Clean on Paper, Dirty on the Road

Troubles with California's Smog Check

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1. Failure of the Smog Check Programme

Reducing emissions of pollutants from cars requires that new vehicles be designed and built to pollute less, and also requires some ongoing inspection and maintenance programme to ensure that a vehicle's operation conforms to those design standards. This paper focuses on these programmes, commonly called Smog Check programmes. The most extensive and well-studied Smog Check programme in the United States is in California. Though that state is not typical in all respects, examining its experience is instructive.

California implemented its first wide-ranging Smog Check programme in 1984. The programme required gasoline-powered passenger cars and light trucks to pass inspection every two years. Inspections were performed at private garages licensed by the state. Garages measured hydrocarbon (HC) and carbon monoxide (CO) emissions and inspected some emission control devices. The US Environmental Protection Agency had estimated that such a programme could reduce emissions of HC and CO by 25 per cent (Sommerville *et al.*, 1993, p.33). The actual results were disappointing: in 1987 reviewers reported that the programme reduced HC emissions by only 12.3 per cent, and reduced CO emissions by only 9.8 per cent. The programme's effectiveness was, at best, half that predicted.

The failure led to changes in 1990, including the use of new equipment designed to reduce the opportunity for faking test results. The report that recommended the changes predicted emission reductions of 28 per cent for HC, 27 per cent for CO, and 12 per cent

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for nitrous oxides (NO_x). Yet a 1993 study (Sommerville *et al.*, 1993, p.57) found reductions of only 19.6 per cent for HC, 15.3 per cent for CO, and 6.7 per cent for NO_x.

In a random roadside survey conducted in 1991, 33.1 per cent of all cars failed the roadside inspection, compared to a 10.6 per cent failure rate during inspections in Smog Check stations. The main difference comes from engine compliance: in 1989 Smog Check stations reported that only 9.6 per cent of all vehicles failed the engine inspection, whereas 33.2 per cent of the cars examined in roadside inspections failed the engine inspection (Sommerville *et al.*, 1991, p.19).

Other data indicate that the inspection programmes were even less effective, or perhaps even totally ineffective. In 1989 and 1990 the state of California conducted random roadside surveys of cars. Since Smog Check programmes have been required only in those regions of the state with poor air quality, we would expect lower emissions from the average vehicle in areas of the state where cars are subject to Smog Check than where they are not. Yet in regions without biennial Smog Checks, 32.8 per cent of the cars had excessive emissions, while in Smog Check regions a higher proportion failed — 37.9 per cent (Walsh, Klausmeir and Seinfeld, 1993, p.9). In regions without Smog Check 23 per cent of cars had defective emission control equipment, while in Smog Check regions a larger proportion had such defects — 24.8 per cent.

These differences may arise for reasons unrelated to Smog Check programmes — perhaps residents of Los Angeles are more inclined to tamper with cars for high performance (hence high emissions) than are residents in other parts of the state, or perhaps the cars they drive are inherently dirtier. Nevertheless, these data suggest that, at best, the Smog Check programme makes little difference. That conclusion is reinforced by other studies which compare the emissions of cars just before they had a Smog Check to cars just after a Smog Check, and thereby effectively control for inter-regional differences.

A 1988 study in California inspected 4,421 vehicles, giving many of them the equivalent of a Smog Check. Cars due for Smog Check within the next 90 days had a failure rate of 39.1 per cent. Cars that had a Smog Check within the previous 90 days had a failure rate of 42.2 per cent. A 1991 study found that cars due for Smog Check within the next 90 days had a failure rate of 32 per cent, while cars that had a Smog Check in the preceding 90 days had a higher failure rate — 37 per cent (Walsh, Klausmeir and Seinfeld, 1993, p.10).[1] Again, it is hard to see that the Smog Check programme is working.

2. Causes of Failure

We see several reasons for the failure of current programmes.: Smog Check stations do not reliably identify problem vehicles; Smog Check stations engage in corruption and fraud; mechanics have difficulty fixing broken cars; and motorists tamper with their cars to make them clean on inspection day.

[1] As we shall see below, emission reductions from a Smog Check programme come from repairing 4 per cent of the cars. A random sample of cars may therefore not capture the effects of the programme.

2.1 Unreliability of Smog Check stations

In an investigation in California, undercover personnel took cars known to be defective to Smog Check stations. Fewer than 60 per cent of stations identified *any* defect with the car, and only 25 per cent found all the defects in the car.[2] In 1990, the US Environmental Protection Agency sent undercover cars with missing catalytic converters to 25 stations in Virginia's Smog Check programme. Only 10 of the 35 inspectors discovered that the converter was missing. The two undercover investigations suggest that garages simply do not identify defects reliably, that they are negligent or incompetent.

