California Enhanced I/M Program Evaluation
TECHNICAL SUPPORT DOCUMENT
PART 2

This portion of the Technical Support Document for the *Evaluation of the California Enhanced Vehicle Inspection and Maintenance (Smog Check) Program (April 2004)* summarizes the results of several technical analyses conducted by the Bureau of Automotive Repair (BAR) and Sierra Research, an independent contractor. Methodologies are explained in each of the following chapters:

2.1 Emission Reductions from the Current Enhanced I/M Program (grams per mile)

This section describes the analyses performed to estimate the emission benefits from the Enhanced Smog Check Program in grams per mile. For analyzing the current program, two techniques are available: (1) evaluation of emissions tests from roadside pullover programs, and (2) evaluation of the results from an emissions model. The emissions benefits derived from these two techniques are described below.

2.1.1 Roadside Data Analysis

The random roadside tests are conducted by BAR with the assistance of the California Highway Patrol. Although the inspection is not mandatory, the majority of motorists pulled over participate in the program. The inspections are conducted by BAR personnel using a portable dynamometer. Both modes of the Acceleration Simulation Mode (ASM) test are run – the "ASM5015" and the "ASM2525". On the ASM5015, the vehicle is run at 15 miles per hour at a load equivalent to 50% of the maximum load encountered on the Urban Dynamometer Driving Schedule (UDDS) used in the Federal Test Procedure (FTP) for vehicle certification. The ASM2525 is a 25 mile per hour test at a load equivalent to 25% of the maximum load encountered on the FTP. On the ASM test procedure, tailpipe pollutant concentrations are measured (i.e., ppm for HC and NOx, percent for CO). Thus, as discussed in detail below, correlation equations have been developed to convert the ASM test results into units of grams per mile (g/mi).

Summary of Available Roadside Data - As noted in the main report, there are two sources of roadside data that can be analyzed to estimate the effectiveness of the Enhanced program: (1) the 1999 Roadside Data; and (2) the 2002 Roadside Data. Specifics of these datasets are summarized below.

- *1999 Roadside Data* - This program was conducted from February 1997 through October 1999. Approximately 27,000 test records were collected over this two and a half year period. The roadside records were then matched with Smog Check records to determine whether the vehicles were subject to an ASM test or a Two-Speed Idle (TSI) test prior to the roadside inspection. Figure 2.1 shows the monthly count of roadside inspections and Figure 2.2 shows the model year distribution of vehicles in the dataset. Note that only vehicles with matching Smog Check records are included in these figures.

- *2002 Roadside Data* - Conducted between January 2000 and October 2002, approximately 13,000 vehicles were tested, and nearly 12,000 of those were able to be matched up with prior Smog Check Records. The monthly count of roadside test records for this program is shown in Figure 2.3, while the distribution of model years is included in Figure 2.4.

Figure 2.1

Histogram of Test Dates for the "1999 Roadside" Data

Only Vehicles with Matching Smog Check Records

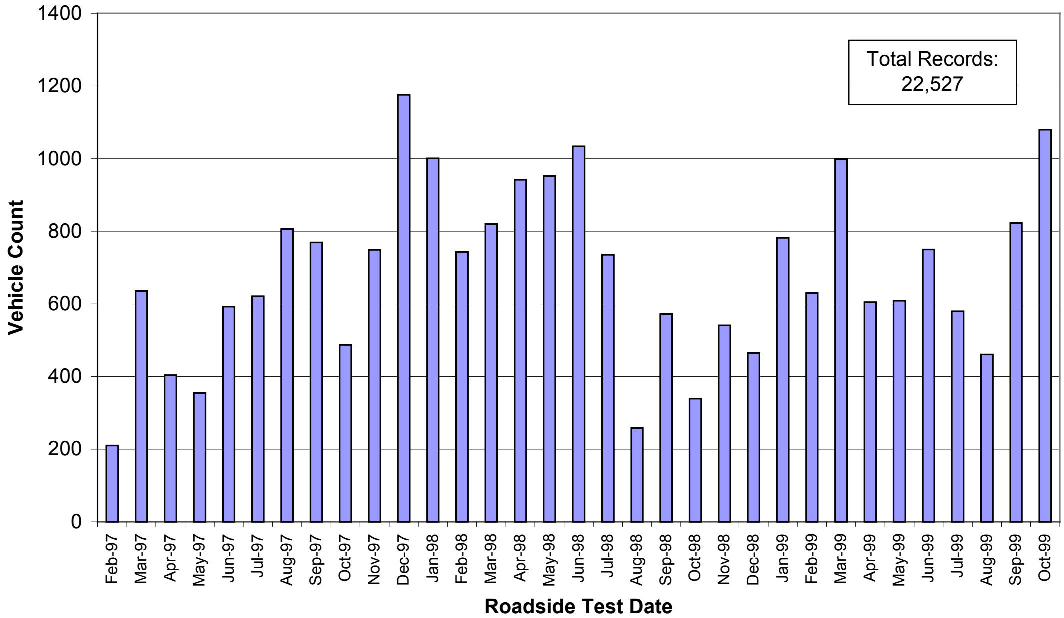


Figure 2.2

Histogram of Vehicle Model Years Included in the "1999 Roadside" Data

Only Vehicles with Matching Smog Check Records

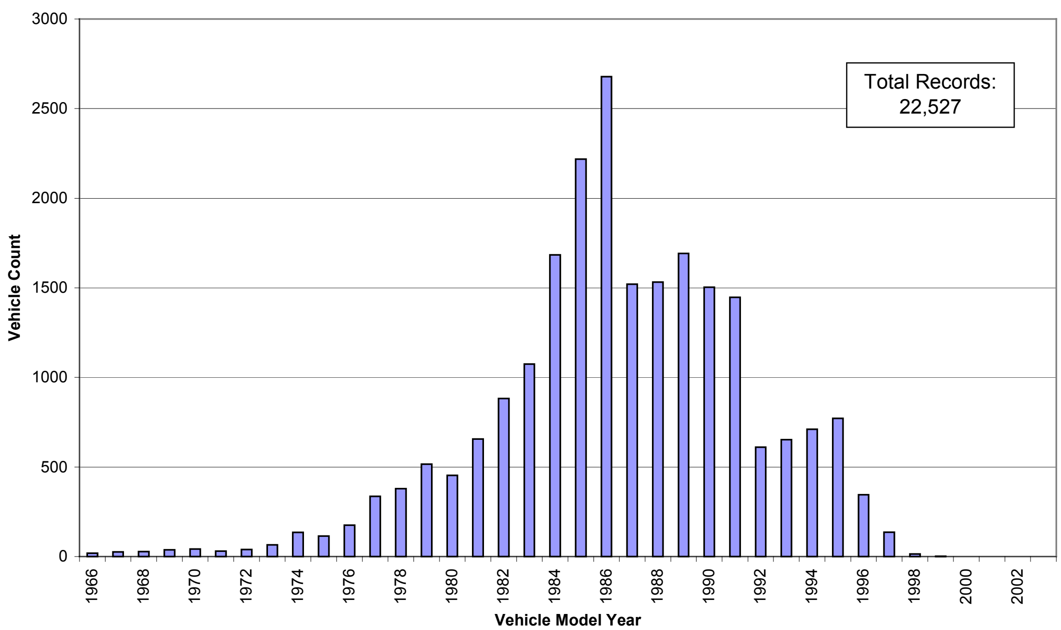


Figure 2.3

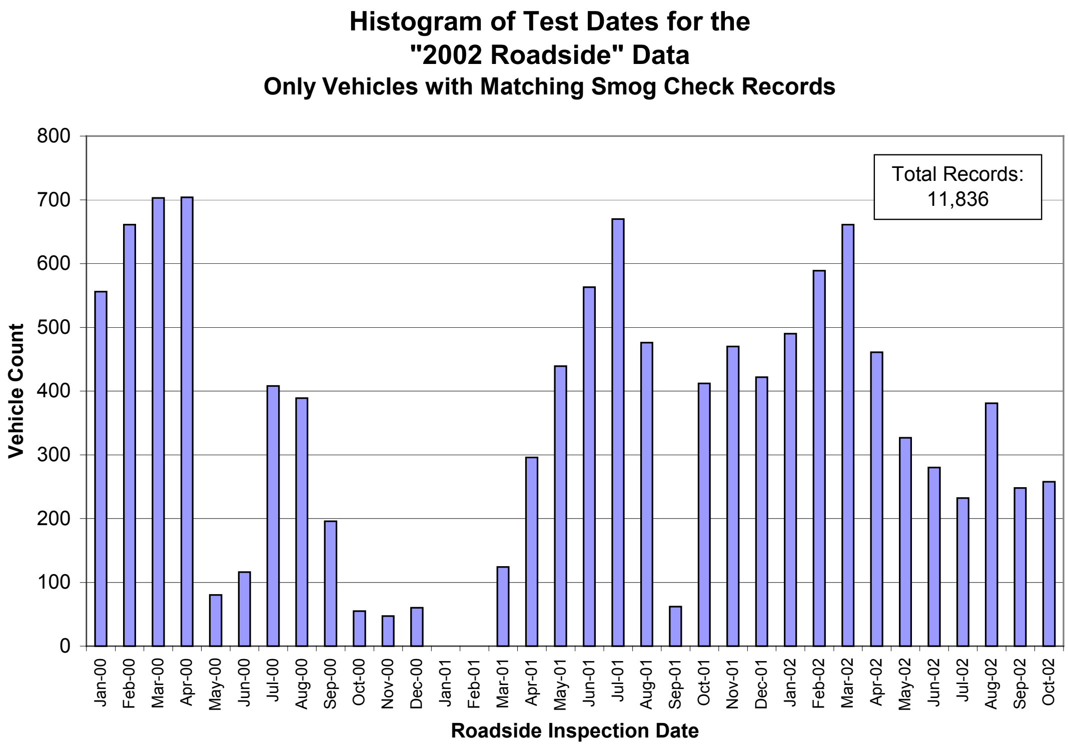
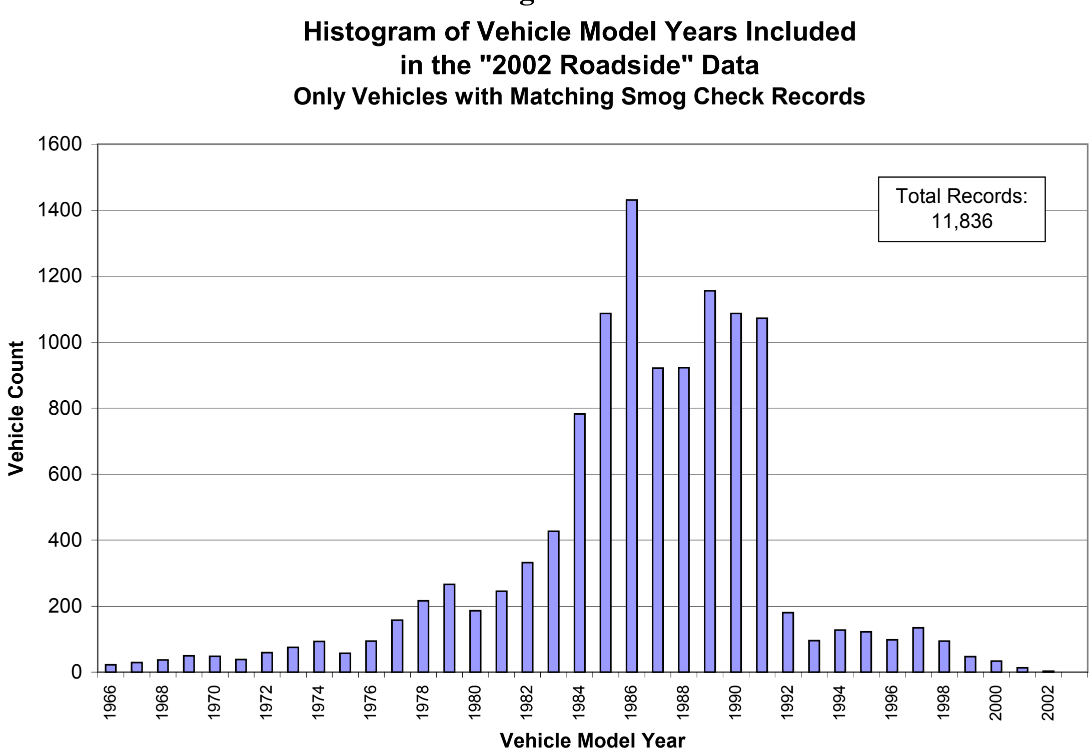


Figure 2.4



Methodology - In the July 2000 evaluation of program effectiveness, the Air Resources Board (ARB) was able to use the 1999 Roadside Program data to compare emissions results from vehicles that had been through the ASM test procedure at a Smog Check station ("After ASM") to emissions from vehicles that had not yet received an ASM inspection ("Before ASM"). These two groups of vehicles were identified by merging official Smog Check records from California's Vehicle Information Database (VID) with the 1999 Roadside data based on matching Vehicle Identification Numbers (VINs) and license plates. Because the time period over which the 1999 Roadside data were collected was during implementation of the BAR97 ASM test in Enhanced I/M program areas, there were an adequate number of vehicles that fell into both the Before ASM and After ASM groups. As noted in the July 2000 report, only vehicles tested from November 11, 1998, through October 29, 1999, were included in the analysis. That limitation was placed on the data because of concerns that vehicles of the same model year tested at the beginning of the program may not be comparable to the same model year vehicles at the end of the program (as a result of emission control system deterioration). In addition, only vehicles with matching data that could be identified were included in the analysis.

