MOBILE EMISSIONS INVENTORIES: EMFAC7G AND EMFAC2000 COMPARISON BY AIR BASIN

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1.0 INTRODUCTION

The California Air Resources Board (CARB) has maintained an on-road emissions inventory model for many years. The previous version of the model, EMFAC7G, was approved in October of 1996. Section 39607(b) of the California Health and Safety Code requires CARB to make periodic improvements in the inventory models to provide the most complete, accurate, and up-to-date mobile emission inventory. As a part of this improvement process, CARB recently released a major modeling update to EMFAC7G; the new significantly revised version of the model is known as EMFAC2000 (v2.02).

The release of EMFAC2000 represents the culmination of a decade of comprehensive review and restructuring of the on-road emissions inventory model. Additional algorithms and programming codes have been added to increase EMFAC2000's versatility and accuracy. Most of the changes in EMFAC2000 are data driven. Since the adoption of MVEI7G, CARB has added more than 5,000 vehicles tested to the inventory study database. This has more than doubled the data used to develop the previous inventories, as in turn has improved our understanding of how emissions change as a function of vehicle age, mileage accumulation and drivers' driving habits. Compared to its precedent model, EMFAC2000 includes substantial changes to both the transportation activity inputs and the emissions factors incorporated in the model. Some of the more important changes in EMFAC2000 are as follows:[2]

- Basic emission rates (BER's) are based on a master data set, which includes vehicles up to the 1998 model year (about twice as many in-use vehicles as was used to develop EMFAC7G BER's). BER's are calculated for 45 model years, an increase from 35 model years in EMFAC7G.
- Basic emission rates are developed from the Unified Cycle, rather than the FTP. There are no cycle correction factors in the EMFAC7G sense, but there are correlations

developed to map the large body of FTP-based emissions used to develop the BER's into UC-based emissions.

- Emission rate correction factors have also been updated using analyses of expanded test data. High emitter correction factors have been eliminated.
- Effects of air conditioning on emissions have been added using a heat index calculated from humidity profiles added in EMFAC2000 and revised temperature profiles. Effects of the Supplemental FTP regulations have also been added.
- Emissions estimates for unregistered vehicles have been added, with the ability to input the percent of unregistered vehicles by vehicle class and calendar year.
- Gasoline buses and mobile homes have been added as new vehicle classes.
- Light-duty particulate matter emission factors have been updated using recent emissions test data from CARB and CRC studies.
- Hot soak and diurnal evaporative emissions factors have been revised using recently available test data from CARB, EPA, and CRC. Hot soaks have been redefined as 35 minutes after engine shut-off.
- The methodology for estimating running loss emissions have been completely revised using recent CRC modal test data; running loss emissions are modeled as a function of time (with running loss rates increasing with trip length).
- Heavy-duty truck emissions are based on chassis rather than engine emission.
- Speed distributions are vehicle class-specific.
- County-specific registration (i.e., age distribution) and mileage accrual rates are incorporated (from statewide averages in EMFAC7G).
- Hourly activity estimates are provided, rather than the six periods modeled in EMFAC7G.
- The graphical user interface (GUI) has been greatly modified with typical Windows pull-down menus, buttons, etc.
- The separate modules of MVEI7G are combined into a single integrated model. The outputs are the same as EMFAC7G, but the user will be able to view model predictions in much greater detail.

As a result of these improvements, the model has become significantly more complex and preliminary tests by CARB suggest that EMFAC2000 substantially increases the estimated emissions inventories.

The purpose of this study is to conduct a more comprehensive analysis of the impact on emission inventories of the migration from EMFAC7G to EMFAC2000. The emission inventories by air basins were calculated using the two models and the results were compared. Generally, substantial increases in mobile emission inventories were estimated from EMFAC7G to EMFAC2000. To explain this marked increase in the mobile emission inventory a case study on San Joaquin Valley air basin was conducted and the changes in emission factors were found to be the major contributor to the increased estimation of the mobile emission inventories.

2.0 METHODS

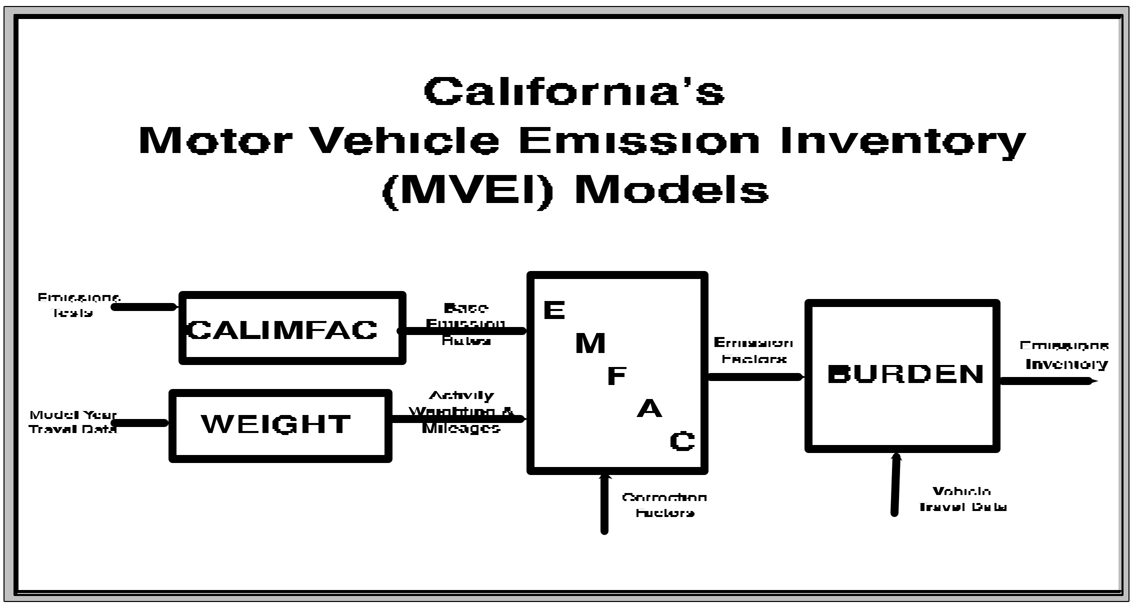
In its simplest form, the on-road inventory is the product of the measured emissions in grams per event, such as grams per mile for running exhaust or grams per hour for evaporative emissions, and the associated vehicle activity resulting in a tons per day estimate. In the computation vehicle activity is disaggregated into populations of vehicles by class, fuel, age and technology groups, and the number of miles traveled per day at different speeds.

The two model structures are significantly different from one another in many respects. For example, exhaust emissions from light-duty vehicles are measured in grams per mile during tests performed on a chassis dynamometer. Since the release of EMFAC7G more data had been collected from vehicles tested over both the Federal Test Procedure and the Unified Cycle or the LA92, which is a more contemporary representation of how light-duty vehicles are driven. The UC based test data were used in developing the basic emission rates for EMFAC2000. In addition, a subset of vehicles was also tested over 13 different driving cycles of varying average speeds. These measurements were used to construct a relationship that described how emissions change as a function of speed for EMFAC2000. In contrast EMFAC7G relies on FTP based emission rates and the speed correction factors were derived from statistical operation on other cycles. For a more detailed description of specific difference in the modeling approach see Gao and Niemeier[4] (2001). In the next few sections we provide a brief description of how the two models differ.

EMFAC7G and EMFAC2000 Model Structures

Figures 1 and 2 present the basic model structure for EMFAC7G and for EMFAC2000, respectively. Beginning with Figure 1, we can see that the primary functions of the four model components of EMFAC7G are as follows:[6]

Figure 1. Block Diagram EMFAC7G[5]



- CALIMFAC is the exhaust emissions data processor to EMFAC7G. CALIMFAC calculates basic emission rates under various levels of Inspection and Maintenance (I/M) for input into EMFAC. Data from three CARB vehicle test programs — the Surveillance Program, Random Roadside Program, and I/M Evaluation Program — are used as the basis for this model.

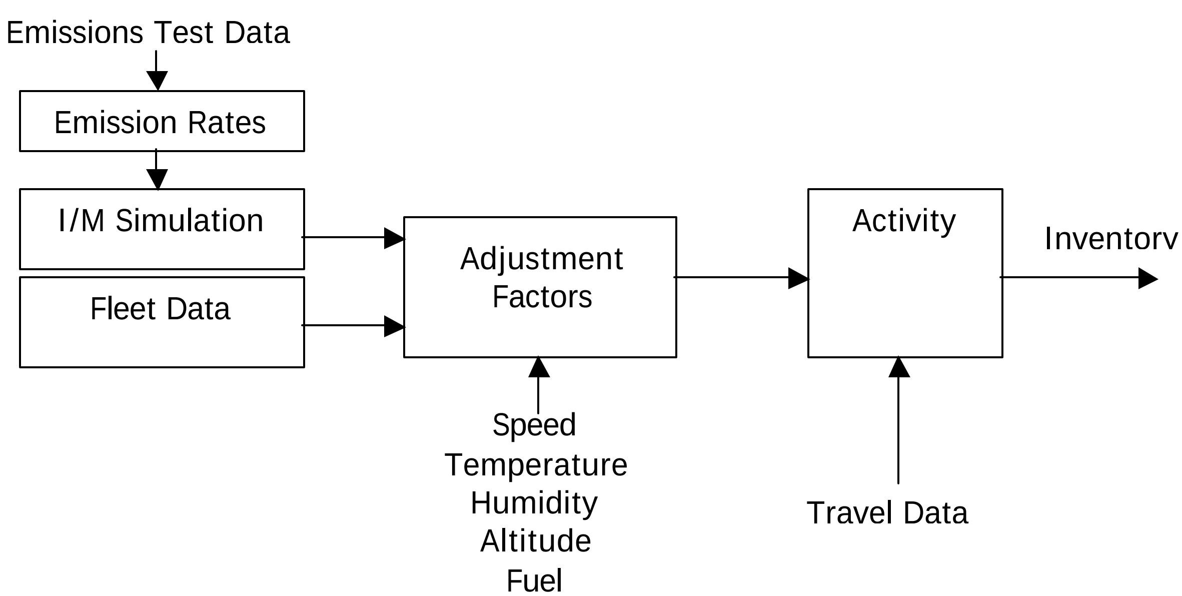
- WEIGHT compiles fleet characteristics data for a given emission inventory for input into EMFAC. In the standard operation of WEIGHT, fleet characteristics and travel fractions by model year are generated for the specified calendar year of the emission inventory. Data input into this model are state average fleet characteristics, such as age distributions and mileage accumulation rates, determined from analysis of California I/M program data.

- EMFAC is the primary model for computing emission factors. Basic emission rate data, under standard conditions, are input into the program and then modified into episodic emission factors through a series of adjustments that account for fuel parameters, temperature, speed, and in-use operation. In addition to the basic emissions test data, data input into EMFAC also includes correction data to account for the effects of speed, temperature, driving cycle, and occurrence of high emitters.

- BURDEN is primarily an activity model where emission factors from EMFAC are converted into total emissions using input travel activity data.

