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CHECKING UP ON SMOG-CHECK:

A CRITIQUE OF TRADITIONAL INSPECTION & MAINTENANCE PROGRAMS

by
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Executive Summary

Efforts to reduce unhealthful air emissions from cars and light trucks have a long regulatory history. Inspection and Maintenance programs (I/M), first introduced in the Clean Air Act of 1963, have evolved into a core component of our national policy to reduce mobile source emissions.

I/M programs typically require that all passenger vehicles (cars and light trucks) undergo periodic testing to determine whether their emission-control systems are performing acceptably. Traditional I/M programs involve inspections either annually or biennially, with inspection protocols that can range from relatively simple and inexpensive tailpipe testing to more complex and expensive dynamometer testing.

Few people dispute either the need or the desire to reduce mobile source emissions in society's quest for cleaner air. However, many people question the central position given to traditional I/M programs in the mobile-source emission-reduction framework of national air quality policy.

Data now demonstrate the ineffectiveness of traditional I/M programs as a method of insuring that vehicle emission systems are kept in good working order. This poses a critical question in a framework of limited resources. How much money should be spent on rituals that have produced only modest benefits? Are there alternative programs that might be more successful in cleaning up polluting vehicles?

Recent research into automobile emission characteristics has demonstrated that some fundamental ideas behind traditional I/M programs are flawed, including assumptions that presume all cars are equally likely to pollute; all cars need to be tested; a universal focus on reducing marginally high-emitting vehicles is more important than targeting only very high-emitting vehicles; and behavioral incentives are less important than technological standard-setting. On the contrary, research indicates that the distribution of vehicle emissions is highly skewed, with a minority of vehicles producing a majority of emissions. Other evidence shows that this high-emitting group can be identified with a fairly broad range of techniques and that drivers of these vehicles can be given incentives that lead to either vehicle

repair or retirement. Still other evidence shows that trying to repair marginal emitters can actually produce higher emission levels, rather than lower them.

These data point to a need for changing the focus of I/M programs to concentrate on identifying and repairing extreme-emitters. A successful program will need to develop methods to ease economic impacts on lower-income people who may have little economic choice but to operate extreme-emitting vehicles. New programs need maximum flexibility regarding choice of emission testing technology as fits each area's needs. States need to look beyond the I/M paradigm to develop a system that takes human behavior into account, and shifts the incentive structure from "clean for a day," to "clean every day." Finally, states need to implement some method of validating I/M program performance, to confirm that hoped-for emission reductions are being realized.

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I. INTRODUCTION

Efforts to reduce unhealthful air emissions from cars and light trucks have a long regulatory history, beginning roughly around 1945. Inspection and Maintenance programs (I/M), first introduced in the Clean Air Act of 1963, have evolved into a core component of our national policy to reduce mobile source emissions.

I/M programs typically require that all passenger vehicles (cars and light trucks) undergo periodic testing to determine whether their emission-control systems are performing acceptably. Inspections are either annual, biennial, or upon sale of the vehicle, and can range from relatively simple and inexpensive tailpipe testing to more complex and expensive dynamometer testing.

Few people dispute the need to reduce mobile-source emissions in the quest for cleaner air. However, many people question the central position given to traditional I/M programs in the mobile-source emission-reduction framework of national air quality policy.

Data now demonstrate the ineffectiveness of traditional I/M programs as a method of insuring that vehicle emission systems are kept in good working order.[1] Analysts have known for some time that the problems with traditional I/M transcend technological issues. They involve the most fundamental ideas behind traditional I/M programs, including assumptions that presume all cars are equally likely to pollute; all cars need to be tested; a universal focus on reducing marginally high-emitting vehicles is more important than targeting only very high-emitting vehicles; and behavioral incentives are less important than technological standard-setting.[2] Copious evidence now indicates that the distribution of vehicle emissions is highly skewed, with a minority of vehicles producing a majority of emissions.[3] As figure 1 shows, this high-emitting group can be identified with a fairly broad range of techniques.