Given the above constraints, the following groups of vehicles were used in the July 2000 analysis of program effectiveness:

- After ASM - These vehicles had completed the ASM test requirements prior to the roadside inspection, either passing the ASM test at a Smog Check station or failing the ASM test at a Smog Check station. This group consisted of 4,233 test records.

- Before ASM - These vehicles had not completed the ASM test requirements prior to the roadside inspection, having been subject to the TSI test used prior to implementation of the Enhanced I/M program requirements. This group consisted of 5,232 test records.

A comparison of the Before and After ASM groups in the July 2000 analysis indicated that the enhanced ASM test procedure was achieving benefits of 14% for HC, 13% for CO, and 6% for NOx relative to the TSI test procedure.

Analysis of the 2002 Roadside data is complicated by the fact that most vehicles should have been through at least one I/M cycle with the BAR97 ASM test procedure. Although there are a number of vehicles in the 2002 Roadside database that received a TSI test prior to the roadside test, those vehicles are in the minority. As a result, the benefits of the current BAR97 ASM program must be evaluated by comparing the 2002 Roadside data for vehicles that had been tested over the ASM procedure ("2002 After ASM") to the 1999 Roadside data for vehicles that had not been tested with the ASM procedure ("1999 Before ASM"). However, because of the three-year difference in when the roadside data were collected, the 1999 Before ASM data must be forecast to a 2002 basis to account for anticipated emission control system deterioration between 1999 and 2002. The approach used to forecast those emissions is discussed later in this section.

Consistent with the July 2000 analysis, data from the 2002 Roadside Program were analyzed as follows:

- For 1974 through 1998 model year vehicles (i.e., the population subject to ASM testing), only test records that had received an ASM test prior to the roadside inspection were included in the analysis;
- For pre-1974 and 1999 through 2002 model year vehicles all test records were combined by model year (these model years reflect vehicles that are not subject to the enhanced program); and
- Only Roadside data collected from October 1, 2001, through October 31, 2002, were included in the analysis.

Table 2.1 summarizes the mean ASM scores by model year from the 2002 Roadside data for vehicles that had been subject to BAR97 ASM testing, subject to the constraints outlined above. As observed in that table, significantly lower average tailpipe emissions (as measured with the ASM test procedure) are being recorded from the newer vehicles in the fleet. In addition to the mean ASM scores, the 95% confidence interval for the mean ASM estimate is also presented. This was calculated based on the methodology presented in the July 2000 evaluation of the Smog Check program.

Because the results in Table 2.1 reflect emissions with the enhanced program implemented, ideally those results would be compared to roadside ASM scores from vehicles subject to the TSI program. The difference between the two sets of numbers would provide an indication of the benefits of the enhanced versus the basic program. However, as discussed above, because the majority of vehicles in the 2002 Roadside database had already been tested with the enhanced BAR97 procedure in their Smog Check inspection immediately prior to the roadside test, the 2002 Roadside data cannot be used to develop the baseline for comparison to the BAR97 results. Instead, the basic program results from the 1999 Roadside data were used for this comparison. However, those results had to be forecast to a 2002 basis. As explained below, this was done by determining the increase in emissions over three years (from 1999 to 2002) as predicted by EMFAC2002 under a basic I/M program. Because the EMFAC2002 analysis was based on FTP-equivalent emissions, the Roadside ASM data (both 1999 and 2002 databases) were first converted to an FTP basis.

Table 2.1

Fleet-Average ASM Emissions Concentrations for Vehicles in the 2002 Roadside Database
1974 - 1998 Model Year Vehicles Were Subject to the BAR97 ASM Test Procedure Prior to the Roadside Test

Model Year	Number Tested	ASM5015 Roadside Results			ASM2525 Roadside Results			EMFAC2002 Travel Fraction
		Mean HC (ppm)	Mean CO (%)	Mean NOx (ppm)	Mean HC (ppm)	Mean CO (%)	Mean NOx (ppm)	
1966	19	378 +/- 294	2.08 +/- 0.96	1179 +/- 362	391 +/- 327	2.11 +/- 1.07	1039 +/- 335	0.0036
1967	20	222 +/- 44	2.81 +/- 1.15	1196 +/- 426	215 +/- 45	2.87 +/- 1.09	1057 +/- 362	0.0009
1968	29	176 +/- 32	2.22 +/- 0.83	1051 +/- 250	174 +/- 33	2.23 +/- 0.82	982 +/- 246	0.0011
1969	45	297 +/- 202	2.00 +/- 0.60	1259 +/- 264	267 +/- 202	2.07 +/- 0.63	1119 +/- 251	0.0015
1970	30	173 +/- 25	1.86 +/- 0.73	1212 +/- 286	167 +/- 28	1.77 +/- 0.72	1134 +/- 316	0.0016
1971	37	375 +/- 316	1.34 +/- 0.46	1270 +/- 188	363 +/- 309	1.41 +/- 0.47	1109 +/- 191	0.0016
1972	44	201 +/- 85	2.04 +/- 0.66	947 +/- 209	197 +/- 96	2.02 +/- 0.66	844 +/- 184	0.0022
1973	44	278 +/- 175	2.14 +/- 0.78	1060 +/- 218	270 +/- 168	2.30 +/- 0.81	947 +/- 199	0.0024
1974	31	254 +/- 176	1.70 +/- 0.91	1012 +/- 301	249 +/- 182	1.68 +/- 0.93	878 +/- 236	0.0016
1975	18	148 +/- 72	0.87 +/- 0.69	1239 +/- 349	145 +/- 76	0.87 +/- 0.70	1120 +/- 331	0.0013
1976	25	213 +/- 179	1.28 +/- 0.55	862 +/- 213	169 +/- 119	1.29 +/- 0.55	741 +/- 195	0.0019
1977	49	198 +/- 225	0.97 +/- 0.52	826 +/- 153	192 +/- 225	1.02 +/- 0.50	697 +/- 146	0.0028
1978	67	167 +/- 81	1.74 +/- 0.55	610 +/- 129	156 +/- 75	1.80 +/- 0.57	528 +/- 114	0.0034
1979	98	161 +/- 67	0.94 +/- 0.40	737 +/- 132	143 +/- 62	0.93 +/- 0.41	647 +/- 119	0.0043
1980	53	112 +/- 41	1.01 +/- 0.51	823 +/- 196	101 +/- 33	1.05 +/- 0.53	707 +/- 167	0.0035
1981	78	98 +/- 23	1.03 +/- 0.52	812 +/- 181	82 +/- 18	0.91 +/- 0.42	685 +/- 164	0.0043
1982	107	94 +/- 17	0.99 +/- 0.42	648 +/- 120	83 +/- 17	1.01 +/- 0.42	524 +/- 91	0.0056
1983	151	96 +/- 16	0.92 +/- 0.31	661 +/- 108	86 +/- 17	0.94 +/- 0.32	544 +/- 90	0.0073
1984	238	108 +/- 31	0.82 +/- 0.22	767 +/- 99	91 +/- 24	0.72 +/- 0.21	653 +/- 93	0.0130
1985	367	92 +/- 12	0.72 +/- 0.17	631 +/- 60	76 +/- 11	0.71 +/- 0.17	530 +/- 53	0.0177
1986	471	78 +/- 7	0.65 +/- 0.13	716 +/- 71	68 +/- 15	0.57 +/- 0.12	610 +/- 60	0.0232
1987	353	85 +/- 13	0.66 +/- 0.17	640 +/- 74	71 +/- 13	0.63 +/- 0.17	525 +/- 64	0.0273
1988	361	60 +/- 7	0.31 +/- 0.11	530 +/- 62	49 +/- 7	0.33 +/- 0.12	454 +/- 53	0.0308
1989	507	54 +/- 5	0.25 +/- 0.06	451 +/- 47	44 +/- 5	0.23 +/- 0.06	389 +/- 45	0.0377
1990	478	51 +/- 16	0.20 +/- 0.07	363 +/- 41	40 +/- 13	0.20 +/- 0.07	304 +/- 34	0.0381
1991	481	47 +/- 7	0.20 +/- 0.06	344 +/- 39	34 +/- 5	0.18 +/- 0.06	285 +/- 32	0.0413
1992	122	41 +/- 8	0.15 +/- 0.04	330 +/- 93	34 +/- 8	0.20 +/- 0.10	296 +/- 83	0.0387
1993	53	30 +/- 15	0.22 +/- 0.29	258 +/- 108	22 +/- 11	0.10 +/- 0.07	249 +/- 101	0.0462
1994	67	22 +/- 6	0.05 +/- 0.02	201 +/- 62	18 +/- 5	0.06 +/- 0.03	189 +/- 58	0.0516
1995	70	16 +/- 5	0.05 +/- 0.02	165 +/- 49	14 +/- 7	0.04 +/- 0.02	180 +/- 54	0.0610
1996	55	10 +/- 3	0.03 +/- 0.01	93 +/- 32	9 +/- 3	0.04 +/- 0.01	80 +/- 31	0.0563
1997	65	8 +/- 2	0.02 +/- 0.01	76 +/- 27	7 +/- 2	0.03 +/- 0.01	76 +/- 28	0.0667
1998	25	7 +/- 2	0.02 +/- 0.01	138 +/- 216	6 +/- 3	0.03 +/- 0.02	129 +/- 193	0.0685
1999	79	7 +/- 3	0.01 +/- 0.00	58 +/- 51	7 +/- 2	0.02 +/- 0.00	67 +/- 46	0.0777
2000	59	5 +/- 1	0.02 +/- 0.00	40 +/- 30	5 +/- 1	0.01 +/- 0.00	32 +/- 25	0.0793
2001	65	5 +/- 1	0.01 +/- 0.00	9 +/- 5	5 +/- 1	0.01 +/- 0.00	24 +/- 24	0.0838
2002	18	6 +/- 2	0.01 +/- 0.01	33 +/- 62	6 +/- 2	0.01 +/- 0.00	33 +/- 52	0.0899
Wtd Average	4879	32 +/- 10	0.19 +/- 0.07	237 +/- 68	28 +/- 10	0.19 +/- 0.07	211 +/- 63	1.0000

Note: For 1966 - 1973 and 1999 - 2002 model year vehicles, all vehicles receiving roadside tests between October 1, 2001, and October 31, 2002, were used to develop average ASM scores including those that were not subject to the BAR97 ASM test procedure prior to the roadside test.

