Evaluation of the Enhanced Smog Check Program:

A Report to the California Inspection and Maintenance Review Committee

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June 19, 2000

Acknowledgements

We would like to acknowledge the following for their support:

David Amlin, Kathy Runkle, Mark Duewel, Jose Lopez-Alvarez, Steve Gould, and Greg Sweet of the Bureau of Automotive Repair for providing us with Smog Check test result data and helping us interpret those data.

Don Stedman of the University of Denver, Ian Stedman, and Lindy Heidt, Bruce Loucks, and Matt Ryan of Environmental Systems Products for collecting and supplying us with remote sensing data.

Chris Terwilliger of the Department of Motor Vehicles and Gary Occhiuzzo of the California Energy Commission for facilitating our use of vehicle registration data.

Sandeep Kishan and Andrew Burnette of Eastern Research Group for providing us data on ASM/FTP emissions testing and helpful comments on our analysis.

Lynn Scarlett, Joel Schwartz, Elizabeth Deakin, and Steven Moss of the IMRC for thoughtful comments and suggestions on our analysis.

Mithra Moezzi and Tyler Cole of LBNL for assistance in analyzing the VID and roadside emissions data.

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Summary

S.1. Objectives

The Inspection and Maintenance Review Committee (IMRC) created by the California State Legislature has contracted with researchers from Lawrence Berkeley National Laboratory and the University of California at Berkeley to evaluate California's current vehicle inspection and maintenance (or I/M) program, referred to as Enhanced Smog Check. The IMRC has requested answers to the following questions:

- How effective is the Enhanced Program in initially reducing vehicle emissions?
- To what extent do reductions persist with time after the test?
- To what extent are motorists avoiding program requirements?
- What are the overall emissions benefits of the program?
- What other factors affect emissions reductions?
- Is there a difference in effectiveness between test-only and test-and-repair stations?
- How effective is the High Emitter Profile in targeting high-emitting vehicles?
- What effect would changes to the program have on program effectiveness?

The IMRC requested an analysis of all relevant and available data, emphasizing the data and analyses that provide reliable results to aid in program evaluation and recommendations for program improvements. This report details the results of our efforts to answer these questions.

Our analyses focus on how Smog Check impacts *exhaust* emissions of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) from the light-duty vehicle fleet reporting for Enhanced Smog Check testing. Program effects on evaporative HC emissions and on trucks greater than 8,500 pounds are not analyzed in this report due to lack of appropriate data on these aspects of the program.

S.2. Findings

This report provides detailed analyses of various elements of the Enhanced Smog Check Program, such as the short-term durability of repairs, the degree of program avoidance, effectiveness by station type, and an estimate of the number of unrecorded pretests. These analyses will help the IMRC make specific recommendations to the California Legislature and Governor on how to improve the effectiveness of the program. In addition, we provide estimates of the actual emissions benefits of the program. Our findings include the following:

- The Enhanced Program achieves substantial emission reductions, the vast majority of which last for at least one year for vehicles that fail, then pass their Enhanced Smog Check (Figure 4, page 15).

- Average HC and CO emissions of vehicles that pass their initial Enhanced Smog Check increase steadily and substantially over the next 6 months and then level off (Figure 6, page 16).

- Average emissions of the overall fleet are reduced by 5% for HC and NOx, and 20% for CO, up to two months after Enhanced Smog Check testing. However, the emissions increase from vehicles that pass their initial test counters the lasting emissions reductions from vehicles that fail initial testing but pass a retest. The result is that four months after completing Smog Check, fleet HC and CO emissions are higher than they were prior to Smog Check (Figure 7, page 17). Emissions would be even higher in the absence of the program.

- We estimate that a single two-year cycle of the Enhanced Smog Check Program prevents *tailpipe exhaust* emissions of approximately 86 tons per day of HC, 1,686 tons per day of CO, and 83 tons per day of NOx from the motor vehicle fleet, based on measurements made under Smog Check test conditions (Table 3, page 34). Based on uncertainties in the value of several key parameters required to generate our estimates, actual benefits could be as low as 40, 864, and 59 tons per day, or as high as 116, 2,235, and 93 tons per day respectively of HC, CO, and NOx. (Table 4, page 36). These results are summarized in the table below.

Estimated Enhanced Smog Check Tailpipe Emission Reductions in Tons Per Day. Lower- and Upper-Bound Estimates Reflect Uncertainties in Parameters Necessary to Calculate Benefits.

	HC	CO	NOx
Lower Bound	40	864	59
Best Estimate	**86**	**1,686**	**83**
Upper Bound	116	2,235	93

- Repair of vehicles that fail an initial Smog Check appears to be the most important mechanism of emission reductions, but maintenance and repairs prior to official Smog Check tests also appear to contribute significant benefits. Benefits from removal of non-passing vehicles appear to be much smaller. (Figures 11 to 13, pages 33 and 34)

- More than 90% of all emission reduction benefits can be attributed to vehicles more than 10 years old, even though such vehicles represent only half of those tested in the program. (Figure 14, page 35).

- The Enhanced Smog Check Program appears to achieve substantial emission reductions beyond those of Basic Smog Check. These include the prevention of roughly 50 to 55 tons per day of HC exhaust, 800 to 950 tons per day of CO exhaust, and 25 to 80 tons per day of NOx exhaust emissions vehicles in Enhanced areas (Tables 1 and 2, page 29).

- Older vehicles that are currently exempt from the Enhanced Program account for 4% to 8% of total on-road emissions, depending on the pollutant (Table 9, page 46).

- Roadside emissions tests indicate that the Enhanced Program is reducing fleet emissions by 17% for HC, 28% for CO, and 9% for NOx.

- An initial, limited remote sensing study suggests a much smaller emissions reduction benefit than is measured under program test conditions or at roadside. The remote sensing data indicate that lasting program benefits can be seen on-road for 6 to 9 months for HC and CO, but for just the first 3 months for NOx (Figure 8, page 20). A much larger remote sensing study should be conducted for on-road validation of emissions reduction benefits measured under test conditions.

- Ten percent of vehicles failing their initial test (1.3% of all vehicles) never receive a passing test. These vehicles have HC emissions 81% higher, and NOx emissions 15% higher, on average, than vehicles that eventually pass their Smog Check test. About one-third of these vehicles were observed driving in Enhanced areas one year after testing. This degree of non-compliance is less than observed in the Phoenix I/M program.

- An additional 5% to 10% of vehicles observed on road are registered in Enhanced areas and eligible for Smog Check testing, but there is no record of them reporting for testing. More research is needed to better quantify the number of vehicles avoiding Smog Check testing altogether.

- Analysis of Smog Check test data indicate that Test-Only stations and Gross Polluter Certification stations, a type of Test-and-Repair station, are equally effective in reducing emissions of Gross Polluter vehicles (Figure 17, page 43).

- Other types of Test-and-Repair stations appear to achieve lower fleet emissions reductions than those achieved at Test-Only stations. However, it is not clear that this is because Test-Only stations are inherently more effective at identifying high-emitting vehicles and ensuring that they are repaired. The data indicate that two other possible causes are that: (1) the vehicle fleet reporting to Test-Only stations has higher initial emissions than the fleet reporting to Test-and-Repair stations, and (2) Test-Only stations have been more closely monitored than Test-and-Repair stations. The latter possibility is supported by the finding that Gross Polluter Certification stations and Test-Only stations, both of which are more closely monitored by BAR than are other stations, are equally effective in reducing emissions from Gross Polluter vehicles.

- Based on Smog Check emissions levels and failure rates of HEP and non-HEP vehicles, the high emitter profile does no better at identifying high-emitting older vehicles, and does slightly better at identifying high-emitting newer vehicles, than random selection (Figure 18, Page 45).

- The vehicle emissions data used to generate the HEP are now several years out of date. New data might improve HEP performance. In addition, it is possible that directing motorists to test-only stations using the HEP changes motorists' behavior, resulting in program avoidance that lowers the apparent effectiveness of the HEP.

S.3. Data

We use three independent sets of vehicle emissions measurements in our evaluation. Each data source has unique strengths and weaknesses, and can best be used to answer different questions about program effectiveness. Using multiple data sources reduces uncertainty and strengthens our analysis. Program elements are analyzed primarily using the database of all Smog Check test records, known as the Vehicle Information Database, or VID. Other data sources include roadside Smog Check tests performed by the Bureau of Automotive Repair through random roadside pullovers, and on-road remote sensing emission measurements performed by the University of Denver and Environmental Systems Products.

The VID data are valuable because they include emissions data for the entire population of vehicles participating in Enhanced Smog Check. This inclusiveness, along with the large number of vehicles measured, provides unbiased samples for comparing sub-groups within the overall fleet. However, the VID may include biased emission measurements resulting from the "fast pass" system[1] and technician behavior.[2] Additionally, the VID as a whole includes a "regression to the mean" bias as vehicles that fail their initial test are re-tested until they pass, whereas vehicles that pass their initial test are not re-tested. VID emissions data are also limited to special test conditions that may not reflect average emissions during on-road driving. The VID data are used to evaluate the durability of repairs, emissions deterioration of vehicles that pass an initial Smog Check, the degree of program avoidance, effectiveness by station type, effectiveness of the High Emitter Profile, and to develop estimates of overall program benefits (exhaust emission reductions) by model year.

Roadside data were collected at sites that could accommodate the spatial needs of the test equipment and pullover process, in randomly selected neighborhoods within Enhanced Smog Check areas. Roadside data are used to estimate the overall benefits of the Smog Check Program on fleet emissions, including benefits derived from maintenance and repair prior to any official Smog Check test or pretest, i.e., benefits that cannot be assessed with VID data only. Roadside data are also not subject to the measurement biases of Fast Pass and technician behavior. However, the sample of vehicles measured in roadside testing may not be representative of the entire population of vehicles participating in California's Enhanced Smog Check Program. Further sampling bias may result when the roadside vehicles are grouped according to their last Smog Check prior to roadside testing (Basic or Enhanced), or by vehicle age. Roadside emissions data are also limited to the special vehicle operating conditions of the Smog Check test. Because of the time, equipment, and personnel expenses involved in roadside testing, too few measurements were made to use the data for an analysis of program elements or to evaluate separately the emission benefits to vehicles that fail, then pass their Smog Check. Roadside data are used primarily to evaluate incremental benefits of the Enhanced Program relative to the Basic Program overall program effectiveness at reducing emissions and non-compliance rates.

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1. Smog Check emission tests are automatically ended once a vehicle maintains emissions below the failure standard for at least 10 seconds.
2. Some Smog Check technicians may attempt to "help" vehicles pass with special conditioning procedures. Fraudulent failing of vehicles to encourage repair and improper passing of vehicles, e.g. by using a known clean vehicle in place of a suspected failing vehicle would also bias test data in the VID.

Remote sensors use the same analytical technique as the Smog Check test equipment to measure HC and CO emissions, but measure pollutant emissions as vehicles are driving by on the road. Information about the vehicles is obtained by matching the vehicle license number to Department of Motor Vehicles registration data, and to the VID. Remote sensing data are valuable because emissions are measured directly under on-road driving conditions from almost the entire fleet of vehicles passing by the sampling site. However, since each vehicle is measured for only a fraction of a second, large numbers of vehicles must be measured in order to generate relatively precise fleet-average emission estimates. For this study, remote sensing data were available from a limited number of sites in Enhanced Smog Check areas. We analyzed data from three sites in the greater Los Angeles area, which might not represent the entire population of vehicles participating in Enhanced Smog Check. Nevertheless, sub-groupings of the vehicle sample, e.g. by time since last Smog Check or "Enhanced-tested" vs. "Basic-tested", are each representative of the overall sample, and can thus be compared to each other without bias. However, the precision of the results depends on the number of measurements available. Remote sensing data are used to estimate overall program effectiveness, average fleet emissions as a function of time since Smog Check, and to evaluate non-compliance rates.

S.4. Methods

The VID-based analysis of program elements generally compares failure rates and emissions of subgroups of vehicles, by model year, during their initial Smog Check test, including official "pretests", and during their final passing tests. Analysis of repair durability in vehicles that fail their initial Smog Check then pass a retest, ostensibly after repair, is accomplished using data from vehicles with more than one Smog Check cycle during a 13-month period (one of the two Smog Check cycles is presumably for change-of-ownership). Initial emissions on the second cycle are compared to emissions on the first cycle, which occurred from one to thirteen months prior. The same method is used to estimate deterioration among the fleet of vehicles passing their initial Smog Check.

Overall benefits of a single 2-year Smog Check cycle are calculated using a combination of the roadside and VID data. Benefits are calculated using a bottom-up approach in which average emission reductions per-vehicle are multiplied by the total number of vehicles affected. Separate estimates are made for benefits from pre-inspection maintenance and repairs, post-failure repair, and removal of vehicles that do not pass Smog Check. The roadside data allow for an estimate of pre-inspection benefits, whereas the VID data provide important information on deterioration following Smog Check and benefits from post-failure repair. The roadside data are also used to estimate the incremental effects of the Enhanced Program relative to the Basic Program. Estimating benefits required assumptions about the rate at which emissions of failing vehicles would continue to deteriorate in the absence of Smog Check, and deterioration of repair benefits in the second year following an Enhanced Smog Check cycle. We provide best estimates of these processes, and assess the effect of our assumptions on estimates of program benefits based on lower and upper bound estimates on the assumed parameters. Our estimates depend on emission reductions measured under ASM test conditions, which likely differ from actual on-road emission reductions. Although we use standard techniques to estimate on-road emissions from Smog Check test emissions, these estimates include significant uncertainties.

S.5. Recommendations for additional work

The analyses and results presented herein are aimed at providing answers to the technical questions posed by the IMRC. The work is not intended to be exhaustive. There are many important issues that could not be fully addressed given the data and time available. Specific uncertainties and limitations are described throughout the report. The analysis of program elements, including the emission trends over time of initially failing and initially passing vehicles, assessments of non-compliance rates, comparisons of test station effectiveness, and the relative emission reduction benefits by model year, are the strongest, most certain results. As described in detail in the report and appendices, estimates of overall program benefits are limited in scope and inherently uncertain. Benefits are estimated only for exhaust emission reductions during a single two-year Smog Check cycle, with a focus on emission reductions during hot-running vehicle operation. Benefits are estimated for the Smog Check Program as implemented under relatively loose NOx emission standards (Phase 3 cut points). Stricter NOx emission standards that were put in place in November 1999 may significantly increase NOx emission reduction benefits. Our analysis does not address evaporative emissions or benefits that extend beyond a 2-year Smog Check cycle because no data were available with which to address these factors.

Additional research on the Smog Check Program should include the following:

- Additional study of program avoidance, including non-registration and fraudulent "re-registration" outside of Enhanced areas while still living and driving in Enhanced areas.
- Ongoing analysis of VID data to assess long-term persistence of repair benefits, station performance, and vehicle attrition rates.
- Systematic studies of Smog Check fraud rates and the degree to which fraud reduces potential program benefits.
- An extensive remote sensing data collection effort (i.e., more than a million vehicles measurements in various areas of the state) should be undertaken to provide on-road data to address program avoidance, persistence of repair benefits, and station performance.

1. Introduction

The Inspection and Maintenance Review Committee (IMRC) of the California State Legislature has contracted with researchers at Lawrence Berkeley National Laboratory and University of California at Berkeley to perform an evaluation of the California's Enhanced vehicle inspection and maintenance (or I/M) program, referred to as Smog Check. The IMRC has requested answers to the following questions:

- How effective is the Enhanced Program in initially reducing vehicle emissions?
- To what extent do reductions persist with time after the test?
- To what extent are motorists avoiding program requirements?
- What is the overall emissions benefit of the program?
- What other factors affect emissions reductions?
- Is there a difference in effectiveness between test-only and test-and-repair stations?
- How effective is the High Emitter Profile in targeting high-emitting vehicles?
- What effect would changes to the program have on program effectiveness?

In addition, the IMRC requested estimates of what effect changes to specific elements of the program would have on the effectiveness of the program. This report summarizes our findings regarding the effectiveness of the Enhanced Smog Check Program in reducing vehicle emissions and these related questions.

Section 2 provides background on in-use vehicle emissions and general evaluation of I/M programs. Section 3 describes the different sources of data we used in our evaluation, and summarizes the advantages and disadvantages of each. Section 4 summarizes the major findings of our evaluation of California's program. More detail on these findings is provided in the attached appendices. Section 5 estimates what effect changes to the program would have on the emissions benefits we estimate for the program. We summarize the conclusions from our evaluation in Section 6. A list of recommended areas for further research is included as Section 7. More detail on the methods we used in our analysis is included in the Appendices.

2. Background

In this section we provide background on the factors that affect vehicle emissions over time, and how these factors complicate the evaluation of any I/M program. Then we list the many elements of an I/M program that contribute to the overall effectiveness of the program in reducing vehicle emissions. Next we briefly discuss an idealized view of how an I/M program is supposed to work, followed by some special issues that are critical to the evaluation of I/M programs. Finally we summarize the important elements of California's Enhanced Smog Check Program.

2.1. Factors affecting in-use fleet emissions

Several factors affect in-use emissions of the vehicle fleet over time. For a given fleet of vehicles, emissions increase over time from two causes: (1) emissions of properly functioning vehicles increase gradually as vehicles age and accumulate mileage, and (2) emissions controls on some vehicles break, malfunction, or are tampered with, leading to sharp increases in emissions. However, this increase in emissions from vehicle deterioration and malfunction is offset by fleet turnover. Fleet turnover comprises three trends: (1) older technology vehicles, built to more lenient emissions standards, are removed from the fleet over time, (2) newer technology vehicles, built to more stringent emissions standards, enter the fleet over time, and (3) vehicles subject to different standards and regulations migrate in from other states and areas. The first two of these trends decrease overall fleet emissions, while the last trend may increase fleet emissions slightly. The presence of an I/M program may hasten fleet turnover compared to that which would have occurred otherwise. Finally, other factors, such as environmental conditions (ambient temperature and humidity), fuel composition, differences in vehicle models, driver behavior, vehicle maintenance, and miles traveled per vehicle, affect the emissions of individual vehicles. Changes in these factors can affect fleet emissions as well. For example, an increase in vehicle miles traveled will increase fleet emissions over time, and seasonal temperature variations can affect fleet emissions rates. These factors must be considered when trying to isolate the effect of an I/M program on fleet emissions. Emissions inventory models, such as EMFAC, combine estimates of program effectiveness with assumptions about vehicle fleet turnover to forecast fleet emissions over time.

2.2. Elements of I/M program effectiveness

Many elements of I/M programs can influence how effective the program is in reducing vehicle emissions. These elements vary from program to program. A comprehensive program evaluation would attempt to estimate the effect of each of these program elements.

- Which pollutants and processes are measured? For example, some states that do not have severe ozone problems do not fail vehicles for exceeding NOx cut points (e.g. Colorado). And most states do not measure evaporative HC emissions directly, but rely on visual inspections of the evaporative emissions controls.
- Which vehicles are targeted? Most states exempt the newest and oldest model years from testing. Some states identify special classes of vehicles, such as High Emitter Profile and Gross Polluter vehicles in California, for special treatment.

- How often are vehicles tested? Some states require testing every year, while others require testing only every other year. California requires vehicles to be tested again when they are sold. Arizona requires that vehicles with high emissions as measured by remote sensors must come in for additional testing and, potentially, repairs. The frequency of the testing will affect how long it takes to identify vehicles with emissions control failures.
- To what extent do motorists perform adjustments and/or repairs to their vehicles prior to the I/M test? And would these adjustments or repairs have occurred in the absence of an I/M program? A survey in Arizona found that one-third of all drivers bring their vehicle in for a tune-up prior to I/M testing. However, it is not clear how many of these tune-ups were induced by the I/M program.
- How effective are the test, and test stations, at identifying high emitters? Different test procedures may be more accurate in identifying vehicles with high on-road emissions. Stations that only test vehicles, and are not allowed to perform repairs on failing vehicles, may be more effective at identifying high emitters. And individual stations may do a better job of diagnosing and fixing the causes of high emissions.
- How long does it take for a vehicle to be repaired and/or pass the test? Failing vehicles that take a long time to be repaired reduce the effectiveness of the I/M program.
- How effective are repairs in reducing emissions, as measured immediately after failing vehicles pass a retest? Do the repairs address the underlying causes of the high emissions?
- How long do the repairs last?
- To what extent are motorists avoiding program requirements (such as vehicles avoiding initial testing, or getting a Basic rather than a required Enhanced test)? How many of the vehicles that never pass continue to be driven in the I/M area?
- How motivated are motorists and technicians to comply with program requirements? To what extent does the program provide incentives to encourage compliance?
- What effect does granting repair cost waivers have on the potential program benefit?

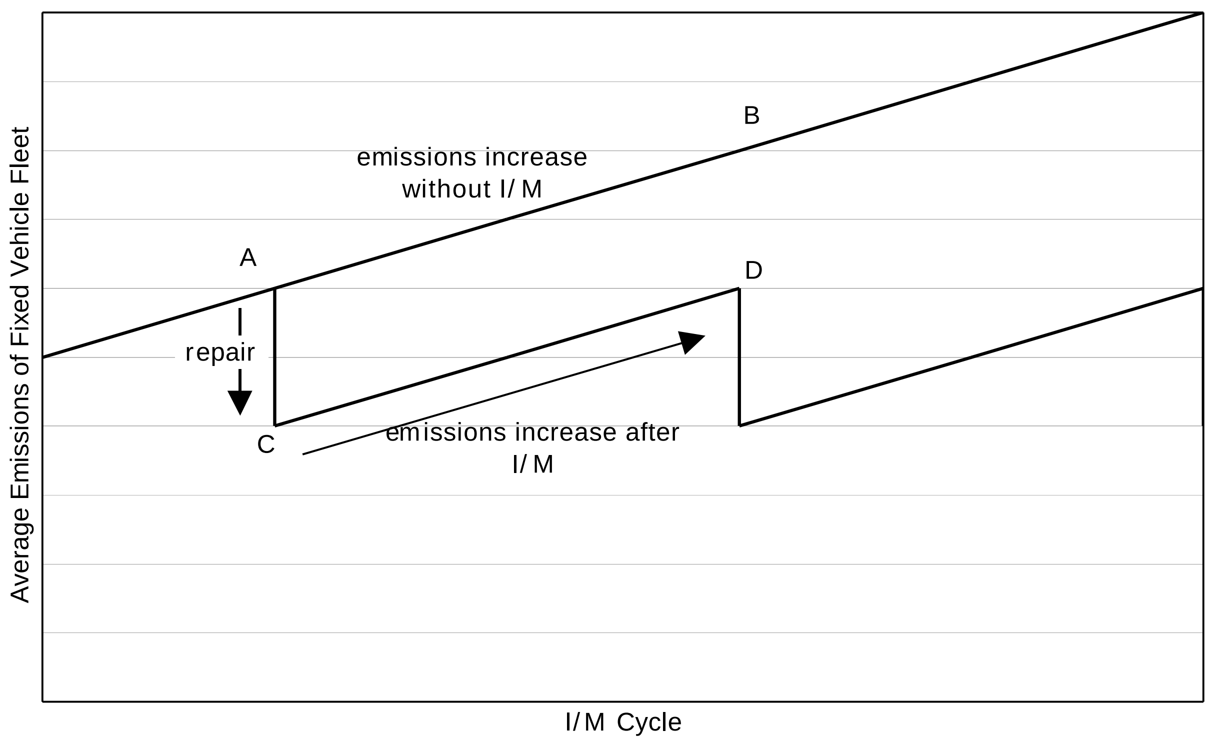
2.3. How an I/M program is supposed to work

The ideal I/M program would reduce vehicle emissions in three ways: (1) the program would encourage vehicle owners to maintain and repair their vehicles prior to testing, (2) vehicles that fail testing would be repaired quickly and effectively, and the repairs would last over time, and (3) vehicles that cannot be repaired to pass the test, or for which repair is too expensive, would be removed from the I/M area. Figure 1 shows an idealized version of how an I/M program is supposed to work. The line AB indicates that emissions of a given fleet of vehicles will continue to increase over time, for the reasons described above, in the absence of an I/M program. The ideal I/M program would identify and repair vehicles with high emissions, resulting in a reduction of emissions from A to C. However, once the fleet of vehicles has been through the program, their emissions will again increase over time, to point D, as some vehicles that initially passed in the program fail, and some vehicles that were repaired fail again. The I/M program attempts to slow down the "natural" increase in vehicle emissions that would occur without the program. The benefit of the program is the area ABDC, and not simply the reduction from A to

C over an entire I/M cycle. Over time, there may be a cumulative benefit of previous cycles of the I/M program.