Still other evidence shows that trying to repair marginal emitters can actually produce higher emission levels, rather than lower them.[4]

As important as these flaws are with regard to traditional I/M program effectiveness, increasing attention is being given to the misguided incentives created by such programs. Rather than creating incentives for motorists to maintain their emission systems in good working order, traditional I/M programs create an incentive to “pass the test” at least cost and inconvenience with little regard for the duration of repairs.[5] Incentives for cheating are manifold for both motorists and mechanics under traditional I/M systems, and a number of observations support the contention that such incentives are indeed producing cheating or inadequate vehicle repairs.[6]

Thus, traditional I/M, which seems to be a coherent policy in the abstract, fails in practice to achieve intended emission reductions. This study reviews the literature on mobile source emission control, I/M program effectiveness, alternative technology potential, and incentive-based approaches to reforming emission control policy.

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[1] Douglas R. Lawson, et al., “Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report,” Prepared for the California I/M Review Committee, Desert Research Institute, Reno, Nevada, November 1995.

[2] Charles Lave, “Clean for a Day: California Versus the EPA’s Smog Check Mandates,” *Access*, University of California Transportation Center, Berkeley, CA, Fall, 1993.

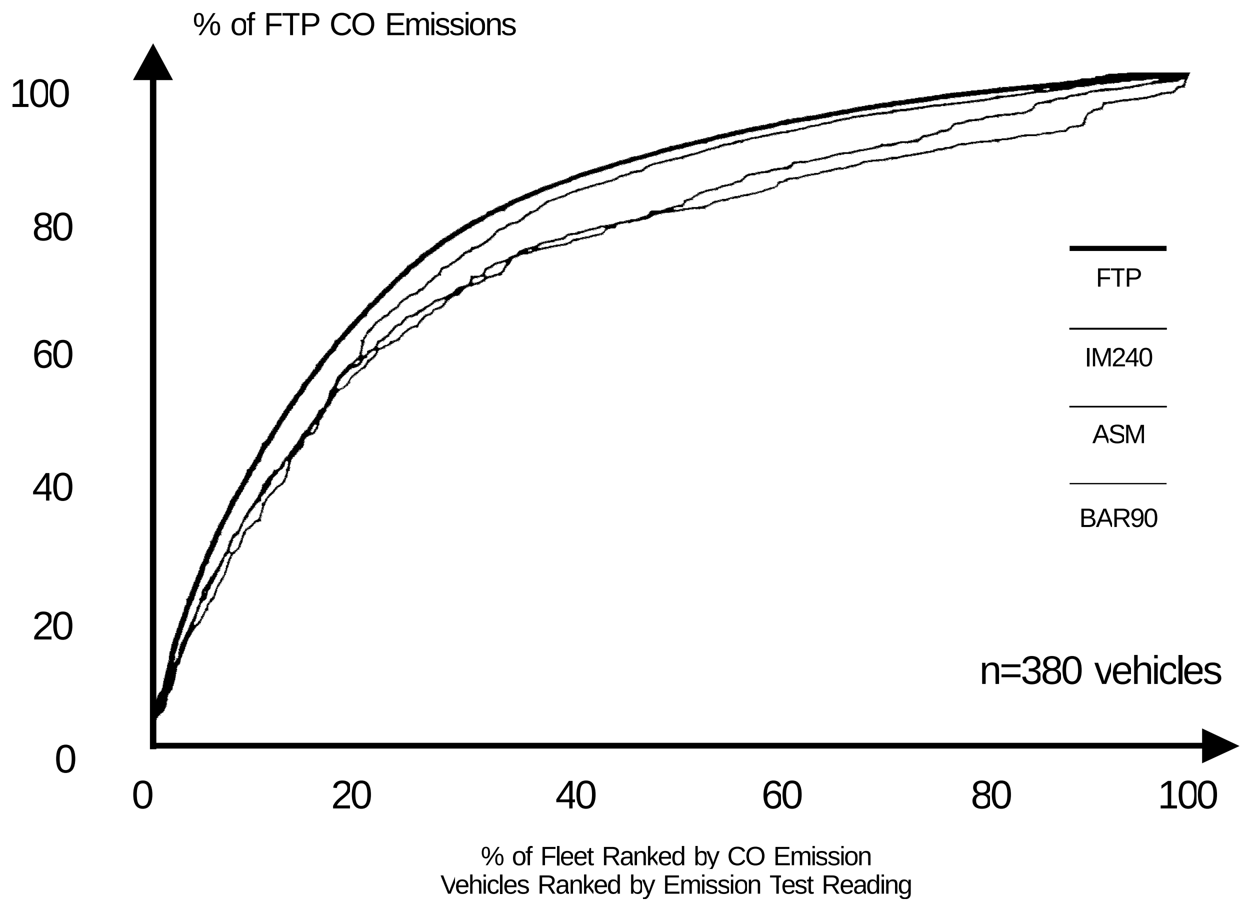
[3] D.H. Stedman, et al., “On-Road Carbon Monoxide and Hydrocarbon Remote Sensing in the Chicago Area,” ILENR/RE-AQ-91/14, Report prepared for the Illinois Department of Energy and Natural Resources, Office of Research and Planning, Chicago, Illinois, October 1991. See also Douglas R. Lawson, et al., “Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report.”