FTP-Based Analysis of the Roadside Data - The ASM concentration data collected in the 1999 and 2002 Roadside programs were converted to predicted FTP emission rates (in grams per mile) using correlation equations that were newly developed for this study. The general approach for developing the correlations followed closely the methodology developed by Radian/ERG for the July 2000 Smog Check evaluation.[1] However, a new dataset was used for this analysis that included additional ASM-FTP test results, particularly for late-model vehicles (i.e., 1996 and newer model year vehicles). The 1999 ERG analysis used a dataset with test scores for 1,372 vehicles, while the current analysis was based on a dataset with test scores for 1,934 vehicles. In addition, separate equations were developed for pre-1990 and 1990+ model year vehicles in the current analysis. Appendix 2A contains a summary of the ASM-to-FTP correlation equations developed for this effort.

The ASM-to-FTP correlation equations presented in Appendix 2A were applied to the roadside ASM test measurements to develop predicted FTP scores for each vehicle in the 1999 and 2002 Roadside databases. Mean emission rates were developed for each model year separately for the "1999 Before ASM" sample and the "2002 After ASM" sample. The model-year-specific FTP-based emissions from the "1999 Before ASM" sample were then forecast to a 2002 basis using results from the EMFAC2002 model in which vehicle emission rates were compared at three years apart. For example, a 1985 model year vehicle would be 14 years old in 1999 and 17 years old in 2002. According to EMFAC2002, the applicable FTP-based HC emission rates for such a vehicle subject to BAR90 I/M would be:

- 1985 MY @ 14 years (CY1999) = 1.474 g/mi
- 1985 MY @ 17 years (CY2002) = 1.525 g/mi

and the ratio of the 17-year emission rate to the 14-year emission rate is 1.525/1.474 = 1.035. Thus, the mean HC emission rate for 1985 model year vehicles in the "1999 Before ASM" sample was multiplied by 1.035 to account for an additional three years of deterioration. These adjustments, which are presented in Appendix 2B, were applied to 1974 through 1998 model year vehicles from the "1999 Before ASM" sample.

The resulting FTP emission rates for the "1999 Before ASM" sample, adjusted to a 2002 basis, and the "2002 After ASM" sample are shown in Table 2.2. The emission rates for each model year were multiplied by the EMFAC2002 travel fraction shown in the table (calculated for calendar year 2002 on a statewide basis), and the sum of those products gave the fleet-average emission rates shown at the bottom of Table 2.2. Several items are worth noting with respect to the estimates contained in the table:

Table 2.2

Fleet-Average Predicted FTP Emission Rates from the 1999 and 2002 Roadside Data
1999 Roadside Data Forecast to a 2002 Basis

Model	1999 Roadside FTP Values Forecast to 2002 BAR90 I/M Stringency ("Before ASM")				2002 Roadside FTP Values BAR97 I/M Stringency ("After ASM")				Percent Emission Reduction by Model Year			EMFAC2002 Travel
Year	(n)	HC (g/mi)	CO (g/mi)	NOx (g/mi)	(n)	HC (g/mi)	CO (g/mi)	NOx (g/mi)	HC	CO	NOx	Fraction
1966	19	12.34	119.4	2.67	19	12.34	119.4	2.67	0%	0%	0%	0.0036
1967	20	10.50	137.8	2.59	20	10.50	137.8	2.59	0%	0%	0%	0.0009
1968	29	9.19	121.8	2.75	29	9.19	121.8	2.75	0%	0%	0%	0.0011
1969	45	9.54	112.3	3.21	45	9.54	112.3	3.21	0%	0%	0%	0.0015
1970	30	7.97	101.8	3.01	30	7.97	101.8	3.01	0%	0%	0%	0.0016
1971	37	8.25	86.2	2.97	37	8.25	86.2	2.97	0%	0%	0%	0.0016
1972	44	7.48	100.4	2.74	44	7.48	100.4	2.74	0%	0%	0%	0.0022
1973	44	7.46	98.4	2.80	44	7.46	98.4	2.80	0%	0%	0%	0.0024
1974	29	7.01	76.1	2.93	31	5.69	67.0	2.30	19%	12%	21%	0.0016
1975	21	4.78	63.7	2.53	18	4.84	53.8	3.17	-1%	16%	-25%	0.0013
1976	32	5.46	53.4	2.61	25	4.74	62.0	2.39	13%	-16%	8%	0.0019
1977	71	4.86	54.5	2.46	49	3.52	43.4	2.19	28%	20%	11%	0.0028
1978	78	4.76	49.2	2.68	67	3.81	54.9	1.84	20%	-12%	31%	0.0034
1979	91	3.63	42.1	2.29	98	2.96	32.5	1.95	18%	23%	15%	0.0043
1980	89	2.92	44.7	1.95	53	2.35	31.2	1.74	19%	30%	11%	0.0035
1981	102	3.04	43.1	1.83	78	2.07	26.6	1.70	32%	38%	7%	0.0043
1982	130	2.56	34.8	1.75	107	1.89	25.5	1.42	26%	27%	19%	0.0056
1983	186	2.50	30.9	2.05	151	1.83	24.6	1.47	27%	20%	28%	0.0073
1984	288	2.40	31.3	1.73	238	1.74	21.7	1.57	27%	31%	9%	0.0130
1985	403	1.90	24.1	1.67	367	1.52	19.5	1.37	20%	19%	18%	0.0177
1986	454	1.51	19.5	1.53	471	1.33	17.3	1.38	12%	11%	10%	0.0232
1987	416	1.40	18.8	1.43	353	1.28	16.6	1.25	9%	11%	13%	0.0273
1988	376	1.24	15.1	1.35	361	0.97	11.6	1.10	22%	23%	18%	0.0308
1989	454	0.96	11.9	1.10	507	0.87	10.6	1.00	10%	12%	10%	0.0377
1990	398	0.72	9.0	0.89	478	0.64	7.6	0.81	10%	15%	10%	0.0381
1991	409	0.61	7.5	0.83	481	0.54	7.1	0.77	11%	6%	8%	0.0413
1992	119	0.71	7.4	0.81	122	0.48	6.4	0.72	32%	14%	10%	0.0387
1993	125	0.45	5.4	0.62	53	0.39	5.1	0.63	15%	6%	-1%	0.0462
1994	132	0.42	4.8	0.62	67	0.30	4.0	0.55	27%	17%	11%	0.0516
1995	225	0.40	4.4	0.54	70	0.24	3.3	0.45	40%	26%	16%	0.0610
1996	232	0.29	3.7	0.39	55	0.19	2.5	0.33	37%	32%	15%	0.0563
1997	61	0.27	2.8	0.32	65	0.15	2.0	0.27	45%	30%	16%	0.0667
1998	64	0.20	2.2	0.23	25	0.13	1.6	0.24	38%	27%	-5%	0.0685
1999	79	0.12	1.4	0.18	79	0.12	1.4	0.18	0%	0%	0%	0.0777
2000	59	0.09	1.1	0.14	59	0.09	1.1	0.14	0%	0%	0%	0.0793
2001	65	0.08	0.8	0.09	65	0.08	0.8	0.09	0%	0%	0%	0.0838
2002	18	0.06	0.6	0.08	18	0.06	0.6	0.08	0%	0%	0%	0.0899
Wtd Average	5474	0.70	8.5	0.62	4879	0.59	7.3	0.56	16%	14%	10%	1.000

Notes:
Emission rates for pre-1974 and 1999+ model year vehicles were set equal to each other for the Before ASM and the After ASM samples for the following reasons:
- Pre-1974 model years were exempt from I/M requirements
- 1999 and newer model years were exempt from I/M requirements

- The pre-1974 model year vehicle emission rates and the 1999 and newer model year vehicle emission rates for the Before ASM and After ASM samples were set equal to each other and were based on all vehicles in the 2002 Roadside database. This was done because these vehicles are exempt from the biennial I/M requirements.

- As a result of the above assumptions, the sample sizes for the 1974 through 1998 model year vehicles are consistent with the "Before BAR97 ASM Smog Check Inspection" dataset presented in the July 2000 Smog Check evaluation report (see Tables III-3 and A-2 of that report).

Results of Roadside Data Analysis – Table 2.3 summarizes the fleet-average FTP-based emissions results from the Roadside data analysis described above.

Table 2.3
Fleet-Average FTP Estimates Based on Roadside Data Analysis

Analysis	I/M Scenario	HC	CO	NOx
Current (Based on 2002 and 1999 Roadside Data)	Before ASM (g/mi)	0.700	8.50	0.620
	After ASM (g/mi)	0.590	7.30	0.560
	Percent Reduction	16%	14%	10%

Adjustment for Two-Speed Idle (TSI) Testing in Enhanced Areas - The benefits of ASM testing presented in Table 2.3 assume that all vehicles subject to ASM testing in Enhanced areas actually receive an ASM test. However, there are conditions under which inspectors can perform a TSI test on a vehicle normally subject to ASM testing. Legitimate reasons include vehicles equipped with full-time four wheel-drive, vehicles with traction control that cannot be disabled, and non-enhanced vehicles being tested in enhanced areas, etc. Inspectors may also incorrectly perform a TSI test on 2WD testable vehicles in Enhanced areas. As a result, the benefits of ASM testing summarized in the table need to be adjusted to account for such TSI testing rather than simply applying them to the entire fleet of vehicles operating in Enhanced areas.

The fraction of vehicles receiving TSI tests in Enhanced I/M areas was determined by evaluating both the 2001-2002 Roadside data and the July 2002 Smog Check VID data. Of those vehicles identified as receiving an ASM or TSI test as their Smog Check inspection prior to the 2001 - 2002 Roadside test (1974 - 1978 only), 12% received a TSI test. A check of the July 2002 VID data for Enhanced areas showed similar results, with 14% of non-heavy duty vehicles (which were not subject to ASM testing in 2002) receiving TSI tests; i.e., 86% received an ASM test.

An additional adjustment was also needed to account for legitimate TSI tests performed in the Enhanced areas on vehicles registered in non-Enhanced areas, which are totally excluded from the analysis of Enhanced program benefits. BAR provided April 2003 VID results which included test counts of ASM Exempt Reasons, which showed that 74.1% of TSI tests of non-HDVs in the Enhanced areas was due to the vehicle being registered in Basic or Change-of-Ownership areas. The 14% TSI fraction observed in the July 2002 VID data (a more robust sample) was therefore multiplied by 25.9% to calculate the appropriate TSI adjustment factor of 3.6%.

These results were used to adjust the "After-ASM" results presented previously such that 96.4% of the fleet was assumed to have received an ASM test ("After ASM" in Table 2.3) and 3.6% was assumed to have the same emission rate as the "Before ASM" fleet (i.e., TSI) in the table. This assumption was made because there is not enough information to determine if the vehicles currently receiving TSI tests have significantly different emissions characteristics than vehicles reflected in the TSI baseline developed from the 1999 Roadside data.

The results of the above analysis are presented in Table 2.4, which shows the percentage of non-heavy duty Enhanced area vehicles receiving a TSI test to be small enough so that this adjustment results in no difference in the g/mi results previously presented in Table 2.3 when they are shown to three significant digits. There is a slight change in the calculated percentage reductions, with HC and NOx benefits dropping by one percentage point each.

Table 2.4
Fleet-Average FTP Estimates Based on 2002 Roadside Data Analysis and Adjusted for TSI Testing in Enhanced Areas

Scenario	I/M Scenario	HC	CO	NOx
All Vehicles Receive an ASM Test (from Table 2.3)	Before ASM (g/mi)	0.700	8.50	0.620
	After ASM (g/mi)	0.590	7.30	0.560
	Percent Reduction	16%	14%	10%
96.4% of Enhanced Area Vehicles Receive an ASM Test	Before ASM (g/mi)	0.700	8.50	0.620
	After ASM (g/mi)	0.594	7.34	0.562
	Percent Reduction	15%	14%	9%

2.1.2 Comparison of Roadside and EMFAC2002 Modeling Results

To provide the closest comparison to roadside data, the EMFAC2002* model was run under the "CALIMFAC" mode, and FTP-based emission factors were requested (without temperature, speed, and other correction factors applied). Table 2.5 summarizes the FTP-based fleet-average emissions results from both approaches. Of note in that table is that the emissions estimates, both in terms of fleet-average gram-per-mile emission rates and percent reductions, are relatively consistent between the two very different approaches that were used to estimate the enhanced ASM benefits relative to the basic TSI program. Although the Roadside data show lower fleet-average emissions, the reductions from enhanced ASM testing are very close when comparing the two sets of estimates.