In reality, the changes in fleet emissions are not as sharp as depicted in Figure 1. First, as discussed above, even without an I/M program fleet turnover will cause emissions to decrease over time. Second, fleet emissions may decrease slightly before point A, as some vehicles are brought in for repair prior to official I/M testing. The reduction in emissions from these repairs is not measured by the initial I/M test. Third, once broken vehicles are identified, several weeks or months may pass before they are fixed, and their emissions reduced to point C. If failing vehicles are properly repaired, post-I/M fleet emissions should then increase (C to D) at a slower rate than the natural deterioration rate in the absence of an I/M program (A to B). However, if repairs to many failing vehicles are not durable, either because the initial repairs did not address the underlying causes of high emissions, or because other components of the repaired vehicles malfunction, the emissions deterioration of the post-I/M fleet will increase at a faster rate than the natural deterioration rate. Finally, the changes depicted in Figure 1 are never observed in real time, since the emissions reduction is spread out evenly over an entire I/M cycle. On average only 4% of the fleet (or 8% in an annual program) is undergoing testing and repair in any given month.

Figure 1. Idealized Model of how I/M Program is Supposed to Work



2.4. Special issues critical to evaluation

Two complex issues must be considered when evaluating any I/M program:

- Emissions rates measured under I/M test conditions (see Section 2.5) may not reflect on-road emissions. I/M tests measure vehicle emissions under somewhat artificial driving conditions, in order to assure that all vehicles are tested under similar conditions, and to minimize the time required for testing. However, any I/M test measures vehicle emissions under only a small fraction of the driving conditions encountered on the road. The Enhanced Smog Check emissions test in particular may not represent on-road emissions, in that the vehicle is tested under a sustained load, a driving condition infrequently encountered in urban driving. A program evaluation that does not account for the difference in emissions measured under I/M test conditions and real-world driving conditions may overstate or understate program benefits, depending on the type of test used in the I/M program.

- Emissions of all vehicles vary somewhat from test to test, even if all environmental and test conditions are held constant. Emissions vary even more under real-world conditions. Test conditions are not completely constant from test to test in any I/M program. Many high-emitting vehicles have emissions that vary widely from test to test, due to the intermittent nature of the malfunction. This variability is sometimes dependent on environmental or other factors, but may be random.

Emissions variability leads to a bias when attempting to calculate average emissions for groups of vehicles that pass or fail their I/M test. This bias can affect the estimation of the average emissions of the vehicle fleet and the emissions benefits of the program. “Passing” vehicles are defined by lower emissions results on their initial I/M test. The average emissions of these vehicles will be higher on a subsequent test, due to emissions variability. Similarly, “failing” vehicles are defined by higher emissions results on their initial I/M test. The average emissions of these vehicles will be lower on a subsequent test, without any repairs being made, solely due to emissions variability. For the same reason, the average emissions of these vehicles will be lower during their final passing test than their true average emissions. If previously failing, properly warmed-up vehicles are re-tested after their passing test, their average emissions will be higher than measured during the passing test, again because of emissions variability. The statistical term for this bias is “regression to the mean”. Appendix A provides a summary of this concept. A program evaluation that does not attribute at least some observed emissions reductions to vehicle emissions variability may overstate emissions benefits of the program.

2.5. Summary of the Enhanced Smog Check Program

The Enhanced Smog Check Program introduced several new requirements for areas of the state with particularly bad air quality (the Los Angeles, San Diego, Sacramento, and Central Valley air basins). Many of these requirements were introduced in June 1998. However, some requirements were introduced later. The major new requirements for the Enhanced Program are:

- Vehicles in Enhanced areas of the state are subject to biennial Acceleration Simulation Mode (or ASM) testing. The ASM test measures a vehicle’s emissions as it is operated steadily under two engine loads on a treadmill-like device called a dynamometer. Testing under load enables the meaningful measurement of NOx emissions, and measurement of HC and CO under conditions more representative than the two-speed idle. The emissions test can last up to 170 seconds, but clean vehicles can pass after only 10 seconds of emissions measurement under each vehicle load. Vehicles in Basic areas of the state continue to receive biennial two-speed idle tests. Vehicles in all areas of the state are required to have an additional Smog Check test when the vehicle is sold (change-of-ownership testing). Pre-1973 vehicles, and vehicles from the four newest model years, are exempted from testing, but testing is required for new vehicles when they are brought into California from other states or when they are sold.

- The California program is considered a "hybrid" program, with two separate networks of test stations: a network of regular stations that can perform both emissions testing and vehicle repair (Test-and-Repair), and a separate network of stations that can only perform emissions testing (Test-Only). There are several types of Test-and-Repair stations, including Gold Shield Guaranteed Repair stations that are certified as performing more effective repairs, and Gross Polluter Certification stations (see below). Under the original legislation, Test-Only stations were to be centrally managed by a single contractor. However, currently any independent station can apply for Test-Only status.

- Acceptable emissions levels, or "cut points", for each mode of the ASM vary by emissions standards category, which is determined by vehicle type (passenger car, light duty truck, heavy light duty truck) and vehicle age. Cut points within each emissions standards category vary by vehicle weight. Weight-based standards are an attempt to relate concentration-based ASM measurements with the gram per mile standards to which vehicles are designed and manufactured (see Part II for details on emissions units). Current HC and CO ASM cut points became effective in June 1998. Initial ASM NOx cut points were not adopted until September 1998, and current NOx cut points did not become effective until October 1999. The current cut points for all three pollutants are higher (less stringent) than the assumed cut points used to estimate the air pollution reduction benefits of the Enhanced Smog Check Program in California's State Implementation Plan.

- Vehicles that exceed a second (higher) set of cut points are classified as "Gross Polluters". A Gross Polluter must pass an emissions inspection at a Test-Only or a Gross Polluter Certification station for Smog Check certification.

- Results of any official emissions test before the first official test are called "pretests" and are recorded and reported to a central database, but are not used to identify vehicles as Gross Polluters.

- 13% of the fleet, identified as fitting a High Emitter Profile,[3] are directed to Test-Only stations for initial and final testing. An additional 2% of the fleet are randomly selected and directed to Test-Only stations, to provide data for program evaluation.

- Owners of failed vehicles can receive either a repair cost waiver (if the owner first makes at least $450 in emissions-related repairs) or an economic hardship extension (if the owner meets low income criteria and makes at least $250 in emissions repairs or has an estimate that a single repair will cost at least $250), which gives the owner another two years to fully repair his or her vehicle.

The California Bureau of Automotive Repair (BAR) is the agency responsible for managing the Smog Check Program.

3. Data sources

In this section we briefly describe the four major sources of data on vehicles and their emissions that we used in our evaluation, and discuss the advantages and disadvantages of each. We use three independent sets of vehicle emissions measurements; each data source has unique strengths and weaknesses, and can best be used to answer different questions about program effectiveness. Using multiple data sources reduces uncertainty and strengthens our analysis.

3.1. Program data: the Vehicle Information Database (VID)

The result of every Smog Check inspection is reported to a central database, the Vehicle Information Database, or VID, via a phone modem connection. The value of the VID data is the enormous number of vehicle emissions measurements. Virtually every vehicle reporting for Smog Check testing (roughly 9 million per year) is included in the VID database. The sheer number of measurements allows the analysis of very specific components of the program, such as results by test station type, air basin, cut point phase, etc.

However, since the VID measurements are used to determine whether a vehicle owner must pay for repairs, and pass a subsequent retest, the VID data do not necessarily give an accurate depiction of in-use emissions. A test station technician has an incentive to minimize the emissions measurement, by over-preparing the vehicle for the test, in order to decrease the likelihood that the vehicle will fail the test. Some technicians may even falsify test results to ensure that a suspected high-emitting vehicle passes the test. On the other hand, some test technicians may make efforts to <u>increase</u> the likelihood that a vehicle will fail the test, in order to charge the owner for unnecessary vehicle repairs. Although technicians are required to submit emissions results of tests conducted prior to official Smog Check testing (pretests), not all do so.

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3. The High Emitter Profile (or HEP) is a computer program that ranks vehicles by the likelihood of them failing their next Smog Check test. The HEP determines the ranking based on three sources of information: (1) the prior Smog Check history of an individual vehicle; (2) the average historical Smog Check failure rate of vehicles of the same year, make, and model; and (3) any remote sensing measurements of the individual vehicle. The HEP is maintained by Eastern Research Group Inc. for BAR.

As a result, the VID data do not fully capture the emissions reductions resulting from any repairs or adjustments made immediately prior to official Smog Check testing. In addition, the emissions measured under the ASM test are not representative of on-road emissions, because the ASM test is run under an artificial condition of sustained constant load, which is rarely encountered in on-road driving in urban areas. As discussed above, vehicles are allowed to pass the test as soon as their emissions dip below the cut points. Emissions of these vehicles that are passed after the minimum test time may not be comparable to emissions of vehicles given the full ASM test. Another limitation of the VID data is that emissions from exempted vehicles, or eligible vehicles avoiding the program, are not measured. Finally, regularly scheduled biennial tests measure only the initial emissions reduction from the program; they do not account for the decline in the emissions reduction benefit as repaired components deteriorate. The change-of-ownership test requirement in California, however, does provide data on the emissions of some vehicles at various times since their last passing Smog Check test.

3.2. Roadside ASM testing

BAR undertook an extensive roadside testing program to provide data for program evaluation. Under the roadside program, vehicles were randomly selected and pulled over by a highway patrol officer. Motorists were asked if they would voluntarily submit their vehicle to emissions testing at the roadside. The testing involved the same inspections (ASM emissions, visual, and functional tests) as are performed in the Smog Check Program (in some cases not all visual or functional tests were performed).

The advantages of the roadside data are that the vehicles tested are a potentially unbiased sample of on-road vehicles. Because the program was voluntary, almost 10% of motorists refused to participate. (Some vehicles were measured by remote sensing as they left a roadside test site. The vehicles of motorists that refused to take a roadside test had emissions that were essentially the same on the remote sensor as the vehicles that participated.) Sites were selected in various locations throughout the Enhanced areas of the state. More older vehicles were intentionally selected for testing to get large enough samples of vehicles with the highest emissions levels. All of the vehicles tested under the roadside program were given a full ASM test, so the measured emissions were not affected by some vehicles receiving a shorter test than others. And because the test sites were located at roadside, most of the vehicles tested had been warmed up prior to testing.

Nonetheless, there are some disadvantages of the roadside data. Random roadside ASM testing is costly and time-consuming. An individual crew consisting of three or four Bureau of Automotive Repair (BAR) technicians, one CHP officer, and a portable dynamometer can measure about 25 vehicles per day. As a result, it took almost three years for the BAR to accumulate the 30,000 vehicle tests in this database. Care must be taken when comparing emissions of Enhanced-tested vs. untested vehicles, either in aggregate or by model year, because vehicles of the same model year were older at the end, compared to the beginning, of the data collection period. To the extent that Enhanced-tested and untested vehicles were measured at different sites, driver socioeconomic factors may influence average emissions and bias apparent program effects. As with the VID data, the emissions measured under the ASM test may not be representative of on-road emissions.

3.3. Remote sensing measurements

The Steven and Michele Kirsch Foundation, Professor Don Stedman of the University of Denver, Environmental Systems Products, and the Coordinating Research Council made available to the IMRC 117,000 remote sensing measurements with valid emissions data and license plate reading at several sites throughout the state. Of these valid readings, 46,000 come from three sites in the South Coast Air Basin area. (The additional 71,000 valid measurements were collected at three sites in Sacramento and the Bay Area. We only discuss the South Coast data in this report). The BAR originally intended to collect a large number (several million) of emissions measurements of vehicles as they drove by remote sensing devices located at various sites throughout the state. These remote sensing data would have provided a second independent source of data with which to evaluate the Enhanced Smog Check Program. However, BAR has not yet begun the collection of these data.

The technique remote sensors use to measure CO and HC, infrared absorption, is the same as used in the BAR97 ASM analyzer. The speed and acceleration of each vehicle are also measured, and can be combined with the roadway grade at the site and typical vehicle characteristics to estimate the instantaneous load on the vehicle at the time of measurement. A video camera placed alongside the remote sensor records each vehicle's license plate, which is stored together with the emissions measurement. Vehicle information is obtained by matching the on-road license plate with registration records. A single remote sensing instrument can measure emissions of thousands of vehicles per day, for a small fraction of the cost of conducting a similar number of ASM tests.

The remote sensing measurements best represent the emissions of the on-road fleet during warmed-up driving. The emissions of most vehicles driving by the sensors are measured, and there is little incentive to avoid measurement. The measurement is unscheduled, so there is no opportunity (or incentive) to prepare a vehicle prior to measurement. All the remote sensing measurements were made over a relatively short time period, so vehicle aging is less of an issue than with the roadside ASM test data.

However, there are also some disadvantages of the remote sensing data. Because remote sensors measure an individual vehicle's emissions during only a fraction of a second, this measurement though instantaneously accurate, may give an imprecise estimate of a given vehicle's *average* emissions at the time of testing. For comparison, an ASM test records the equivalent of 20 to 270 one-second measurements of each vehicle. Imprecision of individual measurements is typically overcome by sampling tens of thousands of vehicles to obtain relatively precise fleet average emissions estimates. Better precision requires the sampling of more vehicles. Evaluating the Smog Check Program, which has the greatest effect on the roughly 40% of on-road vehicles that are more than 10 years old, requires still larger numbers of measurements. The remote sensing data available for this study were insufficient in number to make precise quantitative estimates of program effectiveness, and measurements were made at too few sites to know whether the observed trends apply throughout all Enhanced Smog Check areas.

The remote sensing data can also be used to identify vehicles that never pass Smog Check yet are still being driven in Enhanced areas, as well as vehicles that are unregistered.

3.4. Registration data

The California Department of Motor Vehicles (DMV) maintains a large database of vehicle registration information. We requested a "snapshot" of the vehicle registration database as of October 1999 in order to identify the vehicles measured by remote sensing by matching the videotaped license plates with those in the registration database. We also requested two earlier "snapshots" of the data, from April 1998 and October 1998, to use in estimating how many of the vehicles measured on-road were avoiding the Smog Check Program, and in estimating the number of vehicles, if any, that were re-registering out of Enhanced areas to avoid the Enhanced Smog Check requirements.

DMV could only provide us with the April and October 1998 databases. We therefore had to match license plates of vehicles measured by remote sensing in late 1999 with registration data from late 1998. We hope to obtain additional snapshots of registration data from DMV in the future to more fully analyze motorist avoidance of the Enhanced Smog Check Program.

4. Findings

In this section we discuss the major findings of our analysis. A summary of each finding is provided in italics at the start of each subsection. Each finding includes a basic description of the methodology we used to arrive at our finding. Unless specified otherwise, all results were obtained by analyzing data from the second mode of the ASM test, the ASM2525 test.[4] All average emissions measurements and vehicle counts that we report are based on the number of vehicles given ASM tests at stations in Enhanced areas during the period when Phase 3 NOx cut points were in place (November 11, 1998 through October 3, 1999). We exclude from our emissions analyses all-wheel drive vehicles and all other vehicles that are otherwise not given an ASM test at Enhanced stations.[5] More detail on the methodology used and the results obtained is included in the appendices.

4.1. How effective is the Enhanced Program in initially reducing vehicle emissions?

We used Smog Check records of vehicles that had more than one Smog Check cycle within a 12-month period to estimate the initial emissions reductions from the program. We analyze vehicles that fail their initial test but pass a retest (fail-pass fleet) separately from vehicles that passed their initial test (initial pass fleet). 20% of fail-pass vehicles, and 6% of initial pass vehicles, fail the initial test of their next Smog Check cycle less than 2 months later. We estimate that the initial emissions reduction of the fail-pass fleet is 44% each for HC and NOx, and 72% for CO,

4. Inconsistent preconditioning of vehicles prior to testing is perhaps the largest source of bias in emissions results for different vehicles in the VID. As a result, we believe that the 5015 test may overstate vehicle emissions, particularly for clean vehicles that are tested for only 10 seconds on the 5015 test. By restricting our analysis to the 2525 test results, we know that all vehicles have at least been preconditioned on the 5015. Vehicles requiring a longer warm-up period will not fast-pass the 5015 test. The 2525 test measures vehicle emissions at a slightly lower load on the vehicle than the first test, the 5015 test.

5. Vehicles not given an ASM test are given the conventional two-speed idle test. All-wheel drive vehicles are not given an ASM test because they cannot be driven on the dynamometer. Technicians may determine that some other vehicles, for instance those with bald tires, cannot be safely driven on the dynamometer. Some vehicles tested in Enhanced areas are registered in non-Enhanced areas, and are not required to get an ASM test.

up to 2 months after their initial test. Combining fail-pass and initial pass vehicles, the initial emissions reduction of the overall fleet is 5% each for HC and NOx, and 20% for CO, up to 2 months after initial testing.

As discussed above, comparing the initial to final test result of individual vehicles will overstate the benefit of the program. On average, emissions of failing vehicles will be lower on a subsequent retest than on their initial test.[6] As a result, some initially failing vehicles will pass their final retest without having been repaired and their emissions reduced. On the other hand, the average emissions of passing vehicles will be slightly higher on an immediate retest, again because of test to test variability. (In addition, if vehicles that pass their first test were not properly warmed up prior to the first test, their emissions would decrease on a subsequent retest when the engine and catalyst are warmed up).

The change-of-ownership testing requirement in California allows us to estimate this effect on initial program effectiveness. About 5% of all vehicles have a second Smog Check cycle in the 18-month period of data we analyzed. We call these vehicles the "multi-cycle" fleet. We use vehicles that were originally tested in the first three months of the Phase 3 cut points (November 11, 1998 to February 11, 1999) to ensure that all vehicles were tested under the same cut points, and that the fleet of vehicles tested in each time period after their initial test were roughly the same age. We included results from official recorded pretests in our analysis.

We analyze vehicles that failed their initial test but passed a retest (fail-pass fleet) separately from vehicles that passed their initial test (initial pass fleet). The multi-cycle data indicate that 20% of the fail-pass vehicles fail the initial test of their next Smog Check cycle. Therefore, we use the emissions difference between the initial test on the first cycle and the initial test on the second cycle to estimate the emissions reduction from the fleet of fail-pass vehicles. We estimate that emissions of the fail-pass fleet are initially reduced by 44% for HC and NOx, and by 72% for CO, up to two months after initial testing. These estimates are shown for each pollutant in Figure 2 (HC is expressed as carbon equivalents, or C1, in Figure 2; this unit is 6 times the "hexane-equivalent" HC level reported in the VID).[7]

For initial pass vehicles, the multi-cycle data indicate that 6% would have failed if tested again. The average emissions of the initial pass fleet would be 5% higher for HC, 24% higher for CO, and 7% higher for NOx, if these vehicles were immediately retested.

When we combine the fail-pass and initial pass fleets, the initial reduction in emissions is 5% for HC and NOx, and 20% for CO, up to 2 months after initial testing.

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6. There are three basic reasons for why vehicles may fail an immediate retest: (1) test to test variability of vehicle emissions, particularly for vehicles with emissions near the program cut points and vehicles with intermittent malfunctions; (2) changing environmental or test conditions, such as whether a vehicle was properly warmed up prior to testing; or (3) reporting of passing test results from a known clean vehicle as those from a dirty vehicle (test fraud).

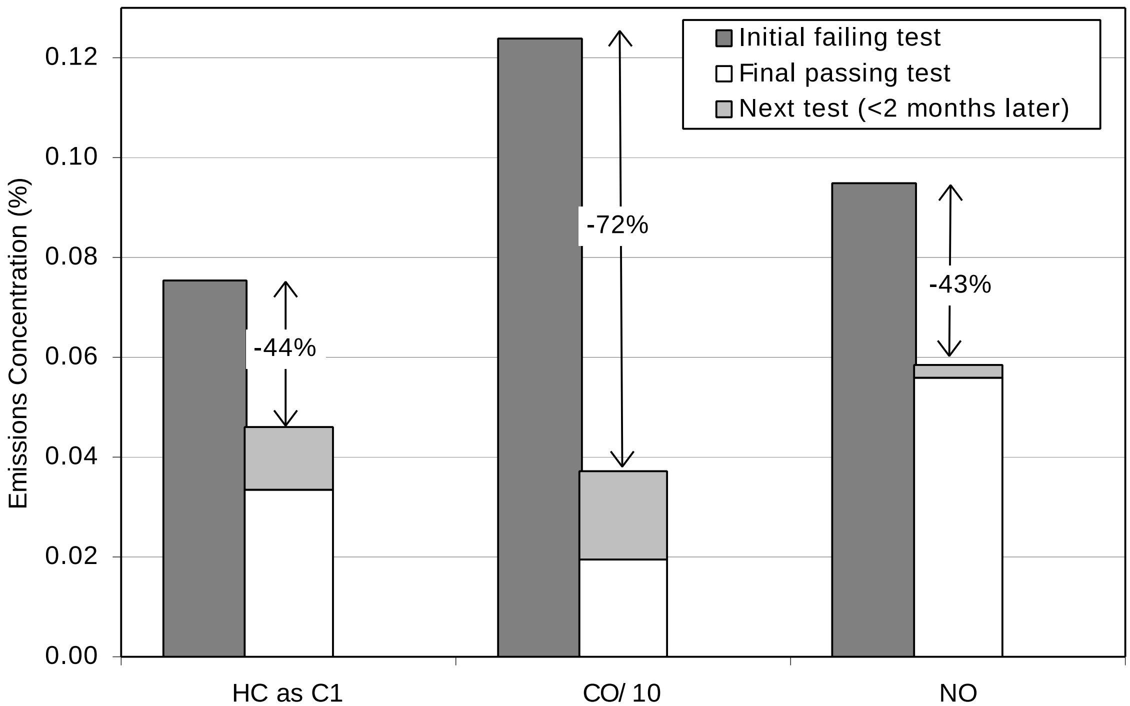
7. This may overstate the initial emissions reductions of the program, as the average emissions of the fail-pass fleet, if retested without any repairs, would be lower than calculated from initial, failing test results. We estimate the magnitude of this effect, and the impact it has on emissions reduction estimates, in Appendix C.