[4] Douglas R. Lawson, et al., “Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report.”

[5] Douglas R. Lawson, et al., “Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report.”

[6] Joseph P. Charney, Deputy District Attorney, Los Angeles California, personal interview.

Figure 1: El Monte Data Set
CO Emission Test "Shootout"



II. BACKGROUND ON AUTOMOBILE EMISSION CONTROL

As Figure 2 illustrates, autos and light trucks contribute a lion's share to the air pollution which plagues many of our urban areas.

Adverse health effects resulting from hazardous air pollutants are well known.[7] While people differ regarding whether the standards are too stringent or not stringent enough, most people support the notion that health damage from auto-generated air pollution is not an acceptable by-product of automobility.

Recent estimates of the precise share of air emissions contributed by cars and light trucks have been revised upward. According to the most-current understanding, mobile sources may produce as much as 75 to 90 percent of the precursor chemicals which lead to the creation of low-level ozone, the most physically irritating component of urban smog. Cars and light trucks are also responsible for up to 96 percent of the poisonous carbon monoxide emitted into polluted urban atmospheres in some areas.[8]

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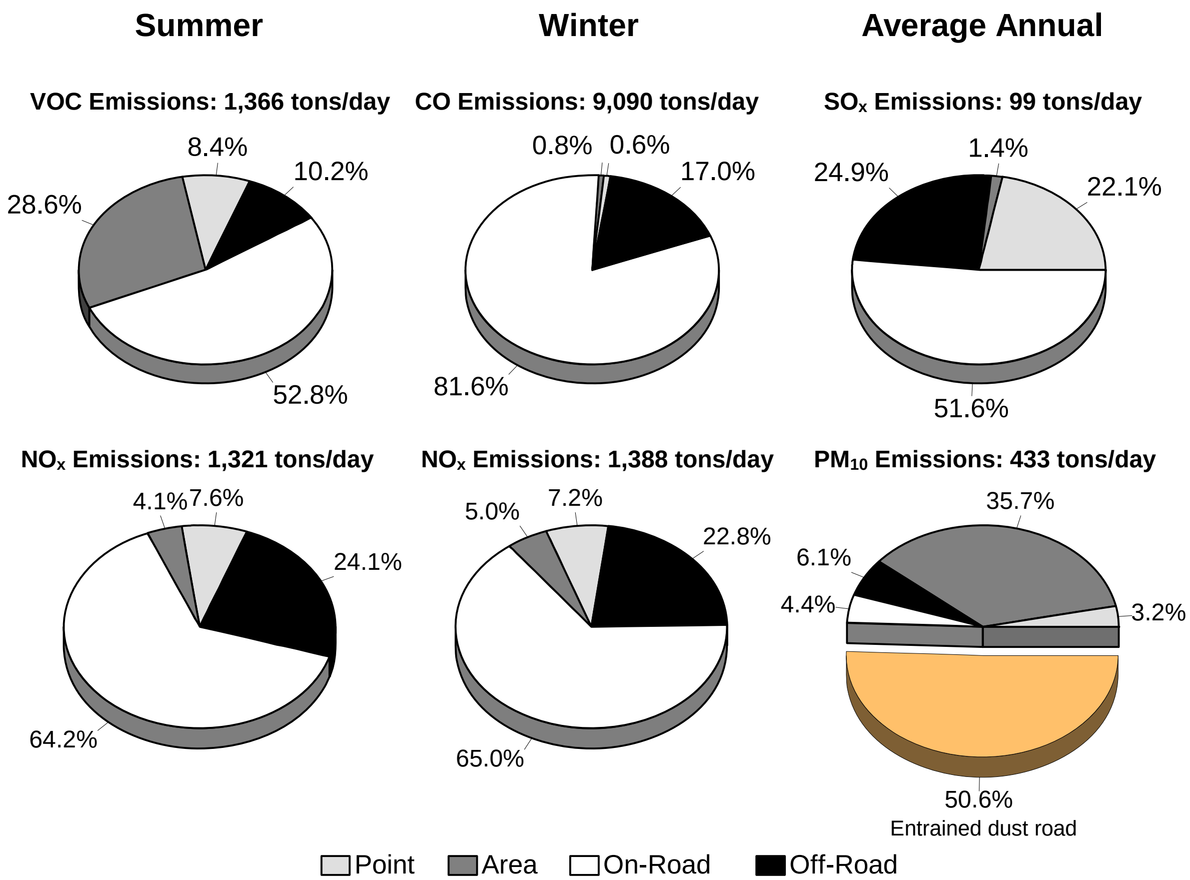
7 American Lung Association, "The Health Costs of Air Pollution: A Survey of Studies Published 1984–1989," New York City, New York, April 1990.