Figure 2 illustrates the basic structure of the EMFAC2000 model. The basic emission rates are modified in the I/M module to simulate the presumption that smog check programs lower emissions. These rates are combined with fleet data to calculate composite emission rates for each vehicle class. Rates are then adjusted for speed, temperature, humidity, altitude and fuel corrections in the adjustment factors module, and then multiplied by vehicle activity to obtain the tons per day estimates.

Figure 2. Basic Structure of the EMFAC2000 Model[1]



EMFAC2000 computes inventory estimates of the total emissions for entire state, subtotals for each of the seventeen air basins, thirteen districts and fifty-eight counties. The model produces emission rates and inventories of exhaust and evaporative hydrocarbons, carbon monoxide, oxides of nitrogen and particulate matter associated with exhaust, tire-wear and brake-wear. Hydrocarbon emissions estimates are produced for total hydrocarbon, total organic gases, and reactive organic gases. These are similar to what are calculated in EMFAC7G. However, lots of improvement were made in EMFAC2000 regarding particulate matter emission estimates, which are calculated for total suspended particulate, particulate ten microns in diameter or less, and particulate 2.5 microns in diameter or less. The model also estimates emissions of oxides of sulfur, lead, and carbon dioxide. The carbon dioxide inventory is also used to estimate fuel consumption.

EMFAC2000 also calculates the emissions inventory for every hour of the day and every month of the year. After selecting a specific month for analysis, the model provides the area specific hourly temperatures and relative humidity, and properly adjusts the properties of dispensed fuel. Emissions inventories can be backcast to 1970 or forecast to the year 2040. EMFAC2000 produces a number of seasonal inventories for different purposes. The annual average inventories are derived by weighting each month of emissions for the year equally for a specific area. An extensive inspection and maintenance simulation program in EMFAC2000 allows users to determine the incremental effects of adding or deleting certain programmatic elements. In contrast, EMFAC7G estimated emissions for calendar years 1970 through 2020. While the ambient temperature data were derived by time of day, other activity data (VMT, starts, and VMT by speed) were derived for an average day and then disaggregated into six time periods. EMFAC7G did not produce an annual average emission inventory, rather ozone and carbon monoxide episodic estimates were weighted together for this purpose.

The EMFAC2000 model presumably increases the accuracy of the estimated emissions for each area over those of EMFAC7G. The assumption that the model increases the accuracy is primarily attributable to the fact that the new model adopts area specific activity data, which also results in longer running times. To compensate for this, the model offers two options for calculating emissions: the “Simple-Average” or “Do-each-sub-area”. The “Simple-Average” option calculates emission inventories faster than the “Do-each-sub-area” option, however, some simplifying assumptions are made.[2]

3.0 INVENTORY COMPARISONS: EMFAC7G AND EMFAC2000

As stated previously, EMFAC2000 includes substantial changes in both transportation activity and emission factors compared to EMFAC7G. In this section, we compare inventories estimated using the EMFAC7G model and those calculated using EMFAC2000. We then discuss the implications of the model changes more specifically using the San Joaquin Valley as an example.

For the purposes of computing these inventory examples, we made the following assumptions:

1) Episodic inventories to assess the worst case conditions for ozone, high ambient temperature and low relative humidity (summer scenario) were calculated using the two models.
2) In EMFAC2000, the air basin and statewide inventories were calculated using the “Simple-Average” option.[2]
3) The model default I/M programs were adopted in both model calculations.

Statewide Emission Inventories

We begin with a comparison of the statewide total emissions inventories, shown in Table 1 and Figure 3. Compared to EMFAC7G, EMFAC2000 increases the total statewide on-road mobile emissions inventories for TOG, CO, NO_x, CO_2, and PM_{10} by 46.9%, 65.3%, 21.9%, and 22.7%, respectively. If we look at changes in the corresponding transportation activity data shown in Table 1 and Figure 4, the vehicle populations, VMT, and daily starts suggest only minimal differences between the two models. This suggests that changes in the emission factors for different technology groups must play a highly significant role in explaining emission inventory changes from EMFAC7G to EMFAC2000.

Table 2 indicates that changes in the LDA and MDT TOG emission inventories contribute significantly to the overall increase of statewide TOG emissions. For the overall increase of statewide CO emissions, again the changes to LDA and MDT CO emission inventories constitute the major part of CO emission increase from EMFAC7G to EMFAC2000. For the change in statewide NO_x emissions the change to HDT NO_x emission alone explains 73.86% of NO_x emission increase for the whole fleet. Table 2 also shows that for the PM_{10} emissions, the statewide PM_{10} emissions increase is mainly attributable to the estimated LDA and LDT PM_{10} emission increases. The HDT PM_{10} emission, on the contrary, shows a decrease.

Table 1. Statewide Mobile Emission Inventory (tons/day) and Associate Transportation Activity Data Estimated by EMFAC7G and EMFAC2000, summer 2001

	TOG	CO	NO_x	CO_2 (/100)	PM_{10}	Vehicle Pop.	VMT(*1000)	Daily Starts
EMFAC7G	965.0	7713.6	1429.8	2921.2	48.6	23524144	824268	1.53E+8
EMFAC2000	1417.2	12747.2	1743.5	5211.4	59.6	23910696	792570	1.63E+8
% Change	46.9	65.3	21.9	78.4	22.7	1.6	-3.8	6.7

Table 2 Contributions by the Changes of Emissions from Different Vehicle Classes to Statewide Emission Inventory Changes from EMFAC7G to EMFAC2000, summer 2001

	TOG	CO	Nox	CO2	PM10
LDA	35.30%	28.86%	4.86%	33.51%	47.92%
LDT	16.47%	21.37%	3.87%	16.44%	71.47%
MDT	32.78%	32.49%	11.51%	18.22%	0.27%
HDT	12.54%	14.67%	73.86%	30.07%	-23.00%
UDB&MC	2.91%	2.61%	5.90%	1.76%	3.34%
Total	100%	100%	100%	100%	100%

Figure 3. Predicted California Vehicle Emissions Planning Inventory, summer 2001

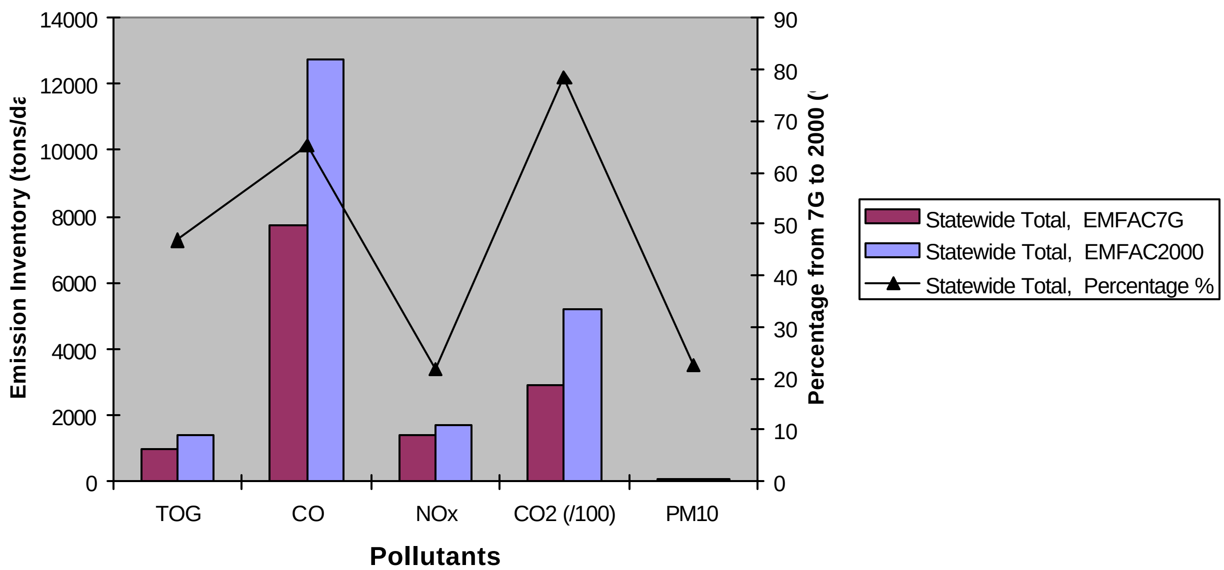
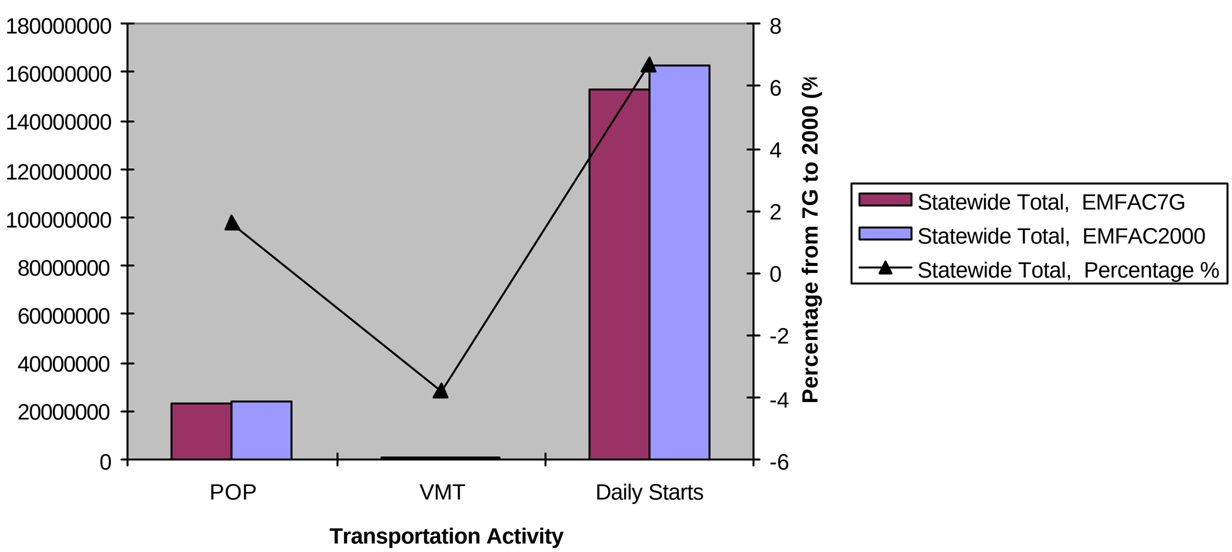


Figure 4. Predicted California Vehicle Activity Data, summer 2001



Air Basin Inventories

The emissions inventory comparisons by air basins for calendar year 2001 between the two models are listed in Table 3 for different pollutants (TOG, CO, NO_x, CO_2, and PM_{10}). The results are also presented graphically in Figures 5 through 9 with the absolute emission inventory and relative percentage changes illustrated. Most air basins, except for Great Basin Valley, North East Plateau, and South East Desert, show substantial inventory increases across all pollutants. However, Table 4 and Figures 10 through 12 show that the associated transportation activities stay fairly constant between the two models relative to the estimated emission inventory increases.