To serve as another comparison point, Figures 2.5, 2.6 and 2.7 show the model-year-specific FTP-based emission rates generated from EMFAC2002 (based on BAR97 I/M) on the same graph as the "After ASM" results from the 2002 Roadside data for HC, CO, and NOx, respectively. Reasonably good agreement is observed in all cases, with the EMFAC2002 model predicted values for HC and CO being higher than the Roadside data in the late-1980s to mid-1990s model years. This is likely a result of improved durability of in-use vehicles that is not reflected in the model. For older model year vehicles (i.e., pre-1980 model year), the Roadside data show higher HC and CO emissions than the EMFAC2002 model predicts.

Table 2.5
Comparison of BAR97 Emissions Benefits in Calendar Year 2002
Based on the Roadside Data Analysis and the EMFAC2002 Model
(FTP-Based Emission Rates)

Analysis	I/M Scenario	HC	CO	NOx
Current Roadside Data Analysis	Before ASM (g/mi)	0.70	8.5	0.62
	After ASM (g/mi)	0.59	7.3	0.56
	Percent Reduction	15%	14%	9%
EMFAC2002 (Passenger Cars; Lt- and Med-Duty Trucks)	Before ASM (g/mi)	0.83	9.5	0.75
	After ASM (g/mi)	0.72	8.1	0.66
	Percent Reduction	13%	15%	12%

*The EMFAC2002 emissions model is described in Part 1 of this document.

Figure 2.5

Comparison of the 2002 Roadside FTP Estimates to EMFAC2002 FTP Estimates
Exhaust HC Emissions With the BAR97 I/M Program

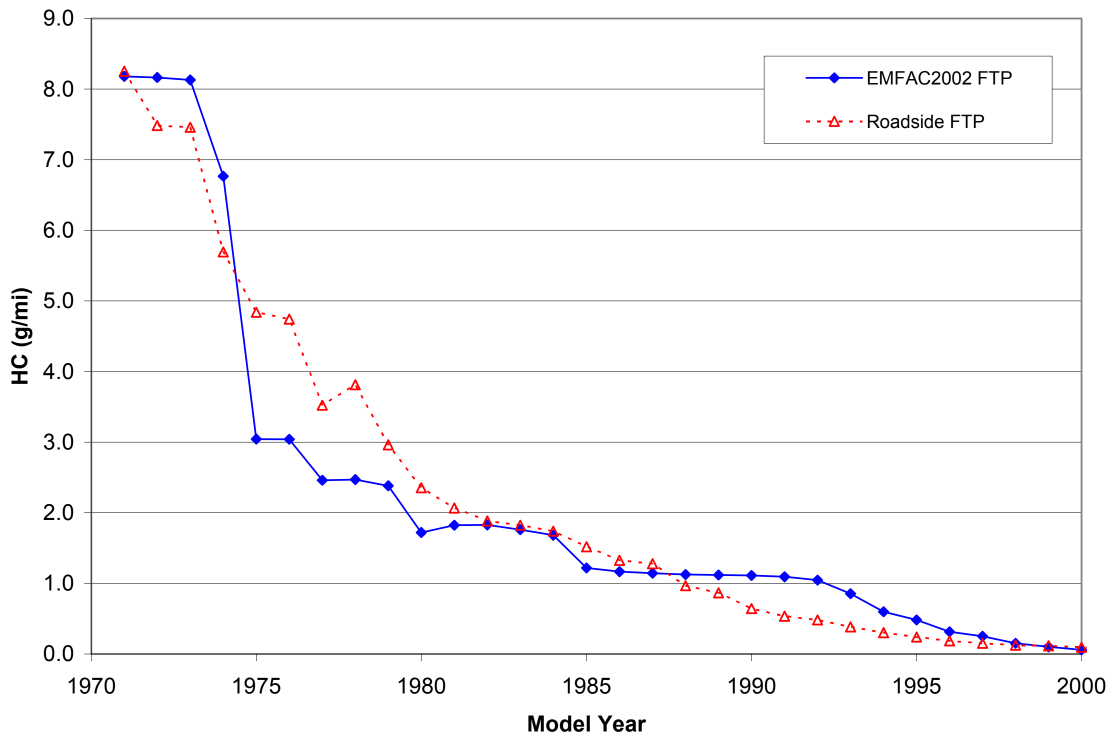


Figure 2.6

Comparison of the 2002 Roadside FTP Estimates to EMFAC2002 FTP Estimates
CO Emissions With the BAR97 I/M Program

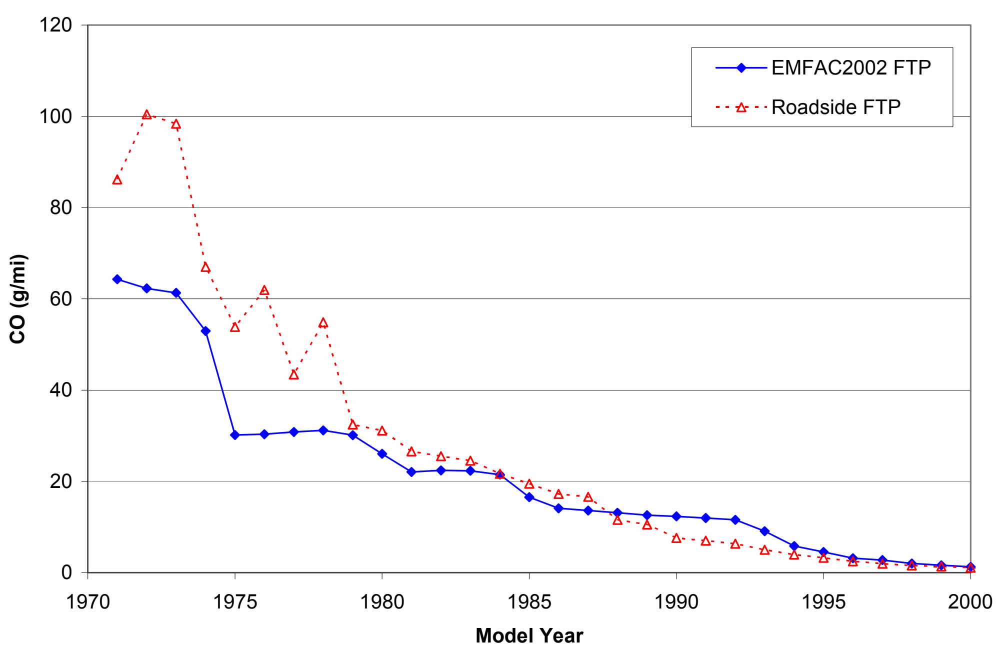
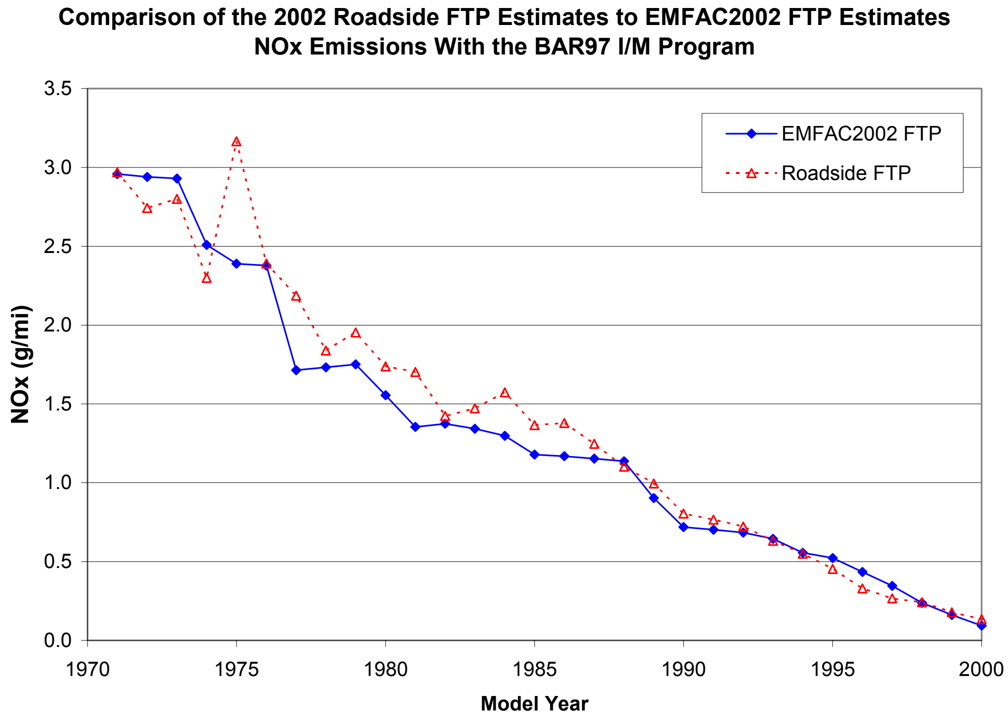


Figure 2.7



2.2 Impact of Exemption of 5 and 6 Year Old Vehicles

As amended by AB2637, Section 44011(a)(4)(B) of the California Health and Safety Code provides for newer vehicles to be exempted from the state's Inspection and Maintenance (I/M) program for an additional two years (for the first six years instead of just four years) beginning January 1, 2004. However, this extension of the model year exemption was contingent upon a finding by the Air Resources Board that it will not prohibit the state from meeting State Implementation Plan (SIP) commitments.

Analysis of currently available data from several different sources was performed to estimate the loss in emission benefits expected to occur as a result of excepting additional new vehicle model years; both exhaust and evaporative emissions impacts were considered in the evaluation. The analysis focused on those areas of the state with Enhanced I/M ASM testing already in place or expected by January 2004 (and thus includes the San Francisco Bay Area).

The results of this analysis are provided in a separate technical support document, dated April 2, 2003, that was developed in support of the Air Resources Board's finding that in order for California to meet its SIP obligations, it would be necessary to exclude Enhanced Smog Check areas from the six-year exemption. The Board also found that exempting five- and six-year old vehicles in Basic Smog Check areas located in severe or extreme federal ozone non-attainment areas from biennial inspections would interfere with the State's ability to meet its SIP commitments. A copy of the separate technical support document is available at http://www.arb.ca.gov/msprog/inusecom/tsdver5.doc.

2.2.1 Predicting the Benefit from Exemption of 5/6 Year Old Vehicles

As a first phase in developing a LEP model, the vehicle lookup table (VLT) row identification (ID) number and overall test result were extracted from ASM test records collected during the period of July 1, 2002 to March 31, 2003. The results were used to determine average failure rate by VLT row ID. This phase included the following analysis steps:

1. The total number of each type of overall result (possible entries are P for pass, F for fail, G for gross polluter, or T for tampered) were counted for each VLT row ID.

2. The number of passes (P), fails (F+G+T), total tests (P+F+G+T), and failure rate [(F+G+T)/(P+F+G+T)] were computed for each VLT row ID.

3. Any VLT row ID with less than 50 total tests was removed from the dataset.

4. All default VLT row IDs (i.e., those that pertain to non-specific test vehicles) were removed from the dataset.

The next phase of the analysis involved the development of a conversion table that would allow the first 10 characters of the vehicle's Vehicle Identification Number (VIN) to be matched to a specific VLT row ID. Using BAR97 data from January 1, 2000 to March 31, 2003, the following analysis steps were performed:

1. VIN and VLT Row ID were extracted from each test record.

2. Records with default VLT row IDs were removed from the dataset.

3. A Vin10 field was added and populated using the first 10 digits of the VIN (VIN stem).

4. The data were grouped by Vin10 and VLT row ID.

5. Records in which more than one VLT row ID was associated with a single Vin10 entry were removed from the dataset, resulting in a completed Vin10-to-VLT Row ID conversion table.

The results of the above analysis phases were then used to develop estimates of the projected loss in HC plus NOx emissions reductions that would occur if an LEP were implemented to "clean screen" five and six year old vehicles. This third phase was done using the following steps:

1. Vehicle records were analyzed to identify the vehicles due for Smog Check inspection in February 2003. This was done by extracting VID records from the DMV_Vehicles table that had a Smog Check inspection due date (SMOG_INSP_DUE_DT) and a DMV registration expiration date (DMV_EXP_DT) equal to this month.