8 Eric M. Fujita and Douglas R. Lawson, "Evaluation of the Emissions Inventory in the South Coast Air Basin," Desert Research Institute, Reno, NV, August 1994.

Policies have been in effect to reduce mobile-source emissions for over 50 years. At the state level, California showed early interest in air pollution, establishing the Bureau of Smoke Control in 1945 and adopting the Air Pollution Control Act in 1947.[9] At the national level, regulation of automobile emissions began with the Clean Air Act of 1963 and continues today through its subsequent amendments.[10] Certification procedures for new cars and the first federal standards for HC, CO, and NOx emissions were promulgated in the early 1970s. Table 1 shows how tailpipe standards for new cars have grown steadily more stringent over time, posing a challenge to the technological abilities of automakers.[11]

Figure 2: Relative Contribution by Source Category to the 1993 Inventory



Source: South Coast Air Quality Management District, 1997 Air Quality Management Plan, *Base Year and Future Emissions,* figure 3-3, p. 3-11.

9 SCAQMD, "Reflections on California's Air Quality History," Undated Draft, distributed in 1996 at SCAQMD functions, available through South Coast Air Quality Management District, Diamond Bar, CA.

10 *Clean Air Act Amendments,* Public Law No. 101-549, 104 Stat. 2399, 1990; also Roger W. Findley and Daniel A. Farber, *Environmental Law in a Nutshell,* West Publishing Company, 1988, pp. 56–97, St. Paul, Minnesota.

11 Jerry Aroesty, et al. "Restructuring Smog Check: A Policy Synthesis (Draft)," Rand Corporation, Santa Monica, CA, October 1994.

Table 1: Tailpipe Standards vs. Time			
	1973	1980	1990
HC	3.4 g/mi	0.41 g/mi	0.25 g/mi
CO	39 g/mi	7.0 g/mi	3.4 g/mi
NOx	3.0 g/mi	2.0 g/mi	0.4 g/mi

Source: Jerry Aroesty, et al. "Restructuring Smog Check: A Policy Synthesis (Draft)."