Future Year Inventories

For a future year case, we calculated the emissions inventories by air basin for summer ozone scenario, calendar year 2010. The 2010 emissions inventories and the corresponding transportation activity data by air basin are provided in Table 5 and Table 6. The inconsistency between the substantial emission inventory changes and the relatively smaller transportation activity changes is also clearly observed.

Table 3. Comparison of the Mobile Emission Inventory (tons/day) Estimated by EMFAC7G and EMFAC2000[1], summer 2001

	TOG			CO			NOx			CO2 (/100)			PM10		
Air Basin	7G	2000	%	7G	2000	%	7G	2000	%	7G	2000	%	7G	2000	%
Great Basin Valley	2.63	3.58	36.1	27.53	30.71	11.6	5.26	3.43	-34.8	8.57	7.7	-10.2	0.16	0.1	-37.5
Lake County	2.39	6.53	173.2	20.7	54.62	163.9	2.91	4.86	67.0	5.51	12	117.8	0.07	0.14	100.0
Lake Tahoe	2.72	4.36	60.3	40.85	46.63	14.1	1.75	3.04	73.7	5.84	8.9	52.4	0.08	0.1	25.0
Mojave Desert		30.9			294.5			33.48			99.1			1.08	
Mountain County	14.99	36.37	142.6	124.43	300.81	141.8	21.75	30.65	40.9	45.25	88.8	96.2	0.66	1	51.5
North Coast	14.42	31.34	117.3	156.38	263.21	68.3	21.6	32.79	51.8	33.12	74.4	124.6	0.56	1.04	85.7
North Central Coast	19.29	30.76	59.5	160.93	265.75	65.1	28.18	37.97	34.7	57.58	96.5	67.6	0.97	1.17	20.6
North East Plateau	5.37	9.56	78.0	53.1	83.5	57.3	13.25	8.09	-38.9	13.39	18.8	40.4	0.54	0.25	-53.7
South Coast	336.45	550.25	63.5	2645.6	5187.8	96.1	529.3	706.51	33.5	1123.8	2177.6	93.8	19.71	24.63	25.0
South Central Coast	39.52	59.49	50.5	335.86	531.51	58.3	55.87	22.41	75.2	120.83	203.2	68.2	1.75	0.79	2.3
San Diego	93.31	116.58	24.9	735.22	1036.4	41.0	118.74	139.33	17.3	283.23	457.4	61.5	3.82	4.99	30.6
South East Desert	58.3			459.81			101.18			178.42			3.55		
San Francisco	183.26	251.15	37.0	1461.6	1914.1	31.0	227.06	263.64	16.1	476.5	886	85.9	6.32	9.02	42.7
San Joaquin Valley	117.11	163.73	39.8	926.57	1674.1	80.7	185.07	241.12	30.3	352.72	599.5	70.0	6.12	7.91	29.2
Sacramento Valley	75.27	116.06	54.2	564.95	1047.3	85.4	117.83	147.9	25.5	216.17	397.8	84.0	4.25	4.79	12.7
Salton Sea		24.11			235.52			27.64			76.5			0.91	
Statewide Totals	965.02	1417.2	46.9	7713.6	12747	65.3	1429.8	1743.5	21.9	2921	5211.4	78.4	48.58	59.62	22.7

[1] Note: The South East Desert air basin was redesignated into the Salton Sea and Mojave Desert air basins in EMFAC2000.

Table 4 Comparison of Transportation Activity Data Between EMFAC7G and EMFAC2000 by Air Basin, summer 2001

Air Basin	Vehicle Pop			VMT (*1000)			Daily Starts		
	7G	2000	%	7G	2000	%	7G	2000	%
Great Basin Valley	32446	33627	3.6	2386	966	-59.5	196701	238937	21.5
Lake County	59903	56585	-5.5	1464	1601	9.4	366681	383735	4.7
Lake Tahoe	50167	41039	-18.2	1663	1118	-32.8	307719	286789	-6.8
Mountain County	404506	401648	-0.7	12708	11392	-10.4	2423364	2711848	11.9
North Coast	280465	309654	10.4	9325	9409	0.9	1715663	2161313	26.0
North Central Coast	508131	515005	1.4	17051	15258	-10.5	3119650	3512145	12.6
North East Plateau	79915	79118	-1.0	4355	2309	-47.0	489552	564260	15.3
South Coast	9407282	9515439	1.1	326321	345512	5.9	58371570	64963936	11.3
South Central Coast	1055431	1094310	3.7	35370	34892	-1.4	7444085	7401806	-0.6
San Diego	2035620	2031723	-0.2	74055	71580	-3.3	12982192	13507693	4.0
South East Desert	773297	863918	11.7	48821	30914	-36.7	5929949	5818684	-1.9
San Francisco	4974010	5038826	1.3	132097	121035	-8.4	29210436	33923692	16.1
San Joaquin Valley	2096840	2160785	3.0	97175	88594	-8.8	18083932	15150018	-16.2
Sacramento Valley	1766066	1769023	0.2	61428	57989	-5.6	12104993	12370189	2.2
Salton Sea		355932			13105			2450754	
Mojave Desert		507986			17809			3367930	
Statewide Totals	23524144	23910696	1.6	824268	792570	-3.8	1.53E+08	1.63E+08	6.7

Table 5. Comparison of the Mobile Emission Inventory (tons/day) Estimated by EMFAC7G and EMFAC2000, summer, 2010

	TOG			CO			NOx			CO2 (/100)			PM10		
Air Basin	7G	2000	%	7G	2000	%	7G	2000	%	7G	2000	%	7G	2000	%
Great Basin Valley	1.21	2.24	85.1	20.42	17.89	-12.4	3.77	2.57	-31.8	10.47	10	-4.5	0.14	0.11	-21.4
Lake County	1.18	4.57	287.3	15.18	36.42	139.9	2.19	3.81	74.0	7.03	15.9	126.2	0.07	0.17	142.9
Lake Tahoe	1.24	2.76	122.6	28.67	25.22	-12.0	1.29	2.28	76.7	7.27	11.4	56.8	0.08	0.11	37.5
Mojave Desert		18.28			176.1			23.07			125.9			1.33	
Mountain County	7.36	23.04	213.0	90.12	177.9	97.4	16.53	22.1	33.7	56.93	116	103.8	0.67	1.14	70.1
North Coast	5.62	19.04	238.8	93.95	150.2	59.9	14.98	22.96	53.3	37.74	88.7	135.0	0.51	1.04	103.9
North Central Coast	8.77	17.84	103.4	100.8	145.8	44.6	21.44	22.53	5.1	66.83	114.6	71.5	0.93	1.22	31.2
North East Plateau	2.62	5.98	128.2	38.84	49.52	27.5	10.74	6.48	-39.7	15.04	23.6	56.9	0.44	0.28	-36.4
South Coast	159.7	285.7	78.9	1753	2616	49.2	391.6	428	9.3	1287	2399	86.4	17.67	26.41	49.5
South Central Coast	16.5	30.34	83.9	194.2	250.6	29.0	38.29	39.7	3.7	128	211.9	65.6	1.56	2.34	50.0
San Diego	46.42	59.85	28.9	493	512.8	4.0	89.61	75.8	-15.4	321.6	501.2	55.8	3.63	5.26	44.9
South East Desert	31.78	33.11	4.2	343.6	316.2	-8.0	86.67	43.51	-49.8	226.3	220.7	-2.5	3.51	2.36	-32.8
San Francisco	81.94	148	80.7	872.3	1038	19.0	154.7	166.5	7.6	509.8	909.1	78.3	5.65	8.78	55.4
San Joaquin Valley	58.62	86.74	48.0	656.5	869.9	32.5	145.1	149.3	3.0	446	754.3	69.1	5.77	8.6	49.0
Sacramento Valley	35.85	62.88	75.4	382	521.1	36.4	94.9	86.21	-9.2	254	461	81.5	3.91	4.89	25.1
Salton Sea		14.83			140			20.44			94.8			1.03	
Statewide Totals	458.8	755.7	64.7	5083	6440	26.7	1072	1043	-2.7	3374	5845	73.2	44.54	62.88	41.2

Table 6 Comparison of Transportation Activity Data Between EMFAC7G and EMFAC2000 by Air Basin, summer 2010

Air Basin	Vehicle Pop			VMT (*1000)			Daily Starts		
	7G	2000	%	7G	2000	%	7G	2000	%
Great Basin Valley	35160	43289	23.1	3024	1311	-56.6	213894	295061	37.9
Lake County	74397	76006	2.2	1958	2244	14.6	458638	495050	7.9
Lake Tahoe	63559	52888	-16.8	2177	1495	-31.3	392698	349544	-11.0
Mountain County	486495	526822	8.3	16704	15575	-6.8	2996947	3434136	14.6
North Coast	311285	374569	20.3	11299	11783	4.3	1911022	2517718	31.7
North Central Coast	595755	624200	4.8	21051	18719	-11.1	3675342	4116171	12.0
North East Plateau	88969	94722	6.5	5163	2906	-43.7	546951	659402	20.6
South Coast	10431662	11058856	6.0	379214	396250	4.5	65936783	74315120	12.7
South Central Coast	1202385	1214727	1.0	39257	38001	-3.2	8292071	7976718	-3.8
San Diego	2323148	2413121	3.9	88118	83515	-5.2	15062992	15623195	3.7
South East Desert	963697	1127791	17.0	64321	40387	-37.2	7731664	7414307	-4.1
San Francisco	5459338	5558130	1.8	145999	129824	-11.1	33667661	36747684	9.1
San Joaquin Valley	2528899	2832744	12.0	127004	118316	-6.8	23140385	19168672	-17.2
Sacramento Valley	2089404	2172071	4.0	76443	71320	-6.7	14571217	14604065	0.2
Salton Sea		461114			16849			3096283	
Mojave Desert		666677			23538			4318024	
Statewide Totals	26654218	28169928	5.7	981794	931645	-5.1	178598307	187716832	5.1

Figure 5. Predicted California Vehicle TOG Emission Ozone Planning Inventory By Air Basin, summer 2001