A potential problem with analyzing the multi-cycle vehicles is that their emissions may be different from vehicles that have not been sold, and that our findings based on that analysis may not be applicable to the overall vehicle fleet. We compared the failure rate, initial and final emissions, and percent emissions reduction of the fail-pass vehicles in the multi-cycle fleet with those in the overall fleet, to determine if the emissions of the multi-cycle fleet are substantively different from the overall fleet. We found that using the multi-cycle fleet may slightly understate the overall effectiveness of the Enhanced Smog Check Program.[8]

The full benefit of the Smog Check Program should include any lasting reduction in emissions due to vehicles being repaired or adjusted prior to Smog Check testing. California's program attempts to measure the effect of repairs made prior to the official test, by establishing an official pretest. Pretest emissions results are recorded, but are not used to determine whether a vehicle officially fails a test, or whether it is identified as a gross polluter. To account for at least some repairs made prior to official Smog Check testing, we base all of our results on all recorded tests, including any pretests (unless specifically stated otherwise). Nevertheless, additional repairs may be performed before the first recorded pretest. We estimate the number of vehicles receiving unofficial pretests, and perhaps repair, in Section 4.5. We also include an assumption of the benefits from pre-inspection repairs in our estimate of program benefits, in Section 4.4. The best way to measure the timing of these repairs, and their effect on emissions, however, is with an extensive remote sensing measurement program.

8. We found that the multi-cycle fleet has lower average emissions, and a lower initial failure rate, by model year than the overall fleet. Final emissions of the two fleets are the same. This means that the reduction in emissions is lower for the multi-cycle fleet (that we analyze) than the overall fleet, and that our estimate of program effectiveness based on the multi-cycle fleet may understate the actual effectiveness. We have no explanations for why the multi-cycle fleet has lower initial emissions than the overall fleet.

Figure 2. Average Emissions of Multi-Cycle Fail-Pass Vehicles



4.2. To what extent do reductions persist with time after the test?

Emission reductions as measured immediately after passing a Smog Check test will decrease over time, as repairs to fail-pass vehicles deteriorate, and emissions controls on initially passing vehicles malfunction. Program data indicate that emissions of the fail-pass fleet are steady for the first 12 months after initial testing. HC and CO emissions from the initial pass fleet increase steadily, and are 30% and 80% higher, respectively, 12 months after the initial test. NOx emissions do not increase over the first 12 months after testing. The increase in emissions from passing vehicles counterbalances the stable emissions from the fail-pass vehicles, so that 4 months after the initial test the HC and CO emissions of the combined tested fleet are higher than at the time of initial testing. Remote sensing data show a smaller increase in tested fleet emissions as the fleet ages and gets further from its last Enhanced Smog Check test. In both cases, emissions of the tested fleet are lower than they would be in the absence of the Smog Check Program. In addition, emissions of the overall fleet continue to decrease from fleet turnover.

4.2.1. Program data

The multi-cycle test data from the VID also allow analysis of how effective vehicle repairs are over time. Although the data indicate that 20% of the fail-pass fleet would fail if retested immediately after their passing test, Figure 3 suggests that this failure rate stays steady and does not begin to increase until about nine months after the initial test. The second cycle failure rate of the fail-pass fleet varies by model year. The failure rate is 26% for 1974 to 1984 vehicles, 21% for 1985 to 1989 vehicles, and 15% for 1990 to 1992 vehicles, over all time periods since the previous Smog Check cycle. Figure 4 shows the change in emissions over time, relative to the emissions of the initial test. Reductions in emissions are represented by negative percentages. Figure 4 indicates that emissions of the fail-pass fleet are quite steady for about 12 months after initial testing, and perhaps begin to increase only about a year after initial testing.

As discussed above, 6% of vehicles that pass their initial test would immediately fail a retest. The failure rate of the initially passing fleet increases steadily over time, as more of these vehicles malfunction and become high emitters. Figure 5 indicates that 10% of the initially passing vehicles would fail a retest 6 months after their initial test, and 15% would fail 12 months later. The failure rate of the initial pass fleet varies substantially by model year. The failure rate is 19% for 1974 to 1984 vehicles, 12% for 1985 to 1989 vehicles, and 6% for 1990 to 1992 vehicles, over all time periods since the previous Smog Check cycle. There is a steady decrease in the failure rate for newer vehicles, from 16% for 1985 vehicles down to 4% for 1994 vehicles.

Figure 6 shows the change in emissions over time, relative to the emissions of the initial test. Increases in emissions are represented by positive percentages. The HC and CO emissions of the initial pass fleet increase as that fleet gets further from its initial Smog Check test, with HC emissions 30% higher, and CO emissions 70% higher, six months after the initial test. HC emissions of the initial pass fleet are fairly steady from six to 12 months after initial testing, while CO emissions increase slightly. NOx emissions of the initial pass fleet increase from two to six months after initial testing, to 10% higher than under the initial test, but then decrease down to 5% higher than the initial test 12 months later. These differences in NOx emissions over time may be because vehicles are being repaired to HC and CO cut points that are relatively more stringent than the current NOx cut points. Some repairs to reduce HC and CO emissions may increase NOx emissions, but not enough to cause the vehicle to fail the relatively loose NOx cut points.

The increase in emissions from initial pass vehicles (87% of the multi-cycle fleet) counters the lasting emissions reductions from fail-pass vehicles (13% of the multi-cycle fleet). As a result, HC and CO emissions of the combined fleet are higher four months after initial testing, as shown in Figure 7. Again, emissions reductions from initial test emissions are shown as negative percentages, while emissions increases from initial test emissions are shown as positive percentages. The increase in NOx emissions of the initial pass fleet are much lower than the increase in HC and CO, so that NOx emissions from the combined fleet are lower than initially tested even 12 months after the initial test. However, all emissions are lower than they would be in the absence of the Smog Check Program.

Figure 3. Repeat Failures of Fail-Pass Vehicles by Time since Previous Cycle

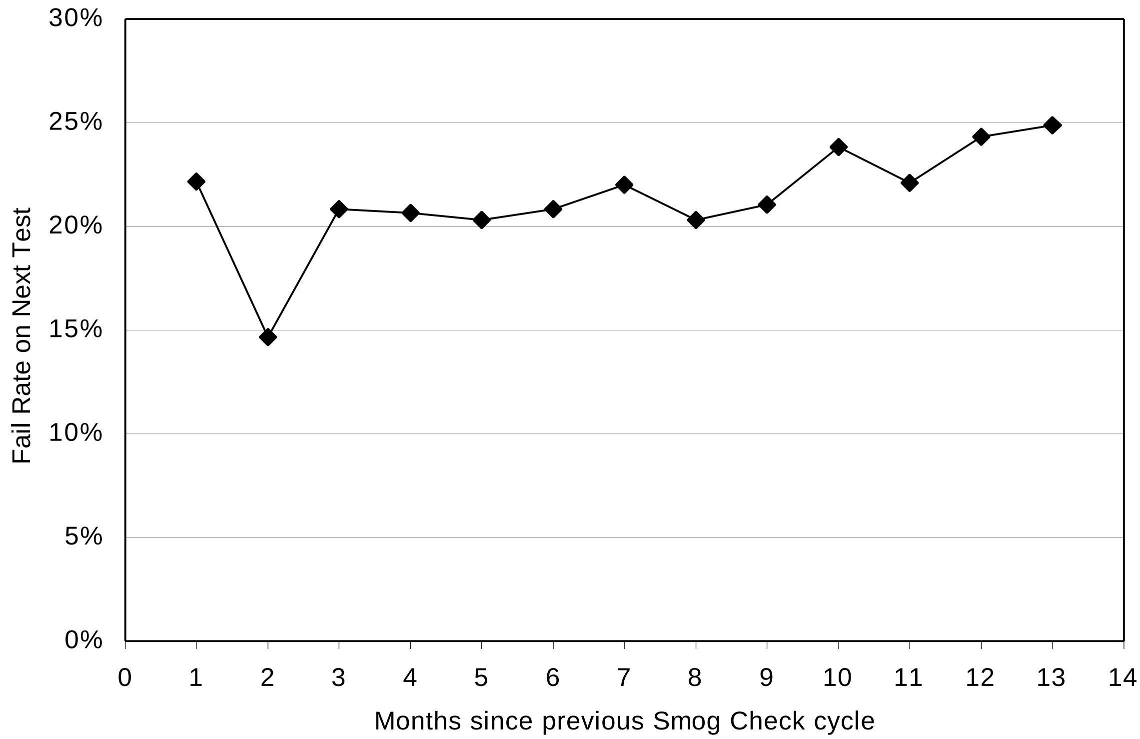


Figure 4. Second Cycle Emissions by Time since Previous Fail-Pass Cycle

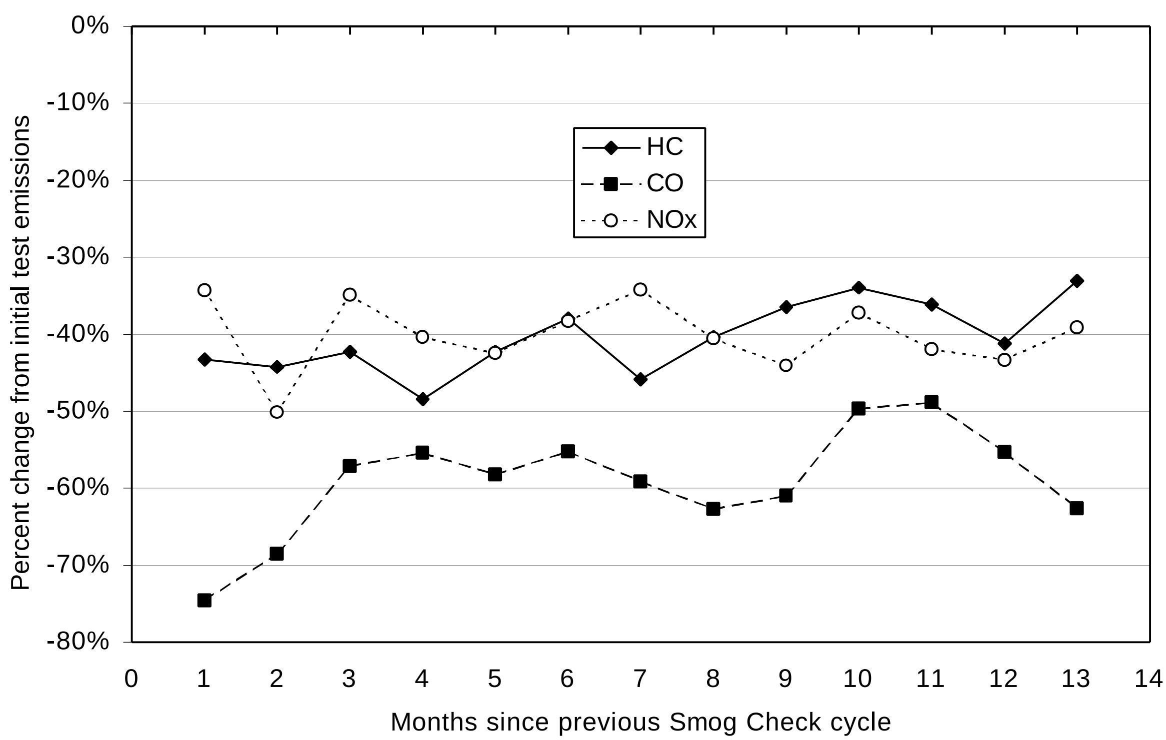


Figure 5. Failure Rate of Initial Pass Vehicles by Time since Previous Cycle

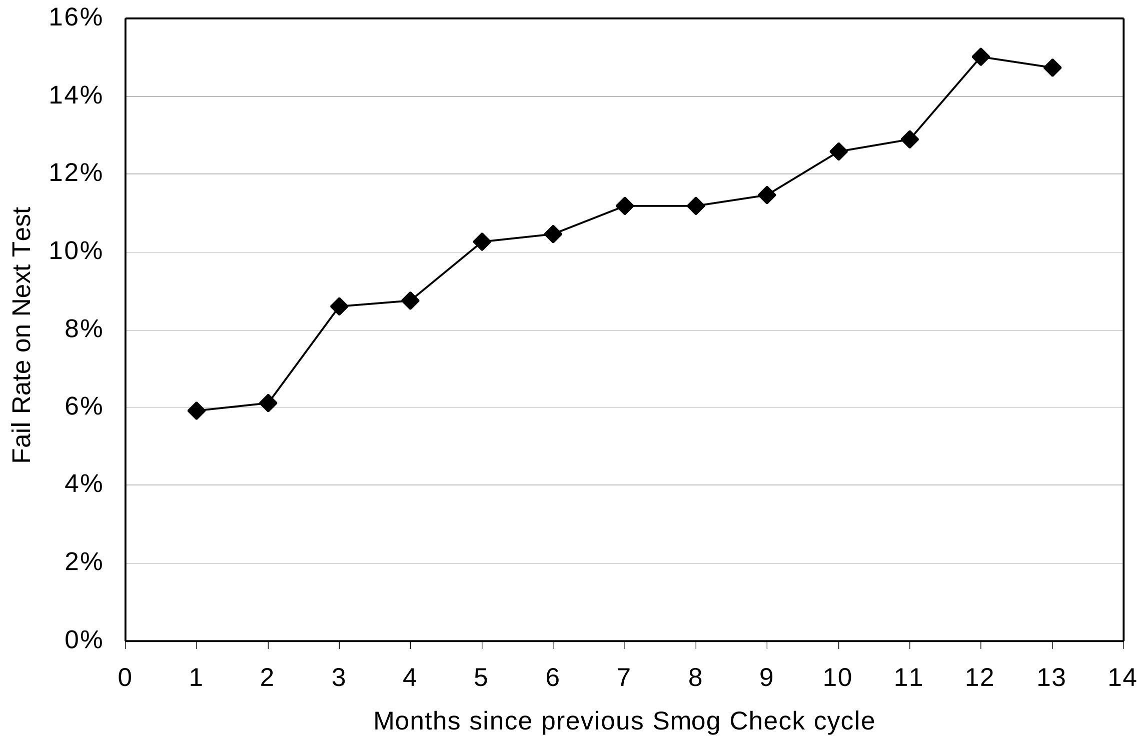
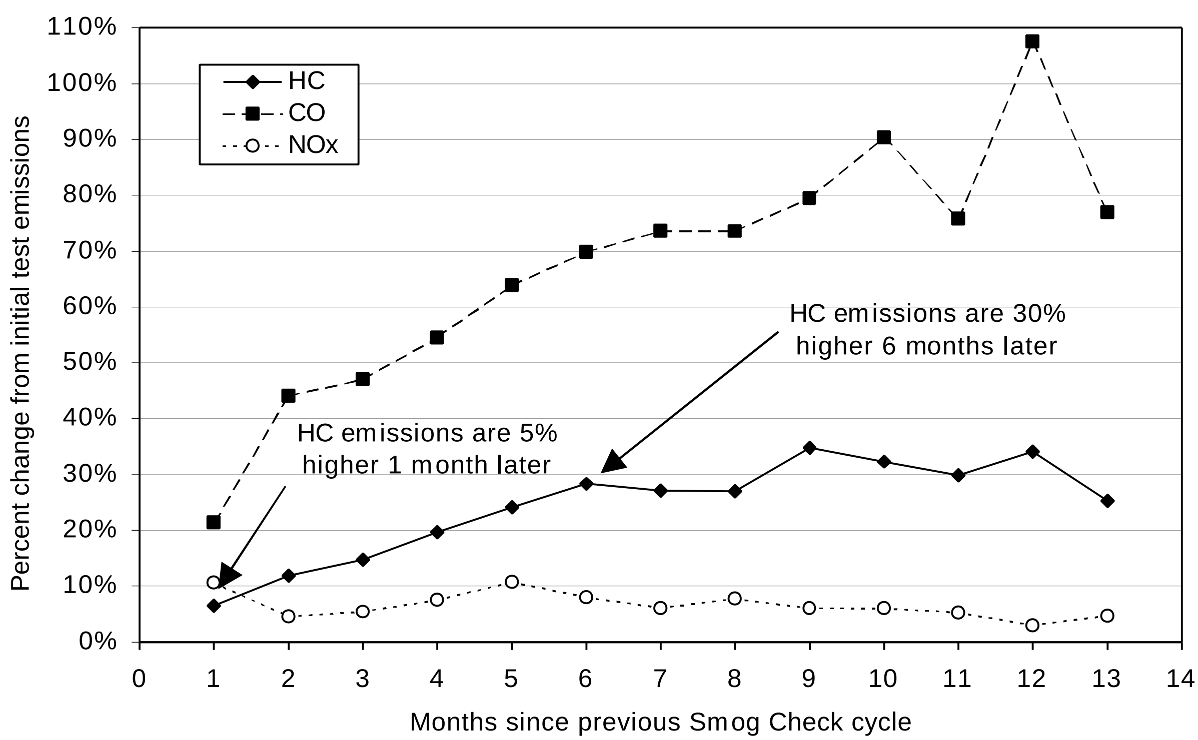
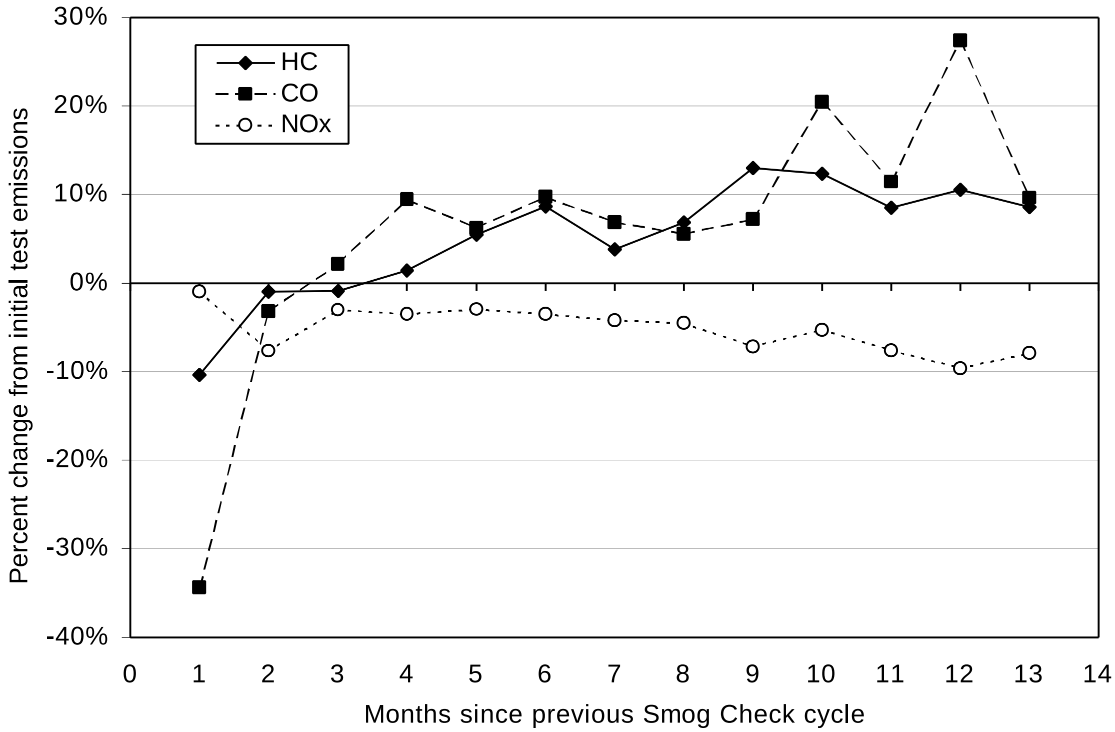


Figure 6. Emissions of Initial Pass Vehicles by Time since Previous Cycle



There is a third group of vehicles in addition to the initial pass and fail-pass groups: those vehicles that fail an initial test but do not receive a subsequent passing test. We refer to these vehicles as "no-final-pass" vehicles. To the extent that such vehicles are removed from the on-road fleet, overall average emissions will decrease relative to the numbers shown below. We address these vehicles more directly in Sections 4.3 and 4.4 below.

Figure 7. Deterioration of Multi Cycle Fleet over Time since Previous Cycle



4.2.2. On-road data

In addition to program data from the VID, we have two sources of on-road emissions data, roadside ASM and remote sensing measurements. Both can be used to estimate program effectiveness. However, as discussed above, each of these data sources has drawbacks that limit their usefulness.

The roadside data were collected from a variety of sites throughout the Enhanced areas of the state, so they are likely to be quite representative of the California vehicle fleet. We compare the roadside emissions of vehicles that had not yet participated in the Enhanced Smog Check Program (the "Untested" fleet) with those of vehicles that had received an Enhanced Smog Check test prior to their roadside test (the "Tested" fleet). We define the Untested fleet as vehicles that: (1) had their roadside test after June 8, 1998,[9] and (2) had their last Basic Smog

9. Because the roadside testing occurred over nearly a three year period, a vehicle of a given model year tested after June 1998 would be on average one and a half years older than a vehicle of the same model year tested before June

Check test more than 12 months before the roadside test and/or an Enhanced test after the roadside test.[10] We weight average gram-per-gallon emissions by model year for each fleet by the same model year distribution, the number of vehicles tested under Phase 3 cut points, to account for any differences in the average vehicle age of each fleet. Finally, we weight the emissions by model year by an estimate of the average number of miles driven annually by each model year[11] and adjusted for differences in average fuel economy by model year[12] to convert from gram-per-gallon to gram-per mile emissions factors.

The roadside data suggest that Enhanced Smog Check is reducing fleet emissions by 17% for HC, 28% for CO, and 9% for NOx. We achieve similar results when we estimate fleet emissions based on the number of remote sensing measurements by model year, rather than on the number of vehicles tested in the program and their assumed annual mileage by model year. More detail on these results, including average emissions by model year for each group of vehicles, is included in Appendix E.

For our remote sensing analysis we use data from three remote sensing sites in the Los Angeles area: the exit ramp from northbound Route 91 to westbound Route 60 in Riverside, the entrance ramp to eastbound Interstate 10 from La Brea, and the Interstate 710 to State Highway 91 interchange in Los Angeles. The Riverside measurements were made from June 28 to July 7, 1999, and the others were made from November 3 to 13, 1999. The remote sensing measurements were made at too few sites to know whether the observed trends apply throughout all Enhanced Smog Check areas of the state.