Current standards require that new cars sold in severe ozone non-attainment regions meet tailpipe standards of 0.25 g/mi. for HC, 3.4 g/mi. for CO, and .4 g/mi. for NOx.[12] This increased stringency comes at a price—the emission-control devices required to achieve this low level of emissions add about $2,000 to the price of a new car sold in areas facing serious pollution problems.[13] To control emissions, modern automobiles sold in polluted urban areas come equipped with sophisticated emission-control equipment, including a three-way catalytic converter, an exhaust gas recirculation system, and an electronic control module that regulates fuel and air injection rates. These technologies have done a great deal to clean up the car and the air that we breathe. A modern car or light truck produces 96 percent less carbon monoxide and hydrocarbons, and 90 percent less NOx than an equivalent vehicle of the 1960s.[14]

In creating the Clean Air Act, however, mandating reduced automobile emissions was not considered sufficient to remedy the auto emission problem. In addition to requiring that new cars meet a certain set of standards, the Clean Air Act also required monitoring of cars as they were used and as they aged, to insure that the emission-control systems kept working. Over time, these Inspection and Maintenance programs (I/M) performed with mixed results, with some analysts claiming that they were highly effective, and others claiming they were very ineffective.[15] The conflicting claims led Congress to study the issue during development of the Clean Air Act amendments of 1990, and to call for the Environmental Protection Agency (EPA) to establish performance standards for basic and enhanced I/M programs, which would be imposed upon states according to the extent of their urban pollution problems.

Under the new guidelines, areas with moderate pollution are permitted to implement a "basic" inspection and maintenance program consisting (usually) of stationary tailpipe testing of emissions at two different engine idle speeds with no load, either at centralized or decentralized, test-only or test-and-repair facilities. Areas considered "serious" nonattainment areas for ozone, or "high-moderate" nonattainment areas for carbon monoxide, however, must implement "enhanced" I/M programs, which were initially defined by EPA as requiring annual testing of all cars at centralized facilities equipped with dynamometers (essentially a treadmill for cars) on which cars can be tested using a simulated driving protocol. Evaporative emissions (emissions that seep out of the car's engine, rather than the tailpipe) were also to be tested, and under-the-hood inspections of hoses, fittings, and emission-control components were also required.[16]

In a nutshell then, the overall policy aimed at reducing automobile-generated air pollution in the United States consists of:

- requiring automakers to develop technologies to reduce tailpipe emissions;[17]

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12 *Clean Air Act Amendments,* Public Law No. 101-549, 104 Stat. 2399, 1990.

13 Patrick Bedard, "Still Smoggy After All These Years," *Car and Driver,* April 1995.

14 U.S. General Accounting Office, "EPA's Inspection and Maintenance Program," GAO/RCED-96-63, p. 4, Washington, D.C., March 1996.

15 For claims of effectiveness see California Air Resources Board, "California Air Quality, A Status Report," Sacramento CA; South Coast Air Quality Management District, 1994 Air Quality Management Plan, Appendix IV-B, District's Mobile Source Control Plan, Diamond Bar California, 1994; U.S. General Accounting Office, "Air Pollution: Limited new Data on Inspection and Maintenance Program's Effectiveness," GA1.13:RCED-96-63, Gaithersburg Maryland. For critiques of I/M performance, Huel C. Scherrer and David B. Kittelson, "I/M Effectiveness as Directly Measured by Ambient CO Data," SAE Technical Paper Series 940302, Warrendale PA; Christopher D. Porter, "Comparing Centralized and Decentralized Vehicle Inspection and Maintenance Programs: Case Study of California and Arizona," Cambridge Systematics, Cambridge MA, February 1996; and Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report."

16 "EPA guidelines on enhanced I/M programs," 40 CFR (Code of Federal Regulations) Part 51, pursuant to *Clean Air Act Amendments,* Public Law No. 101-549, 104 Stat. 2399, 1990.

17 Including the development of Low Emission Vehicles (LEVs), Ultra-low Emission Vehicles (ULEVs), Zero-Emission Vehicles (ZEVs), and soon, "Super-Ultra-Low Emission Vehicles (SULEVs)".

- requiring I/M programs to insure continued functionality of these controls; and
- requiring various transportation-control measures aimed at reducing vehicle miles traveled or trips taken when these first two methods fail to satisfy the total reduction requirements.[18]

III. EVALUATION TOUCHSTONES

As Charles W. Anderson pointed out in "The Place of Principles in Policy Analysis:"

> *In order to make a policy decision, one must invoke some criteria of evaluation. We cannot decide whether a proposal for public action is desirable or undesirable, whether the results of a public program are to be adjudged a success or a failure, except in the light of a standard."*[19]

While values do play a role in weighting the importance given to various criteria in the different schools of policy analysis, two broad touchstones stand out as having nearly universal acceptance. Efficiency and fairness are well accepted as criteria of central importance in evaluations of public policy, and, increasingly, environmental policy.

