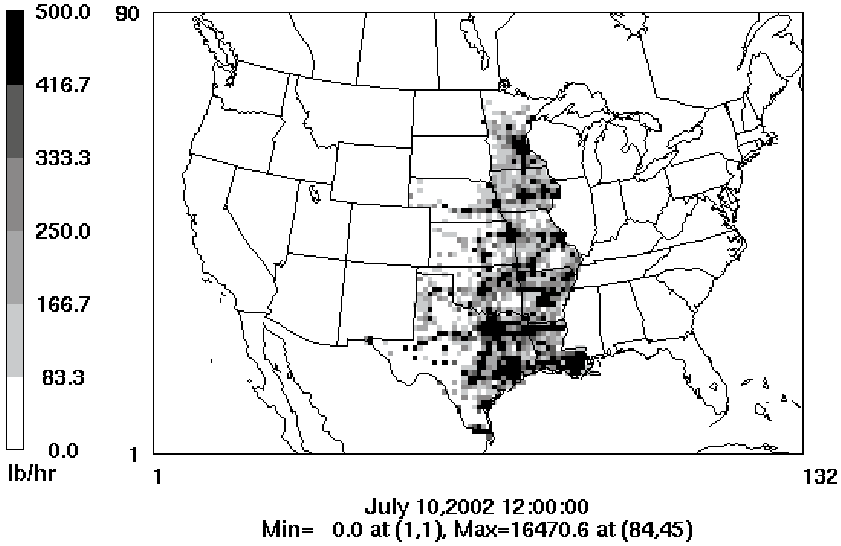


Figure 5. Monthly variation in on-road mobile source activity by vehicle type.

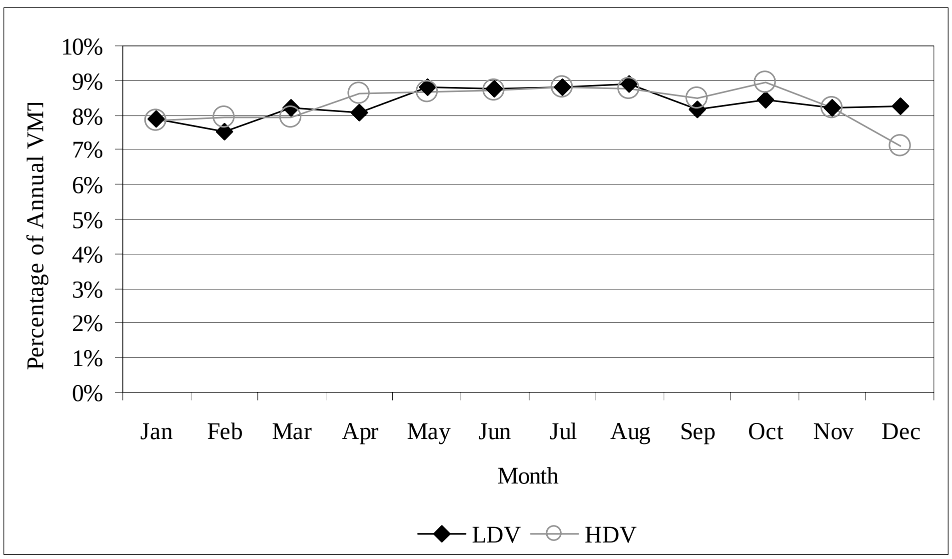


Figure 6. Weekly variation in on-road mobile source activity by vehicle type.