Vehicle information was obtained by matching the license plates in the remote sensing database with license plates in DMV's registration database. DMV matched the Riverside data to current registration data. However, the measurements at the other sites were matched to registration data from October 1998, i.e. one year prior to the on-road measurement. All vehicles were also matched to VID records, so vehicles that were not matched with registration data could be identified from VID data. Most of the remote sensing measurements occurred under transient conditions with absolute engine loads comparable to the load on the ASM test. A small number of remote emissions measurements at negative loads were removed because emissions of HC and NOx are different under these conditions than under positive loads. Further limiting the remote sensing measurements to those collected under loads very similar to those of the ASM test decreases precision (due to having fewer measurements) but does not change estimates of average on-road fleet emissions. See Appendix F for details on our analysis of the remote sensing data.

1998. Since all of the roadside tests before June 1998 are of the Basic I/M fleet, including the pre-June 1998 tests would lower the average vehicle age, and therefore emissions, of the Basic I/M fleet, and introduce a bias in our estimate of program effectiveness.

10. We limit the Basic I/M fleet in this way to minimize the effect of the last Basic Smog Check test on the Basic I/M fleet, and to make our roadside analysis more comparable to the analysis done with program data. Our Basic I/M fleet had their roadside test on average 21 months after their Basic Smog Check test, while our Tested fleet had their roadside test on average six months after their Enhanced Smog Check test.

11. We used BAR's travel fraction calculator for average vehicle miles by model year. The calculator is described in Section 4 of Part II.

12. Singer, B.C. and R.A. Harley, "A fuel-based inventory of motor vehicle exhaust emissions in the Los Angeles area during summer 1997," *Atmospheric Environment*, 2000, V34, N11, 1783-1795.

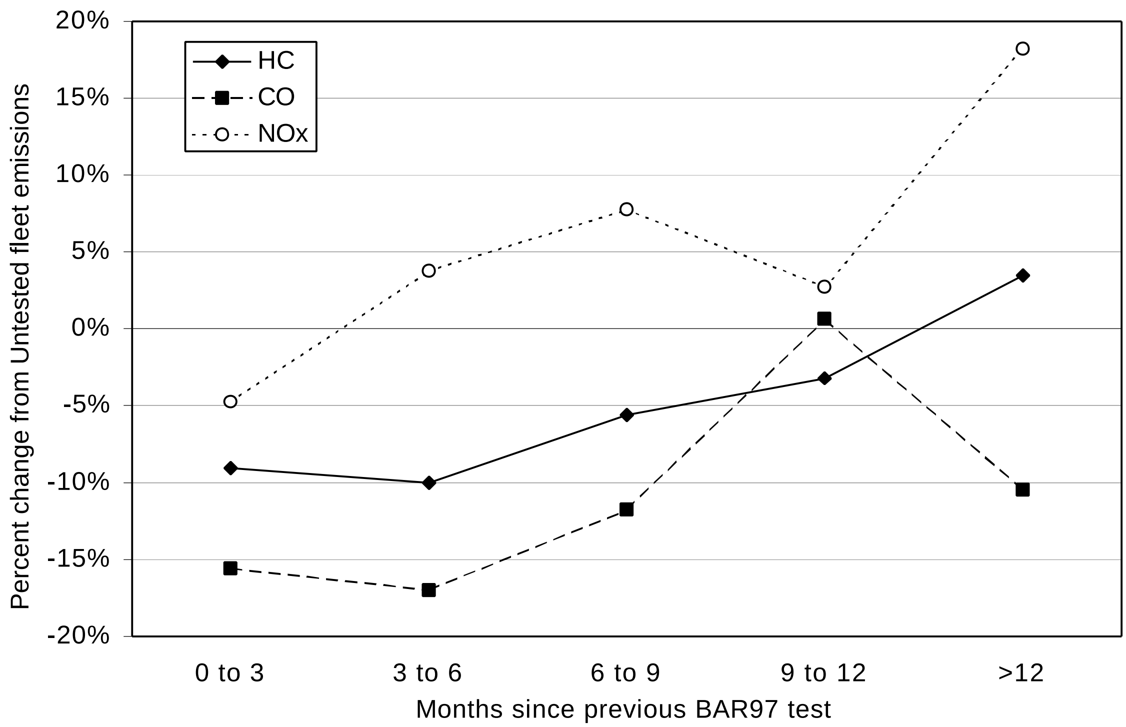
As in the analysis of roadside tests, we compare the remote sensing emissions of the Untested fleet with those of the Tested fleet. Untested vehicles had their last Basic Smog Check test more than 12 months before the remote sensing measurement and/or an Enhanced test after the remote sensing measurement. We weight the average gram-per-gallon roadside emissions by the same vehicle distribution, annual vehicle miles traveled, and fuel economy by model year assumptions as in the roadside analysis.

Overall remote sensing HC and CO emissions of the Tested fleet are lower than those of the Basic I/M fleet. The benefit of the Enhanced Program, as measured by remote sensing, is 4% for HC and 10% for CO. However, the remote sensing NOx emissions of the Tested fleet are 5% higher than those of the Untested fleet. As calculated, the uncertainty of each fleet emissions estimate is comparable to, or larger than, the differences between the two fleet estimates. The data may be re-analyzed in the future using more sophisticated statistical techniques (e.g., Monte Carlo sampling from the available data) to more precisely characterize average emissions differences.

Figure 8 shows that emissions of the on-road fleet increase with time since their Enhanced Smog Check. Potentially significant HC and CO emission benefits are seen during the first six to nine months, when the Tested fleet is compared to other vehicles observed on road that have not yet been tested in the Enhanced Program (the Untested fleet). NOx emissions of the Tested fleet appear higher than the control Untested fleet within three to six months after Smog Check. These results should be considered as only potentially, and not definitively, relevant to our Enhanced Smog Check Program evaluation for the following reasons. First, the data were collected at three on-road sites in the Los Angeles area that may not be representative of the overall Enhanced Smog Check fleet. Second, the uncertainties associated with the calculated fleet average emission factor for each time period, and for the Untested fleet, are as large or larger than the differences between and among them. A more extensive remote sensing study that samples much larger numbers of vehicles will eliminate the second problem. There are approximately 3,000 to 3,800 vehicles represented in the average emission factor for each time period in Figure 8, but most of these were newer vehicles on which the Smog Check Program has a marginal effect at best.

The time-series results in Figure 8 should not be compared directly to the results of the combined initial pass and fail-pass multi-cycle VID fleet in Figure 7. The multi-cycle analysis tracks the *same* vehicles by time since their last Smog Check, whereas Figure 8 compares emissions of tested vehicles to a control group of *different* vehicles that have not yet been through the Enhanced Program. The untested vehicles in Figure 8 have had at least one year (most have had closer to two years) to deteriorate since their last Basic Smog Check, whereas the tested vehicles have had substantially less time to deteriorate since their last Enhanced Smog Check. More detail on these results is included in Appendix F.

Figure 8. Remote Sensing Emissions by Time since Previous BAR97 Test



4.3. To what extent are motorists avoiding program requirements?

Three groups of vehicles avoid Smog Check requirements: (1) no-final-pass vehicles that remain on the road despite never having passed the Smog Check test, (2) registered vehicles that are never tested in the program, and (3) vehicles that are not registered in California. Program data indicate that 10% of vehicles that fail their initial Smog Check never receive a passing test. These vehicles have HC emissions 81% higher, and NOx emissions 15% higher, on average than vehicles that eventually pass their Smog Check test. About one-third of these vehicles continue to be driven in Enhanced areas one year after testing. 15% of Gross Polluter vehicles receive a passing test at a regular Test-and-Repair station, rather than at a Test-Only or Gross Polluter Certification station, as required. About 5% to 10% of the registered vehicles observed on-road appear to be completely avoiding Smog Check testing.

4.3.1. No-final-pass vehicles

The program data indicate that 10% of all vehicles that failed their initial Smog Check test (or 1.3% of all vehicles) did not receive a passing test. This is based on an analysis of vehicles tested in the first two months of Phase 3 cut points only, allowing all vehicles nearly a year to obtain a final pass. Figure 9 indicates that the no-final-pass rate is highest for older vehicles, peaking at the 1981 model year and decreasing dramatically for newer vehicles. The average initial emissions of no-final-pass vehicles are 81% higher for HC, 97% higher for CO, and 15% higher for NOx than the average initial emissions of fail-pass vehicles. Figure 10 shows the average initial HC emissions of initial pass, fail-pass, and no-final-pass vehicles, and the final emissions of fail-pass vehicles, by model year.

It is possible that the owners of some of the no-final-pass vehicles received a repair cost waiver or economic hardship extension, and have up to two years to repair their vehicle. Waived vehicles are not identified in the VID database. However, BAR reports that only 5,000 vehicles received waivers or extensions over the 18 months of the program we analyzed. These vehicles represent less than 1% of all failed vehicles, and 4% of all no-final-pass vehicles. It is also possible that some of the no-final-pass vehicles did receive a passing test that is not in the database. One possibility is that the final passing test of some of these vehicles has a different vehicle identification number (or VIN) than the initial failing test. We attempted to match no-final-pass vehicles with a passing test for a vehicle with a different VIN but the same license plate. We estimate there are as many as 5,500 of these vehicles. Excluding vehicles that received a waiver or extension, and accounting for potentially passing tests missing in the data we analyzed, lowers our estimate of the no-final-pass rate from 10% to 9% of all vehicles failing their initial test.

15% of all Gross Polluter vehicles received a passing test at a regular Test-and-Repair station, with no record of a subsequent passing test at a Gross Polluter Certification (GPC) or Test-Only station. We classify these vehicles as fail-pass vehicles, because they passed their last Smog Check test, even though that passing test was not at a Test-Only or GPC station, as required. These vehicles represent 3.3% of all vehicles that failed their initial test.

Some of these no-final-pass vehicles may no longer be operating in the Enhanced areas, perhaps because they could not meet Smog Check requirements. The removal of these vehicles, and some of their emissions, from the Enhanced areas is a benefit of the program. However, some of these vehicles may still be driven in Enhanced areas. Both sources of on-road data, the roadside ASM tests and the remote sensing measurements, indicate that about one-third of no-final-pass vehicles are still being driven in Enhanced areas one year after their initial test.

This degree of program non-compliance is better than observed in the Phoenix IM240 program, where 26% of the vehicles that failed initial testing never received a passing test in the next 3 to 15 months; half of these vehicles were observed on road more than two years later.[13]

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13. Wenzel, Tom, *Using Program Test Result Data to Evaluate the Phoenix Smog Check Program,* Report to the Arizona Department of Environmental Quality, November, 1999.

Figure 9. No-Final-Pass Rate by Model Year

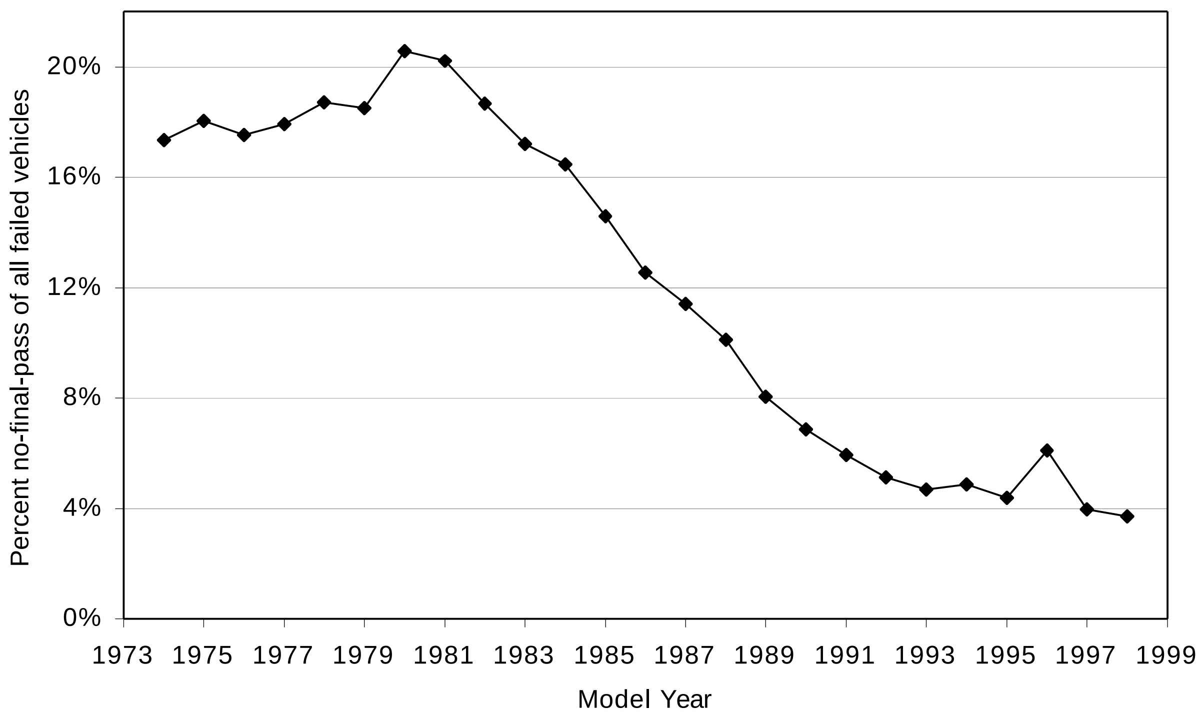
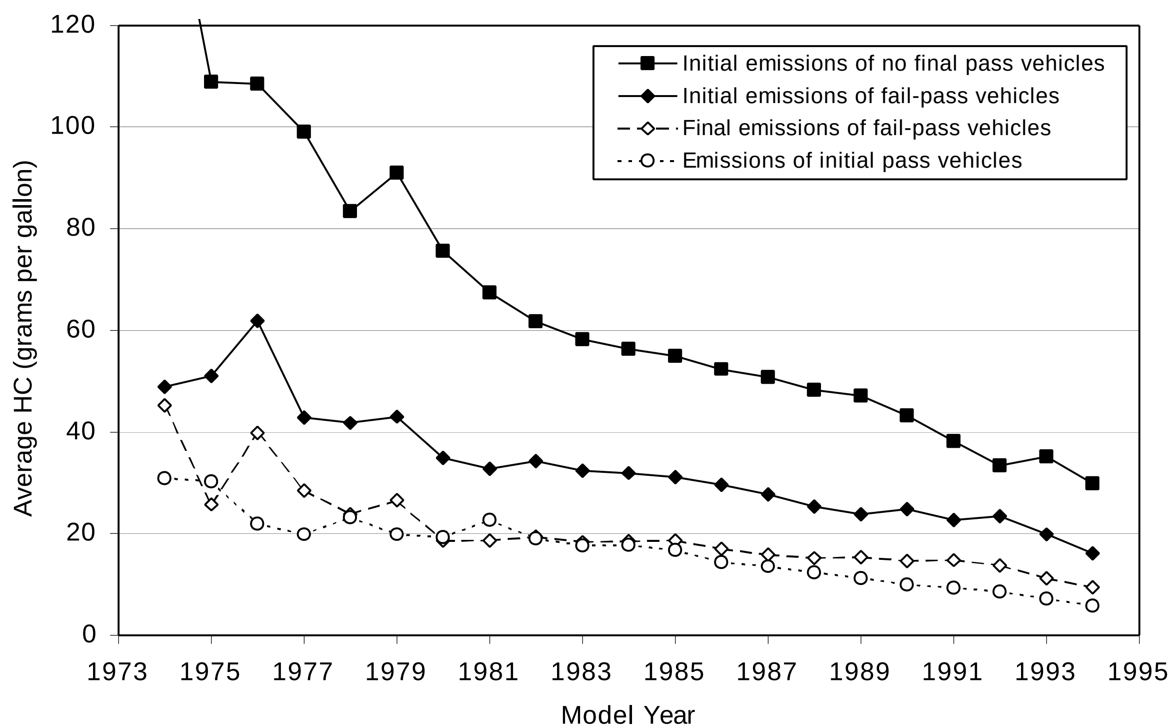


Figure 10. HC Emissions by Smog Check Result



4.3.2. Vehicles registered but avoiding program

10% of vehicles measured on road by remote sensing are registered in Enhanced areas and eligible for Smog Check, but there is no record of them reporting for testing. It is possible that these vehicles are participating in the Enhanced Program, but are not in our database. About 5% of all Smog Check test records sent to the central database are legitimate tests but do not fit the proper data layout format. If we assume that all of these "bad" data records are tests of unique vehicles not included in the data we analyze, then a conservative estimate of program avoidance is 5%.

One measure of non-participation in the Enhanced Program is the rate of vehicles re-registering out of the Enhanced areas. A time series of registration data, spanning the introduction of the Enhanced Program, is necessary to determine if the re-registration rate changed after the onset of the Enhanced Smog Check Program. We have requested such a time series of registration data from DMV.

4.3.3. Unregistered vehicles

As discussed earlier, DMV has not yet been able to fulfill our request for more recent vehicle registration data. With more recent registration data we can estimate the non-registration rate of the vehicles measured by remote sensing and the roadside ASM tests.

4.4. What are the overall tailpipe emissions benefits of the program?

We estimate that in 1999, the Enhanced Smog Check Program reduced emissions by 86 tons per day for HC, 1680 tons per day for CO, and 83 tons per day for NOx. Repair of vehicles that fail an initial, official Smog Check appears to be the most important mechanism of emission reductions, but benefits from pre-inspection maintenance and repair may also be significant. Benefits from removal of non-passing vehicles also account for a small portion of total benefits. In 1999, more than 90% of all benefits can be attributed to vehicles more than 10 years old, even though such vehicles represent only half of those tested in the program. These estimates are based on Phase 3 failure cut points. NOx reductions may now be greater, as NOx cut points were made more stringent in October 1999.

4.4.1. Estimating Smog Check benefits: Introduction and definitions

The goal of Smog Check is to reduce emissions of the on-road vehicle fleet compared to what emissions would be without Smog Check. Since the Smog Check Program does not aim to reduce overall vehicle usage, benefits are generally achieved by reducing emission *rates*, i.e. the mass of each pollutant emitted per gallon of fuel burned or per mile traveled, of vehicles affected by the program. Benefits are calculated as the product of a reduced emission rate and an activity factor that includes the number of vehicles affected and the estimated activity per vehicle. Benefits are discussed in terms of tons of pollution reduced or avoided per day.

Enhanced Smog Check benefits can be described in at least three different ways. ***Cumulative*** benefits include emission reductions of the current Smog Check cycle and any carryover benefits from previous cycles. The most direct method for estimating such benefits would be to compare two fleets that are similar in every way except that one fleet has never participated in Smog

Check. In practice, it is difficult to find such a group of never-participating vehicles.[14] *One-cycle* benefits are the full benefits from just the current cycle of Smog Check. It is also relevant to discuss the *incremental* benefits of the Enhanced Program, by comparing emissions of vehicles participating in Enhanced I/M to emissions if the Basic Program had been continued rather than switching to the Enhanced Program. The incremental benefits are then the extra benefits achieved from the Enhanced Program, over and above those that would have been achieved if the Basic Program had been continued. Each of these methods must consider the deterioration of each group of vehicles, i.e. those participating and those not yet participating in Enhanced Smog Check, over the same time period since their previous Smog Check cycle.

The Enhanced Smog Check Program achieves emission reductions through at least three processes:

1. Through maintenance and repairs performed in preparation for official Smog Check tests or pre-tests (*pre-inspection maintenance*);
2. Through *repair* of vehicles that fail an official Smog Check test;
3. Through migration and retirement of failing vehicles that motorists are unable or unwilling to repair to pass a Smog Check (*removal*).

Smog Check also raises awareness of motor vehicle pollution and its impacts, and thus may encourage behavior that reduces motor vehicle related air pollution.

The Enhanced Smog Check test directly measures tailpipe exhaust emissions of HC, NOx, and CO, and includes a functional gas cap test to identify at least one major source of evaporative HC emissions. The visual inspection covers additional evaporative emission control devices, and can, in principle, identify (and lead to the repair of) these emission sources.

We estimate both incremental and one-cycle *exhaust* benefits of Enhanced Smog Check using the roadside and VID databases. Incremental exhaust benefits are estimated because of the unique opportunity to do so with the roadside data. One-cycle exhaust benefits are estimated to respond to the question posed by the IMRC and to provide emission reduction estimates for the cost-effectiveness calculations in Part IV. *Evaporative* HC emission reduction benefits were not estimated in this analysis because there were insufficient data to do so. We do, however, include evaporative benefits estimated by the California Air Resources Board using the EMFAC2000 model in our estimates of total one-cycle program benefits.

Both incremental and one-cycle exhaust benefits are estimated using “bottom-up” approaches, in which an average per-vehicle emission reduction is multiplied by the total activity of affected vehicles. Incremental benefits are estimated by assuming roadside vehicles with a prior Enhanced test represent the on-road fleet under Enhanced Smog Check, and that vehicles with only a Basic test prior to the roadside pullover represent the on-road fleet under Basic Smog Check. Differences in average emission factors by model year are applied to the entire fleet of vehicles participating in Enhanced I/M. One-cycle benefits are developed from separate

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14. To isolate the effect of the I/M program requires two fleets that are similar in all other respects, including: age distribution, mileage accumulation, general maintenance level (which may be related to income or social factors), quality of vehicle emission control systems (some makes and models are known to perform better in use), etc.

estimates of the benefits obtained from pre-inspection maintenance, post-failure repair, and Smog Check induced retirement or migration out of Enhanced areas, using a combination of VID and roadside data.

4.4.2. Incremental benefits of Enhanced Smog Check: Methods

The roadside data were collected over a period starting before the implementation of the Enhanced Program, and continuing through to the present day. The data available at the time of this study included mostly vehicles that were tested at the roadside before receiving an official Enhanced Smog Check. Most of these vehicles participated in Basic Smog Check. The data included a smaller sample of vehicles already participating in the Enhanced Program. The *goal* of the Bureau of Automotive Repair in collecting these data was to capture vehicle samples of each group (Basic and Enhanced participants) that were randomly[15] selected, and thus representative of the same population, i.e. the vehicle fleet covered by California's Enhanced Smog Check Program.

However, there are several potential biases in the roadside database. First, roadside data were collected exclusively during working hours at locations that could accommodate the test equipment. The population from which the sample was drawn may therefore not represent the on-road fleet in Enhanced areas.[16] The early months of roadside testing only captured "Basic I/M" vehicles because the Enhanced Program had not yet started. In later months, roadside testing included an increasing percentage of vehicles participating in Enhanced I/M, and Basic I/M vehicles in the later months of their cycle. Since roadside testing occurred over several years, vehicles of the same model year were significantly older in the last months of testing than in the first months of testing. This likely leads to an age bias when using all roadside data to compare emissions by model year of Basic and Enhanced I/M fleets. To reduce this bias, we excluded roadside tests conducted before June 8, 1998, which by definition were all on vehicles that had not yet received an Enhanced Smog Check. The remaining database is still biased because the Basic I/M vehicles are tested on average much longer after their last Smog Check than the Enhanced I/M sample. Since both the Basic and Enhanced programs are expected to have some effect on emissions, relative effectiveness should be compared as a function of I/M cycle time, or by comparing two fleets with a similar distribution of times since their last Basic or Enhanced Smog Check. There is also a potential regional bias since the balance of vehicles from the South Coast Air Basin (Los Angeles, Orange, Riverside and San Bernardino counties) vs. other Enhanced areas differs substantially between the Basic I/M and Enhanced I/M fleets.[17] The effects of these potential biases are noted but not quantified in this report.