Most public policy is probably formulated with these two criteria in mind. But experience tells us these criteria are too often lost sight of in the conflict-ridden process of policy implementation, or through an overly narrow focus that disregards the potential for external impacts of one aspect of public policy upon others. As a result, public policy often needs to be revisited, to examine it in light of changing circumstances and accumulated evidence that can show whether or not the policy is efficient and fair. In short, public policy needs frequent check-ups.

Of course, efficiency and fairness are broad concepts, each of which subsume a host of other important criteria that also have a place in analysis of environmental policy.

A. EFFICIENCY

It would be nice if we had unlimited resources with which to simultaneously address all problems at full throttle, but we don't. Since we have limited resources, and environmental policy must co-exist with other public policy endeavors involving crime reduction, education, welfare, and so on, environmental policy must be efficient. It must achieve desired goals, and must do so using least-cost methods, since wasted resources cannot be applied to solve other social problems. And inefficient programs that consume private-sector resources reduce the ability of people to maintain and increase their standard of living.

For an air quality policy such as I/M to be considered efficient, it should, then:

- reduce excess air emissions by causing better emission-system maintenance;
- produce emission reductions at the lowest cost when evaluated against alternative policies;
- produce net benefits, such that the positive aspect of environmental improvement is not swamped by negative policy impacts transferred out of the environmental arena and into other arenas;
- be designed to endure and evolve, rather than require contentious and costly overhauls, while displaying reduced efficiency over time.

B. Fairness

Besides being efficient, public policy must also be fair, not only from a moral standpoint, but also from a functional one—experience tells us that rules which impose burdens on one group to benefit a larger group, or adversely affect

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[18] Such as employer-based trip reduction, zoning policy, parking policy, and, in the future, perhaps, emissions-pricing strategies. See U.S. Department of Transportation and U.S. EPA, "Clean Air Through Transportation: Challenges in Meeting National Air Quality Standards," August 1993, pp. 5, 29.

[19] Charles W. Anderson, "The Place of Principles in Policy Analysis," *American Political Science Review,* Vol. 73, no. 3, September 1979, pp. 711–723.

some people in ways that simply create new problems are unlikely to withstand the concerted resistance of the targeted group.[20]

For a policy to be deemed fair, it should:

- put the major burden of remediation upon the creator of the problem;[21]
- not shift the harm from one arena (e.g., the environment) to another arena (e.g., the economy);
- not shift the harm being done from one group to another;
- not penalize those who do not contribute to the problem; and
- preserve individual choice to the extent possible.

IV. EVALUATING INSPECTION AND MAINTENANCE

I/M programs embody the idea that some mechanisms must be put into place to insure that cars are kept in clean-running condition. This basic idea is reasonable. Air pollution from vehicles does impose harms upon other individuals who must breath polluted air, and the right to be free from involuntary exposure to harms is a core value of our society. However, the specific mechanisms embodied by traditional I/M program requirements have produced dubious benefits, sometimes at high cost.

What follows in this section is an examination of where and how traditional I/M programs match up (or fail to match up) with the criteria of efficiency and fairness as outlined above.

A. Efficiency

In order to demonstrate efficiency (at any level), one has to first demonstrate effectiveness at some level. In the case of I/M, this means (at the very least) insuring that cars are operated more cleanly after leaving the repair shop as the result of I/M programs than they would be without such programs in place.[22]