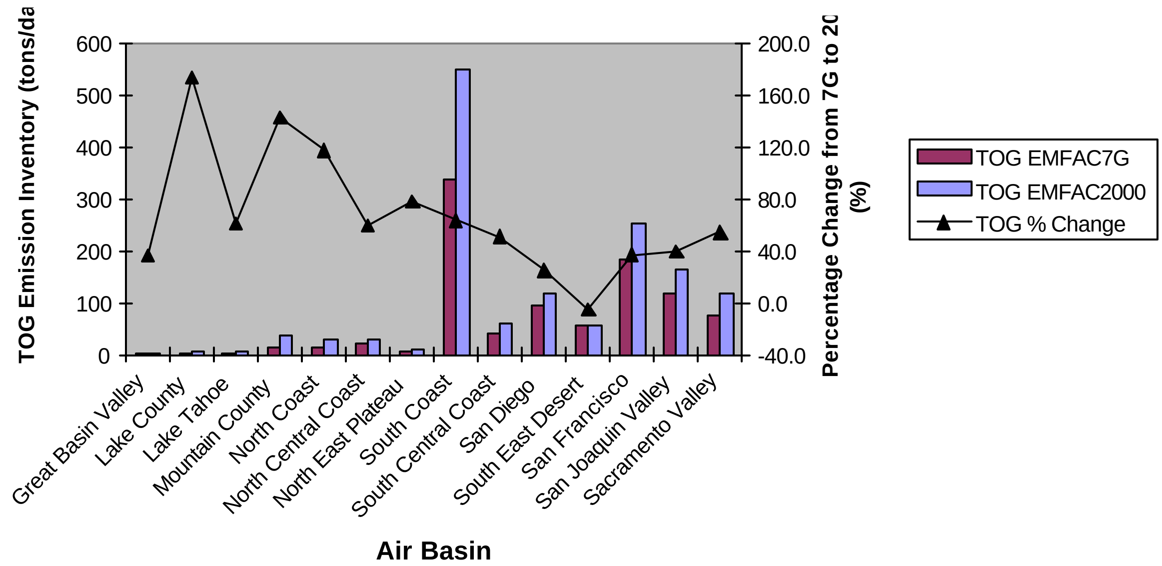


Figure 6. Predicted California Vehicle CO Emission Ozone Planning Inventory By Air Basin, summer 2001

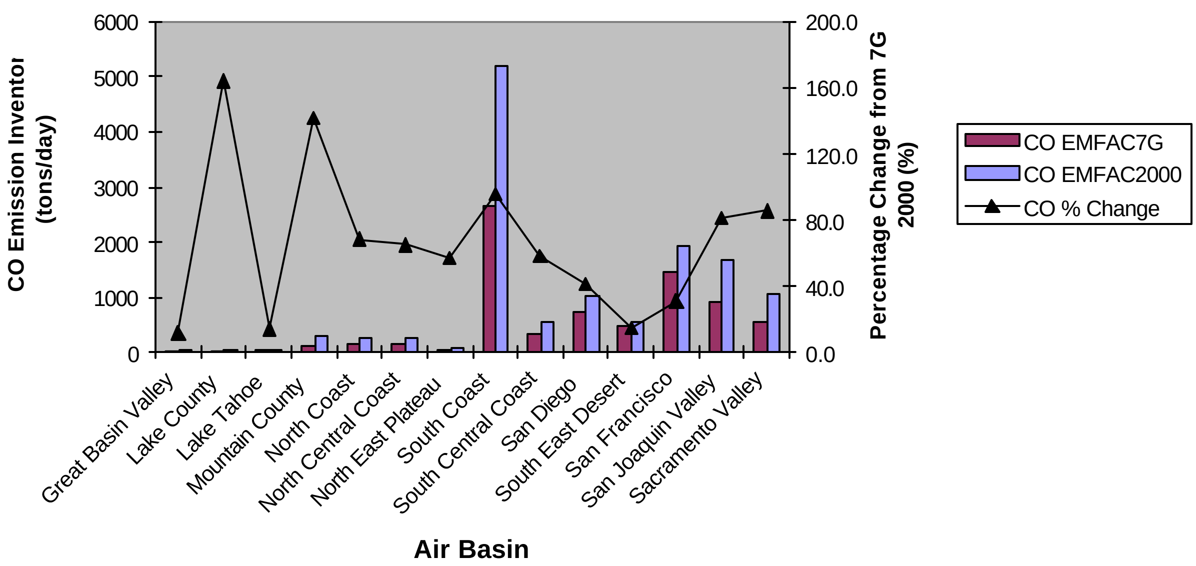


Figure 7. Predicted California Vehicle NOx Emission Ozone Planning Inventory By Air Basin, summer 2001

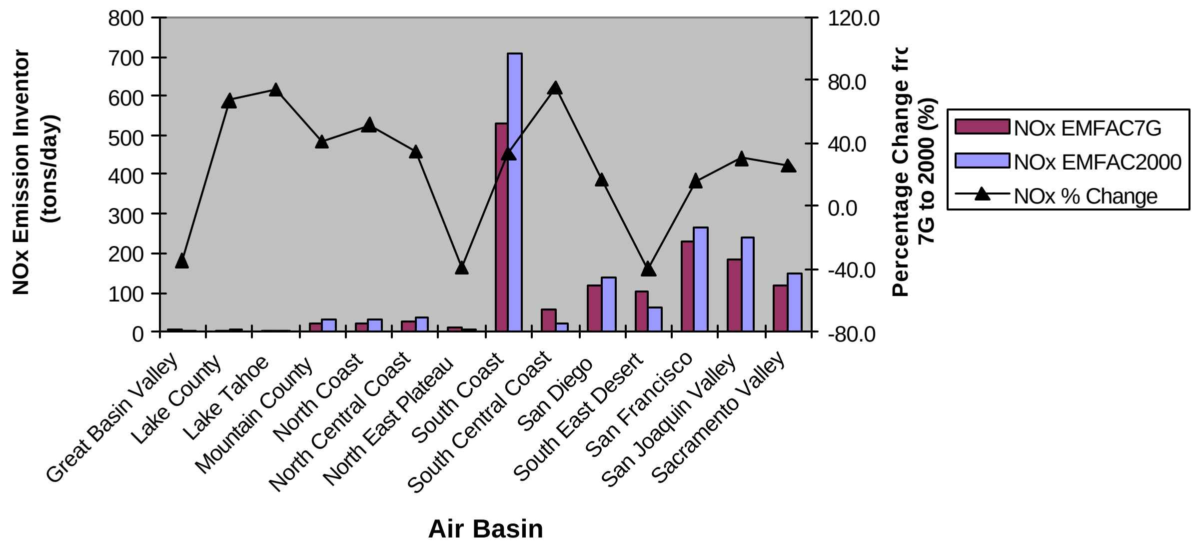


Figure 8. Predicted California Vehicle CO2 Emission Ozone Planning Inventory By Air Basin, summer 2001

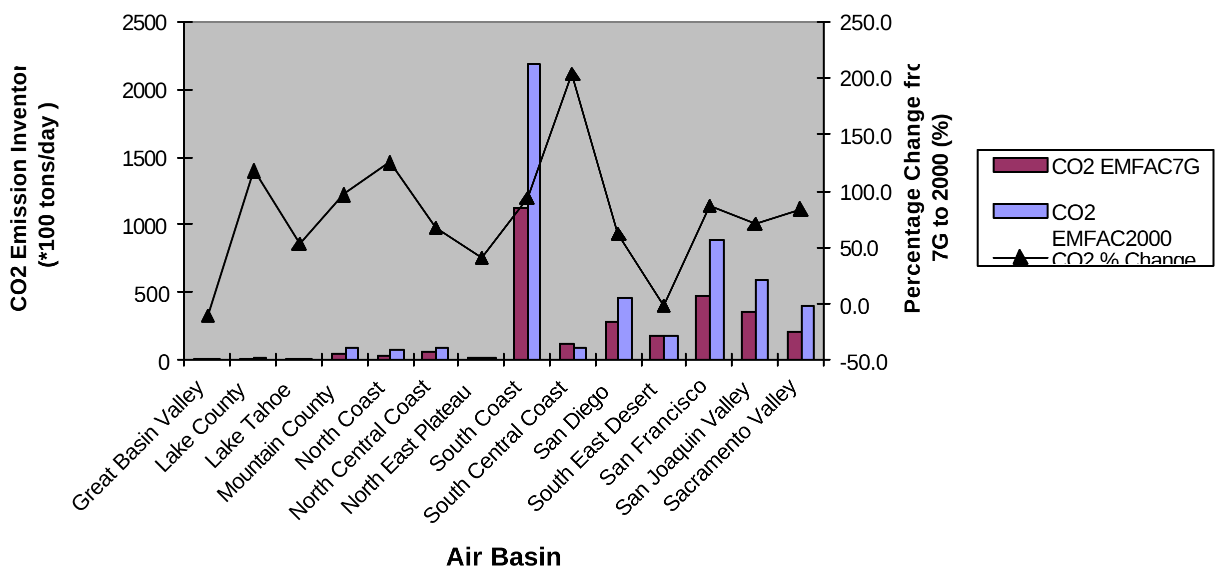


Figure 9. Predicted California Vehicle PM10 Emission Ozone Planning Inventory By Air Basin, summer 2001