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15. Sampling was not designed to be completely random in that older vehicles were intentionally over-sampled. However, the program did aim to produce sample fleets that were each representative of the overall on-road fleet in Enhanced areas of the state.
16. Sampling did not occur on sections of streets with retail or commercial space or during rush-hours, evenings or weekends. This is an unquantified potential bias.
17. Roadside testing occurred exclusively in the South Coast Air Basin for many of the early months of the Enhanced Program, i.e. months in which the majority of vehicles tested were Basic I/M participants. A larger percentage of Enhanced I/M vehicles were sampled in later months, when the sampling program expanded to other Enhanced areas of the state.

On the positive side, the roadside data should include none of the test biases – fast-pass, variable pre-conditioning, fraud and cheating – which are of concern when using the VID data.

As mentioned, we started with the roadside data collected after June 8, 1998 only. Using the license plate and vehicle identification number, we attempted to match each roadside vehicle to its last Smog Check record in the Vehicle Information Database. Vehicles were included in one of three groups, according to their prior Smog Check: (a) prior Smog Check was Basic, (b) prior Smog Check was Enhanced, and (c) no record of Smog Check.[18] For CO and HC, we included all vehicles with an Enhanced Smog Check record, since cut points for CO and HC haven't changed since the start of the program. For NOx, we included only those vehicles receiving an Enhanced Smog Check during Phase 3, i.e. with so-called "gross polluter" NOx cut points. The Enhanced I/M group included 4,029 vehicles for CO and HC, and 2,112 vehicles tested under Phase 3 NOx cut points. The Basic I/M group included 5,728 vehicles. The average time elapsed since the last Smog Check was 166 days for the Enhanced I/M group used for CO and HC, 115 days for the vehicles tested only under Phase 3 cut points, and 557 days for the Basic I/M group.

Average emissions by model year are calculated for each group of vehicles using two methods. First, ASM 2525 emissions are expressed as the grams of each pollutant emitted per gallon of fuel consumed (g/gal units).[19] This method uses direct ASM emissions to estimate emission reductions during all hot running vehicle operation. Previous research[20] has shown that for CO and HC, fleet average emissions measured at moderate load[21] can be used with good accuracy to estimate emissions over most on-road driving.[22] However, this research was based on remote sensing measurements of vehicles in transient on-road operation, whereas the ASM is a steady-state loaded mode test. Appendix D shows that vehicles participating in Smog Check have higher on-road emissions than those measured during their initial Smog Check ASM tests in the VID, even when the on-road measurements are limited to those made at the same load as the ASM.[23] For NOx, the on-road measurements match the ASM measurements more closely, but emissions over the full range of on-road loads are higher than emissions at the moderate load of the ASM test. If emission *reductions* on the ASM (on a percent basis) apply to all loaded hot running vehicle operation, we expect that this method likely understates emission benefits for all

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18. A small number of vehicles did not have a Smog Check prior to the roadside test, but did have a Smog Check after the roadside test. We excluded these vehicles from our analysis.
19. See Appendix D for the equations used to calculate g/gal emission factors.
20. Singer, B.C. "A Fuel-Based Approach to Estimating Motor Vehicle Exhaust Emissions". Ph.D. Dissertation, U.C. Berkeley, 1998. Chapter 5.
21. Load is the power required to move the vehicle, i.e. the power required to overcome resistances to movement, such as friction between the tires and the roadway, air drag, etc. See Appendix F.
22. As represented by CARB's Unified driving cycle, which is based on chase-car data collected in California in the early 1990s.
23. Based on remote sensing measurements at three sites in Southern California. Analysis of a small number of vehicles measured by remote sensing immediately after a roadside ASM finds a similar discrepancy. However, when the analysis is limited to only those vehicles that fail the roadside ASM immediately prior to remote sensing measurement, the discrepancy disappears.

hot running vehicle operation (on a total mass basis). An implicit assumption is that reductions in g/gal emission factors apply throughout all vehicle operation, including the cold start period.[24]

A second method uses the ASM to FTP conversion equations developed by Eastern Research Group (ERG).[25] These statistical models predict fleet average emissions that would be measured on the Federal Test Procedure (FTP) from actual ASM measurements of all vehicles in the fleet. The models were developed using actual ASM and FTP emission measurements of vehicles recruited by the California Air Resources Board for their in-use vehicle surveillance programs,[26] and for a study on the effectiveness of the ASM test as a tool to identify and repair of high-emitting vehicles (the 1994 El Monte Pilot Study). Emissions are expressed in units of gram of pollutant emitted per mile traveled. Implicitly, this method assumes that the ASM to FTP relationships for the test fleet apply to the overall on-road fleet and that the FTP is a good surrogate for in-use vehicle operation. The FTP includes a cold start[9] and thus should capture any reduction in cold start emissions arising from repairs attributable to the Smog Check Program. However, to the extent that the relative proportion of driving that occurs during cold start differs between the FTP test and in-use vehicle operation, emission reductions during the FTP may not reflect overall in-use reductions.

For each set of emission factors, emissions by model year of the Enhanced I/M fleet are subtracted from emissions by model year of the Basic I/M fleet to determine the incremental effect of Enhanced I/M on reducing average emissions of vehicles that participate in the program. Since the Basic I/M fleet was tested at roadside a longer period after its previous Smog Check than the Enhanced I/M fleet (on average 18 months as opposed to 6 months), this calculation likely overstates the incremental benefits of Enhanced I/M. Direct ASM and FTP-modeled emission factors for the Enhanced I/M and Basic I/M fleets are included in Appendix D.

Emission differences by model year are then multiplied by the number of vehicles of each model year that participate in the Enhanced Smog Check Program, and estimates of the total gallons of fuel used and total miles of travel by vehicles of each model year. The number of participating vehicles is determined directly from the VID. We first identified the total number of unique vehicles by model year that received an Enhanced Smog Check during the 327-day period of Phase 3 cut points. We then adjusted this number to a full two years of testing to include the entire biennial Smog Check fleet, and adjusted again to include vehicles whose test records do

24. Cold start operation refers to the period just after a vehicle is started. For properly functioning vehicles, tailpipe emissions are elevated during cold start because the catalytic converter and other emission control devices are not operational until they are heated to high temperatures by engine exhaust – a process that takes between 30 seconds and several minutes. Cold start emissions are often described in incremental terms, i.e. as additional emissions beyond those that would occur if vehicles were always operated in fully warmed up conditions. Our method assumes the same absolute emission factor reduction during cold start as during other driving, i.e. no additional benefit is applied to incremental cold start emissions.

25. ERG, *Models for Estimating California Fleet FTP Emissions from ASM Measurements.* Draft Report. Prepared for the California Bureau of Automotive Repair by T.H. DeFries, C.F. Palacios, S.D. Kishan (Eastern Research Group) and H.J. Williamson (Radian International). December 25, 1999.

26. The data for the ASM to FTP conversion were from CARB surveillance programs 13 and 14.

not conform to the typical VID data structure.[27] Vehicles receiving two-speed idle emission tests (and not ASM tests) during their Enhanced Smog Check were assumed to achieve the full emission benefit for CO and HC and no emission benefit for NOx. Travel estimates by model year were provided by BAR. Fuel use was estimated by assuming the on-road fleet exhibits the average fuel economy by model year implicit in EMFAC2000.[28] The product, in units of grams of emissions reduced per year of travel, is converted to units of tons per day. The implicit assumption is parallel deterioration of the two fleets, over a two-year period. Appendix D provides additional detail on the number of vehicles, average travel by model year and average fuel economy by model year.

4.4.3. Incremental benefits of Enhanced Smog Check: Results

Two estimates of the incremental effectiveness of Enhanced Smog Check at reducing *tailpipe exhaust* emissions are shown in Tables 1 and 2. An estimate of the evaporative benefits of Enhanced Smog Check, developed by CARB using the EMFAC2000 model, is included in our discussion of total one-cycle benefits below. Estimates shown in Table 1 were derived from FTP-modeled emissions (see Methods section above) and therefore should include any Smog Check reductions in cold start emissions. Results shown in Table 2 were calculated based on hot-running emissions during the ASM test, and do not include potential Smog Check reductions in cold start emissions. To the extent that repairs reduced cold start emissions of the ARB test fleet (used to develop the ASM to FTP conversion model), we would expect the benefits shown in Table 1 to be higher than those shown in Table 2.

Overall, the two different methods produce similar benefit estimates for HC and CO, but very different results for NOx. For both CO and NOx, estimates that are supposed to include reductions to additional cold start emissions are actually lower than the estimates for hot-running benefits. Benefits estimated with the direct ASM method are about 15% higher for CO and 2.4-3.3 times higher for NOx. Theories about the cause for these discrepancies are described in Appendix D. HC emission reductions estimated using the ASM to FTP conversion method are 10% higher than the direct ASM method. This difference may result from benefits achieved during cold start, over-prediction of actual FTP reductions using the ASM to FTP model,[29] or other differences in the methodologies.

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27. The adjustment for atypical data formats applies a factor of 1.05 to the number of vehicles for each model year. This factor is derived from comparing the total number of these "bad format" records to the total number of valid format records in the VID.
28. Provided by Jeff Long, Mobile Source Control Division, California Air Resources Board, May 2000.
29. The ASM to FTP model over-predicted measured FTP HC reductions for the fleet used to develop the models. The differences were 8% for model year 1974-1979, 4% for model year 1980-1986, 32% for model year 1897-1991 and 20% for model year 1992 and newer vehicles. Personal Communication: David Amlin, California Bureau of Automotive Repair, May 2000.

Table 1. Estimated incremental *tailpipe exhaust* benefits of Enhanced Smog Check, as compared to Basic Smog Check, using the ASM to FTP conversion model (see text). *Units are tons per day of pollution prevented.*

Model Years	HC	CO	NOx
74-80	24	170	3
81-85	26	447	10
86-90	5	167	15
91-95	1	43	-2[1]
1974-1995	56	827	25
Including evap	82	827	25

[1] Negative benefit estimates result from small differences between average emissions by model year of the roadside and Smog Check initial test data, magnified by the large number of recent model year vehicles.

Table 2. Estimated incremental *tailpipe exhaust* benefits of Enhanced Smog Check, as compared to Basic Smog Check, using ASM 2525 emissions in g/gal units (see text). *Units are tons per day of pollution prevented.*

Model Years	HC	CO	NOx
74-80	27	173	3
81-85	21	509	18
86-90	2	219	46
91-95	0	55	14
1974-1995	51	956	82
Including evap	76	956	82

4.4.4. Total one-cycle benefits of Enhanced Smog Check: Methods

Overall one-cycle benefits are estimated using a combination of VID and roadside data. Separate estimates are made for benefits from pre-inspection maintenance and repairs, post-failure repairs, and removal of vehicles that fail, and never pass Enhanced Smog Check. Benefits are estimated for two years of a single Enhanced I/M cycle even though the effects of a single Enhanced I/M cycle may persist beyond 2 years. Lasting effects are likely to be confounded by the next cycle of I/M. Estimating one-cycle benefits requires assumptions about several key parameters, including how much of the difference between on-road and initial in-program emissions should be attributed to pre-inspection maintenance, what fleet emissions would be if Smog Check were ended, and emissions through the second year following Enhanced Smog Check. As a result of these assumptions, there is substantial uncertainty in the estimated benefits. Our approach is to state clearly where assumptions are needed, which assumptions are made for our “best” estimate, and to indicate the sensitivity of our results to the assumed parameters.

The calculation proceeds roughly as described for the estimate of incremental benefits, but is based exclusively on ASM 2525 emissions, expressed in g/gal units. For each benefit component, we estimate the reduction in average emission rate by model year, and multiply this difference by the activity of the vehicles affected. In all cases the activity by model year is based on an estimate of average travel by model year provided by BAR and an estimate of fleet-average fuel economy by model year provided by CARB. These values are provided in Appendix D.

One major uncertainty about all of these estimates revolves around the following question: How much of the calculated benefits would be achieved if there were no Smog Check Program? It is unlikely that all maintenance and repairs that help to reduce emissions occur only because of Smog Check, even though much maintenance and many repairs may coincide with Smog Check testing. In the absence of Smog Check, many vehicle owners would likely perform necessary maintenance on their vehicles. This question cannot be answered quantitatively given the data available.

Pre-inspection maintenance and repairs. Industry representatives have long argued that significant maintenance and repairs occur prior to official Smog Check testing. We estimate the benefit of this phenomenon by comparing roadside ASM emissions of vehicles that participate in Smog Check, but have been measured before their initial Enhanced test,[30] to the initial ASM emissions of the California Enhanced I/M fleet (from the VID). These emission factors by model year are included in Appendix D. The lower emissions seen at the initial Enhanced Smog Check test may result from several factors other than emission benefits of pre-inspection maintenance and repairs, including special preparation of some vehicles to pass their Smog Check without lasting repairs,[31] fraudulent passing of vehicles,[32] and bias in the roadside vehicle sample.[33]

The emission difference by model year is assumed to apply throughout a two-year I/M cycle, for all vehicles that pass their initial Smog Check.[34] This assumes deterioration in the absence of

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30. The Basic I/M fleet from the roadside data that we use to estimate the effect of pre-inspection repairs is slightly different from the fleet that we use in our estimate of incremental program benefits. For the estimate of incremental benefits, we use all vehicles that had a roadside test after June 1998 and after a Basic Smog Check test. For the estimate of pre-inspection repairs, we use a subset of these vehicles that received their Basic Smog Check test more than one year before their roadside test. We use this subset of vehicles to represent on-road emissions of vehicles shortly before their initial Enhanced Smog Check.

31. For example, by running the vehicle at high speeds prior to the Smog Check test, so that the catalyst is super-heated. Some degraded catalysts may work effectively only when heated to very high temperatures.

32. For example, some high-emitting vehicles may have low emission test results because another clean vehicle was tested in its place (this practice is known as "clean-piping").

33. The comparison of ASM emissions measured at roadside and reported in the VID is also biased because clean vehicles are allowed to fast-pass the VID test. It is likely that average emissions in the VID would be even lower if all vehicles were required to be tested over the full ASM test, as in the roadside testing. Table D.5 in Appendix D provides some evidence of this preconditioning effect. For newer vehicle model years, the VID emissions tend to be slightly higher than emissions measured during roadside testing. Therefore, it is likely that our use of the difference between roadside and VID tests understates the effect of pre-inspection repairs.

34. We note that fail-pass and no-final-pass vehicles contribute to the average emission rates at the roadside and in the initial VID emission results. We do not include these vehicles in the number affected by pre-inspection because

Smog Check (starting at levels observed by roadside ASM testing) would be similar to deterioration following pre-inspection maintenance. Emission reductions and benefits are assumed to extend for 2 years. The number of vehicles for each model year is obtained by adjusting the number of initial pass vehicles tested during Phase 3 of the Enhanced I/M Program to a year of testing, and adding an estimated number of vehicles with bad data records (as defined above in Section 4.3.2.). Full HC and CO credit is given to vehicles receiving two-speed idle tests, but such vehicles are not assumed to derive any NOx benefit. For our "best estimate", we attribute 75% of the difference in emission rates to pre-inspection maintenance. This assumed fraction of the difference between roadside and VID emissions that is attributable to pre-inspection maintenance, as opposed to test fraud, is another major assumption in our estimate of program benefit. Our reasoning for this assumption is that, at best, none of this difference is attributable to test fraud, implying that pre-inspection maintenance accounts for all of the difference. On the other hand, we believe that it is unlikely that test fraud could account for more than half of this difference, implying that pre-inspection maintenance accounts for the remaining half. Therefore our best estimate assumes that 75% of this difference is attributable to pre-inspection maintenance, and that the remaining 25% is attributable to other causes, including test fraud. We test the sensitivity of our results to this assumption in our lower and upper bound estimates. Our lower bound attributes only 50% of this difference to pre-inspection benefits; our upper bound estimate attributes 100%.

Post-failure repair. We estimate benefits from post-failure repair[35] using the multi-cycle data described previously, supplemented by data from the overall Enhanced I/M fleet. We use the initial, failing emissions test results of the multi-cycle, fail-pass fleet as a starting point, and make assumptions about the deterioration that would occur for these vehicles if they didn't participate in Smog Check. Initial Smog Check average emissions by model year are shown for these vehicles in Appendix D. No adjustment is made for the regression to the mean effect on initial emissions of the fail-pass fleet, even though we acknowledge that emissions would likely be lower if the same vehicles were simply re-tested without repair.[36] For our best estimate, we assume that the emissions of these vehicles would reach the same levels of those that fail, then never pass their Smog Check, by the end of the two-year period. We assume a stable average emission rate as a lower bound on potential deterioration,[37] and assume that emissions reach no-final-pass levels in one year as an upper bound on deterioration (emissions are then assumed to stay constant at no-final-pass levels through the second year in the upper-bound scenario).

After-repair emissions are characterized by the initial test result on the *next* Smog Check test of the multi-cycle fleet. We use the next Smog Check test results to account for the known bias of the final (passing) test results for fail-pass vehicles (see Sections 4.1 and 4.2). As shown in Section 4.2, emissions of fail-pass vehicles remain relatively constant for the first 12 months

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in the separate benefits estimates made for these vehicles, different assumptions are made about their potential deterioration in the absence of Smog Check.

35. We acknowledge that some vehicles that fail then pass in Enhanced Smog Check likely are not repaired (as shown by the rate of recidivism shown in Section 4.2), and may fail, then pass based solely on emission variability. Nevertheless, we often refer to the repairs made to these vehicles as a group.

36. The effect of regression to the mean on this estimate is discussed in Appendix D.

37. The lower bound assumption is consistent with our observation that HC emissions of initial pass vehicles appear to steadily increase and then "level off" after about 9 months following their passing test.

following their initial Smog Check test. We assume for our best estimate that fail-pass vehicles deteriorate in the second year following Enhanced Smog Check at the same rate as initial pass vehicles during their first year after Smog Check. Our upper bound benefit estimate assumes no deterioration of fail-pass vehicle emissions in year 2 and our lower bound estimate assumes deterioration back to initial test emission levels by the end of year 2. Second-cycle emissions of the initial pass fleet are included in Appendix D.

Differences in the with/without Enhanced I/M emission factors described above are credited to all vehicles that failed, then passed during Phase 3 cut points, again adjusted for a full year of Smog Check testing and including the records with bad data formats. Vehicles receiving two-speed idle tests are again given full credit for HC and CO, and no credit for NOx, for the best and upper bound estimates. The lower bound estimate assumes no emission reductions for cars given two-speed idle tests.

Removal of no-final-pass vehicles. As discussed in Section 4.3.1, about 10% of failing vehicles never receive a passing test but only a third of these no-final-pass vehicles are still observed on the road a year later. The removal from Enhanced Smog Check areas of vehicles that do not pass their Smog Check test is a benefit that may be attributed to the program. We quantitatively estimate this benefit by assuming no-final-pass vehicles are replaced with an average initial passing vehicle that is 5 years newer for best and upper bound estimates. Lower bound estimates assume no-pass vehicles are replaced with same-age passing vehicles. Emissions of no-final-pass vehicles are assumed to stay constant in the absence of the program. We use the second cycle emissions of the initial pass fleet to account for deterioration of these vehicles. As a simplifying assumption, we calculate benefits as if the removal of no-final-pass vehicles occurs without delay. The total number of vehicles affected is determined from the VID records during Phase 3 testing, and adjusted to include two-thirds of all no-final-pass vehicles over a 2-year Smog Check cycle.

4.4.5. Total one-cycle benefits of Enhanced Smog Check: Results

All benefits are estimated for two years following Enhanced I/M testing under Phase 3 cut points. The benefits are thus equivalent to those that would be observed from an on-road fleet comprised of vehicles distributed throughout their biennial Smog Check cycle. Figures 11 through 13 show the "best" estimate of benefits from pre-inspection maintenance and repairs, post-failure repairs, and removal of no-pass vehicles, by model year.[38] Overall benefits are summarized in Table 3, which also includes an estimate of evaporative benefits developed by the California Air Resources Board (CARB) using the EMFAC2000 model.[39]

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38. Pre-inspection benefits vary substantially from year to year because of uncertainty in the roadside emission factors for individual model years (see Appendix D). In these figures, pre-inspection benefits are averaged over the following model year groups: 1974-1980, 1981-1985, 1986-1990 and 1991-1995. The figure shows negative pre-inspection emissions benefits for newer model years because these vehicles have higher VID emissions than roadside emissions; we suspect that this result may be due to incomplete preconditioning in the VID tests, as noted earlier and explained in Appendix D.