2. The Vin10 entries from the DMV_Vehicles table were matched to the Vin10-to-VLT row ID conversion table created in Phase 2 above. This allowed the VLT row ID for each vehicle identified under Phase 3, Step 1 to be determined from the VIN.

3. The VLT row ID identified for each subject vehicle under Phase 3, Step 2 was matched to the VLT row ID and VLT failure rate dataset developed previously in Phase 1, Step 2.

4. All vehicles from Phase 3, Step 1were sorted in descending order based on the VLT failure rate. The vehicles were then grouped and counted by VLT row.

5. The following equation was used to compute the percent contribution of the vehicles in each VLT row to the overall BAR97 failure rate for the dataset:

$$Percent\ of\ Failures = \frac{N_{VLTRow} \times FR_{VLTRow}}{\sum \left(N_{VLTRow} \times FR_{VLTRow} \right)} \qquad (1)$$

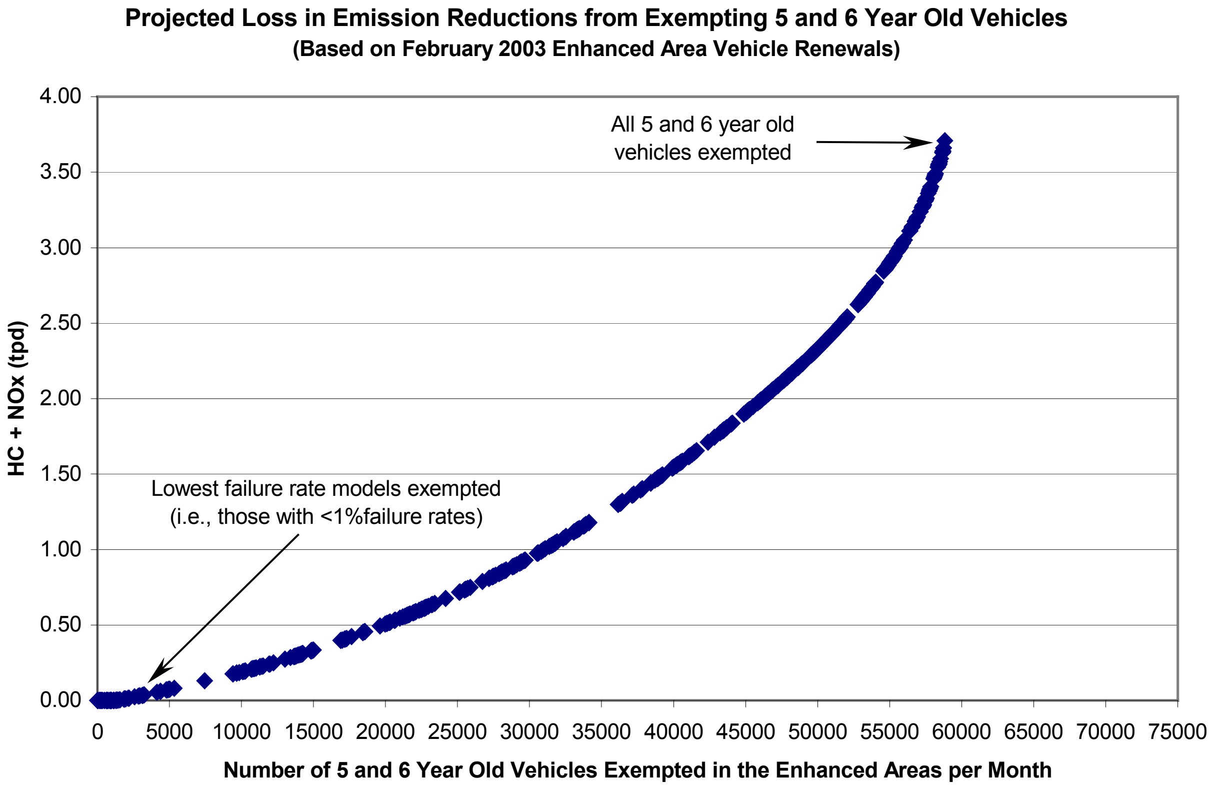
   where: N_{VLTRow} = number of vehicles in an individual VLT row
   FR_{VLTRow} = failure rate of the individual VLT row

6. The percent of failures computed for individual VLT rows were then multiplied by a factor of 3.71* to estimate the tons per day (tpd) of ROG+NOx emissions reductions that would be lost if the vehicles in those rows were exempted from biennial Smog Check inspection requirements.

<u>Results</u> - The above methodology was used by BAR to estimate the loss in emission reductions that could occur in 2005 if five and six year old vehicles are exempted from biennial inspections under a LEP scenario in which the cleanest vehicles are exempted first. Figure 2.8 shows the cumulative impact in 2005 of exempting various numbers of these vehicles.

* As shown in Table 1.5 of http://www.arb.ca.gov/msprog/inusecom/tsdver5.doc, 3.71 tpd is the total loss in ROG+NOx benefits that is projected to occur in 2005 if all five and six year old vehicles are exempted from biennial inspections. This approach implicitly assumes that there would be a proportional loss in benefits from each vehicle exempted under a LEP aimed at the five and six year old vehicles.

Figure 2.8



Reliance on Existing Test Data - Implicit in the above calculation of benefits is that test results from five and six year old vehicles would be available to determine average failure rate by VLT row. However, if these vehicles are being clean screened and not tested, no data would be available for them. The intended approach to this issue is to use change of ownership (COO) inspection data from four year old vehicles* to develop the needed failure rate information that would allow low emitting five and six year old vehicles to be clean screened.

The COO inspection rate has historically been assumed to be 17% on a fleetwide basis. For this analysis, the fraction of newer vehicles that received a COO inspection each year was determined on a model year specific basis to assess the feasibility of using test results from three and four year old vehicles to construct the LEP model for five and six year old vehicles. This was done by comparing the number of initial tests (by model year) found in BAR's "Executive Summary Report" for calendar year 2002 to estimated vehicle population (by model year) from EMFAC2002. Because the newer model year vehicles receiving inspections are not yet subject to a periodic biennial inspection, it was

* This may be supplemented with COO data from three year old vehicles to provide sufficient representative results on a VLT row-specific basis. If the three and four year old data are combined, the three year old results will be "aged" to put all failure rates on a common age basis.

assumed that these vehicles were undergoing a COO inspection. A summary of the results is shown in Table 2.6.

Table 2.6
Fraction of Change of Ownership Inspections for 1-4 Year Old Vehicles

Model Year	Vehicle Age (Year)	EMFAC2002 Population	Smog Check Initial Tests	Percentage Change of Ownership
2002	1	1,467,166	104,434	7%
2001	2	1,447,171	220,950	15%
2000	3	1,440,685	246,075	17%
1999	4	1,470,906	417,603	28%

The Year 3 numbers are consistent with the 17% fleetwide COO rate mentioned above. While the Year 4 COO rate is considerably higher (i.e., 28%), some of these tests are likely to be required biennial inspections due to early compliance of model year 1999 vehicles in 2002. The 17% COO rate is therefore considered an acceptable estimate for 3-4 year old vehicles.

As detailed elsewhere in the Report to the Legislature, it is recommended that two year old and newer vehicles be exempted from COO inspections. It is emphasized that clean screening five and six year old vehicles will be dependent on continuing the COO inspections on three and four year old vehicles to provide a source of the data needed to populate the LEP model. While it might be possible to use test results from another I/M program to populate the model, an increasing number of programs are exempting the first four model years from inspection. This, coupled with concerns regarding the representativeness of non-California test data, means that continuing COO Smog Check inspections for three and four year old vehicles are a necessary component of any effort to clean screen five and six year old vehicles.

2.3 Evaluating Station Performance

This section discusses the methodology used to examine Smog Check station performance. Several statistical techniques are provided that compare the ability of Test-Only and Test-and-Repair stations to properly identify polluting vehicles. In addition, roadside data and Smog Check inspection data are used to evaluate the quality and durability of Smog Check repairs.

2.3.1 Station Ranking Analysis

The first method to evaluate station performance involved the ranking of test stations by their relative performance levels, using a methodology previously developed and used in the June 2000 Smog Check station performance report.[2] This approach ranks stations based on their actual failure rate compared with the expected failure rate. Smog Check test records (VID data) are used to calculate expected and reported failure rates. An individual station's expected failure rate is based on the average failure probability (Fprob) of the set of vehicles tested at the station. The difference between the actual and average failure rate is divided by the standard error of the average failure rate to determine the number of standard deviations between the actual and average failure probabilities.

$$N_\sigma = (F_p - FR) / \text{Std Err} \tag{2}$$

Where:
- F_p = Average expected failure rate at a station
- FR = Actual failure rate at a station
- Std Err = Standard error of the expected failure rate at a station
- N_σ = Station performance ranking

N_σ is used to rank the stations. Stations ranked at the top report failure rates that exceed the average failure rates and thus have negative N_σ values. Stations ranked at the bottom report failure rates that are much lower than average failure rates and therefore have positive N_σ values.

For the current analysis, the station ranking was done using VID data collected from December 2000 through November 2001. Aborted tests, hands-on, and training mode tests (collectively referred to as invalid tests) were eliminated from the dataset. Vehicle-specific failure probabilities were assigned using the latest "Fprob" dataset available at the time of the analysis.

Only initial tests were considered in this ranking. To determine whether tests were the initial test for the inspection cycle, six months of data prior to December 2000 were examined. A test was considered an initial test if there was no other test of the vehicle occurring in the previous six months. Each vehicle could only be considered once in the analysis. For example, if a vehicle appeared once in December 2000, and again in November 2001, only the December event was included in the analysis.

Once the initial tests were identified and all invalid tests removed, the mean of the Fprobs, the standard error of the Fprob, and the failure rate were determined for each station. From this, the ranking metric, N_σ, was calculated using Equation (2). Stations having fewer than 30 initial inspections performed during the analysis period were excluded from the analysis.

Using the ranking metric, stations were grouped into quartiles. The top 25% of the stations, which were the 25% of stations with the lowest N_σ score (these could be negative), were considered the "Best" stations, whereas the 25% of the stations with the highest N_σ score were considered the "Worst" stations. The "Fprob" dataset was provided by ERG and includes Fprob values, vehicle model year, make, model, and engine displacement information decoded from the VIN using a contractor (Eastern Research Group or ERG) supplied VIN-decoder-based application.

Results –The current results were compared to those from the analysis performed for the 2000 station performance report. The top portion of Table 2.7 shows the results of the 2000 analysis. It used the older Fprobs, which were current at the time, and VID data collected in 1999. The bottom portion of the table shows the updated station performance results that were developed in the current analysis.

Table 1.7
Percent of Stations by Rank Using Smog Check Inspection Records
(Based on Data Collected in 1999 and 2001)

1999 Evaluation				
Ranking (Percent)	**Enhanced Test-Only**		**Enhanced Test and Repair**	
	Percent of Stations	**Percent of Vehicles Inspected**	**Percent of Stations**	**Percent of Vehicles Inspected**
0 - 25 (Best)	59.9	12.8	21.2	19.3
25 – 50	21.5	3.6	25.4	17.3
50 – 75	12.3	2.5	26.4	18.1
75 – 100 (Worst)	6.3	1.4	27.0	25.0
All	100.0	20.2	100.0	79.8
2001 Evaluation				
Ranking (Percent)	**Test-Only**		**Test and Repair**	
	Percent of Stations	**Percent of Vehicles Inspected**	**Percent of Stations**	**Percent of Vehicles Inspected**
0 – 25 (Best)	58.1	19.2	19.8	16.2
25 – 50	18.9	4.5	26.1	12.9
50 – 75	12.4	3.0	27.1	14.9
75 – 100 (Worst)	10.6	3.6	26.9	25.7
All	100.0	30.4	100.0	69.6

2.3.2 Repeat Emissions Analysis

The second method used to identify potential improper or fraudulent station performance involved repeat emissions analysis. This approach involved analyzing the degree of similar emissions scores among all test results recorded by each individual emissions analyzer to identify instances of suspected "clean piping" (i.e., fraudulently measuring emissions from a clean vehicle during the testing of a different vehicle in order to falsely pass an otherwise failing vehicle). Statistical cluster analysis was used to identify similar emissions scores and group them for further analysis.