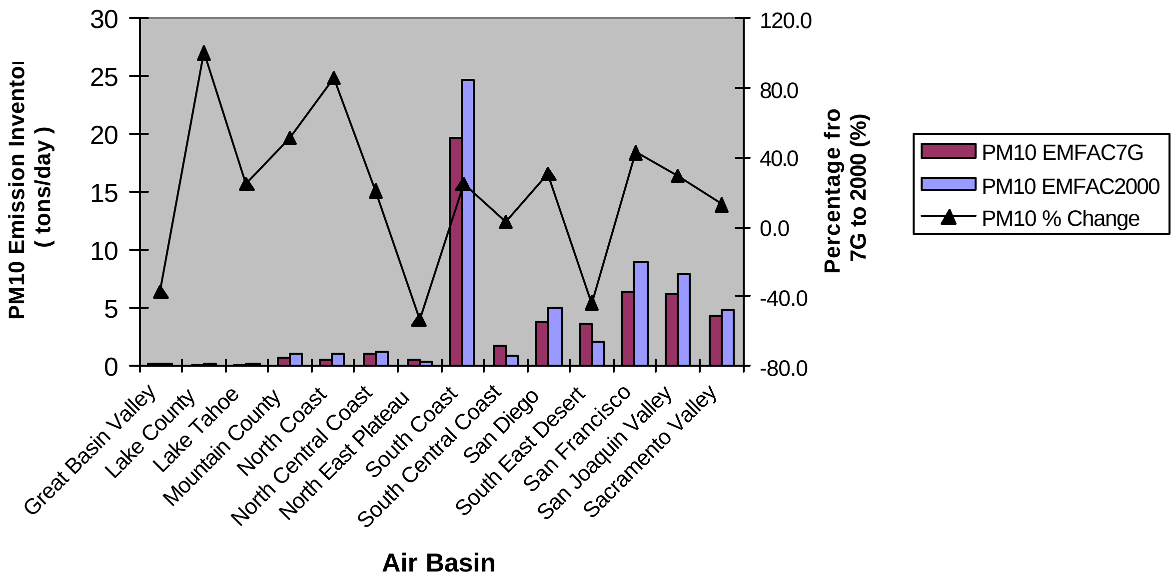


Figure 10. Predicted California Vehicle Population By Air Basin, summer 2001

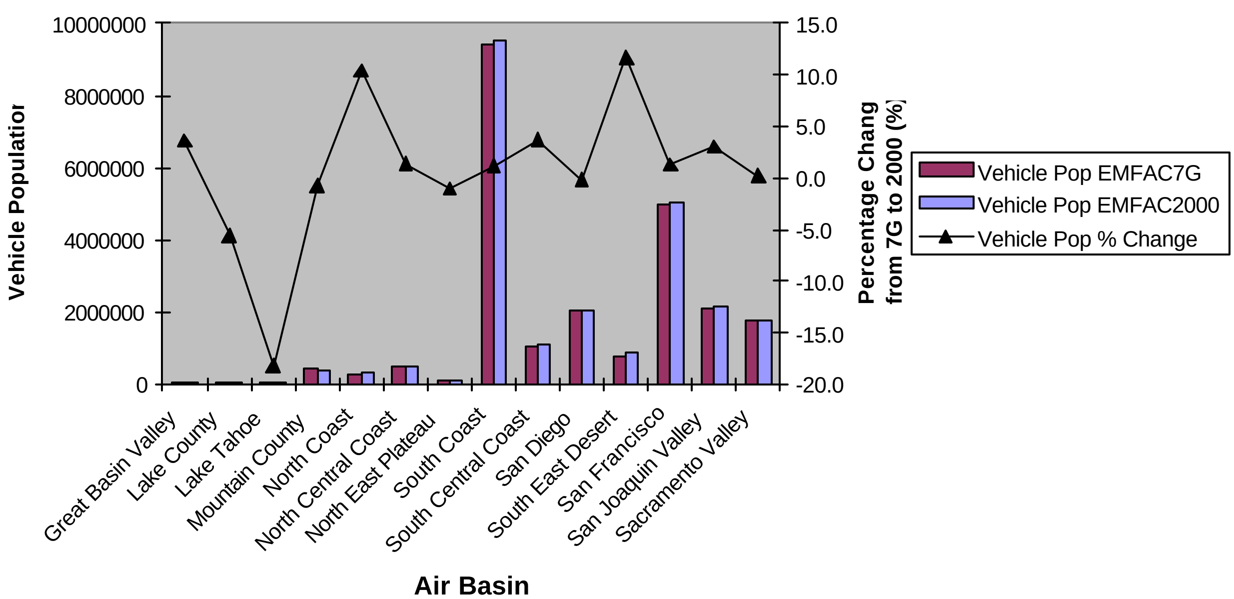


Figure 11. Predicted California Vehicle Miles Traveled By Air Basin, summer 2001

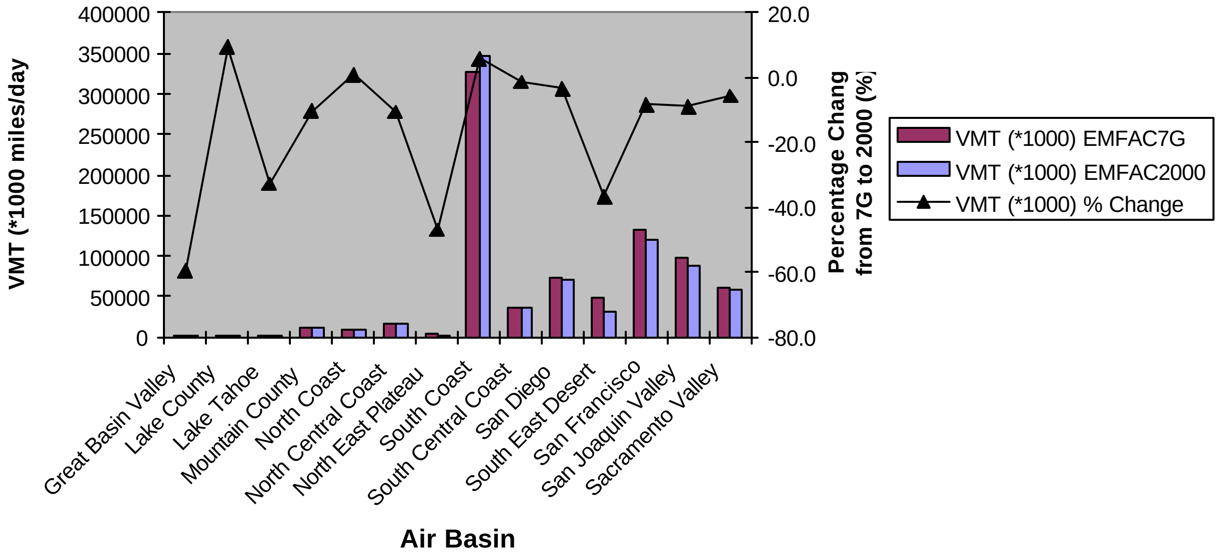
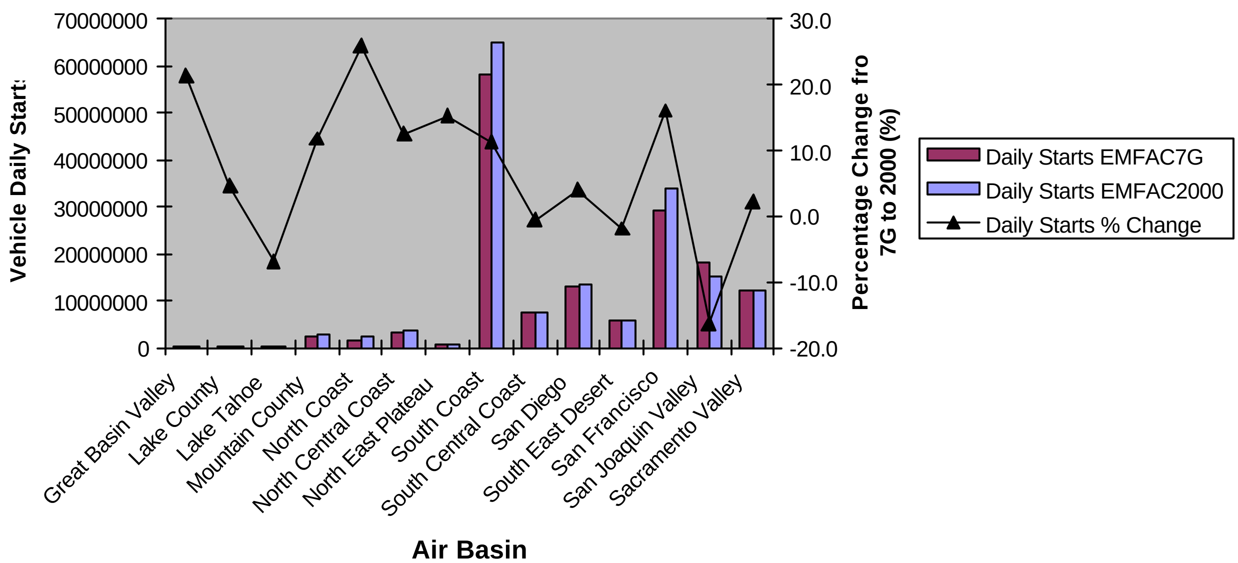


Figure 12. Predicted California Vehicle Daily Starts By Air Basin, summer 2001



Since an emission inventory is calculated by multiplying an emission factor by its associated transportation activity, it would appear that changes in transportation activity alone are not sufficient to account for the increases in emission inventories shown above. In the next section we use the San Joaquin Valley air basin as an example to explore and isolate those factors contributing to the increased emissions seen between the two models.

4.0 THE SAN JOAQUIN VALLEY AIR BASIN

The U.S. Environmental Protection Agency is preparing to "bump-up" the San Joaquin Valley (SJV) to a severe classification with a 2005 attainment date. This triggers the need to develop a new clean air plan and CARB is considering using EMFAC2000 for this plan update. This case study will explore how changes in the emission models could impact the development of the emissions inventory.

Table 7 shows the ozone (summer) emission inventory and the associated transportation activity data for the San Joaquin Valley (SJV) Air Basin for calendar year 2001. Compared to EMFAC7G results, EMFAC2000 computes an increase in total organic gases (TOG) of 39.8%, from 117.1 tons/day to 163.7 tons/day. Carbon monoxide emissions increase by 80.7% between the two models, while oxides of nitrogen (NO_x) and particulate matter less than ten microns in diameter (PM_{10}) inventories increase by about 30%. Estimates of carbon dioxide (CO_2) emission increase significantly (70%). While emissions increase substantially between model versions, the associated transportation activity data increase by only 3% for vehicle population, and decrease by 8.8% and 16.2% for VMT and daily starts, respectively.

Table 6. On-Road Mobile Emissions Inventories and Transportation Activity Data, San Joaquin Valley Air Basin, summer 2001

Pollutant	EMFAC7G	EMFAC2000	% Change
TOG (tons / day)	117.1	163.7	39.8
CO (tons / day)	926.6	1674	80.7
NO_x (tons / day)	185.1	241.1	30.3
CO_2 (tons / day)	35270	59950	70
PM_{10} (tons / day)	6.12	7.91	29.2
Vehicle Pop	2096840	2160785	3.0
VMT (*1000)	97175	88594	-8.8
Daily Starts	18083932	15150018	-16.2

There is a range of possible explanations for the increases in emissions inventories between the two models. We studied the running exhaust emissions from light-duty automobiles (LDA's) as an example to explore the possible reasons. The LDA's were selected because of a better-developed emission inventory calculation methodology and their importance to mobile emission inventory.

Figures 13 through 17 show comparisons between EMFAC7G and EMFAC2000 of the LDA running exhaust TOG, CO, NO_x, CO_2, and PM_{10} emissions in tons per day by LDA technology groups. The comparisons of the associated transportation activity (vehicle population, VMT, and daily starts) between the two models are given in Figures 18 to 20. A clear pattern is observed in these two sets of figures: estimated emissions increased significantly while the predicted transportation activity decreased from EMFAC7G to EMFAC2000. To be more specific, LDA total running exhaust emissions of TOG, CO, NO_x, CO_2, and PM_{10} present increases of 39.5%, 66.1%, 11.1%, 24.3%, and 193.9%, respectively, while the corresponding transportation activity data show decreases of 3.99%, 13.02%, and 31.99% for vehicle population, VMT, and daily starts, respectively.

If we divide the LDA running exhaust emissions in the two models by their associated VMT's it is clear (by a rough approximation) that the emission factors in grams per mile increase even more than the emissions, given that emissions increase while VMT decreases. This hypothesis can be verified by looking at the emission factor versus speed curves calculated from the two models. One point worth noticing is that EMFAC7G has a standard output for emission factors (grams/mile) vs speed distribution for the vehicle class/tech groups while EMFAC2000 does not. To obtain the emission factors in grams per mile vs speed distribution from EMFAC2000 we divide the emission rate in grams per hour by the corresponding speed (miles/hour) in EMFAC2000 impact rate output file. To make the two sets of the emission factors from the two models comparable, we calculated the emission rates in EMFAC2000 under the same environmental conditions (temperature, relative humidity) as those produced in EMFAC7G. The comparisons of the emission factors for TOG, CO, NO_x, CO_2, and PM_{10} of LDA CAT emissions are given in Figures 21 through 25. The apparent increases in emission factors at almost all speed levels are also consistent with the substantial increases in emission inventory estimates.