2.2 Fraud

Another explanation for ineffective inspections is corruption. A motorist may bribe a mechanic to pass a car that should fail. Alternatively, a garage may take the initiative in passing cars that should not — perhaps to assure a customer that the repairs he had just paid for were done properly. Another motivation arises from garages with the policy "Pass or Don't Pay". The garage earns the inspection fee only if it issues a smog certificate. Finally, a mechanic may tinker with cars to get them to pass because he does not have the time or expertise to do proper repairs.

2.3 Failure to repair cars

An effective Smog Check programme must not only identify cars with excess emissions, but also repair them. We saw that in a random roadside sample of cars, the emissions of recently smog-certified cars were not lower than the emissions of cars almost two years after their Smog Check.

More direct evidence of ineffectual repairs comes from the repair histories of a sample of 682 cars tested by the California Air Resources Board (CARB) and found to be defective. Undercover drivers then took each of these cars to private garages for a Smog Check. If the private garage discovered that the car was defective, the garage was asked to repair it, and then retest it. When these repaired cars were returned to CARB, their emissions levels were tested again. The CARB tests used the procedure that the federal Environmental Protection Agency considers to be definitively accurate, the Federal Test Procedure (FTP). For these 682 cars, we knew CARB's original FTP test results and their post-repair FTP test results. Table 1 shows a ranking of the cars by their pre-repair emissions levels (the left column). The table also reports the reduction in emissions after repairs (the right column); a negative number indicates an increase in emissions.[3] These data suggest that of the cars that are repaired after failing a Smog Check, over half of the CO and HC reduction comes from the repair of only the dirtiest 10 per cent. Many of the cars are subject to expensive tests and repairs to no good effect at all. In fact, almost half the cars came out of the repair process dirtier than they went in.

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[2] This ability to identify engine defects visually has improved little since a review in 1986, in spite of major efforts by the Bureau of Automotive Repair (Sommerville *et al.*, 1993, p.51).

[3] Lawson (1990) shows a similar result for different data.

Table 1

Comparison of Emissions Before and After Repair

Pre-repair Decile	*Hydrocarbon Emissions*		*Carbon Monoxide Emissions*	
	Percentage of total	*Percentage of total reductions*	*Percentage of total*	*Percentage of total reductions*
10th	44.2	83.6	31.7	67.6
9th	15.2	10.2	19.5	22.4
8th	10.7	5.2	14.4	22.7
7th	8.2	4.4	10.6	2.9
6th	6.6	2.4	7.8	0.8
5th	5.3	–3.6	5.7	–2.7
4th	3.9	0.8	4.2	–9.1
3rd	2.8	–1.5	2.9	–0.4
2nd	1.9	–1.1	2.0	–2.5
1st	1.1	–0.4	1.1	–1.8

Repair problems are not limited to Californian mechanics. The General Accounting Office (Peach, 1992) reports that Smog Check programmes in other states also have problems fixing dirty or defective vehicles. For example, in a state programme considered by the US EPA to be one of the nation's best, of all the cars that had failed an inspection and then been repaired, nearly 40 per cent were still unable to pass the emission test.

2.4 Tampering

Motorists sometimes disconnect smog control devices to increase performance, reconnect the devices just before a smog inspection, and then disconnect them immediately afterwards. Alternatively, a motorist may have a defective emission control component removed, to avoid the expense of proper repairs. Such activity constitutes *tampering*, the *deliberate* alteration of the emission control system.

Tierney (1991) finds that in states with decentralised Smog Check programmes the tampering rates were 8 per cent for catalytic converters, 11 per cent for evaporative canisters, 12 per cent for inlets, and 13 per cent for fuel switching (using leaded instead of unleaded fuel). Random roadside studies of pre-1980 cars in California found tampering rates of 48 per cent in 1987, 45 per cent in 1989, 41 per cent in 1991, and 38 per cent in 1992. The overall tampering rate, for all model years, was 15.1 per cent. The reduction in tampering over time suggests that Smog Check programmes were having some effect. But even a low tampering rate can generate a lot of pollution.