39. Personal communication: Kim Heroy-Rogalski, California Air Resources Board, June 2000.

Figure 11. Estimated HC Emissions Prevented by Enhanced I/ M

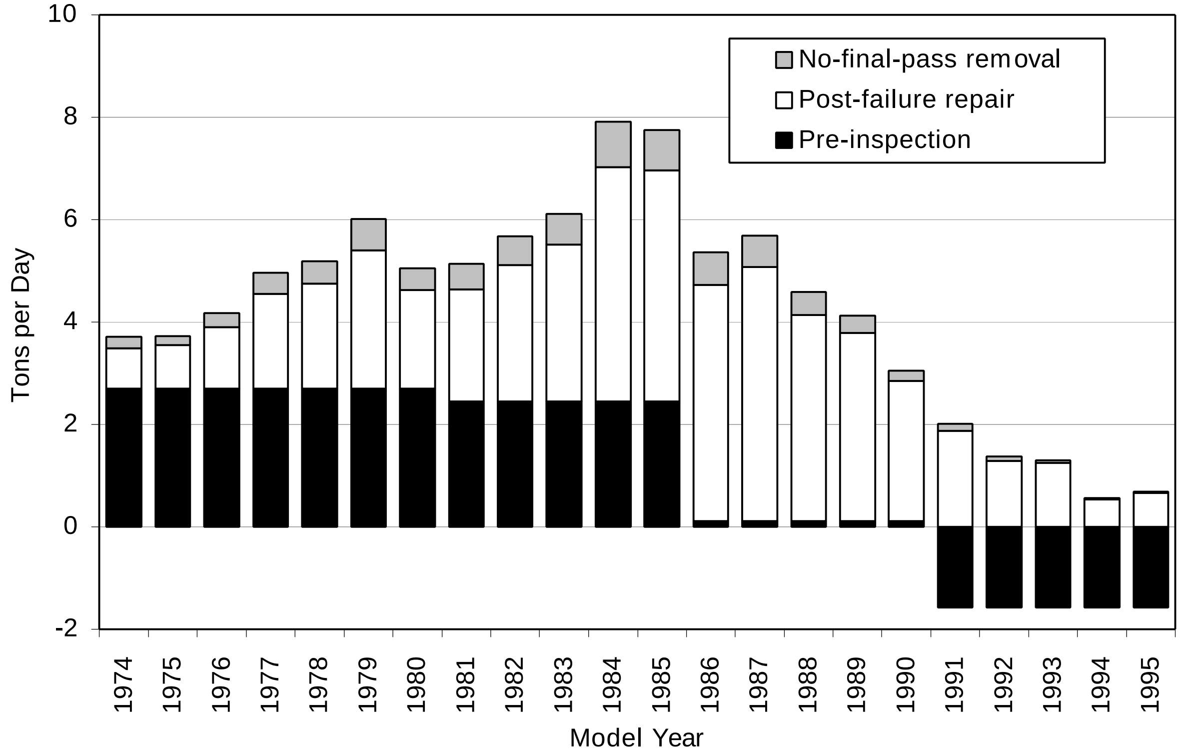
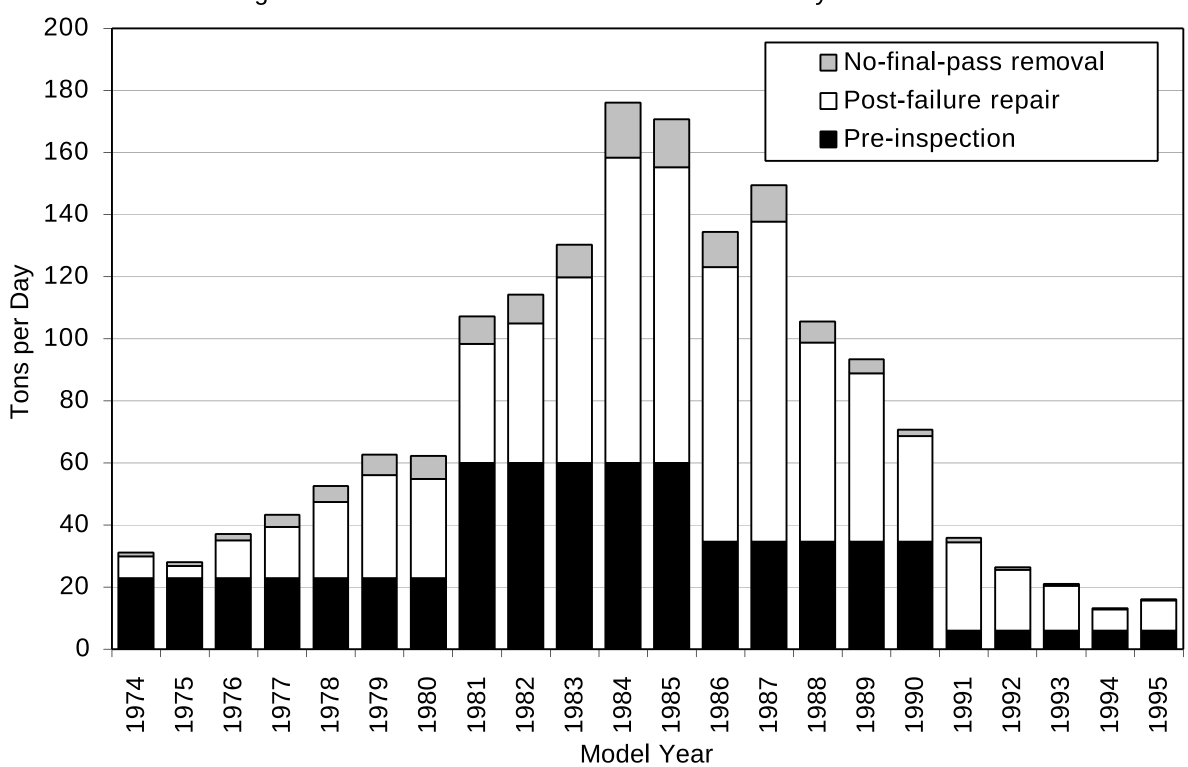


Figure 12. Estimated CO Emissions Prevented by Enhanced I/ M



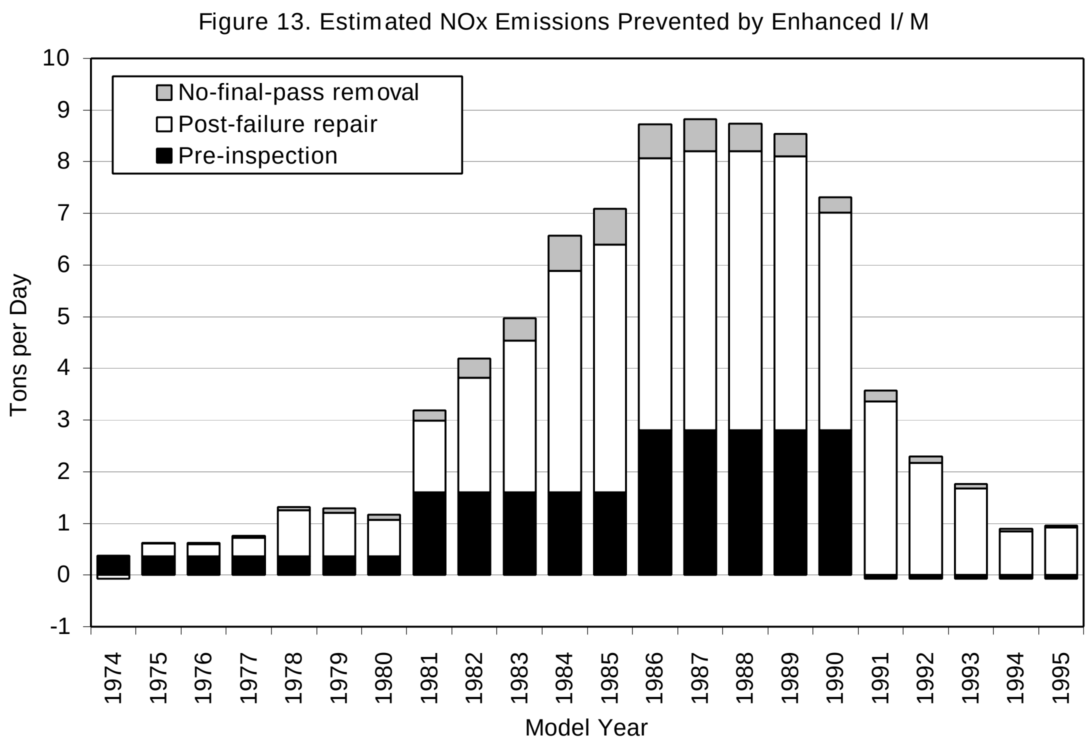


Table 3. Best estimate of benefits from Enhanced Smog Check, in tons per day of pollution prevented *(see text for details on methods and uncertainties).*

Process	HC	CO	NOx
Pre-inspection	24	664	24
Post-test repair	54	892	53
No-pass removal	8	131	6
All	86	1686	83
Including evap[39]	112	1686	83

These results suggest that repair of vehicles that fail their initial official Smog Check likely accounts for the largest fraction of benefits, but that maintenance and repair prior to official tests and pre-tests also contributes a large fraction of total benefits. Removal from Enhanced areas of vehicles that fail initially but never pass appears to contribute much less to total benefits. The CARB estimate of evaporative emission benefits suggests that this too may be an important component of Enhanced Smog Check.

The overall one-cycle benefits can also be compared to the incremental benefits of Enhanced Smog Check presented in Table 2. The similarity of the NOx benefit estimates is not surprising since the Basic Program is not expected to impact NOx emissions (all benefits thus occur from the Enhanced Program). The degree to which the numbers agree is reassuring since they were calculated largely from different data sets. Results for CO and HC are consistent with the expectation that continuing the Basic Program would have produced some benefits. Total one-cycle HC and CO benefits of Enhanced Smog Check are greater than the incremental benefits of Enhanced vs. Basic.

The distribution of benefits by vehicle model year is summarized in Figure 14 below. Figures 11 through 14 indicate that the large majority of benefits are obtained from vehicles that are 10 to 20 years old. Substantial benefits are obtained from vehicles more than 20 years old, but few benefits appear to result from testing of vehicles that were 5 to 9 years old in 1999. The negative benefits that appear to be associated with pre-inspection of these 5 to 9 year-old vehicles result from small differences in average emission factors multiplied by a large number of vehicles. The emission factors are shown in Appendix D.

The "efficiency" of testing vehicles from each model year is shown implicitly in Figure 14, and explicitly in Figure 15. Figure 14 indicates, for example, that 85% of estimated NOx benefits, 91% of estimated CO benefits, and all estimated HC benefits are obtained from only the oldest 49% of the vehicles currently eligible for testing (model years 1989 and older). Figure 15 shows tons per day of emissions reductions per 10,000 vehicles tested in each model year. The figure indicates that testing of the oldest vehicles is most efficient for HC reductions, but NOx reductions are more efficiently obtained from middle-aged (10- to 20-year-old) vehicles.

Figure 14. Cumulative Benefits and Vehicles Tested in Enhanced I/M

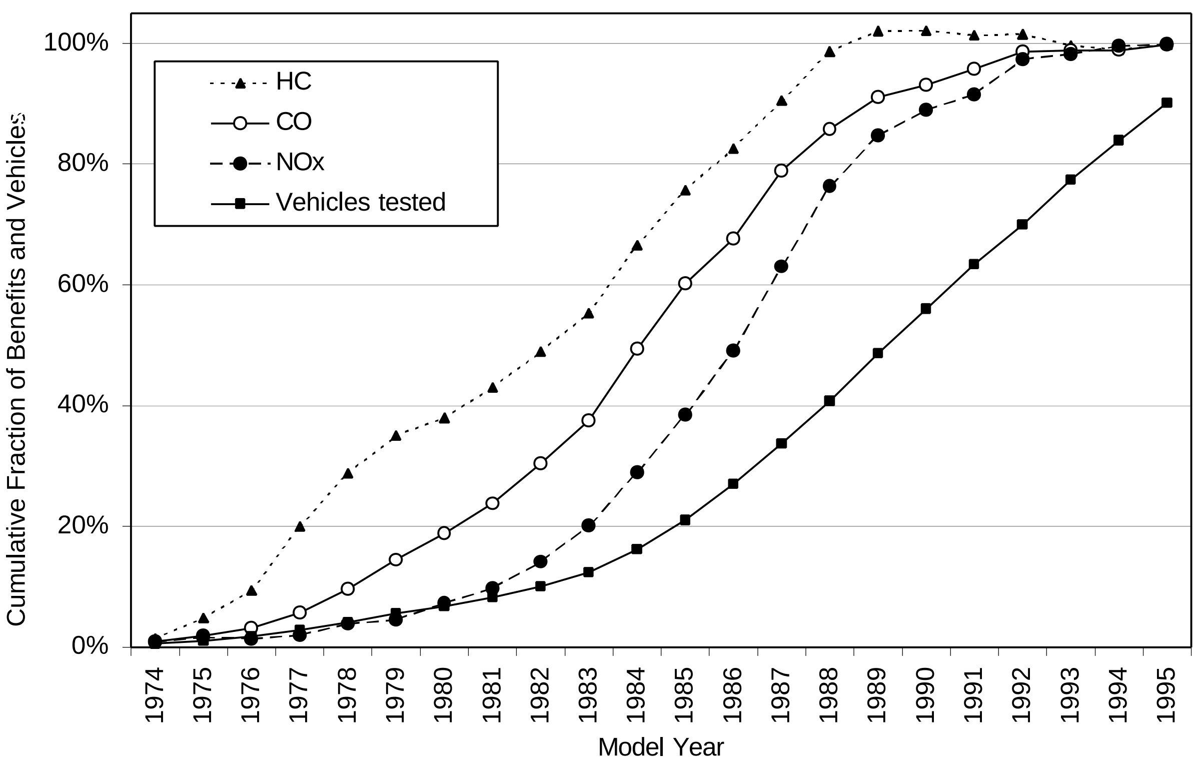
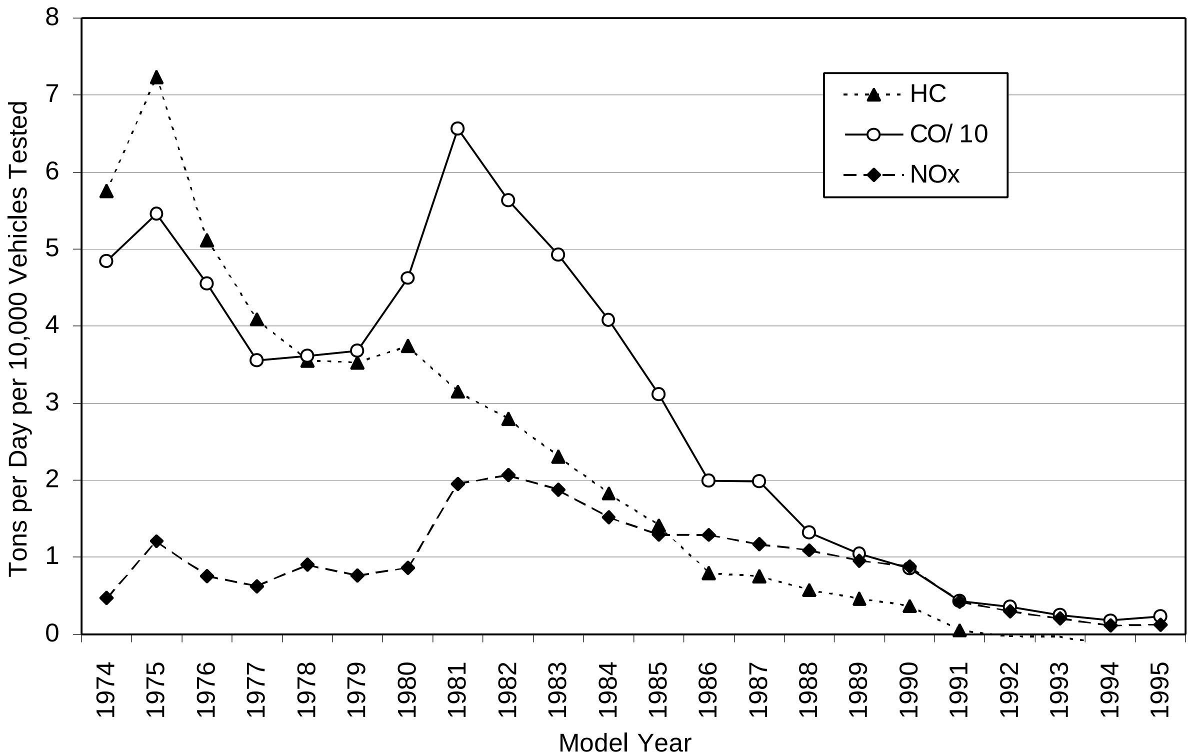


Figure 15. Estimated Efficiency of Enhanced I/ M Program



As mentioned previously, many assumptions were required to estimate program benefits. The "best" estimates presented above thus include significant uncertainty. Table 4 provides quantitative estimates of the sensitivity of our best program benefit estimates to the assumptions we used. These ranges are based on the bounding assumptions discussed in the Methods section above, and address only some of the uncertainty in our benefit estimates. Additional sources of uncertainty not addressed in Table 4 include: (a) the relationship between ASM test and actual on-road emission reductions, (b) use of CARB (EMFAC2000) estimates of average fuel economy by model year, (c) use of BAR's estimate of average annual miles traveled by model year, (d) potential sample bias in the roadside data, (e) potential test biases in the VID data, and (f) statistical bias from using initial Smog Check results to characterize average emissions of fail-pass and no-final-pass vehicles. The sensitivity of benefit estimates to various assumptions is discussed in more detail in Appendix D.

Table 4. Estimated Enhanced I/M Program benefits (tons per day of pollution prevented). *The ranges reflect uncertainty in assumptions about deterioration in the absence of Smog Check, deterioration of repaired vehicles in year 2 of an Enhanced I/M cycle, and pre-inspection benefits. Benefit estimates are based on Phase 3 NOx cut points.*

Process	HC	CO	NOx
Pre-inspection	16 - 32	442 - 884	16-32
Post-test repair	19 - 73	342 - 1176	40-53
No-pass removal	4.4 - 11	70 - 174	2.4-7.7
All	39 - 116	864 - 2235	59 - 93
Including evap[39]	65 - 142	864 - 2235	59 - 93

4.4.6. Caveats

The estimated program benefits described above should be considered with caution in light of the following caveats.

1. Some of the emission reductions attributed to Smog Check may result from maintenance and repairs that coincide with Smog Check testing, but which would have occurred even if Smog Check did not exist. Likewise some vehicle removal that we attribute to Smog Check might have occurred anyway.[40]

2. Emission reductions measured under ASM test conditions may not translate directly to on-road benefits. Our method uses emission reductions on the static loaded mode of the ASM test to estimate benefits during transient in-use vehicle operation.

3. Our method does not include estimates of I/M Program effects on incremental cold start emissions. Our method assumes that absolute reductions in average emission factors (in g/gal) units apply over all fuel usage, i.e. apply during cold start as well as hot stabilized driving. However, no additional benefit is assumed for incremental cold start emissions, i.e. for the extra emissions that occur for a short period after vehicles are started.

4. Our best estimates assume that vehicles receiving a two-speed idle as part of their Enhanced Smog Check achieve the same emission HC and CO reductions as those vehicles tested on the ASM.

5. Our estimates of repair and removal benefits do not account for regression to the mean effects on the initial emission test results of fail-pass and no-final-pass vehicles. Accounting for the regression to the mean effect would lower estimated benefits from repair and removal.

6. Our analysis does not account for delays in vehicle repair and removal.

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40. That benefit is credited only for those vehicles receiving an initial Smog Check test. We assume that most owners would not pay to have a Smog Check test unless they intended to continue driving the vehicle.

7. Our estimate does not account for fleet turnover in the two-year period. Some vehicles will be removed from the Enhanced areas for reasons unrelated to Smog Check requirements. For example, households may relocate to other areas or states, vehicles may be resold to owners in other areas or states, or vehicles may be retired for reasons unrelated to their emissions. The effect of fleet turnover will reduce vehicle emissions overall, but these reductions cannot all be credited to the program. Also, some vehicles that were tested in Enhanced areas will not remain in such areas throughout the next 2 years.

8. Our estimate is sensitive to the estimates of average in-use fuel economy by model year provided by CARB, and average vehicle miles of travel by model year provided by BAR. Actual reductions could be higher or lower, depending on the accuracy of the EMFAC2000 fuel economy estimates. Use of sales-weighted, EPA average new car fuel economy (adjusted for in-use conditions) instead of the estimates provided by CARB would greatly reduce the estimated program benefits.

4.5. What other factors affect emissions reductions?

There are several other elements of the Enhanced Smog Check Program that affect the estimation of emissions reductions caused by the program. In this section we discuss three of these elements: (1) the recording of emissions results of pretests prior to the official test, (2) the use of fast pass, and (3) the time between identification and repair of failing vehicles.

4.5.1. Pretests

If vehicles are repaired or adjusted prior to official testing, this will increase the effectiveness of the program in reducing emissions. Our estimates of initial program effectiveness include the benefit of repairs or adjustments made after official pretests. Over 18 months, 4.2% of vehicles receive a recorded pretest prior to the official initial test. More older vehicles receive pretests than newer vehicles: 11% of 1974 vehicles receive pretests, while only 1% of 1998 vehicles receive pretests. Only 1% of vehicles that have a pretest fail their initial official test. We compared fleet failure rates and average emissions over the 18-month period including pretests and then excluding pretests. The overall program failure rate drops from 12.6% including pretests to only 10.5% after pretests are excluded. Table 5 shows that repairs after official pretests account for 6% of the overall reduction in HC, 2% of the reduction in NOx, and 14% of the reduction in CO, as reported in the VID.

Table 5. Comparison of fleet average emissions over 18 months, including and excluding official pretests

	Including Pretests			Excluding Pretests			
Pollutant	Initial	Final	Redn	Initial	Final	Redn	Diff
HC (ppm)	50	41	19%	47	40	15%	-6%
NOx (ppm)	415	374	10%	406	371	9%	-2%
CO (%)	0.29	0.17	40%	0.25	0.17	33%	-14%

Some technicians abort the test, or code the test as an unofficial training test, if they suspect the vehicle will fail Gross Polluter cut points. It is possible that some of the aborted and training tests are in effect "unofficial" pretests. We looked at the fraction of aborted tests by station type to estimate the number of vehicles receiving unrecorded/unofficial pretests. Technicians at Test-Only stations have less incentive to abort a test, or code the test as a training test, if they suspect a vehicle will fail Gross Polluter cut points. We assume that the difference between the fraction of aborted and training tests at Test-and-Repair stations and Test-Only stations is the rate of unofficial pretests. 12% of all tests at Test-and-Repair stations are aborted, while only 6% of all tests at Test-Only stations are aborted. Similarly, 4% of all non-aborted tests at Test-and-Repair stations are coded as training tests, while less than 1% are so coded at Test-Only stations.[41] Therefore, we estimate that as much as 10% (6% + 4%) of all vehicles at Test-and-Repair stations receive an unofficial pretest (see Appendix B for more details). Some of these vehicles may receive repairs or adjustments that would reduce their emissions prior to official testing.

As discussed above in Section 4.4, we use the roadside data to estimate the benefit of any repairs or adjustments made prior to an official recorded pretest. However, the best way to measure the timing of these repairs, and their effect on emissions, is with an extensive remote sensing measurement program.

4.5.2. Fast pass

Vehicles are allowed to pass after as little as 10 seconds of emissions measurement on each mode of the ASM. As a result, emissions of some passing vehicles would be lower if they were tested for the full 170 seconds of the ASM (as vehicles warm up, emissions decrease). We examined total test duration (ASM plus visual and functional inspections) to estimate the effect of the number of "fast passes" on different groups of vehicles. We assume that groups of vehicles with shorter overall test durations are more likely to have been fast passed than vehicles with longer test durations. Tests of older vehicles take longer than tests of newer vehicles. We weight all fleet average test durations by the same model year distribution to account for difference in test duration by vehicle age. Tests of passing vehicles take on average 11 minutes. Tests of failing vehicles take about 13 minutes, while tampered vehicles take the longest at 15 minutes. Tests conducted under current (Phase 4) cut points take slightly longer than tests conducted under initial cut points.

The analysis of test duration only indicates which groups of vehicles were likely to have been fast passed. We hope to analyze in the future second-by-second roadside ASM tests to estimate the effect of fast passing of vehicles on the emissions of passing vehicles and the overall fleet.