Agency claims of high I/M program effectiveness are common. The EPA claims that enhanced I/M programs can yield a 28 percent overall emission reduction.[23] California agencies, long considered to be on the “cutting edge” of air pollution control methods, put forward similar claims. The California Air Resources Board claims that the institution of Smog Check programs in California led to a 25 percent overall reduction in automobile emissions statewide since the late 1980s.[24] The South Coast Air Quality Management District (SCAQMD) has a more specific breakdown, crediting basic I/M programs with reductions of 18 percent for volatile organic carbon (a key constituent of photochemical smog), 15 percent for carbon monoxide, and seven percent for oxides of nitrogen.[25] The SCAQMD’s Air Quality Management Plan includes an estimate that enhanced I/M programs would result in a 28 percent reduction in volatile organic carbon, 31 percent reduction in carbon monoxide, and nine percent reduction in oxides of nitrogen.[26]

[20] California’s experience with Rule 1501, which mandated that large employers exert pressure on employees to carpool, is an example. In the case of one large company, over $1,000,000 was spent annually to administer such programs to employees who did not want them—ridesharing actually went down each year, while program expenditures went up. (Green, Kenneth P., “Costs of Compliance with Environmental Regulations: A Case-Study of Rule 1501 Compliance Efforts at Five Hughes Aircraft Company Business Units,” Doctoral Dissertation, *University of California, Los Angeles*, May 1994).

[21] With limited exceptions where the case can be made that extenuating circumstances existed, such as an ignorance of the effect, or an inability to refrain from the activity while preserving life and limb.

[22] Of course, not all cars can be operated as cleanly as others, simply because of the vehicle’s age and emission-control technology.

[23] U.S. DOT and U.S. EPA, “Clean Air Through Transportation: Challenges in Meeting National Air Quality Standards,” August 1993, p. 19.

[24] California Air Resources Board, “California Air Quality, A Status Report,” 1991; *Los Angeles Times*, January 14, 1996.

[25] California Air Resources Board, “California Air Quality, A Status Report.”

[26] South Coast Air Quality Management District, 1994 Air Quality Management Plan, Appendix IV-B, District’s Mobile Source Control Plan, 1994, p. MON-7.

1. A Lack of Effectiveness

But data gathered at both state and federal levels don't support such optimistic claims, either for absolute performance or relative performance of all traditional I/M program types, despite estimated annual expenditures of $3 billion by states and motorists to comply with the I/M requirements of the Clean Air Act.[27] Recent studies show, in fact, that in return for that expenditure, the public is receiving little clean air benefit.[28]

In terms of absolute performance, I/M program effectiveness has been tested via direct measurements of ambient levels of CO in the Minnesota, Arizona, and California I/M programs.

When promoting its preferred I/M program in Minnesota, EPA predicted a CO reduction ranging from 25 to 30 percent. But a study of ambient CO level reductions by Huel Scherrer and David B. Kittelson at the University of Minnesota revealed an overall decline of only 1.3 percent, with a margin of error of 1.4 percent.[29]

In an Arizona study, vehicle fleet emissions in I/M program regions were compared to fleet emissions in non-I/M areas.[30] As seen in Table 2, the study found no significant difference in either CO or HC emissions between the fleets.

Table 2: Comparison of Emissions of I/M and non-I/M Fleets in Arizona

Fleet	Mean %CO	Mean %HC	Average Model Year	Age-Adjusted Mean %CO	Age-Adjusted Mean %HC
I/M	1.06	0.077	1984.7	0.99	0.088
non-I/M	0.81	0.075	1986.7	0.89	0.070

Source: Zhang, et al., 1994.

And in the most extensive evaluation of I/M programs to date, Douglas Lawson, Patricia Walsh and Paul Switzer conclude:

> *Whether we examine "broken" vehicle failure rates (where "broken" refers to vehicles that were classified by EPA as tampered with, arguably tampered, or malfunctioning), tampering only failure rates (according to the type of tampering inspection carried out in different I/M program areas), or idle test failure rates for CO and HC, we observe only small differences between vehicles in I/M program areas and vehicles not subject to any I/M program.*[31]

The lack of I/M program effectiveness to date transcends program type as well as the presence or absence of a program. In terms of relative performance of centralized and decentralized testing, several studies show little difference between these traditional programs with regard to assuring that vehicles are maintained.[32] As can be seen in Table 3, vehicle failure rates are not significantly higher in areas without I/M programs than they are in areas that have either decentralized or centralized facilities.