3. A Few Cars Emit Most of the Pollutants

We saw from the repair data that many of the benefits of the Smog Check come from repairing only a few cars. These data also show that most of the emissions from cars that fail the Smog Check come from a few cars. We analysed the records of 682 cars that had failed a Smog Check in California (see Table 1). Ten per cent of these cars accounted for 44 per cent of the HC emissions by the group. And the cleanest 50 per cent of these dirty cars emitted only 15 per cent of the HC emissions in the group. Since among all cars about half the HC emissions come from about 20 per cent of the cars (which is the average failure rate on Smog Inspection) it appears that 2 per cent of the cars account for over 20 per cent of all HC emissions. These data have an important implication for policy. Consider the EPA's goal of using Smog Check programmes to reduce emissions by 25 per cent. This goal could be satisfied by identifying and repairing some 2-3 per cent of cars.

Similar results hold for a sample of all cars, not only those that failed a Smog Check. Naghavi and Stopher (1993) used a remote sensing unit to measure CO and HC emissions in Baton Rouge, Louisiana. They found that more than half the CO was emitted by 6.9 per cent of the vehicles.[4] About half the HC was emitted by 20 per cent of the vehicles measured.[5] Over 80 per cent of the vehicles were clean, contributing only 24 per cent of total emissions. For HC emissions, 70 per cent of the vehicles emit less than the mean.

A similar study was conducted by Stedman and Bishop (1990) in Chicago. Half the CO was emitted by 8 per cent of the vehicles. Of 671 vehicles measured four times or more, twelve (1.8 per cent) were responsible for 13 per cent of the CO emissions.

4. Ideas for Programme Improvement

4.1 Remote sensing

A chemist at the University of Denver, Donald Stedman, has developed a new device to measure car emissions. It shines an infrared light beam across the road and measures the characteristics of the light that passes through the exhaust plume. The device can measure CO and HC content now, and it is currently being developed to measure nitrogen oxides as well. Remote sensing is fast, cheap and unobtrusive. It measures the emissions as the cars drive by and detects cars with excessive emissions. Photographic equipment can automatically record the car's licence plate, and the motorist can be sent a notice.

The EPA points out that these one-second snapshot readings may be unusually high or low, compared to a long sample: the remote sensor will miss some polluters and harass drivers of some clean cars. The way round the accuracy problem is to flag only those cars with very high emission readings on the remote sensor. This guards against "false fails". Since the pollution problem comes from a few, extreme, polluters, this strategy will handle the problem. In small-scale testing, it was possible to set a fail criterion for the device that

[4] When we say "half the CO" here, we mean half of the on-road CO measured by the sensors. These measurements systematically miss the brief cold-start period of high emissions from all cars, and other emission patterns from changes in acceleration, grades and so on. This caveat applies also to the next paragraph.

[5] The cars with high emissions of CO need not, however, be the same cars that emit high HC.

produced very few false identifications, while still catching most of the high polluters.[6] Also, the device proved sufficiently inexpensive to permit the necessary frequency of annual monitoring.

Remote sensing provides pervasive surveillance, so that a car owner who tampers with his car is always at risk of being caught. It also provides an element of surprise. Surprise and frequency of inspection should discourage tampering, since the offender will continually be called to closer inspection after being flagged on the road by a remote sensor. The promise of remote sensing is supported by studies that show that increasing the certainty of punishment is more effective than increasing the penalties of punishment (Heineke, 1988; Witte, 1980).

Random testing conducted by remote sensors may be useful even if its results are used only to notify a driver that his vehicle has high emissions. To the extent that high emissions are associated with poor fuel economy or poor performance, a driver so notified would have an incentive to repair his car.

4.2 Limitations of remote sensing

Remote sensing suffers from taking only a snapshot of emissions, and we know that emissions vary with acceleration, grade, speed, and engine heat. Also, remote sensing requires that cars pass single-file. Some of these problems can be reduced by locating remote sensors on highway exit ramps, where warm cars pass single-file under fixed conditions. Furthermore, because remote sensing testing is so cheap — perhaps 50 cents per reading — a programme could use multiple readings to determine whether a car should report for more detailed inspection.

Another disadvantage of remote sensing is that, except for cars called to detailed inspection, it does not get under the hood (bonnet) of the car to test for evaporative and other non-tailpipe emissions. Such emissions may be important, but currently no cost-effective way is known to inspect for them.

Will motorists devise some method of foiling remote sensing? There are four basic approaches they might try:

(1) Tampering to alter the contents of the exhaust plume. This would require an additional gas source, mixed with the true exhaust, or an additive to the fuel. These methods are expensive or inconvenient, and may interfere with the proper functioning of the car. Heavy fines could be imposed for these varieties of tampering.

(2) Reducing the plume, by altering the tailpipe or by turning off the car as it went past a remote sensor. Again, these methods may prove expensive or inconvenient.