Cluster analysis works by organizing information about variables so that relatively homogenous groups, or "clusters," can be formed. To visualize how cluster analysis works, consider a two-dimensional scatter plot. Cluster analysis will attempt to identify a locus of points by "drawing" circles on the plot in such a way as to fit the maximum number of points within each circle. On a three-dimensional plot, the circle becomes a sphere in order to fit data along all three dimensions. While it becomes increasingly difficult to visualize how this process works as the number of variables increases, cluster analysis can cluster items along many different dimensions.

All four emissions constituents—HC, CO, NOx, and CO_2—were considered relative to each other in the cluster analysis of VID data. Readings from each of the four constituents had to be similar in order for inspection results to be considered similar. The likelihood of this occurring randomly at a much higher frequency at certain stations relative to the overall network average is very low. A high incidence of test results that show similar emissions for all four constituents is therefore considered strong evidence of potential clean piping.

Due to the intensive computing required by the repeat emissions analysis, only two months of VID data were used, June and July 2001. From these data, initial tests were determined using the criteria described above under the station ranking analysis. Since the analysis was focused on test results from June-July 2001, data from the period of December 2000 through May 2001 were used for the initial test determination. All invalid (aborted, hands-on, and training mode) tests were also eliminated from the dataset.

Having identified initial inspections, the next step was to attempt to remove the cleanest vehicles that would tend to produce similar emission results because the emissions would all be near zero, or, in the case of CO_2, near 14.7%. For this reason, 1996 and newer vehicles were eliminated, as were vehicles where HC, CO, and NOx were below 10 ppm, 0.2%, and 10 ppm, respectively.

Using the resulting dataset, the test results were grouped into clusters by emission scores using identically sized clusters. In other words, the size of the cluster was constrained by the relative differences in emission scores rather than the number of inspections within a cluster. As previously mentioned, a cluster contains vehicle inspection results where the emissions for each of the four constituents are similar.

The number of vehicles in a cluster could be set to any amount greater than or equal to one. For this analysis, clusters were considered only if they contained at least four inspections and the total number of inspections within a cluster was greater than 4% of the total number of inspections performed by the station. The latter criterion ensured that stations performing large numbers of inspections, which would naturally have higher numbers of repeat emissions based simply on random variation, would not be improperly identified.

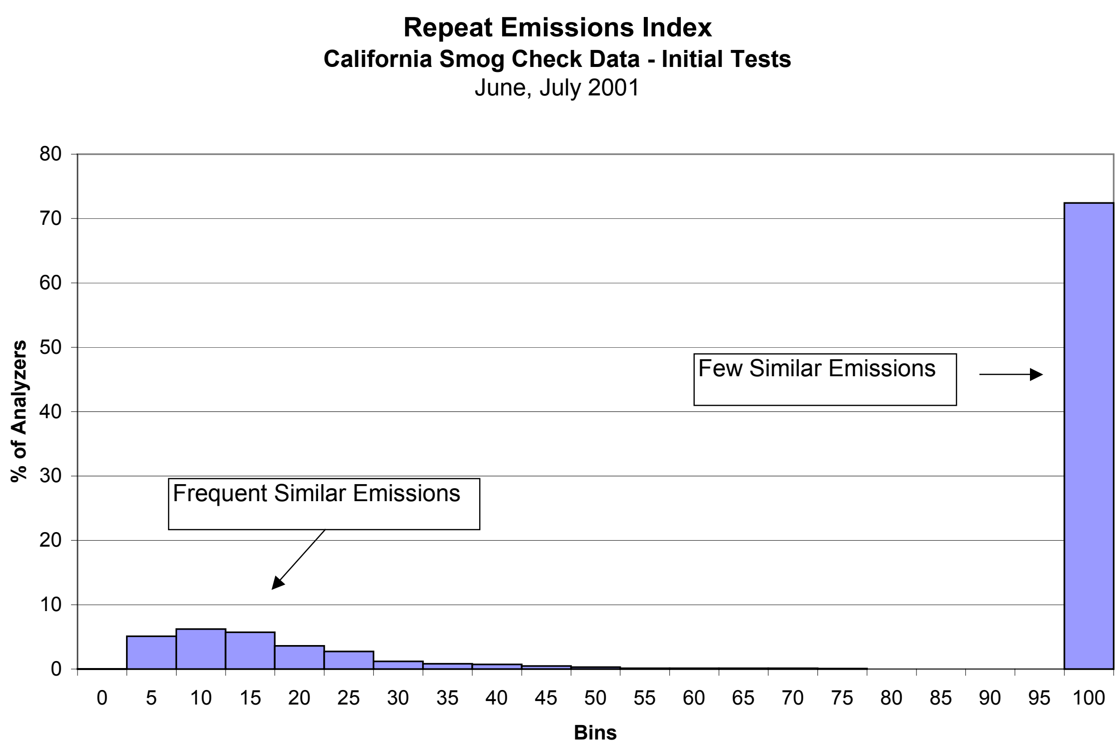
Once the number of significant clusters for each station was determined, index scores were developed to rank the stations from zero to one hundred based upon the number of clusters found according to the following formula.

$$\text{Station Index Score} = [(\text{Max} - \text{Current}) / (\text{Max} - \text{Min})] * 100 \quad (3)$$

Where: Current = Number of clusters for a given station
Max = Number of clusters for worst performing station
Min = Number of Clusters for best performing station

<u>Results</u> – Based on Equation (3), zero represents the station with the greatest number of clusters while 100 represents stations with the fewest number of clusters (zero). Figure 2.9 shows the distribution of index scores resulting from this analysis.

Figure 2.9



The figure shows that, as expected, most (nearly 75%) Smog Check stations report relatively few similar emissions scores, as evidenced by their index scores of 100.

However, the incidence of near-zero index scores is a strong indication that these stations may be engaging in fraudulent clean piping activities.

Table 2.8 compares repeat emissions results to the ratio of the actual/average station failure rate for three performance groupings: those "worst performers" with index scores of less than 15, medium performers that have index scores of 15 to less than 100, and best performers that have index scores of 100. Within each of these groups, actual/average failure rate ratios are shown for Test-and-Repair and Test-Only stations, as well as the combined total of all Smog Check stations.

Table 2.8
Repeat Emissions Index Score versus Actual/Average Failure Rate*

Repeat Emissions Index Rate	Station Type	Fail Rate/ Average Fail Rate	Percent of Station Type
Less than 15 (Worst)	Test & Repair	0.76	20.4
	Test-Only	1.20	1.3
	Total	0.81	
Greater than or equal to 15 and less than 100	Test & Repair	0.88	11.6
	Test-Only	1.16	3.0
	Total	0.88	
100 (Best)	Test & Repair	0.96	68.0
	Test-Only	1.18	95.7
	Total	1.05	
Total		0.99	

*Average Actual Failure Rate / Average Failure Probability

The results shown in the table support the validity of using repeat emissions analysis to identify possible problem stations. Test-Only stations clearly show the best results based on repeat emissions index scores. The distribution of repeat emissions performance among the Test-Only and Test-and-Repair station categories is summarized in Table 2.9.

Table 2.9
Summary of Repeat Emissions Analysis Results

Repeat Emissions Index Rate	Enhanced Test-Only	Enhanced Test and Repair
	Percent of Stations	Percent of Stations
100 (Best)	95.7	66.4
Greater or equal to 15 and less than 100	3.0	12.3
Less than 15 (Worst)	1.3	21.3
All	100.0	100.0

There is also good correlation between the repeat emissions rankings and the ratio of actual to average failure rates, particularly for the Test-and-Repair stations. As shown in Table 2.8 the best, middle, and worst Test-and-Repair stations have respective actual/average failure ratios of 0.96, 0.88, and 0.76. That is, the best performers have the highest average failure rate, while the worst performers have a lower than average failure rate.

While insufficient roadside data are available to further validate the repeat emissions results, the strong correlation between these index scores and station type suggests that the indicator is doing a good job of identifying questionable station performance.

2.3.3 Roadside Data Analysis

The third method used to examine Smog Check station performance involved analyzing test data obtained from the roadside inspection program and comparing the results of that analysis to VID data from official Smog Checks. For this analysis, test results from the roadside dataset were matched with the chronologically nearest test from the VID database for each vehicle.

The roadside data utilized in this analysis were collected from January 2000 to October 2002. The roadside results were separated into two groups. The before-Smog Check group included those vehicles for which roadside test results were available from within one year prior to the Smog Check inspection date. After-Smog Check vehicles included those for which roadside results were available from within one year after the Smog Check inspection date. Failure rates were computed for both groups of vehicles and emissions results were computed for the vehicles included in the after-Smog Check group.

Data within each vehicle sample used in the analysis were weighted to the vehicle model year travel fractions contained in EMFAC2002 to maximize consistency between estimated mass emissions results and projections from the model. The EMFAC2002 travel fractions, split into four model year groupings, are shown in Table 2.10. 1996 and newer models were omitted from the travel fractions and subsequent analysis since there were insufficient roadside data in this model year grouping to produce statistically valid results.

Table 2.10
EMFAC2002 Model Year Travel Fractions
(Model Years 1974 through 1995)

Model Year Group	Weighting
1974-1979	0.033
1980-1986	0.165
1987-1991	0.383
1992-1995	0.419
Total	1.000

Roadside and VID results were then compared using tailpipe (ASM) failure rates and average emissions scores. All ASM emissions scores were converted to an FTP basis for this analysis, using the ASM-to-FTP correlation equations presented in Appendix A, which were described previously.

Average Roadside Emissions Results – Table 2.11 shows the difference between the average emissions of vehicles that pass their initial smog inspection and those that must be repaired to pass the inspection. As noted above, these results were obtained by applying the EMFAC2002-based model year travel fractions in Table 2.10 to the raw roadside test data.

Table 2.11
Average Emission Scores For Roadside Vehicles
Following Their Smog Check Inspection*
(Model Years 1974-1995)

Smog Check Result	FTP HC (g/mi)	FTP CO (g/mi)	FTP NOx (g/mi)
Passing After Initial Failure	1.09	13.53	1.16
Passing Initial	0.76	9.93	0.88
Difference	0.33	3.60	0.28

* Based on roadside vehicles tested between January 2000 and October 2002.

Roadside Versus VID Tailpipe Failure Rates – Roadside tailpipe failure rates were examined relative to recorded VID failure rates in order to gain a better understanding of how failure rates achieved at Smog Check stations compared with those observed in the roadside data. Unfortunately, due to a number of factors such as deterioration in emissions performance over time, pre-inspection repairs, and inconsistent test results, it is difficult to determine what the expected failure rate should have been.

Presumably, roadside tests results occurring before an initial Smog Check would have similar failure rates to the actual Smog Check results. The main source of differences, aside from fraud, would be either pre-inspection repairs that would occur after the roadside inspection, or vehicle emissions deterioration that might occur between the time when the roadside test occurred and the time of the Smog Check inspection.

Similarly, roadside tests occurring after a vehicle passed its Smog Check should be relatively similar to the Smog Check results. Aside from fraud, the principle source of discrepancy would be emissions deterioration occurring after the vehicle passed its inspection.

Overall Smog Check versus roadside failure rates were computed for the 1974-1999 model year test fleet. To better reflect the actual Smog Check test fleet, results were corrected to the model year distribution in the VID database from December 2000 through November 2001 (in lieu of the EMFAC2002 travel fractions). Table 2.12 shows the resulting model year weighting factors, split into five model year groupings, that were used.

Table 2.12
Model Year Weighting Factors from California VID Data, 12/00 through 11/01
(Model Years 1974 through 1999)

Model Year Group	Weighting
1974-1979	0.033
1980-1986	0.153
1987-1991	0.303
1992-1995	0.292
1996-1999	0.218
Total	1.000

* The individual values do not sum up to 1,000 due to rounding

Table 2.13 shows resulting Smog Check versus roadside failure rates for the 1974-1999 model year test fleet. Only records where the roadside test occurred within one year of the I/M test were considered in the analysis.