By studying the model outputs and analyzing the source codes of the model implementations, we find that there are four major modifications adopted in EMFAC2000 that account for the bulk of the increase in LDA TOG running exhaust inventory for the SJV Air Basin in year 2001. These changes include: modifications to the driving cycle; speed adjustment factors; emission factors updates; and redistribution of vehicle age. In EMFAC2000, the large database of FTP emissions data is converted to the Unified Cycle (UC) basis. As tested by CARB, approximately 11% of the increased exhaust TOG can be attributable to the data-driven modifications to the cycle adjustments.[1]

Speed adjustment factors come into play because the emission rate test cycles compress an immense range of possible driving conditions into one "average" driving cycle. The UC has an average speed of 27.4 mile per hour. However, under the real driving conditions vehicles can be operated at far higher or lower average speed than 27.4 miles per hour. Emissions vary with speed in a non-linear manner and additional adjustment factors are used to reflect this variation. Thirteen new cycles with differing average speeds were developed using subsets of the UC driving data to develop the speed correction factors in EMFAC2000. The revision of these correction factors in the new model, as illustrated in figures 21 to 25, increases the LDA exhaust TOG by approximately 10%.

Information from multiple FTP tests of about 2,600 vehicles and 250 vehicles tested over the UC was used in EMFAC7G. The number of vehicles used in the development of EMFAC2000 is more than twice that amount and includes 1,000 vehicles tested over both the FTP and UC. One major conclusion of this testing was that emission rates are higher than those previously used. This is especially true for older (early 1980s) vehicles. Compared to EMFAC7G, the basic emission rates for light-duty passenger cars increase by 50 to 100 percent in EMFAC2000, depending upon model year. Thus these changes to the emission rates for exhaust TOG account for about a 20% increase in the inventory.[1]

In EMFAC7G, the number of model years of passenger cars assumed to exist in any one calendar year was 35. EMFAC2000 extends the age distribution for all vehicle classes to 45.

Also EMFAC2000 assumes a higher retention rate and a longer useful life for passenger cars compared to MVEI7G. Hence the revised age distributions used in EMFAC2000 result in a higher class-specific inventory estimate. Overall, vehicle fleet age redistribution increases the inventory for LDA TOG by about 20%.

For the carbon monoxide exhaust emissions three revisions to the model account for the major part of the emissions increase. They are changes to the basic emission rates (+30%), adjustments to the speed adjustment factors (+20%) and the correction to the fuel adjustment factors used in EMFAC7G (+15%).

Oxides of nitrogen emissions (NO_x) for LDA show only a very slight increase relative to the increase of the entire fleet. More than half of the NO_x inventory increase is attributable to heavy-duty diesel vehicles and "off-cycle" NO_x. The other NO_x inventory increases are caused by increases in the emission rates of light trucks.

Figure 17 shows that there is a significant increase in LDA PM_{10} emissions (193.9%). The majority of this change is attributable to the addition of "smoky" vehicles and cycle adjustments (FTP to UC)[2].

Figure 13. Comparison of On-Road LDA TOG Running Exhaust in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

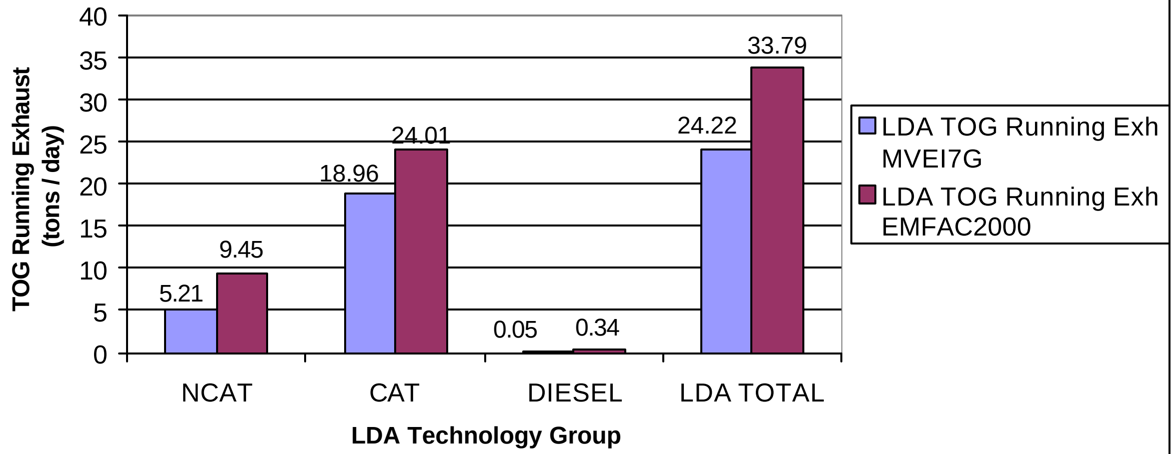


Figure 14. Comparison of On-Road LDA CO Running Exhaust in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

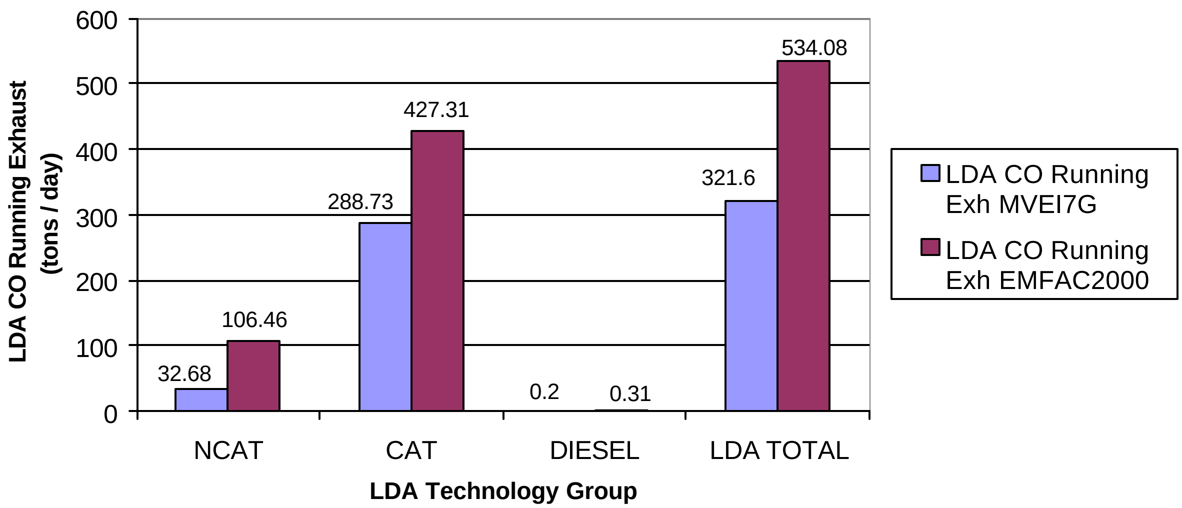


Figure 15. Comparison of On-Road LDA NOx Running Exhaust in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

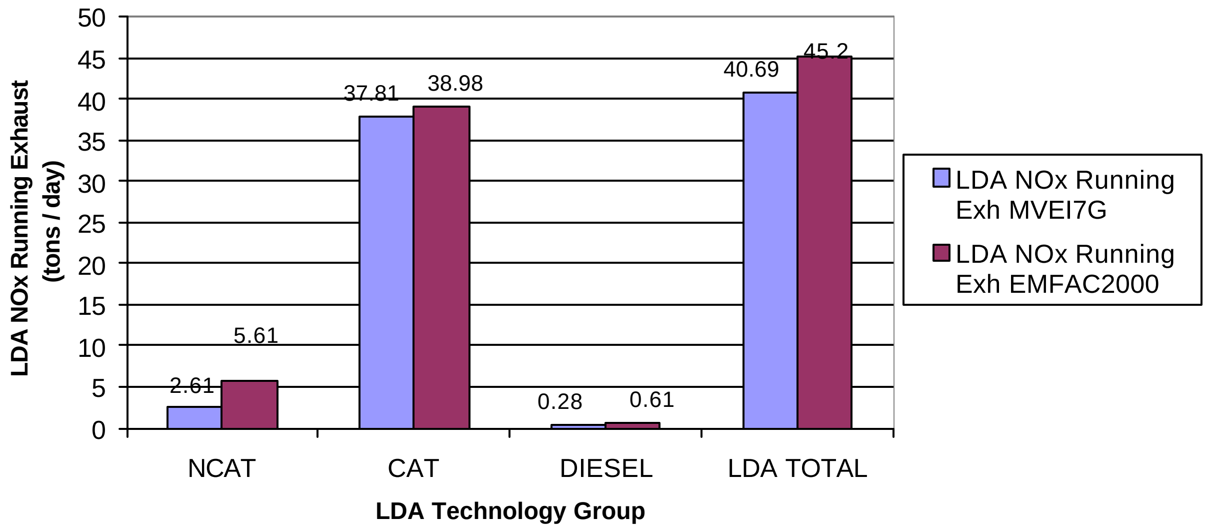


Figure 16. Comparison of On-Road LDA CO2 Running Exhaust in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

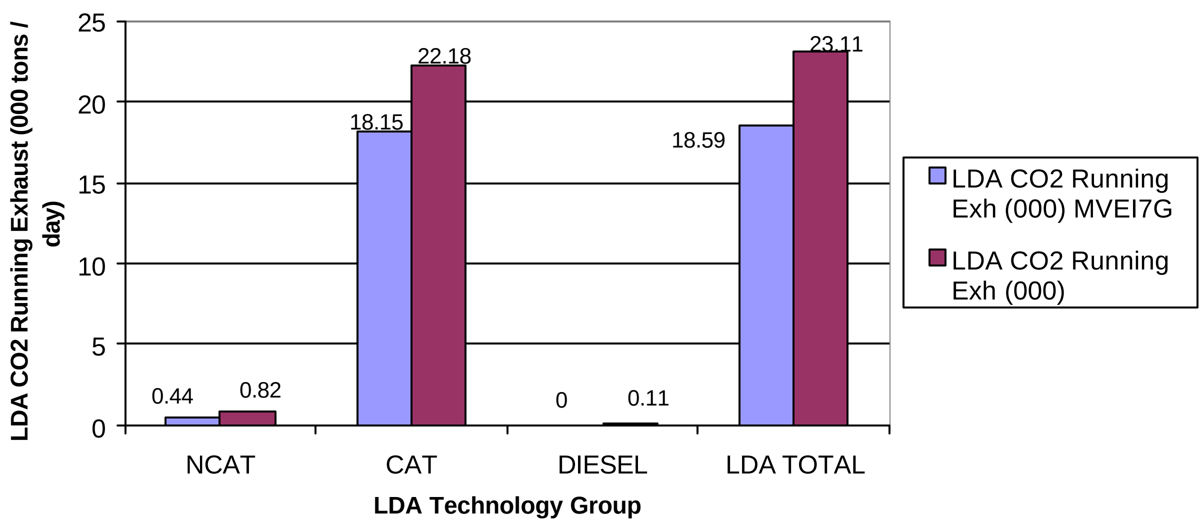


Figure 17. Comparison of On-Road LDA PM10 Total Exhaust in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