4.5.3. Days and time to pass

How long it takes owners of failed vehicles to repair their vehicles will impact the effectiveness of the program. 33% of all fail-pass vehicles that fail their initial test pass a retest on the same day. Of these, 28% pass a retest within 30 minutes of the initial test, and 50% pass a retest within an hour. 90% of all fail-pass vehicles have passed a retest within 45 days of their initial test, 95% have passed within 90 days, and 98% have passed within 6 months. The average time to pass after failing an initial test is 19 days. The time it takes to pass after failing an initial test

41. We did not have time to examine the rate of training tests for this analysis. We hope to analyze the training tests in the future.

varies by station type. Vehicles that have their final passing test at a Gross Polluter Certification station take on average 15 days to pass, while vehicles that receive a passing test at Test-Only stations take on average 21 days to pass. Vehicles that either fail gross polluter cut points or have been tampered take on average 27 days to pass, while vehicles that just fail the emissions test take on average 15 days to pass. As discussed above, some vehicles never receive a passing retest.

4.6. Is there a difference in effectiveness between Test-Only and Test-and-Repair stations?

Test-and-Repair stations appear to achieve lower fleet emissions reductions than those achieved at Test-Only stations. However, it is not clear that this is because Test-Only stations are inherently more effective at identifying high-emitting vehicles, and ensuring that they are repaired. The data indicate that two other possible causes are that: (1) the vehicle fleet reporting to Test-Only stations is dirtier initially than the fleet reporting to Test-and-Repair stations, and (2) Test-Only stations have been more closely monitored and regulated than Test-and-Repair stations. The latter possibility is supported by the finding that Gross Polluter Certification stations and Test-Only stations, both of which are more closely monitored by BAR than are other stations, are equally effective in reducing emissions from Gross Polluter vehicles.

The Enhanced Program established a network of Test-Only stations, with the assumption that these stations would do a better job at identifying high emitters, and ensuring that these vehicles are repaired, than Test-and-Repair stations. If this were so, we would expect that vehicles tested at Test-Only stations would have higher initial failure rates and higher percent emissions reductions by model year than vehicles tested at Test-and-Repair stations.[42] We compared the random sample of directed vehicles that had their final test at Test-Only stations with all non-directed vehicles that reported initially to Test-and-Repair stations. Table 6 shows that, after correcting for model year differences between the vehicle populations reporting to each station type, the random sample certified at Test-Only stations has a higher failure rate and percent reductions than the non-directed fleet tested at Test-and-Repair stations. One reason for the larger percent reduction is that initial emissions are higher at Test-Only stations, so the reduction potential is greater. Figure 16 shows the initial and final HC emissions by model year for vehicles certified at each type of station.

A question arises as to whether the higher failure rate and higher initial emissions at Test-Only stations is due to better detection of high emitters, or does it reflect a fundamental difference in the fleet of vehicles reporting to Test-Only? 53% of the vehicles reporting to Test-Only stations are directed; of these, 80% were identified as High Emitter Profile (HEP) vehicles, and thus are likely to be high emitters. Since the purpose of the HEP is to direct the suspected dirtiest 13% of vehicles to Test-Only stations, we would expect that the non-directed vehicles reporting to Test-

42. All percent reductions reported in this section are based on the initial and final tests of the first Smog Check cycle for the entire vehicle fleet; they are not based on the initial test of the first and second Smog Check cycle of the multi-cycle fleet, as described in sections 4.1 and 4.2.

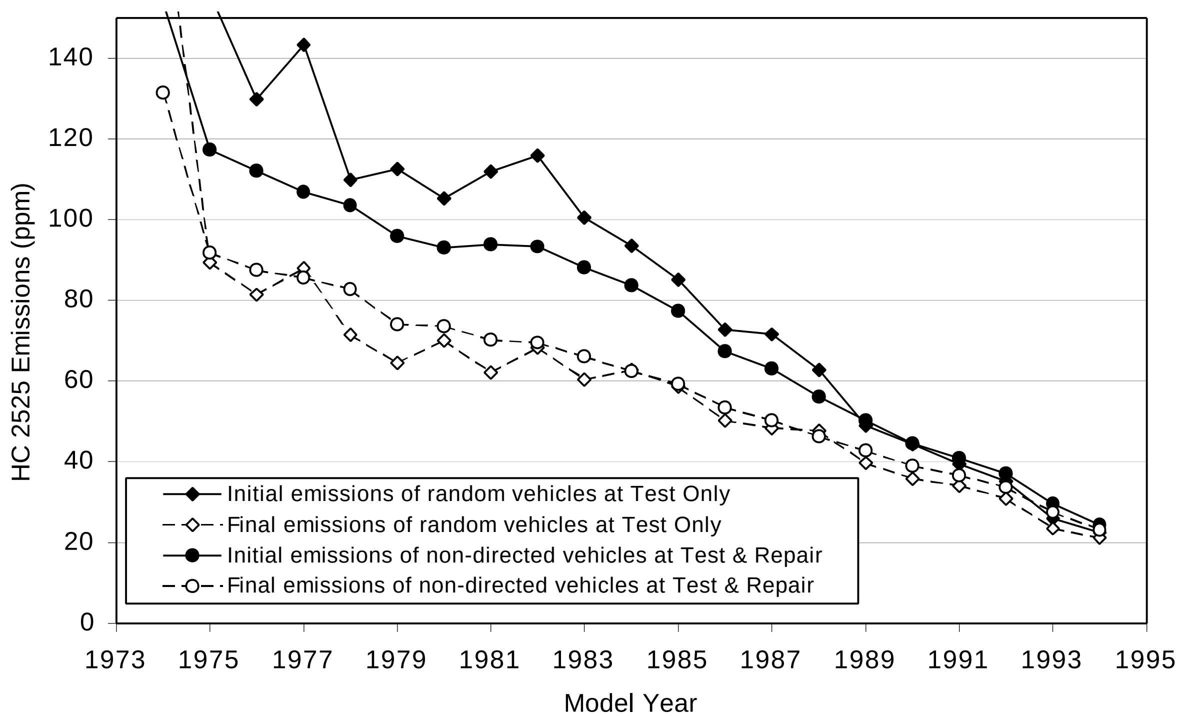
and-Repair stations have lower emissions, and thus less emissions reduction potential, than the directed vehicles certified at Test-Only stations.[43]

Table 6. Comparison of random directed vehicle fleet certified at Test-Only stations and non-directed fleet certified at Test-and-Repair stations

	Test-Only	Test-and-Repair
Failure Rate	22%	13%
Initial Emissions		
HC (ppm)	63	58
CO (%)	0.41	0.32
NOx (ppm)	485	468
Final Emissions		
HC (ppm)	45	47
CO (%)	0.19	0.20
NOx (ppm)	401	417
Percent Reduction		
HC	28%	18%
CO	53%	38%
NOx	17%	11%

43. We cannot compare the directed fleets that report initially to Test-Only and Test-and-Repair stations, since nearly half of the directed vehicles that report initially to Test-and-Repair stations get their final passing test at a Test-Only station. Since there are virtually no pretests conducted at Test-Only stations, we suspect the reason these directed vehicles are initially reporting to a Test-and-Repair station is to get a pretest. The highest emitters of the directed fleet, therefore, may be reporting initially to Test-and-Repair stations.

Figure 16. Initial and Final HC Emissions by Station Type and Model Year

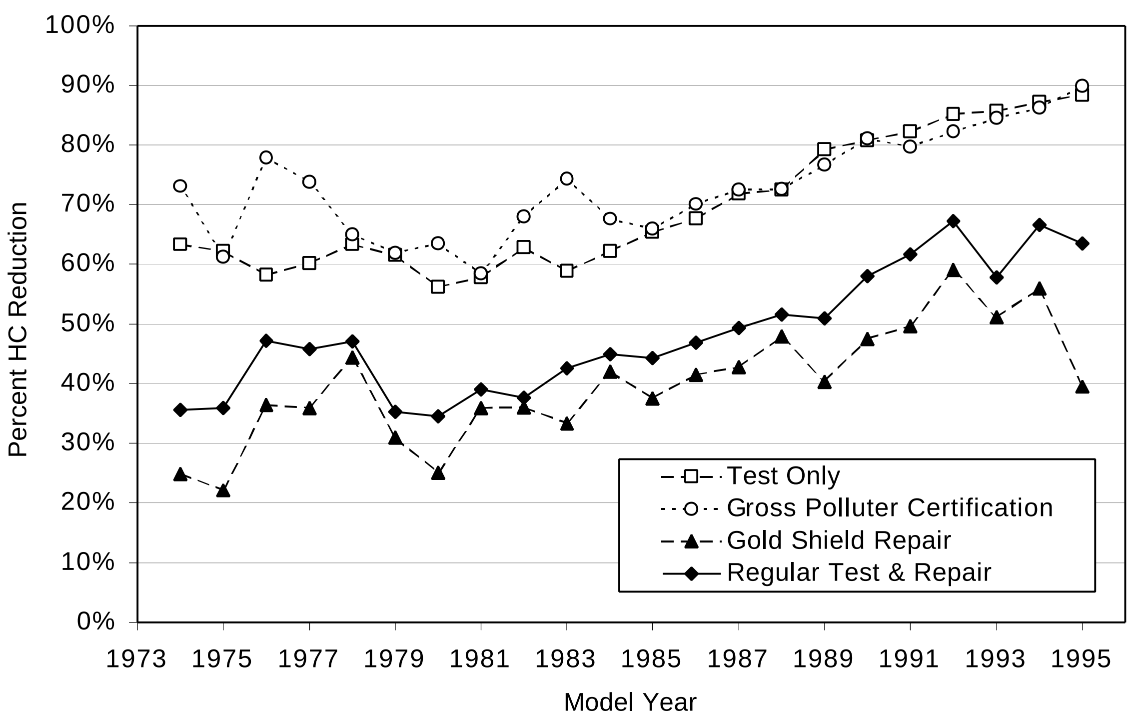


We also compared the results of Gross Polluter vehicles that were certified at Test-Only and Test-and-Repair stations. The results are shown in Table 7. Gross Polluters certified at Test-Only stations have slightly lower initial emissions but higher percent reductions than Gross Polluters certified at regular Test-and-Repair stations. However, Gross Polluter Certification stations appear to be doing as good, if not a slightly better, job as Test-Only stations at reducing emissions of Gross Polluters. Initial emissions of Gross Polluters are lower, and emissions reductions slightly larger, at GPC stations than at Test-Only stations. Figure 17 shows the percent reduction in HC emissions by model year for each station type. Gold Shield Guaranteed Repair stations appear to be slightly less effective than regular Test-and-Repair stations in repairing Gross Polluter vehicles. One possible explanation for the better performance of Test-Only and GPC stations compared to other Test-and-Repair stations is that these stations have been more closely monitored than other Test-and-Repair stations.

Table 7. Comparison of Gross Polluter vehicle fleet certified at Test-Only and Test-and-Repair stations

	Test-Only	Regular Test-and-Repair	Gross Polluter Certification
Initial Emissions			
HC (ppm)	330	338	317
CO (%)	4.27	4.21	4.11
NOx (ppm)	522	511	500
Final Emissions			
HC (ppm)	106	204	91
CO (%)	0.90	1.95	0.73
NOx (ppm)	480	520	466
Percent Reduction			
HC	68%	40%	71%
CO	79%	54%	82%
NOx	8%	-2%	7%

Figure 17. Average HC Emission Reductions from Gross Polluter Vehicles by Station Type



4.7. How effective is the High Emitter Profile in targeting high-emitting vehicles?

The high emitter profile does no better at identifying high-emitting older vehicles, and does slightly better at identifying high-emitting newer vehicles, than random selection.

The High Emitter Profile (or HEP) is a computer program that ranks vehicles by their predicted likelihood failing their next Smog Check test. The HEP determines the ranking based on three sources of information: (1) the prior Smog Check history of an individual vehicle, (2) the average historical Smog Check failure rate of vehicles of the same year, make, and model, and (3) any remote sensing measurements of the individual vehicle. The HEP is maintained by ERG for BAR.

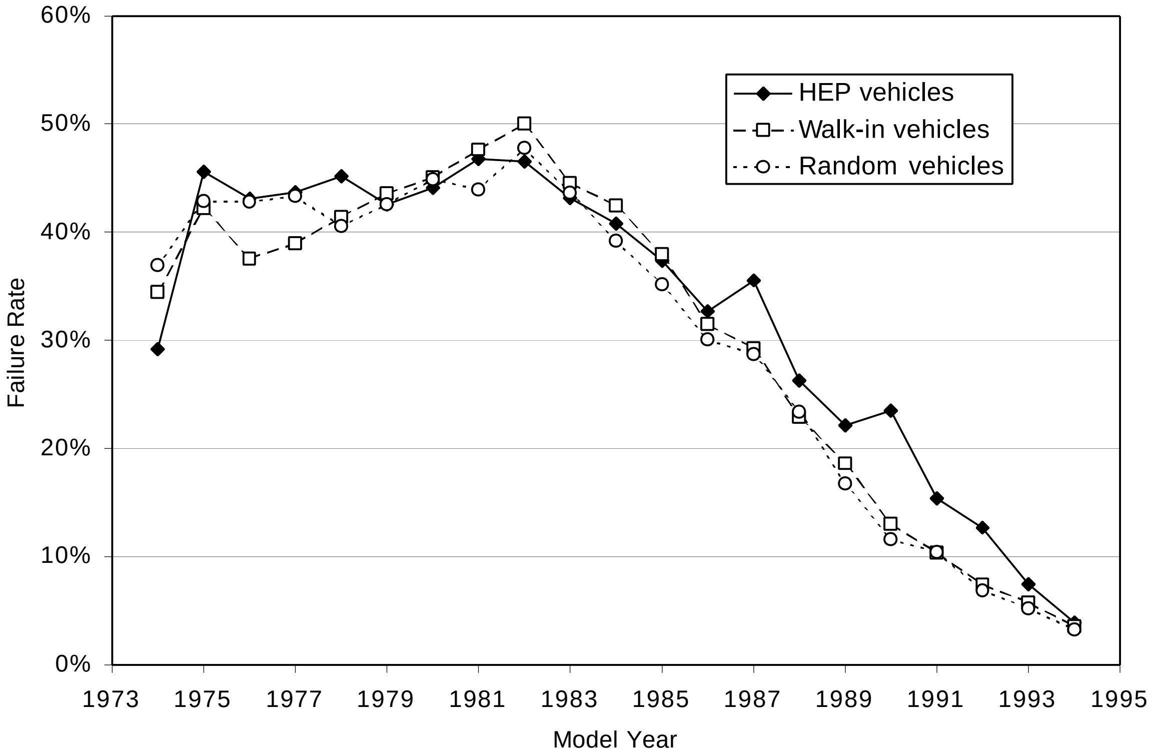
If the HEP is effectively identifying high-emitting vehicles, we would expect the failure rate and average initial emissions by model year to be higher for HEP-directed vehicles than for randomly directed and non-directed vehicles. Table 8 compares the failure rate and initial emissions of each vehicle fleet at Test-Only stations, after adjusting for model year differences. The HEP-directed vehicles have a slightly higher failure rate and average emissions than the randomly directed and non-directed vehicles. Figure 18 indicates that the failure rates of HEP vehicles are slightly higher than those of non-HEP vehicles for 1987 and newer vehicles. However, the failure rates and initial emissions for 1986 and older vehicles are the same.[44]

Table 8. Comparison of vehicle fleets certified at Test-Only stations

	HEP Directed	Random Directed	Non-Directed
Failure Rate	26%	22%	23%
Initial Emissions			
HC (ppm)	71	63	68
CO (%)	0.45	0.41	0.46
NOx (ppm)	520	485	494

44. BAR informs us that the current version of the HEP was developed in 1996 using model-specific failure rates under a different test cycle than the ASM, the IM240. The HEP may perform better once it has been updated with more recent data from ASM testing. In addition, it is possible that directing motorists to test-only stations using the HEP changes motorists' behavior, resulting in program avoidance that lowers the apparent effectiveness of the HEP.

Figure 18. Failure Rates at Test Only Stations by Vehicle Type and Model Year



5. What effect would changes to the program have on program effectiveness?

In this section we estimate what effect certain changes to the program would have on our estimates of program benefits. We analyze the effect of three program changes on our estimates: (1) changing the groups of vehicles currently exempted from the program, (2) tightening the current cut points, and (3) ensuring a higher rate of vehicle compliance. We also list other possible changes to the program. We do not estimate the impact of these changes on our estimated program benefits in this report.

5.1. Change vehicle exemptions

Figures 11 through 16 show our estimate of the program benefit by model year, as well as the benefit by model year per 10,000 vehicles tested. The figures demonstrate that the total benefit is concentrated in middle-aged vehicles, and the benefit per vehicle tested is much higher for older vehicles than newer vehicles. Therefore, requiring that additional model years of older vehicles (1973 and older) be tested may be more cost-effective than the testing of newer vehicles.

We used the remote sensing data to estimate the total amount of emissions from model years of vehicles currently exempted from the program. Table 9 shows that 1973 and older vehicles, which account for only 1% of the vehicles, account for 4% to 8% of all on-road emissions, while 1996 and newer vehicles not tested under Smog Check,[45] which make up 22% of the fleet, account for 5% to 10% of all on-road emissions, depending on the pollutant (see Appendix F for more detail on the analysis of fleet on-road emissions using remote sensing data).

Table 9. Fraction of Remote Sensing Emissions from Exempted Vehicle Groups, South Coast Air Basin

Vehicle group	Percent of Readings	Percent of Emissions		
		HC	NOx	CO
1973 and older	1%	7%	4%	8%
1996 and newer	22%	10%	5%	5%
All exempted vehicles	23%	17%	9%	13%

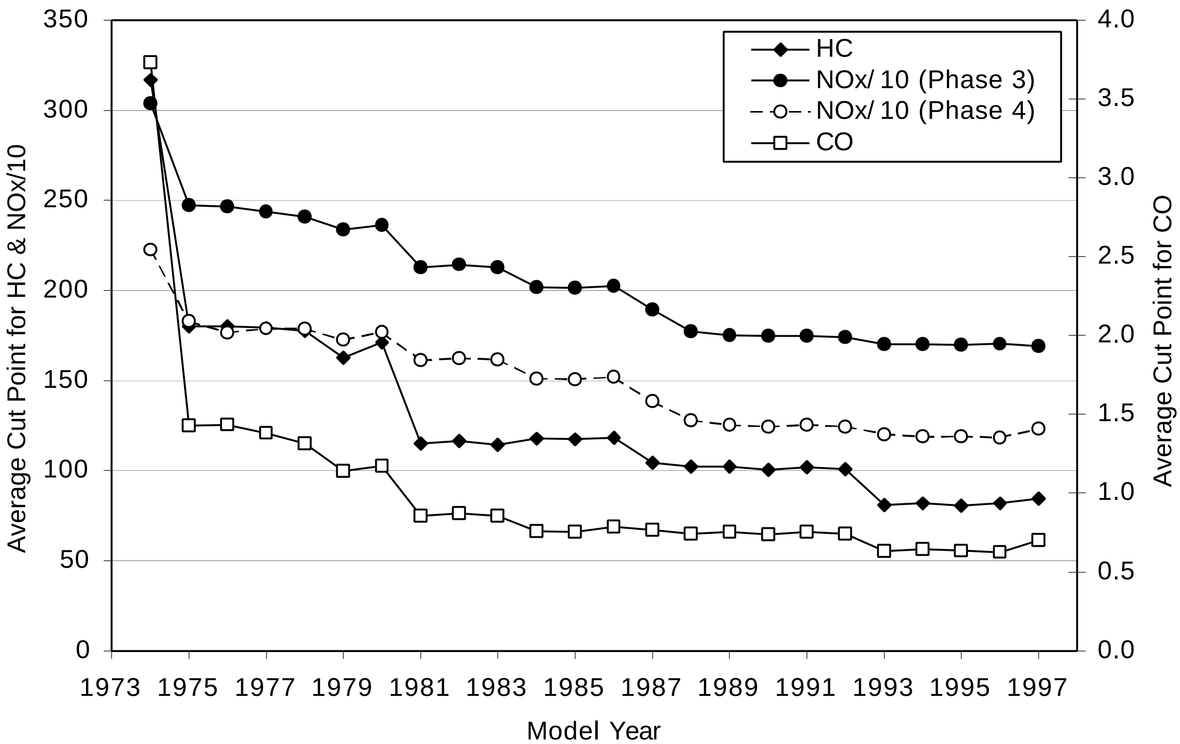
5.2. Tighten cut points

Tightening cut points will result in more vehicles failing Smog Check testing, and may result in larger emissions reductions. However, cut points should not be set so low that a large number of vehicles fail the cut points that would pass if retested without any repair.

Figure 19 shows the average cut points by model year for vehicles tested in 1999. Average HC and NOx (divided by 10) cut points are shown on the left axis, while average CO cut points are shown on the right axis. The figure indicates that cut points for the oldest vehicles are considerably higher than the cut points for newer vehicles. We analyzed the efficiency of the

45. These are vehicles that were first sold in California; 1996 and newer vehicles that were purchased in other states and subsequently re-registered in California are required to have a Smog Check test.

Figure 19. Average ASM 2525 Cut Point Levels, 1999



current cut point levels by applying the cut points to all of the vehicles given a roadside ASM, and comparing the distribution of vehicle emissions to the cut point levels. Figures 20 and 21 compare the ratio of all three pollutants to the current cut point levels (and NOx to Phase 3 cut points), for 1975 to 1980 and 1993 to 1995 passenger cars, respectively. The figures show the cumulative fraction of vehicles on the vertical axis, and the emissions level, in terms of the ratio to the cut point level, for each pollutant on the horizontal axis. For example, Figure 20 indicates that almost 35% of the roadside vehicles in emissions standards category 4 (1975 to 1980 passenger cars) have emissions at or above the current CO cut point, 27% have emissions at or above the HC cut point, 8% have NOx emissions at or above the Phase 3 NOx cut point, and almost 16% have NOx emissions at or above the Phase 4 NOx cut point.

If the cut points fall in the region where the emissions distribution is very flat, there are relatively few vehicles with emissions close to the cut point, and the chance of improperly failing a vehicle is relatively low. Figure 21 indicates that the emissions distribution of newer vehicles (emissions standards category 8, or 1993 and newer passenger cars) is quite skewed, with most vehicles having very low emissions and a few vehicles with very high emissions. The location of the cut points in the flat region of the emissions distribution indicates that the current cut points for newer vehicles may be too high (too loose), and perhaps could be lowered. Figure 20 shows that the emissions distributions of older cars are less skewed, and that the current cut points may be appropriate for older vehicles.