Table 2.13
Smog Check versus Roadside Tailpipe Failures for All 1974-1999 Model Year Vehicles*
(Roadside Results Within 1 Year of Smog Check Results)

	Count	Smog Check Failure Rate	Roadside Failure Rate
Roadside Before Smog Check	3521	14.1	18.0
Roadside After Smog Check	4661	0.0	15.1

* Results corrected to VID vehicle distribution for 12/2000 through 11/2001.

To be consistent with how pass/fail decisions are made during Smog Check inspections; the results shown in the table are based on the same fast-pass logic as programmed into the BAR97 test systems. This is important since the fast-pass test procedure essentially gives vehicles multiple chances to pass throughout the test (i.e., whenever consecutive10-second average readings for HC, CO and NO are all below the applicable standards). Comparing full duration roadside results to Smog Check inspection results with fast pass enabled could therefore skew this comparison. To avoid this, second-by-second data from the roadside tests were analyzed to determine the failure rates with fast pass enabled.

The table clearly shows large disparities between the Smog Check and roadside failure rates. 15.1% of the vehicles that passed their Smog Check were found to fail a subsequent roadside tailpipe test that occurred within a year of the Smog Check. In addition, there was a failure rate difference of 3.9% (18.0%-14.1%) in vehicles failing a previous roadside test versus when they showed up for their Smog Check.

A potential key contributor to roadside failures among vehicles that had previously passed their Smog Check is in-use emissions deterioration; i.e., defects occur in these vehicles after their Smog Check that cause failing emissions scores at the roadside. Therefore, to better help understand the results shown in Table 2.13 the amount of time in days that transpired between the roadside and Smog Check inspections was analyzed. Presumably, the larger the amount of time that transpired between the tests, the greater the amount of vehicle emissions deterioration that may have occurred. Table 2.14 shows the average time in days between the roadside and Smog Check inspection for the test results used to calculate the failure rates subsequently shown in Table 2.15. Since roadside results had to fall within one year of the Smog Check inspection to be included in the dataset, it makes sense that the average time is in the ballpark of 180 days.

Table 2.14
Average Days between Roadside and Smog Check Inspection
For All 1974-1999 Model Year Vehicles*
(Roadside Results Within 1 Year of Smog Check Results)

	Roadside Before Smog Check	Roadside After Smog Inspection
Average Days	151	169

* Results corrected to VID vehicle distribution for 12/2000 through 11/2001.

However, the 3.9% decrease in failure rate seen between the pre-Smog Check roadside fast-pass results and the actual Smog Check results is directly counterintuitive to the theory that emissions deterioration is the cause of the disparity in the roadside and Smog Check results. While pre-inspection repairs could account for a portion of the difference between pre-Smog Check roadside inspection and the actual Smog Check results, the large disparity in the post-Smog Check roadside inspection and actual Smog Check results appears to reflect a degree of fraudulent testing. In fact, the difference in roadside failure rates between the before and after Smog Check tests is only 2.9%.

To provide additional insight into this issue, the roadside versus Smog Check data were further analyzed by looking strictly at the vehicles that failed their initial I/M inspection from the “Before” sample and those that passed after failing their initial test from the “After” sample. This analysis step thus focused on those vehicles that failed Smog Check and were presumably repaired before being issued an inspection certificate.

Table 2.15 shows the results of this analysis. For the pre-Smog Check group shown in the table, of the vehicles that eventually failed their initial Smog Check, only 69.2% failed their roadside inspection. While this disparity may seem large, it is possible because all of these vehicles supposedly passed their previous Smog Check. Those that fail the subsequent Smog Check might be expected to deteriorate in a linear fashion. As a result, almost three-quarters of the failing vehicles would fail at three-quarters of the way through their biennial inspection cycle.

Table 2.15
Smog Check versus Roadside Tailpipe Failures for Initially Failing
1974-1999 Model Year Vehicles*
(Roadside Results Within 1 Year of Smog Check Results)

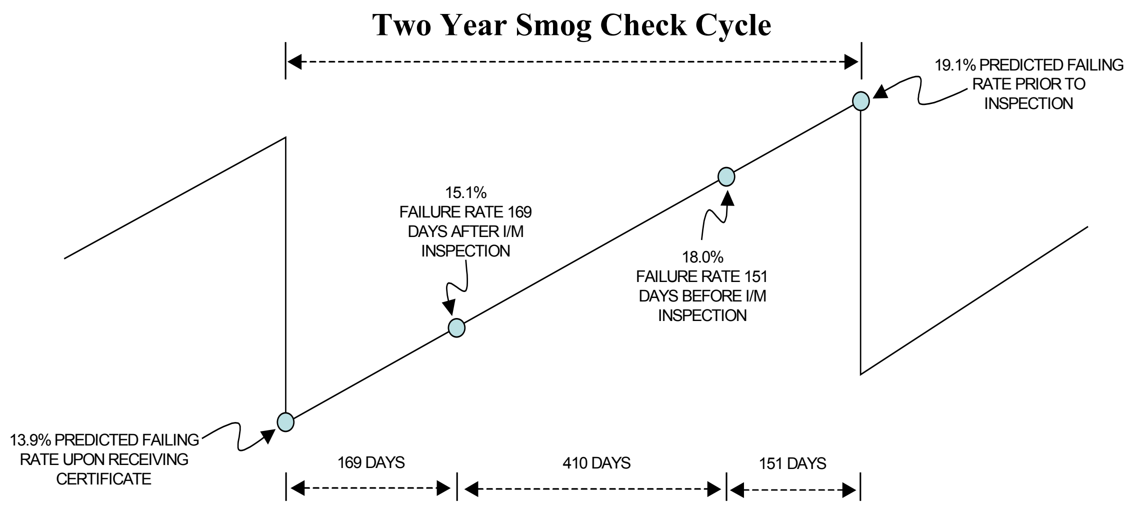
	Count	Smog Check Failure Rate	Roadside Failure Rate
Roadside Before Smog Check	692	100.0	69.2
Roadside After Smog Check	735	0.0	40.4

* Results corrected to VID vehicle distribution for 12/2000 through 11/2001.

In reality, however, not all of the vehicles are repaired at the start of the cycle, as shown by the after-Smog Check results shown in Table 2.15. Of the vehicles that failed their Smog Check and were supposedly repaired, 40.4% failed a roadside inspection that was subsequently conducted within six months on average of the Smog Check. This failure rate appears much higher than can be accounted for by vehicle deterioration, even if it is assumed that repaired vehicles are likely to have significantly higher deterioration rates than passing vehicles.

While unknown factors related to elements such as the actual rate of vehicle emissions deterioration, the amount of pre-inspection repairs that are occurring, and the degree of test fraud among inspection stations remain, an effort was made to estimate what the failure rate should have been at the time of the Smog Check inspection. For this effort, the vehicle deterioration rate was assumed to be linear. Based on this assumption, it is possible to extrapolate the "actual" overall Smog Check failure rate using the roadside failure rates and the amount of time (relative to the biennial inspection cycle) transpiring between the roadside and the I/M test. Figure 2.10 shows the relationship between failure rate and time since/before Smog Check based on the roadside test results. The roadside failure rates (15.1% and 18.0%) and the times between the roadside tests and Smog Check inspections (169 and 151 days) shown in the figure are taken directly from the results contained in Tables 2.13 and 2.14.

Figure 2.10
Variation in Failure Rates over Smog Check Cycle



To estimate the before and after Smog Check failure rate at the time of the Smog Check, a linear extrapolation of the roadside data was performed. Using the observed roadside failure rates (with fast pass enabled) shown in Figure 2.10, the rate of emissions deterioration per day was calculated as follows:

$$\text{Change in Failure Rate / Day} = (18.0 - 15.1) / 410 = 0.00707 \quad (4)$$

The failure rate for vehicles about to get a Smog Check can then be calculated as follows:

$$18.0 + (0.00707 \times 151) = 19.1\% \quad (5)$$

Similarly, the failure rate immediately after Smog Check can be calculated as follows:

$$15.1 - (0.00707 \times 169) = 13.9\% \quad (6)$$

The results of Equations (5) and (6) are respectively shown in Figure 2.10 as predicted failing rates prior to initial inspection in an I/M cycle and upon receiving an I/M certificate at the end of the previous biennial I/M cycle. If the relationship between failure rate and time since Smog Check is truly linear, this could indicate falsified test results. However, it is possible that more of the vehicles actually pass Smog Check after receiving ineffective or partial repairs and then deteriorate rapidly. Regardless of whether the deterioration is linear or non-linear, this analysis suggests that a portion of the vehicles that fail Smog Check are not getting effectively repaired.

2.4 Estimating the Emission Benefits from the Inspection of Smoking Vehicles

Based on testing by Southwest Research Institute (SWRI)[4,] smoking vehicles have average particulate emission rates of 0.27 g/mi during the warmed up portion of the standard exhaust emissions test. In contrast, vehicles in proper repair have particulate emission rates at least 90% lower. Based on the particulate emissions measured in the SWRI study, the benefits of repairing each smoking vehicle would be at least 0.24 g/mi. A 1999 study for the South Coast Air Quality Management District (SCAQMD)[5] indicated that a sample of 18 smoking gasoline vehicles and 5 smoking Diesel vehicles had a particulate emissions rate of 0.35 g/mi on the IM240 test (Diesel and gasoline vehicles had almost exactly the same level of particulate emissions). The study noted that particulate emissions from non-smoking vehicles on the IM240 cycle have been reported to be 0.051 to 0.094 g/mi. Using the high end of this range, the difference in particulate emissions between smoking and non-smoking vehicles is 0.26 g/mi.

The visual survey of on-road vehicles included in the SCAQMD study found that between 1.1 and 1.8% of the light-duty fleet emits some visible smoke, with smoking vehicles primarily consisting of both gasoline and Diesel vehicles that are 8-18 years old. Of the smoking vehicles, 73% were determined to be gasoline-fueled. Based on the 2002 edition of Ward's Motor Vehicle Facts and Figures[6] total passenger car and light truck registrations in California for calendar year 2000 were 26.2 million; 1.1% of this total is 289,000 smoking vehicles. If gasoline vehicles account for 73% of the smoking vehicles, the total number of gasoline-fueled smoking vehicles is 211,000.

Using a conservative estimate that the Smog Check program could cause the repair of 200,000 smoking gasoline-fueled light-duty vehicles driving 30 miles per day, the potential benefits are statewide reductions in particulate emissions of 1.65 tons per day (0.25 g/mi reduction times 30 mi/day times 200,000 vehicles). The repair of smoking vehicles would also be expected to provide some additional reductions in HC, CO, and NOx emissions.

2.5 References

1. Evaluation of California's Enhanced Vehicle Inspection and Maintenance Program (Smog Check II)," Final Report, Air Resources Board, July 12, 2000.
2. "Models for Estimating California Fleet FTP Emissions from ASM Measurements," Final Report, prepared by Eastern Research Group for the Bureau of Automotive Repair, December 17, 1997.
3. "Smog Check Station Performance Analysis (Based on Roadside Test Results)," prepared by dKC and Eastern Research Group, for California Bureau of Automotive Repair, Engineering and Research Branch, June 27, 2000.
4. "Measurement of Primary Exhaust Particulate Matter Emissions From Light-Duty Motor Vehicles," November 1998.
5. Durbin, T.D., Smith, M.R., Norbeck, J.M. and Truex, T.J., "Population Density, Particulate Emission Characterization, and Impact on the Particulate Inventory of Smoking Vehicles in the South Coast Air Quality Management District," J. Air & Waste Management Assoc., 1999, 49(1), 28-38.
6. Ward's Motor Vehicle Facts & Figures 2002, Ward's Communications.

Appendix 2A

Revised ASM-FTP Correlation Equations

As noted in the text of this report, revised correlation equations were developed that predict FTP scores from ASM results. The general methodology followed that developed for the July 2000 evaluation of the Smog Check Program.* One difference, however, is that two sets of equations were developed for the current effort – one based on pre-1990 model year vehicles and the other based on 1990 and newer model year vehicles. The correlations are summarized below, followed by the regression statistics for these correlations.