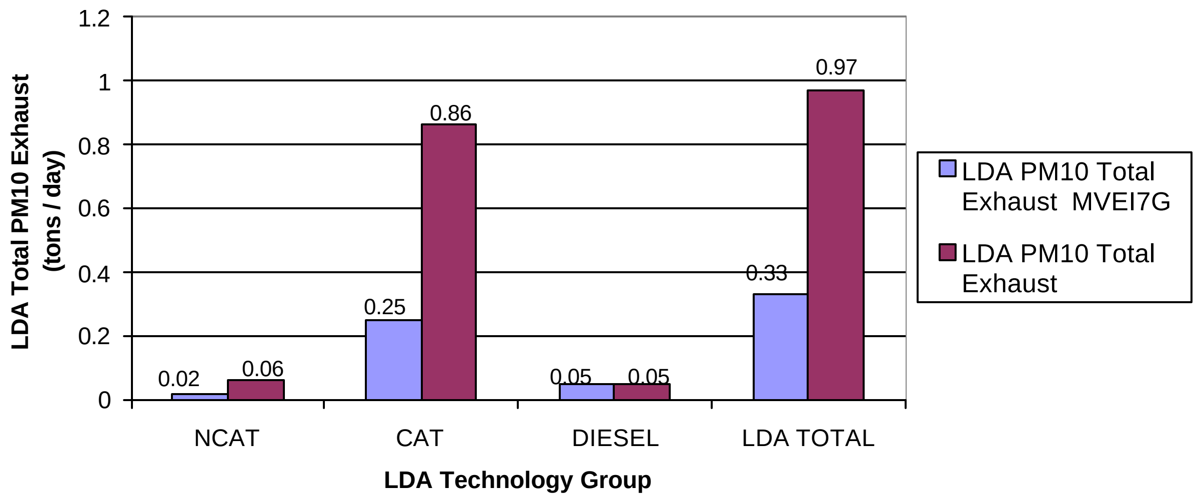


Figure 18. Comparison of Vehicle Population in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

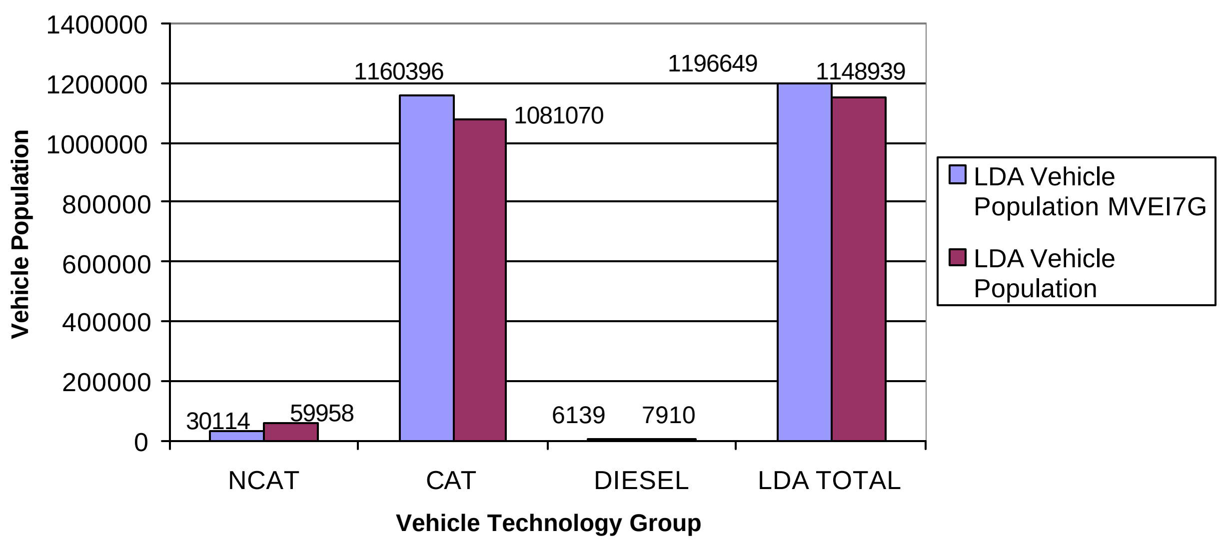


Figure 19. Comparison of of Daily VMT/1000 in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

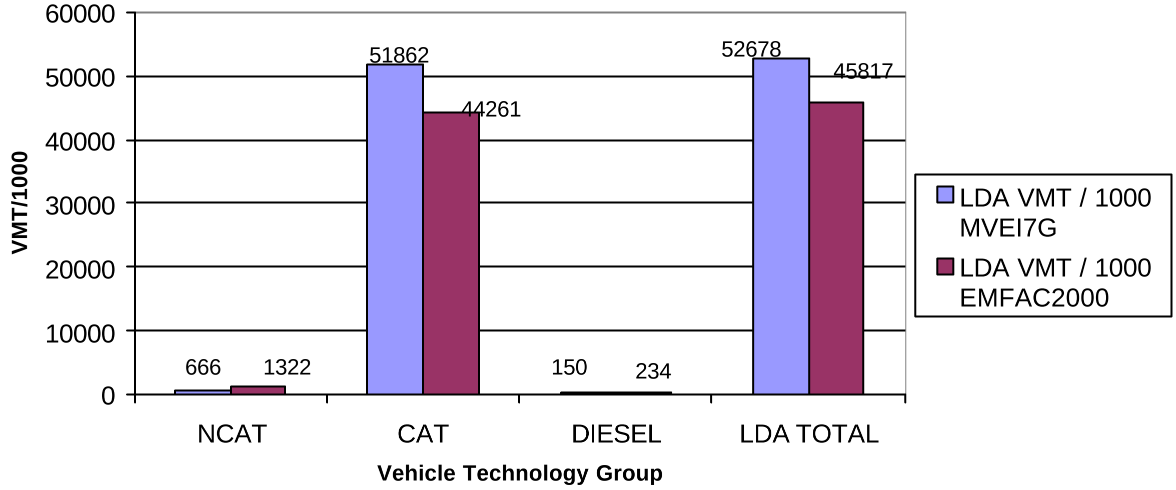


Figure 20. Comparison of of Daily Starts in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

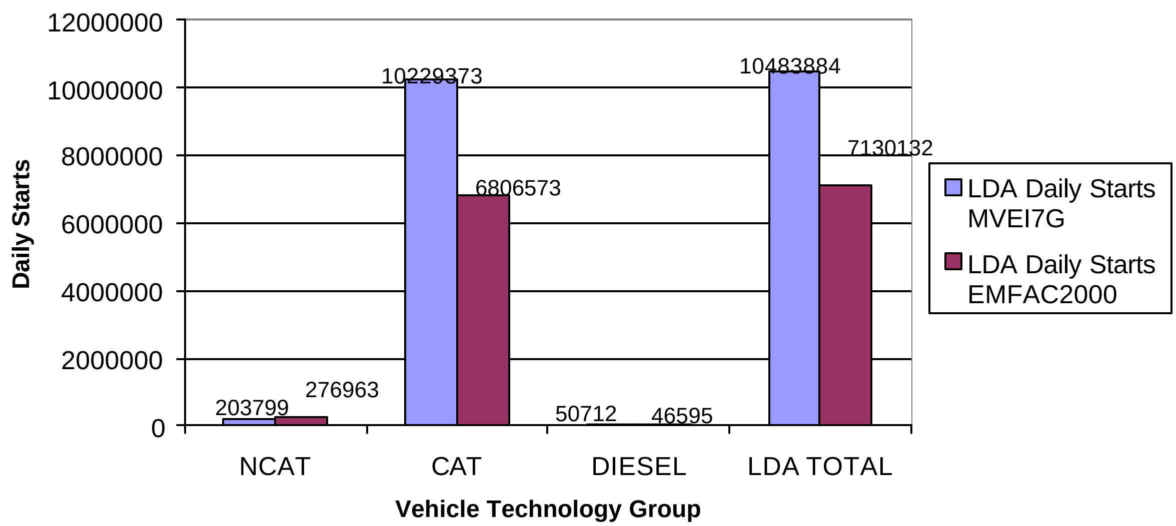


Figure 21. Comparison of LDA CAT TOG Running Exhaust Emission Factors in MVEI7G and EMFAC2000 for SJV Air Basin, summer 2001

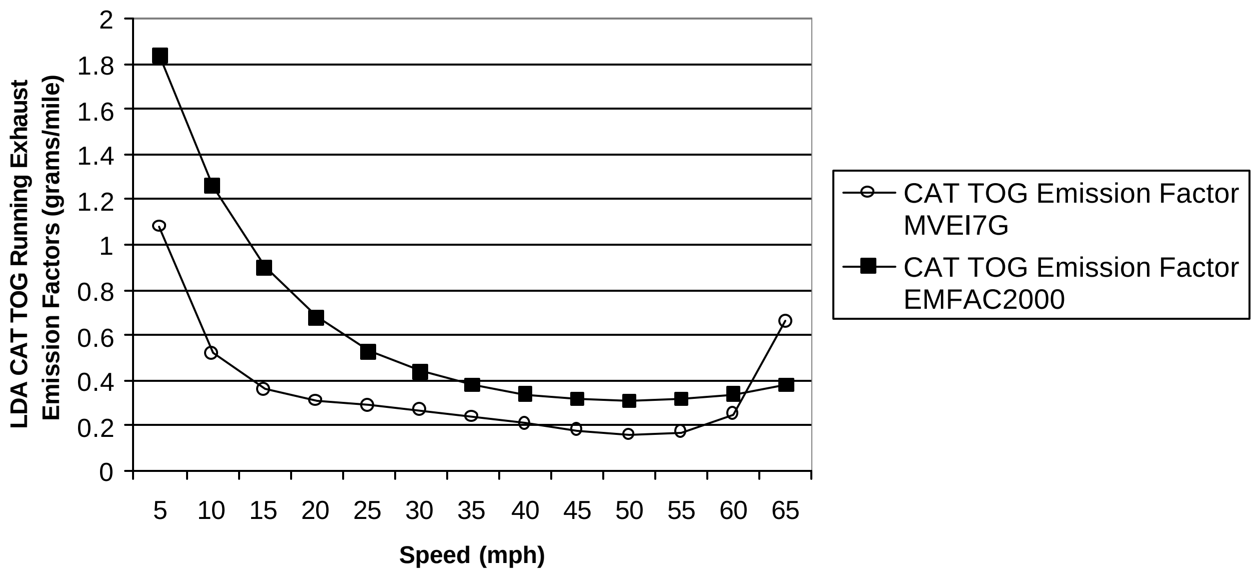


Figure 22. Comparison of LDA CAT CO Running Exhaust Emission Factors in MVEI7G and EMFAC2000 for SJV Air Basin , summer 2001