(3) Obstructing the licence plate, such as by splattering it with mud or putting a trailer

[6] It should also be noted that testing vehicles while under load, with dynamometers, does not eliminate the problem of false identifications. The General Accounting Office (Peach, 1992) reports: "We reviewed EPA data on vehicles that were initially tested at the Hammond, Indiana testing site and subsequently tested at EPA's contractor laboratory facility in New Carlisle, Indiana. We found that test results can vary substantially from one location to the other. We identified 64 vehicles — 1986 model year or newer — that failed the IM240 [dynamometer] test at the Hammond testing site and were sent for further test and repair services at the contractor's laboratory. Eighteen of the 64 vehicles, or 28 per cent, that initially failed an IM240 test at the Hammond testing site passed a second IM240 test at the laboratory in New Carlisle, even though no repairs were made to the 18 vehicles."

hitch in front of it. These problems could be mitigated by the policing of licence plate legibility.

(4) Keeping their car unregistered so the programme is not able to identify the car and notify the motorist. This problem is common to all inspection methods.

4.3 Universal inspection is not necessary

Given that emissions are concentrated among a few cars, it is surprising that all current Smog Check programmes require inspection for every car. Such universal inspection is rare indeed in other policy areas.[7] The Internal Revenue Service does not audit all income-tax returns. Few democracies subject all tourists to customs inspections; they rely on proclamations and random enforcement. The US EPA and the Occupational Safety and Health Administration do not inspect all businesses, but rely on filed reports and random inspections.

Universal inspection may be necessary if the owner of the car has little information about the emissions of his car — how can he repair devices when he does not know they are broken? — or if the government cannot identify likely high polluters without testing all cars. Though perfect information is unavailable, we do know about some characteristics of cars that make them likely to be high emitters.

We have some data on the relation between a car's age and its emissions. Sommerville *et al.* (1993, p.137) find that in 1991 the average level of HC emissions for cars 16 years old or older was almost five times the level of cars less than ten years old.[8] The older cars had three times the annual CO emissions. In 1991, the overall failure rate of cars at Smog Checks was 20.7 per cent. But 1990-model cars had a failure rate of only 1.3 per cent; cars built before 1979 had a failure rate of 26.6 per cent (Sommerville *et al.*, 1991, p.9). These data suggest that it may be wise for Smog Check programmes to stop treating all cars equally.

4.4 Centralised inspection

The US Environmental Protection Agency (EPA) seeks to improve Smog Check programmes by upgrading the inspection equipment and by separating testing from repair services. Under the EPA's "centralised" programme, motorists have their cars tested at one of a small number of test-only stations; if they fail they seek repairs from the private sector and return for testing. The EPA claims that, compared to California's "decentralised" system of independent test-and-repair stations, centralised inspection results in greater emissions reductions for the following reasons:

(1) More sophisticated testing is performed using treadmill-like machines that test the car under load;

(2) The inspectors are better trained and more closely supervised; and

(3) There is no conflict of interest for inspectors, whereas in the decentralised system a mechanic sometimes inspects a vehicle that he has just repaired.

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[7] The notable exception is the Food and Drug Administration which tests all drugs for safety and effectiveness.

[8] This calculation takes the lower annual mileage of older cars into account.

However, such centralised inspection is nonetheless *anticipated* inspection, so motorists can still tamper before and after the test. And sophisticated, expensive, equipment such as that recommended by the EPA can show significant variability (Peach, 1992). This variability probably comes mainly from variability in the behaviour of broken cars ("flippers"), but this is a problem that more expensive test equipment does not solve. More sophisticated equipment may give more telling measurements, but the problem with current programmes lies in bad incentives for human beings and difficulties in repairing cars, rather than in inadequate testing devices.

Do existing centralised programmes in fact show a greater effectiveness in reducing emissions? Scherrer and Kittelson (1994) studied the ambient CO in the Minneapolis/St. Paul area, where centralised inspection prevails. They find that ambient CO levels are, on average, 1.3 per cent (plus or minus 1.4 per cent) lower than the ambient levels that would exist if there were no programme at all. The authors say (p.51) that this reduction is "negligible in comparison to the continuous reductions" occurring by virtue of developments independent of the inspection programme.

Some of the problems with centralised testing may be alleviated with experience. But we do not see why Smog Check programmes should put all their eggs in one basket, especially given the past failures of scheduled inspection programmes. And though remote sensing is imperfect, its effectiveness may improve with experience. It is worth trying.

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