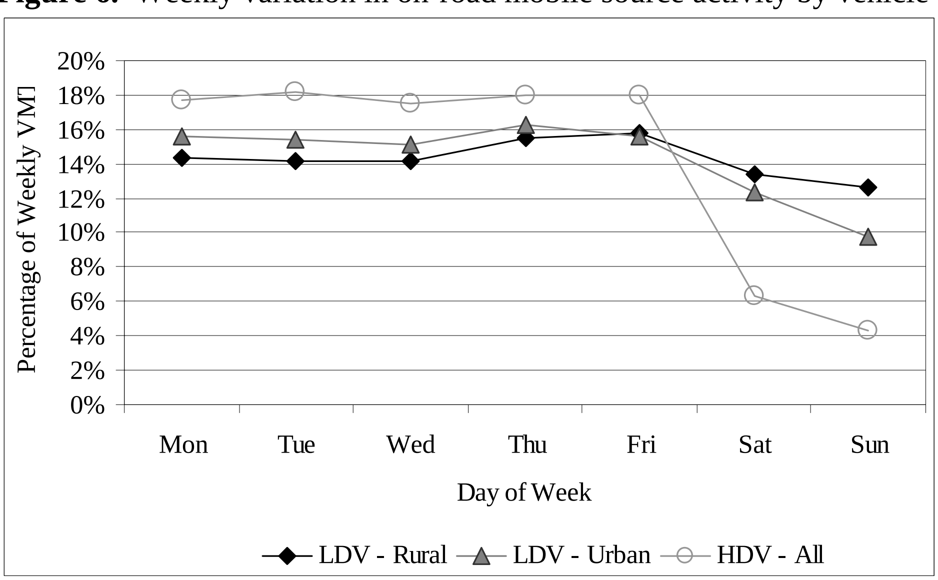
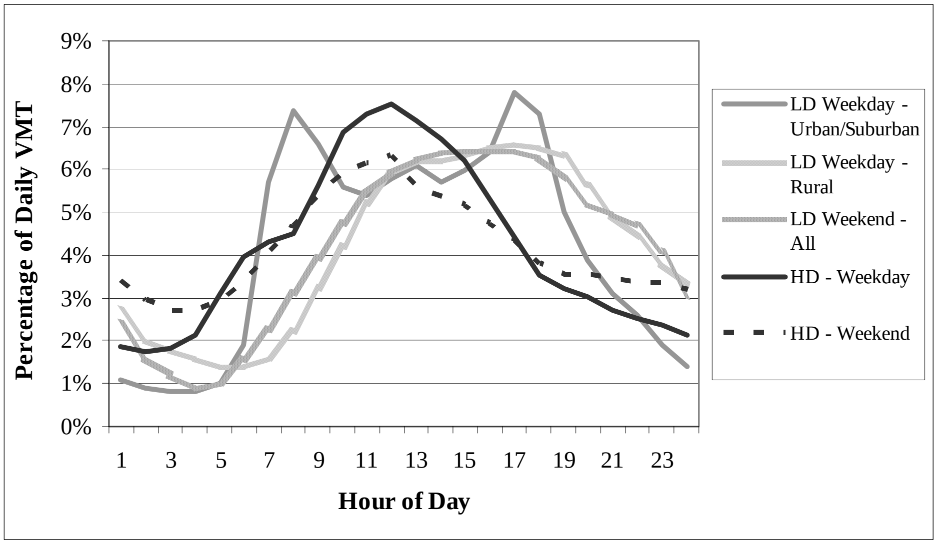


Figure 7. Diurnal variation in on-road mobile source activity by vehicle type.



RECOMMENDATIONS FOR FURTHER INVENTORY DEVELOPMENT

Further improvements could be implemented by continuing to acquire and incorporate local data as they become available, such as (1) recently available and locally generated VMT estimates for Kansas City, Minneapolis-St. Paul, and Little Rock; (2) results of the fuels testing program of the Texas Department of Agriculture (which were unavailable for this project); and (3) reports of fuels sulfur contents that refiners will begin submitting to EPA beginning in February 2005 for diesel and February 2007 for gasoline. Additional recommendations for further research are suggested to address the following potential sources of uncertainties in the inventories, roughly in order of importance:

1) Unusual vehicle age distributions and duplicate VIN records were observed in DMV databases of vehicle registrations.
2) Existing VMT distributions could be refined to better represent the increasing popularity of SUVs and light trucks.
3) Fuels testing programs could be deployed or improved to better represent fuels characteristics.
4) VIN decoding yielded too few records corresponding to alternative-fueled vehicles to allow improvements to this component of the inventory (though this affects future-year projections more than the 2002 inventory).
5) Day-specific inventories (Monday, Tuesday, etc.) may be superior to assuming all weekdays are the same and both weekend days are the same for photochemical modeling purposes.