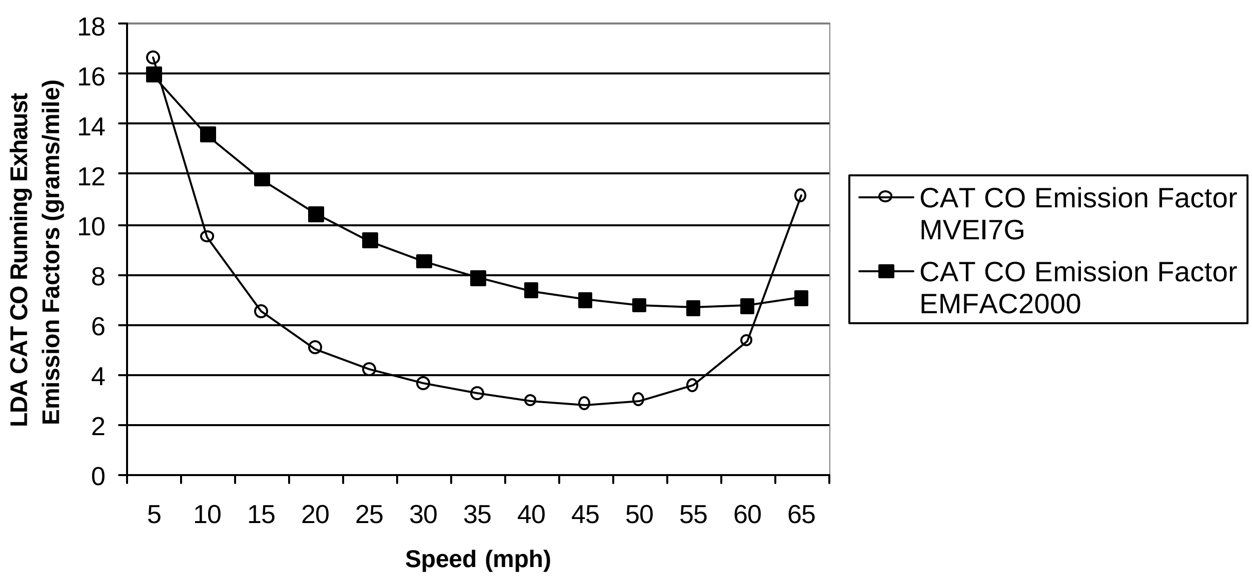


Figure 23. Comparison of LDA CAT NOx Running Exhaust Emission Factors in MVEI7G and EMFAC2000 for SJV Air Basin On-Road Emission Inventory, CY 2001, Summer Ozone

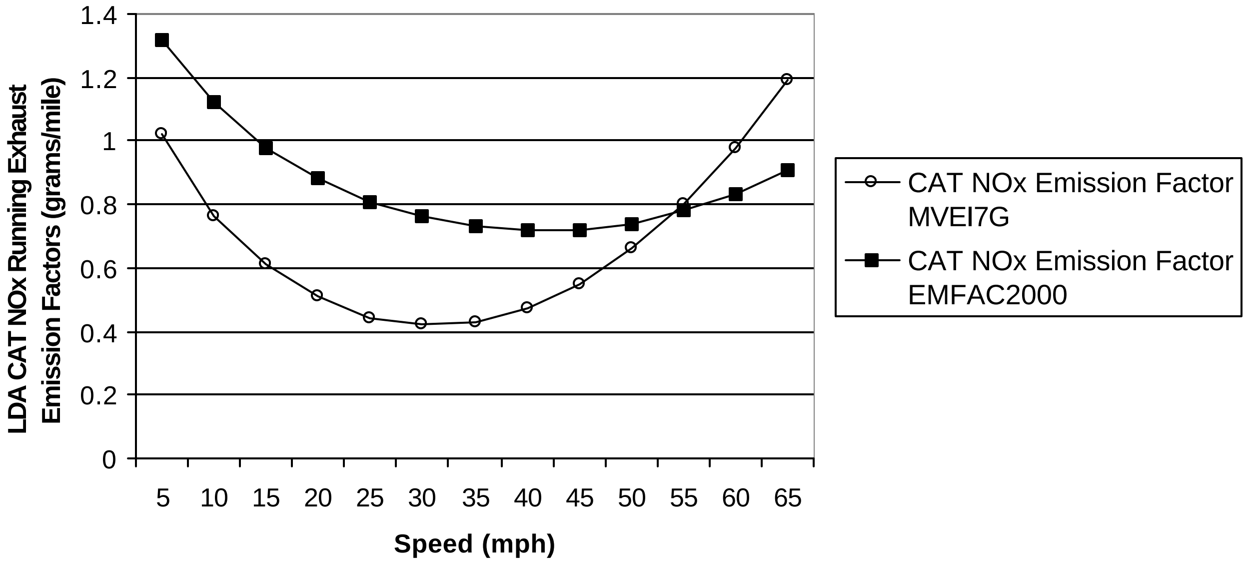


Figure 24. Comparison of LDA CAT CO2 Running Exhaust Emission Factors in MVEI7G and EMFAC2000 for SJV Air Basin , summer 2001

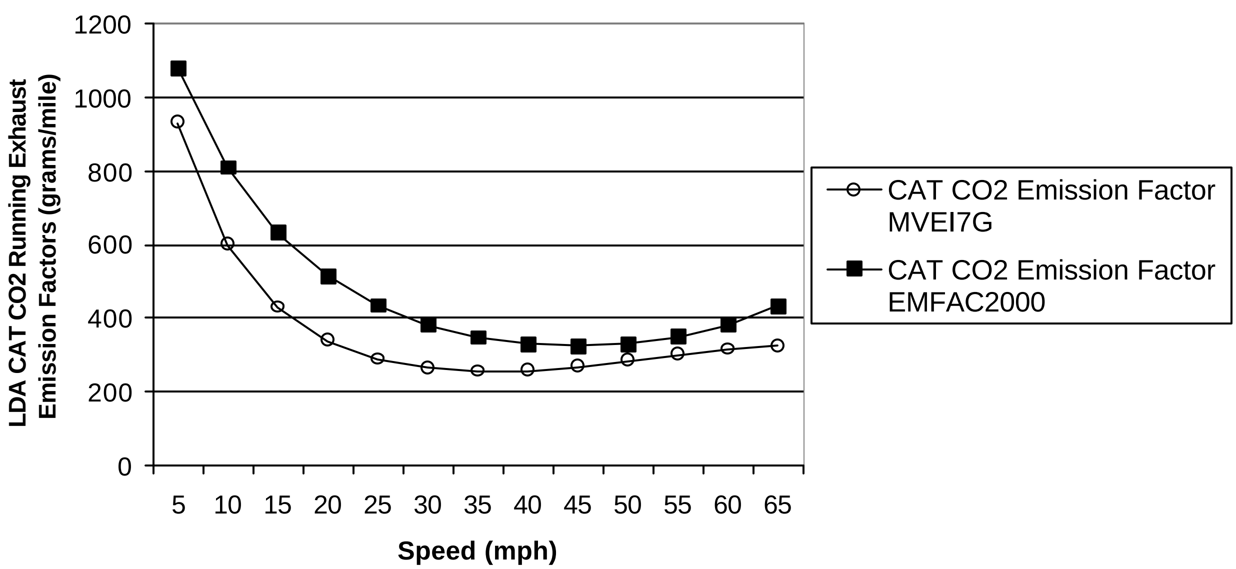
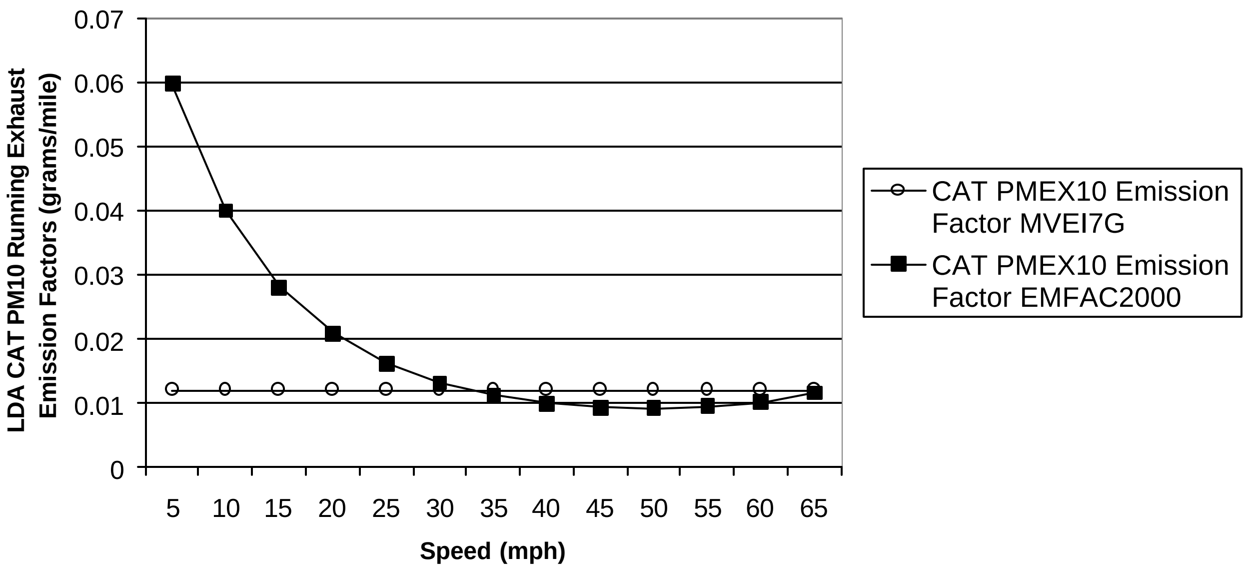


Figure 25. Comparison of LDA CAT PM10 Running Exhaust Emission Factors in EMFAC7G and EMFAC2000 for SJV Air Basin, summer 2001



Note: The gasoline PM exhaust emission factors in EMFAC7G were taken from U.S. EPA's PART5 model, which is the PM portion of MOBILE5.[8]

5 CONCLUSION

The newly revised mobile emission inventory model, EMFAC2000, represents a significant change to the previous on-road vehicle emissions inventory model, EMFAC7G. Compared to EMFAC7G, EMFAC2000 increases estimated emissions substantially. In this study, following a summary of the most important changes to model, we conducted a comparative study of the predicted California on-road mobile emission inventories estimated by the two models by air basin. As an illustrative example, the emission factors were developed for San Joaquin Valley (SJV) Air Basin using EMFAC7G and EMFAC2000. The source codes of the two models were also explored and compared to obtain a full understanding of the scientific basis for the difference between the two models.

The differences between the two models include basic emission rates, driving cycle adjustments, speed adjustment factors, updates to the emissions factors, changes to vehicle fleet age distribution, and county specific environmental parameters, etc.. Four changes to the estimation methodology are responsible for the majority of the differences between the EMFAC7G and EMFAC2000 results of the inventories for exhaust emissions for light-duty vehicles. These include modifications to the basic emission rates, adjustments to the driving cycle, the development of new speed adjustment factors and the inclusion of gross emitters for particulate matter, or "smoky" vehicles. The changes in emission factors are mainly data-driven and result from the addition of more vehicles tested over UC. These new data indicate that vehicle emissions are higher than what had been projected in the previous version of the inventory model. The modifications made in the updated model, EMFAC2000, better reflect the real world emission characteristics of on-road fleets.

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