Figure 20. Emissions Distributions of Roadside Vehicles,
Emissions Standards Category 4 (1975-80 Passenger Cars)

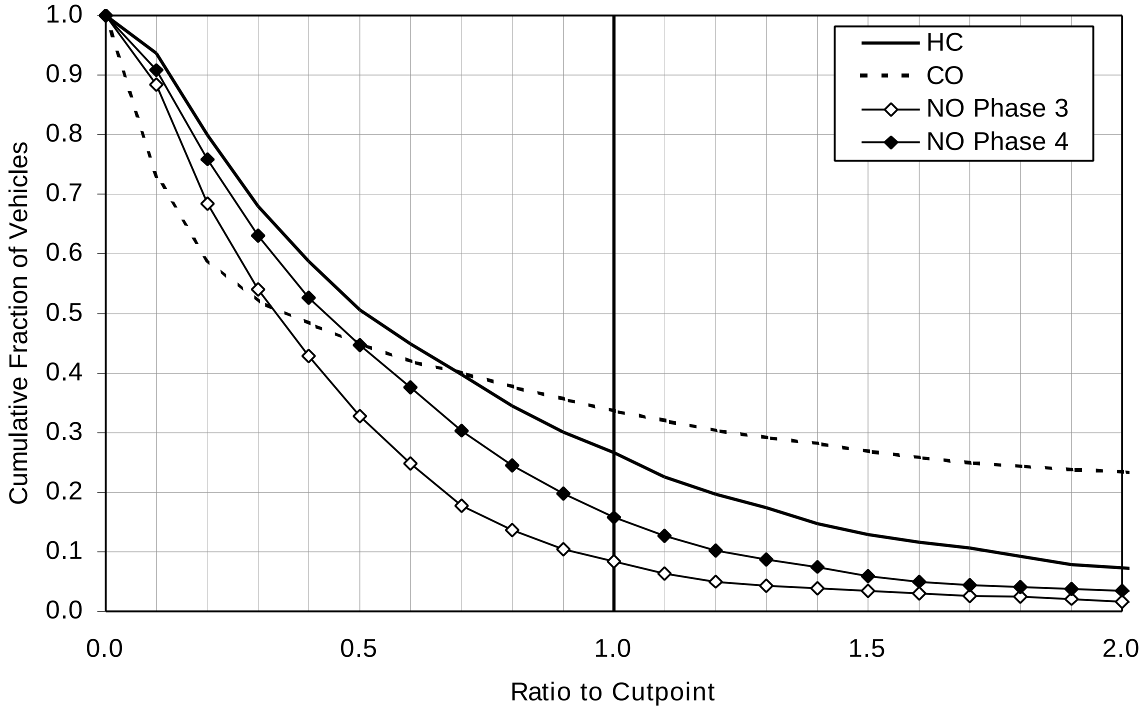
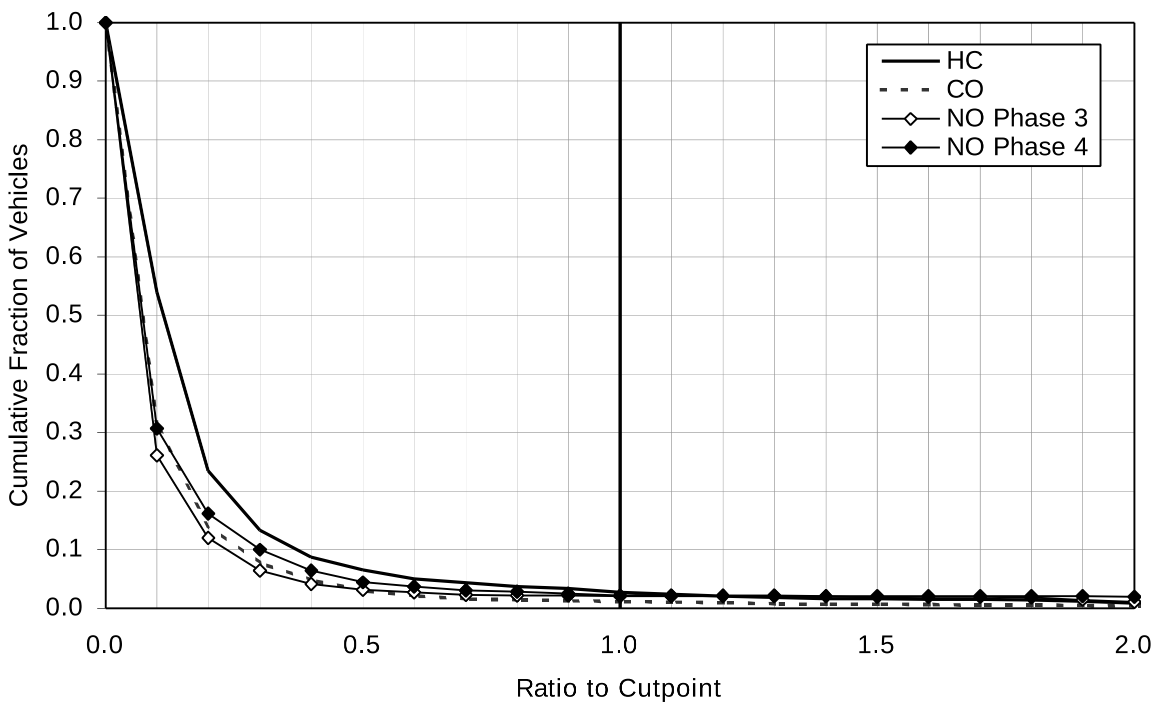


Figure 21. Emissions Distributions of Roadside Vehicles
Emissions Standards Category 8 (1993 and Newer Passenger Cars)



5.3. Enforce vehicle compliance

Our best estimate of program benefit indicates that 7% to 10% of the benefit comes from the removal of vehicles that cannot be repaired to pass Smog Check testing, and the replacement of those vehicles with normal emitting vehicles. This estimate is based on the observation that 33% of the no-final-pass vehicles continue to be driven in Enhanced areas of the state. Stronger enforcement of Smog Check requirements might result in more of the no-final-pass vehicles being removed from Enhanced areas. If we assume that all of the no-final-pass vehicles are replaced by the average vehicle, our best estimate of the benefit of the program would increase by about 5%.

Our estimate of program benefit from the South Coast remote sensing data found that 12% to 13% of all on-road emissions come from untested, but Smog Check eligible, vehicles. (Our estimate of total on-road emissions excludes emissions from unregistered vehicles and vehicles currently registered in other states; see Appendix F for more detail on the analysis of fleet on-road emissions using remote sensing data). The program would be even more effective if these registered but non-participating vehicles complied with program requirements.

5.4. Other changes not analyzed

Several other changes to the program might improve program effectiveness and cost-effectiveness. We describe these changes here, but did not explicitly analyze them as part of this study.

5.4.1. More frequent testing

Our analysis indicates that 20% of the fail-pass vehicles, and 6% of vehicles that pass initial testing, fail a subsequent test as little as one month later. More frequent testing of vehicles would identify these failing vehicles sooner, and make the program more effective. Vehicles suspected of being high emitters could be subject to more frequent ASM testing. Another alternative, used by the state of Arizona, is to use on-road remote sensing to identify on-road high-emitters. Remote sensing allows for the identification of vehicles that: (1) malfunction between Smog Check cycles, (2) pass a Smog Check despite having emissions control problems, (3) have repairs that reduce emissions during ASM conditions, but not during transient on-road driving. Although individual remote sensing measurements are not as precise as properly conducted ASM tests, cut points can be set loose enough to ensure that identified vehicles are truly high-emitters. Alternatively, the state could require a vehicle to report for a mid-cycle Smog Check only if it “fails” more than one remote sensing “test”. The use of an extensive remote sensing network to collect multiple measurements on individual vehicles over time would offer the following additional benefits: (1) improved understanding and identification of intermittent high emitters (vehicles with large emissions variability), (2) improved data to estimate the durability of repairs with time, (3) better data for estimating on-road benefits of the Smog Check Program, and (4) more extensive data on vehicles that are driven more on-road. To defray the cost of remote sensing, vehicles that receive multiple “clean” remote sensing results without any high emissions results could be relieved from biennial testing.

5.4.2. Improve repairs

Our analysis indicates that, for the vehicles that apparently are repaired, the repairs are durable, lasting for at least the first year after initial testing. However, emissions of repaired vehicles may begin to increase after the first year after testing. Our benefit estimate assumes that, at a minimum, emissions of fail-pass vehicles will increase in the second year at the same rate as observed for the initial pass vehicles in the first year after testing. Policies to encourage more durable repair would improve program effectiveness. Methods that might improve vehicle repair include: (1) requiring enhanced diagnostic and repair training for technicians; providing incentives to technicians to repair all broken or malfunctioning components, rather than merely reducing vehicle emissions to pass the test, (2) supplying motorists with information on each individual repair station's record on repairing vehicles, and (3) providing motorists with incentives to seek effective and durable repairs. Few data or other evidence are currently available to test the effect of these measures on repair effectiveness.

5.4.3. Eliminate repair cost waivers/hardship extensions

Under the current program, failed vehicles can receive a repair cost waiver or economic hardship extension. BAR reports that only 5,000 vehicles received either of these extensions over the 18 months of the program we analyzed. These waived vehicles represent 4% of all no-final-pass vehicles, and less than 1% of all failed vehicles. Waived vehicles are not identified in the VID database, so we cannot estimate the potential emissions reductions of disallowing repair cost waivers. The small number of vehicles involved, though, suggests that eliminating waivers would have a small impact on program effectiveness. However, it may be cost-effective to require that these vehicles be repaired once they have been identified.

5.4.4. Fully centralize program

If Test-Only stations perform a better job of identifying high-emitting vehicles, and ensuring that they are properly repaired, than Test-and-Repair stations, program effectiveness could be improved by requiring that all vehicles be tested at Test-Only stations. However, while our analysis indicates that Test-Only stations appear to be more effective than all Test-and-Repair stations in reducing emissions from all vehicles, Gross Polluter Certification stations appear to be just as effective as Test-Only stations in reducing emissions from Gross Polluters. Therefore we conclude that separating testing from repair alone is not responsible for the difference in effectiveness between station types. Rather, it is likely that performance of all stations would be improved with increased oversight and enforcement, which BAR currently applies to only Test-Only and Gross Polluter Certification stations.

6. Summary

The Inspection and Maintenance Review Committee (IMRC) created by the California State Legislature has contracted with researchers at Lawrence Berkeley National Laboratory and the University of California at Berkeley to evaluate California's current vehicle inspection and maintenance (or I/M) program, referred to as Enhanced Smog Check. The IMRC has requested answers to the following questions:

- How effective is the Enhanced Program in initially reducing vehicle emissions?
- To what extent do reductions persist with time after the test?
- To what extent are motorists avoiding program requirements?
- What are the overall emissions benefits of the program?
- What other factors affect emissions reductions?
- Is there a difference in effectiveness between test-only and test-and-repair stations?
- How effective is the High Emitter Profile in targeting high-emitting vehicles?
- What effect would changes to the program have on program effectiveness?

The IMRC requested an analysis of all relevant and available data, emphasizing the data and analyses that provide reliable results to aid in program evaluation and recommendations for program improvements. This report details the results of our efforts to answer these questions.

Our analyses focus on how Smog Check impacts *exhaust* emissions of hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NOx) from the light-duty vehicle fleet reporting for Enhanced Smog Check testing. Program effects on evaporative HC emissions and on trucks greater than 8,500 pounds are not analyzed in this report.

We use three independent sets of vehicle emissions measurements in our evaluation. Each data source has unique strengths and weaknesses, and can best be used to answer different questions about program effectiveness. Using multiple data sources reduces uncertainty and strengthens our analysis. Program elements are analyzed primarily using the database of all Smog Check test records, known as the Vehicle Information Database, or VID. Other data sources include roadside Smog Check tests performed by the Bureau of Automotive Repair and on-road remote sensing emission measurements.

The VID-based analysis of program elements generally compares failure rates and emissions of subgroups of vehicles, by model year, during their initial Smog Check test, including official "pretests", and during their final passing tests. Analysis of repair durability in vehicles that fail their initial Smog Check then pass a retest, ostensibly after repair, is accomplished using data from vehicles with more than one Smog Check cycle during a 13-month period (one of the tests is assumed to be for change-of-ownership). Initial emissions on the second cycle are compared to emissions on the first cycle, which occurred from one to thirteen months prior. The same method is used to estimate deterioration among the fleet of vehicles passing their initial Smog Check.

Overall benefits of a single 2-year Smog Check cycle are calculated using a combination of the roadside and VID data. Benefits are calculated using a bottom-up approach in which average emission reductions per-vehicle are multiplied by the total number of vehicles affected. Separate estimates are made for benefits from pre-inspection maintenance and repairs, post-failure repair, and removal of vehicles that do not pass Smog Check. The roadside data allow for an estimate of pre-inspection benefits, whereas the VID data provide important information on deterioration following Smog Check and benefits from post-failure repair. The roadside data are also used to estimate the incremental effects of the Enhanced Program relative to Basic I/M. Estimating benefits required assumptions about fleet deterioration that would occur in the absence of Smog Check and deterioration in the second year following Enhanced Smog Check testing. We provide best estimates of these processes, and assess the effect of our assumptions on estimates of program benefits based on lower and upper bound estimates on the assumed parameters. The effect of Smog Check on full, real-world driving cycle emissions is also highly uncertain, and could not be fully addressed in this report.

This report provides detailed analyses of various elements of the Enhanced Smog Check Program, such as the short-term durability of repairs, the degree of program avoidance, effectiveness by station type, and an estimate of the number of unrecorded pretests. These analyses will help the IMRC make specific recommendations to the State Legislature on how to improve the effectiveness of the program. In addition, we provide estimates of the actual emissions benefits of the program. Our findings include the following:

- The Enhanced Program achieves substantial emission reductions, the vast majority of which last for at least one year for vehicles that fail, then pass their Enhanced Smog Check (Figure 4, page 15).

- Average HC and CO emissions of vehicles that pass their initial Enhanced Smog Check increase steadily and substantially over the next 6 months and then level off (Figure 6, page 16).

- Average emissions of the overall fleet are reduced by 5% for HC and NOx, and 20% for CO, up to two months after Enhanced Smog Check testing. However, the emissions increase from vehicles that pass their initial test counters the lasting emissions reductions from vehicles that fail initial testing but pass a retest. The result is that four months after completing Smog Check, fleet HC and CO emissions are higher than they were prior to Smog Check (Figure 7, page 17). Emissions would be even higher in the absence of the program.

- We estimate that a single two-year cycle of the Enhanced Smog Check Program prevents *tailpipe exhaust* emissions of approximately 86 tons per day of HC, 1,686 tons per day of CO, and 83 tons per day of NOx from the motor vehicle fleet, based on measurements made under Smog Check test conditions (Table 3, page 34). Based on uncertainties in the value of several key parameters required to generate our estimates, actual benefits could be as low as 40, 864, and 59 tons per day, or as high as 116, 2,235, and 93 tons per day respectively of HC, CO, and NOx. (Table 4, page 36). These results are summarized in the table below.

Estimated Enhanced Smog Check Tailpipe Emission Reductions in Tons Per Day. Lower- and Upper-Bound Estimates Reflect Uncertainties in Parameters Necessary to Calculate Benefits.

	HC	CO	NOx
Lower Bound	40	864	59
Best Estimate	**86**	**1,686**	**83**
Upper Bound	116	2,235	93

- Repair of vehicles that fail an initial Smog Check appears to be the most important mechanism of emission reductions, but maintenance and repairs prior to official Smog Check tests also appear to contribute significant benefits. Benefits from removal of non-passing vehicles appear to be much smaller. (Figures 11 to 13, pages 33 and 34)

- More than 90% of all emission reduction benefits can be attributed to vehicles more than 10 years old, even though such vehicles represent only half of those tested in the program. (Figure 14, page 35).

- The Enhanced Smog Check Program appears to achieve substantial emission reductions beyond those of Basic Smog Check. These include the prevention of roughly 50 to 55 tons per day of HC exhaust, 800 to 950 tons per day of CO exhaust, and 25 to 80 tons per day of NOx exhaust emissions vehicles in Enhanced areas (Tables 1 and 2, page 29).

- Older vehicles that are currently exempt from the Enhanced Program account for 4% to 8% of total on-road emissions, depending on the pollutant (Table 9, page 46).

- Roadside emissions tests indicate that the Enhanced Program is reducing fleet emissions by 17% for HC, 28% for CO, and 9% for NOx.

- An initial, limited remote sensing study suggests a much smaller emissions reduction benefit than is measured under program test conditions or at roadside. The remote sensing data indicate that lasting program benefits can be seen on-road for 6 to 9 months for HC and CO, but for just the first 3 months for NOx (Figure 8, page 20). A much larger remote sensing study should be conducted for on-road validation of emissions reduction benefits measured under test conditions.

- Ten percent of vehicles failing their initial test (1.3% of all vehicles) never receive a passing test. These vehicles have HC emissions 81% higher, and NOx emissions 15% higher, on average, than vehicles that eventually pass their Smog Check test. About one-third of these vehicles were observed driving in Enhanced areas one year after testing. This degree of non-compliance is less than observed in the Phoenix I/M program.

- An additional 10% of vehicles observed on road are registered in Enhanced areas and eligible for Smog Check testing, but there is no record of them reporting for testing. More research is needed to better quantify the number of vehicles avoiding Smog Check testing altogether.

- Test-Only stations and Gross Polluter Certification stations, a type of Test-and-Repair station, are equally effective in reducing emissions of Gross Polluter vehicles (Figure 17, page 43).

- Other types of Test-and-Repair stations appear to achieve lower fleet emissions reductions than those achieved at Test-Only stations. However, it is not clear that this is because Test-Only stations are inherently more effective at identifying high-emitting vehicles and ensuring that they are repaired. The data indicate that two other possible causes are that: (1) the vehicle fleet reporting to Test-Only stations has higher initial emissions than the fleet reporting to Test-and-Repair stations, and (2) Test-Only stations have been more closely monitored than Test-and-Repair stations. The latter possibility is supported by the finding that Gross Polluter Certification stations and Test-Only stations, both of which are more closely monitored by BAR than are other stations, are equally effective in reducing emissions from Gross Polluter vehicles.

- The high emitter profile does no better at identifying high-emitting older vehicles, and does slightly better at identifying high-emitting newer vehicles, than random selection. (see Figure 18, page 45).

The analyses and results presented herein are aimed at providing answers to the technical questions posed by the IMRC. The work is not intended to be exhaustive; there are many important issues that could not be fully addressed given the data and time available. Specific uncertainties and limitations are described throughout the report. Overall, we feel that the analysis of program elements, including the emission trends over time of initially failing and initially passing vehicles, assessments of non-compliance rates, comparisons of test station effectiveness, and the relative emission reduction benefits by model year are the strongest, most certain results. As described in detail in the report and appendices, estimates of overall program benefits are limited in scope and inherently uncertain. Benefits are estimated only for exhaust emission reductions during a single two-year Smog Check cycle, with a focus on emission reductions during hot running vehicle operation. Benefits are estimated for the Smog Check Program as implemented under relatively loose NOx emission standards (Phase 3 cut points). Stricter NOx emission standards that were put in place in November 1999 may significantly increase NOx emission reduction benefits. Our analysis does not address evaporative emissions or benefits that extend beyond a 2-year Smog Check cycle.

7. Recommendations for further analysis

We have assembled very large databases of information on California vehicles and their emissions for this evaluation of the Enhanced Smog Check Program. These data are an incredibly rich resource of information that can be tapped for many analyses, not just of the effectiveness of the Smog Check Program but of trends in fleet emissions as well. We have a long list of areas for future research that we are prepared to undertake, given funding. This list is divided into issues that can be analyzed in the next few months with existing data, and issues that will require additional data.

7.1. Can be done with existing data

- Evaluate effectiveness of Basic Program. We can apply the analyses summarized in this report to the fleet of vehicles reporting for Smog Check testing under the Basic Program.
- Analyze effect of fast pass. We can analyze the second-by-second roadside ASM tests to estimate the difference in emissions of vehicles "fast-passing" the ASM test with vehicles that receive the full ASM test.
- Analyze repair cost and emissions reductions. We can analyze the cost of vehicle repairs, by vehicle type and age, component repaired, station type, and other variables, to learn about what variables impact the cost of vehicle repairs. Repair costs can be matched to emissions reductions on a per-vehicle basis, to study the cost-effectiveness of repairs by several variables.
- Analyze program effectiveness by zip-code and average income. We can determine if program effectiveness varies by a crude measure of vehicle owner income: the average income by zip-code where the vehicle is registered.
- Analyze failure rate and in-use emissions by vehicle year and model. The massive number of VID measurements allows the analysis of failure rate, and average emissions, by vehicle year and model. Results from this analysis can be compared to similar analyses we have made using I/M and remote sensing data in other states. Because emissions can vary substantially by vehicle model, even for vehicles of the same age, it is important to account for differences in the vehicle models that make up different vehicle populations.
- Review other evaluations. We can review other evaluations of the Smog Check Program, and explain differences between those reviews and ours.
- Audit individual test stations. We can develop measures of station performance, and use such measures to assess the performance of individual test stations.
- Examine bad test records. A more thorough analysis of the bad test records may enable us to make a better estimate of the no-final-pass rate and the degree of program avoidance.
- Examine aborted test records. A more thorough analysis of the aborted tests may enable us to estimate the emissions reductions from repairs made after unofficial pretests.
- Estimate ping-pong rate. We can estimate the number of vehicles that pass at a Test-and-Repair station, only to fail at a Test-Only station.

7.2. Requires additional data

- Analyze more than two years of data from the Enhanced Program. In June 2000 the Enhanced Program will have been in effect for two years. At that time there will be many more vehicles that have more than one Smog Check cycle. The second cycle will be two years later than the initial cycle for most of these vehicles. An analysis of these vehicles will enable us to estimate the deterioration of repairs made under initial cut points over a two-year period. We also may be able to estimate the long-term deterioration of repairs made under Phase 3 cutpoints. Similarly, we can estimate the long-term increase in emissions from initial pass vehicles. A much larger sample of multi-cycle vehicles will also enable us to estimate mileage accrual rates by vehicle type and model year, by comparing odometer readings of multiple cycles of the same vehicle. More than two years of data will also allow us to study the degree of fleet turnover and vehicle migration over a two-year period.
- Analyze registration data. Additional snapshots of DMV registration data can be used to determine how many no-final-pass vehicles managed to keep their registration current, and to estimate how many vehicles are re-registering into Basic areas to avoid Enhanced Smog Check requirements.
- Analyze more remote sensing data. We strongly encourage BAR to begin an ongoing, large-scale remote sensing program. Such a program would be a relatively cheap means of collecting enough data to perform an independent evaluation of the Smog Check Program. A large remote sensing program is the best way to estimate: (1) the contribution of exempted, unregistered, and out-of-state vehicles to total on-road emissions, (2) the effect of any repairs or adjustments made to vehicles prior to official Smog Check pretests, (3) the degree to which no-final-pass vehicles are avoiding program requirements, and (4) the effectiveness of OBDII systems, and their use in the Smog Check Program, on in-use emissions. EPA will soon publish a guidance document encouraging states to use remote sensing measurements to supplement the evaluation of their I/M programs. The cost of a large-scale remote sensing program could be offset by adopting a clean screen program that would exempt clean vehicles from biennial Smog Check testing.
- Study emissions differences between ASM and remote sensing measurements. We propose to design an experiment to more rigorously test the same vehicle measured under ASM testing and remote sensing. A controlled experiment would lead to better understanding of the differences in emissions measured under the two methods.