Pre-1990 Model Year Correlation Equations

```
FTP_HC = 1.2648 * exp( - 4.67052
                      + 0.46382 * hc_term
                      + 0.09452 * co_term
                      + 0.03577 * no_term
                      + 0.57829 * wt_term
                      - 0.06326 * my_term
                      + 0.20932 * trk)

FTP_CO = 1.2281 * exp( - 2.65939
                      + 0.08030 * hc_term
                      + 0.32408 * co_term
                      + 0.03324 * co_term**2
                      + 0.05589 * no_term
                      + 0.61969 * wt_term
                      - 0.05339 * my_term
                      + 0.31869 * trk)

FTP_NOX = 1.0810 * exp( - 5.73623
                      + 0.06145 * hc_term
                      - 0.02089 * co_term**2
                      + 0.44703 * no_term
                      + 0.04710 * no_term**2
                      + 0.72928 * wt_term
                      - 0.02559 * my_term
                      - 0.00109 * my_term**2
                      + 0.10580 * trk)
```

* "Models for Estimating California Fleet FTP Emissions from ASM Measurements," Final Report, prepared by Eastern Research Group for the Bureau of Automotive Repair, December 17, 1999.

where:

```
hc_term = ln( (ASM1_HC*ASM2_HC)^.5 ) - 3.72989
co_term = ln( (ASM1_CO*ASM2_CO)^.5 ) + 2.07246
no_term = ln( (ASM1_NO*ASM2_NO)^.5 ) - 5.83534

MY_Term = model_year - 1982.71

wt_term = ln( vehicle_weight )

TRK = 1 if a light-duty truck
TRK = 0 if a passenger car
```

<u>1990 and Newer Model Year Correlation Equations</u>

```
FTP_HC = 1.1754 * exp( - 6.32723
                       + 0.24549 * hc_term
                       + 0.09376 * hc_term**2
                       + 0.06653 * no_term
                       + 0.01206 * no_term**2
                       + 0.56581 * wt_term
                       - 0.10438 * my_term
                       - 0.00564 * my_term**2
                       + 0.24477 * trk) ;

FTP_CO = 1.2055 * exp(   0.90704
                       + 0.04418 * hc_term**2
                       + 0.17796 * co_term
                       + 0.08789 * no_term
                       + 0.01483 * no_term**2
                       - 0.12753 * my_term
                       - 0.00681 * my_term**2
                       + 0.37580 * trk) ;

FTP_NOX = 1.1056 * exp( - 6.51660
                       + 0.25586 * no_term
                       + 0.04326 * no_term**2
                       + 0.65599 * wt_term
                       - 0.09092 * my_term
                       - 0.00998 * my_term**2
                       + 0.24958 * trk)
```

where:

```
hc_term = ln (ASM1_HC*ASM2_HC)^.5 ) - 2.32393  ;
co_term = ln (ASM1_CO*ASM2_CO)^.5 ) + 3.45963  ;
no_term = ln (ASM1_NO*ASM2_NO)^.5 ) - 3.71310  ;
```

```
MY_Term = model_year - 1993.69;
wt_term = ln( vehicle_weight )

TRK = 1 if a light-duty truck
TRK = 0 if a passenger car
```

For cases in which the HC or NO ASM scores are zero, they are set to 1 ppm; for cases in which the CO ASM score is zero, it is set to 0.01%.

<u>Pre-1990 Model Year Regression Statistics</u>

The REG Procedure
Model: MODEL1
Dependent Variable: ln_HC

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1093.54025	182.25671	577.41	<.0001
Error	1297	409.39250	0.31565		
Corrected Total	1303	1502.93275			

Root MSE	0.56182	R-Square	0.7276
Dependent Mean	0.06770	Adj R-Sq	0.7263
Coeff Var	829.89853		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-4.67052	0.65373	-7.14	<.0001
HC_Term	1	0.46382	0.01970	23.54	<.0001
CO_Term	1	0.09452	0.01306	7.24	<.0001
NO_Term	1	0.03577	0.01356	2.64	0.0085
Wt_Term	1	0.57829	0.08111	7.13	<.0001
MY_Term	1	-0.06326	0.00347	-18.24	<.0001
TRK	1	0.20932	0.03794	5.52	<.0001

Pre-1990 MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL2
Dependent Variable: ln_CO

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	970.89596	138.69942	304.94	<.0001
Error	1296	589.48099	0.45485		
Corrected Total	1303	1560.37696			

Root MSE	0.67442	R-Square	0.6222
Dependent Mean	2.53978	Adj R-Sq	0.6202
Coeff Var	26.55439		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-2.65939	0.78778	-3.38	0.0008
HC_Term	1	0.08030	0.02385	3.37	0.0008
CO_Term	1	0.32408	0.01576	20.57	<.0001
CO_Term2	1	0.03324	0.00581	5.72	<.0001
NO_Term	1	0.05589	0.01641	3.41	0.0007
Wt_Term	1	0.61969	0.09759	6.35	<.0001
MY_Term	1	-0.05339	0.00418	-12.77	<.0001
TRK	1	0.31869	0.04566	6.98	<.0001

Pre-1990 MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL3
Dependent Variable: ln_NOx

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	524.77234	65.59654	332.12	<.0001
Error	1295	255.77379	0.19751		
Corrected Total	1303	780.54613			

Root MSE	0.44442	R-Square	0.6723
Dependent Mean	0.18766	Adj R-Sq	0.6703
Coeff Var	236.81646		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-5.73623	0.50376	-11.39	<.0001
HC_Term	1	0.06145	0.01209	5.08	<.0001
CO_Term2	1	-0.02089	0.00382	-5.47	<.0001
NO_Term	1	0.44703	0.01235	36.18	<.0001
NO_Term2	1	0.04710	0.00452	10.43	<.0001
Wt_Term	1	0.72928	0.06227	11.71	<.0001
MY_Term	1	-0.02559	0.00343	-7.46	<.0001
MY_Term2	1	-0.00109	0.00036841	-2.96	0.0031
TRK	1	0.10580	0.03001	3.53	0.0004

<u>1990 and Newer Model Year Regression Statistics</u>

1990+ MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL1
Dependent Variable: ln_HC

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	281.90354	35.23794	167.72	<.0001
Error	621	130.46828	0.21009		
Corrected Total	629	412.37182			

Root MSE	0.45836	R-Square	0.6836
Dependent Mean	-1.49075	Adj R-Sq	0.6795
Coeff Var	-30.74692		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-6.32723	1.01565	-6.23	<.0001
HC_Term	1	0.24549	0.01782	13.77	<.0001
HC_Term2	1	0.09376	0.00876	10.70	<.0001
NO_Term	1	0.06653	0.01206	5.52	<.0001
NO_Term2	1	0.01206	0.00494	2.44	0.0150
Wt_Term	1	0.56581	0.12551	4.51	<.0001
MY_Term	1	-0.10438	0.00835	-12.50	<.0001
MY_Term2	1	-0.00564	0.00221	-2.55	0.0110
TRK	1	0.24477	0.04993	4.90	<.0001

1990+ MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL2
Dependent Variable: ln_CO

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	279.65432	39.95062	135.81	<.0001
Error	622	182.96667	0.29416		
Corrected Total	629	462.62098			

Root MSE	0.54236	R-Square	0.6045
Dependent Mean	1.09071	Adj R-Sq	0.6000
Coeff Var	49.72596		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	0.90704	0.03971	22.84	<.0001
HC_Term2	1	0.04418	0.01098	4.02	<.0001
CO_Term	1	0.17796	0.02229	7.98	<.0001
NO_Term	1	0.08789	0.01374	6.39	<.0001
NO_Term2	1	0.01483	0.00582	2.55	0.0110
MY_Term	1	-0.12753	0.01029	-12.40	<.0001
MY_Term2	1	-0.00681	0.00262	-2.60	0.0096
TRK	1	0.37580	0.04756	7.90	<.0001

1990+ MY Vehicles
Humidity Corrected NOx Values

The REG Procedure
Model: MODEL3
Dependent Variable: ln_NOx

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	302.70933	50.45155	224.16	<.0001
Error	623	140.21962	0.22507		
Corrected Total	629	442.92894			

Root MSE	0.47442	R-Square	0.6834
Dependent Mean	-1.00840	Adj R-Sq	0.6804
Coeff Var	-47.04652		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-6.51660	1.04669	-6.23	<.0001
NO_Term	1	0.25586	0.01166	21.94	<.0001
NO_Term2	1	0.04326	0.00501	8.63	<.0001
Wt_Term	1	0.65599	0.12926	5.08	<.0001
MY_Term	1	-0.09092	0.00810	-11.22	<.0001
MY_Term2	1	-0.00998	0.00228	-4.38	<.0001
TRK	1	0.24958	0.05150	4.85	<.0001

Appendix 2B

EMFAC2002 Calendar Year 1999 and Calendar Year 2002 Emission Factors and Ratios Used to Forecast the "1999 Before ASM" Roadside Data to a Calendar Year 2002 Basis

	CY 1999 Emission Factors (g/mi)			CY 2002 Emission Factors (g/mi)			CY2002/CY1999 Ratios		
MYR	HC	CO	NOX	HC	CO	NOX	HC	CO	NOX
1974	6.7725	56.4781	2.6857	6.9646	57.1811	2.5865	1.028	1.012	0.963
1975	3.2843	33.8806	2.6708	3.4767	34.8401	2.6071	1.059	1.028	0.976
1976	3.2821	34.0682	2.6568	3.4712	35.0540	2.5936	1.058	1.029	0.976
1977	2.7866	35.8303	1.9040	2.8884	37.2258	1.8811	1.037	1.039	0.988
1978	2.7875	36.2720	1.9238	2.9049	37.5453	1.9027	1.042	1.035	0.989
1979	2.6688	34.8167	1.9423	2.8015	36.0398	1.9169	1.050	1.035	0.987
1980	2.0780	31.6443	1.7858	2.0816	31.7817	1.7895	1.002	1.004	1.002
1981	2.2995	27.8516	1.6037	2.4027	28.1250	1.6166	1.045	1.010	1.008
1982	2.2649	28.1308	1.6089	2.3795	28.5167	1.6253	1.051	1.014	1.010
1983	2.1904	27.9615	1.5791	2.3051	28.4482	1.5983	1.052	1.017	1.012
1984	2.0936	27.0603	1.5504	2.2340	27.5887	1.5739	1.067	1.020	1.015
1985	1.4737	19.8008	1.3558	1.5253	20.7302	1.4121	1.035	1.047	1.042
1986	1.4072	16.4931	1.3024	1.4741	17.4210	1.3842	1.048	1.056	1.063
1987	1.3686	15.6993	1.2651	1.4450	16.7384	1.3547	1.056	1.066	1.071
1988	1.3318	14.9322	1.2255	1.4191	16.1538	1.3245	1.066	1.082	1.081
1989	1.2744	13.8375	0.9742	1.3884	15.1668	1.0612	1.089	1.096	1.089
1990	1.1984	13.1702	0.7775	1.3626	14.6061	0.8576	1.137	1.109	1.103
1991	1.1013	12.6712	0.7424	1.3327	14.1666	0.8345	1.210	1.118	1.124
1992	1.0034	12.1304	0.7026	1.2894	13.6857	0.8082	1.285	1.128	1.150
1993	0.7907	9.3548	0.6333	1.0506	10.7411	0.7454	1.329	1.148	1.177
1994	0.5243	5.7396	0.5181	0.7295	6.8987	0.6254	1.391	1.202	1.207
1995	0.3943	4.2177	0.4630	0.5791	5.4100	0.5773	1.469	1.283	1.247
1996	0.2269	2.1779	0.3688	0.3326	3.2523	0.4591	1.466	1.493	1.245
1997	0.1786	1.9196	0.2954	0.2714	2.9028	0.3724	1.520	1.512	1.261
1998	0.1194	1.5484	0.2129	0.1745	2.2130	0.2717	1.461	1.429	1.276