Investigate Databases of Vehicle Registrations

Unusual features in several states' databases of vehicle registrations were noted, including (roughly in order of importance) unexpected numbers of duplicate VINs, unusually large proportions of old light-duty vehicles, and unexpectedly small numbers of light-duty vehicles less than 2-3 years in age. High frequencies of duplicate VINs are sources of error in fleet distributions in and of themselves—particularly in Iowa, where the frequency of duplicates could only be reduced to 6%. However, high frequencies of duplicate records may only be one symptom of general database maintenance problems—retention of outdated records, mis-assignment of records, etc.—that cannot be easily recognized and remedied without in-depth review and diagnosis. The possibility that unidentified errors in the vehicle registration databases are related to unusual vehicle age distributions in some states is a cause for concern. MOBILE6 models older vehicles with higher emission rates due to their levels of deterioration and outdated emissions control technologies. Therefore, errors in this component of the vehicle population distributions significantly impact emission inventories of on-road mobile sources. In addition, errors across all age ranges can significantly impact projections of emission inventories to future years.

Use Fleet Distributions to Refine VMT Distributions

Patterns of SUVs and light-duty-truck use have been shifting rapidly in recent years. However, for this study, VMT distributions by vehicle type for many areas of the CENRAP were based on EPA defaults, which are based on predictions and data from a number of years ago. Errors in the VMT distributions by vehicle type can be significant because emissions standards vary across the classes of light-duty vehicles, and emissions from gasoline-fueled vehicles differ considerably from those of diesel-fueled vehicles. VMT distributions could be refined or adjusted by using vehicle registration data. This approach is based on the assumption, which we believe is well-founded, that due to recent trends in vehicle ownership and driver behavior, many light-duty trucks (e.g., SUVs) are now driven in a manner similar to passenger vehicles. Thus, the proportion of VMT that should be assigned to each vehicle type and fuel type are approximately equal to the proportion of vehicles registered in each vehicle- and fuel-type category. (Note that this assumption has already been applied in EPA Region I.) Alternatively, the VMT mix could be calculated from registration data using the vehicle type-specific assumptions about annual mileage accumulation rates that are part of the MOBILE6 model.

Improve Fuels Testing Programs

For 2002, data were available from three of the CENRAP states (Kansas, Minnesota, and Missouri), and it is likely that Texas will have data for future calendar years. Oklahoma conducts tests but currently does not maintain a database of results. (Oklahoma's Department of Agriculture deferred to the Oklahoma Corporation Commission, which is the lead agency for fuel testing in that state.) Other CENRAP states do not currently test for fuel parameters relevant to mobile source emissions modeling. We recommend encouraging fuel testing programs in states where they are not yet planned—Louisiana, Arkansas, Iowa, and Nebraska—and encouraging the Oklahoma Department of Agriculture to archive and maintain records of their existing fuels testing program.

Improve Inventories for Alternative-Fueled Vehicles

VIN decoding yielded too little information to support improvements to the inventory of alternative-fueled vehicles. In addition, alternative fuels are rarely tested, and region-specific data were not identified. While these uncertainties have little effect on the 2002 inventory, they may become more important when future-year emission inventories are projected to 2018 and beyond. Alternative-fueled vehicles may compose significantly larger proportions of vehicle fleets in the future and trace levels of sulfur in alternative fuels may become more important as sulfur levels in diesel and gasoline fuels continue to decline due to existing regulations.

Prepare Inventories Specific to the Days of the Week

Driving activities for on-road motor vehicles appear to vary with each day of the week. Therefore, a day-specific approach may be preferable to a simple weekday-weekend approach for some photochemical modeling applications. In general, urban VMT declines on Sundays from weekday levels to an even greater extent than on Saturdays. Friday evening VMT is somewhat higher than on other weekday evenings, and daily total VMT on Mondays is usually somewhat below average for weekdays in urban areas. Day-specific patterns are also likely to occur in rural areas. The 2002 CENRAP inventories reflect the most significant weekday-weekend patterns supported by research results from other areas of the United States. However, further improvements could be made by investing in research projects that investigate region-specific, day-of-week patterns for both rural and urban areas.

CLOSING REMARKS

The use of local data significantly altered the CENRAP's emission inventories from earlier versions produced on the basis of MOBILE6 defaults. Use of region-specific fuels characteristics and temperatures caused $PM_{2.5}$ and SO_x emissions estimates to decrease by roughly 20%; use of county-level registration distributions affected emissions of CO and VOC by +30% to +40% in states with large proportions of old vehicles; and use of region-specific VMT fractions substantially increased estimates of NO_x and $PM_{2.5}$ emissions from heavy-duty vehicles. In conclusion, adherence to the EPA's recommended guidance for the use of local- and region-specific data produces substantial improvements to emission inventories and should be given high priority.

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KEY WORDS

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Missouri
Nebraska
Oklahoma
Texas

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