Table 3: Normalized Failure Rates by Program, 1985-1992 Tampering Surveys

27 Fred Singer "EPA's Strict Clean Air Standards Spur Backlash," *Human Events*, July 1994, p. 639.

28 Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report."

29 Huel C. Scherrer and David B. Kittelson, "I/M Effectiveness as Directly Measured by Ambient CO Data," SAE Technical Paper Series, SAE International, February 1994.

30 Y. Zhang, et al., "Final Report: Tucson Intersection Study of Automobile Emissions," University of Denver, Department of Chemistry, Denver, CO, September 1994.

31 Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report," p. 34.

32 Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report," p. 44. See also Lawson, et al., "Emissions from in-use motor vehicles in Los Angeles: A pilot study of remote sensing and the inspection and maintenance program," *Journal of Air & Waste Management Association*, 1994, Issue 44, p. 447.

Program Type	HC>100ppm, percent	HC>400ppm, percent	CO>1%, percent	CO>4%, percent
Decentralized	25.7	7.9	18.5	8.7
None	28.0	8.8	20.8	10.4
Centralized (roadside)	24.3	5.8	16.3	6.2
Centralized (I/M lane)	26.6	5.7	14.7	5.6

Note: The reported difference between non-I/M and I/M program types should be considered as upper limit values because of the difference in refusal rates from different survey locations. [Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985-1992, Final Report," p 40.] (Note in original) Source, Lawson and Walsh, "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs," Report to the California I/M Review Committee, Desert Research Institute, November 1995.

Nor does other evidence clearly support the claim that EPA's requirement of dynamometer emission testing will produce any better results than the pre-existing decentralized test facilities using idle tests.[33] In fact, EPA's claims for improved I/M performance are themselves based on a questionable assumption: that "loaded test" programs can't be "gamed" as previous test protocols could. And though EPA laid much of the blame for the failure of traditional I/M at the feet of independent test-and-repair facilities, available data do not support the assumption that test-only facilities would improve effectiveness.[34]

Also, evidence indicates that there is no significant difference in the level of repair given to high-emitting automobiles after detection by traditional I/M programs, regardless of type. In a 1991 Chicago study, University of Denver researcher Donald Stedman and his colleagues showed that the emission rates of cars that had been recently tested differed little from cars that had not been tested for a long time, thus demonstrating that I/M-instigated repairs were not enduring in any significant sense.[35] Another study of 59,000 in-use vehicles stopped at random from 1985 to 1992 shows no significant difference in the number of vehicles with broken emission control systems on the road correlating to either the presence or type of I/M testing.[36]

Finally, there is evidence that I/M's current focus on all cars might do more harm than good—Lawson found that the emissions from a significant percentage of marginal emitters (those cars that are only slightly above the acceptable emissions level) actually **increased** after attempts to repair their emission systems.[37]

2. A Lack of Focus

Traditional I/M programs were developed before the advent of remote sensing, and before the accumulation of knowledge as to the emission-distribution pattern that exists in our automobile fleets. One cannot fault a regulation (or those who wrote it) for not being prescient, but one can question whether or not the requirements were short-sightedly closed to future developments in knowledge and technology.

Information regarding the ineffectiveness of traditional I/M programs and the skewed emission characteristics of the automobile fleet (Figure 3)[38] have been accumulating for almost ten years, but this information has generally not influenced the evolution of the regulations. In fact, the EPA has expended far more energy in prescribing a sequence of new universal-testing technologies to replace previous universal-testing technologies than they have in exploring measures to refine the focus of testing in response to new information.

[33] Joel Schwartz, "An Analysis of the USEPA's 50-Percent Discount for Decentralized I/M Programs," Prepared for the California I/M Review Committee, Sacramento, CA, February 1995.

[34] Joel Schwartz, "An Analysis of the USEPA's 50-Percent Discount for Decentralized I/M Programs."

[35] D.H. Stedman, et al., "On-Road Carbon Monoxide and Hydrocarbon Remote Sensing in the Chicago Area," ILENR/RE-AQ-91/14, Report prepared for the Illinois Department of Energy and Natural Resources, Office of Research and Planning, October 1991.

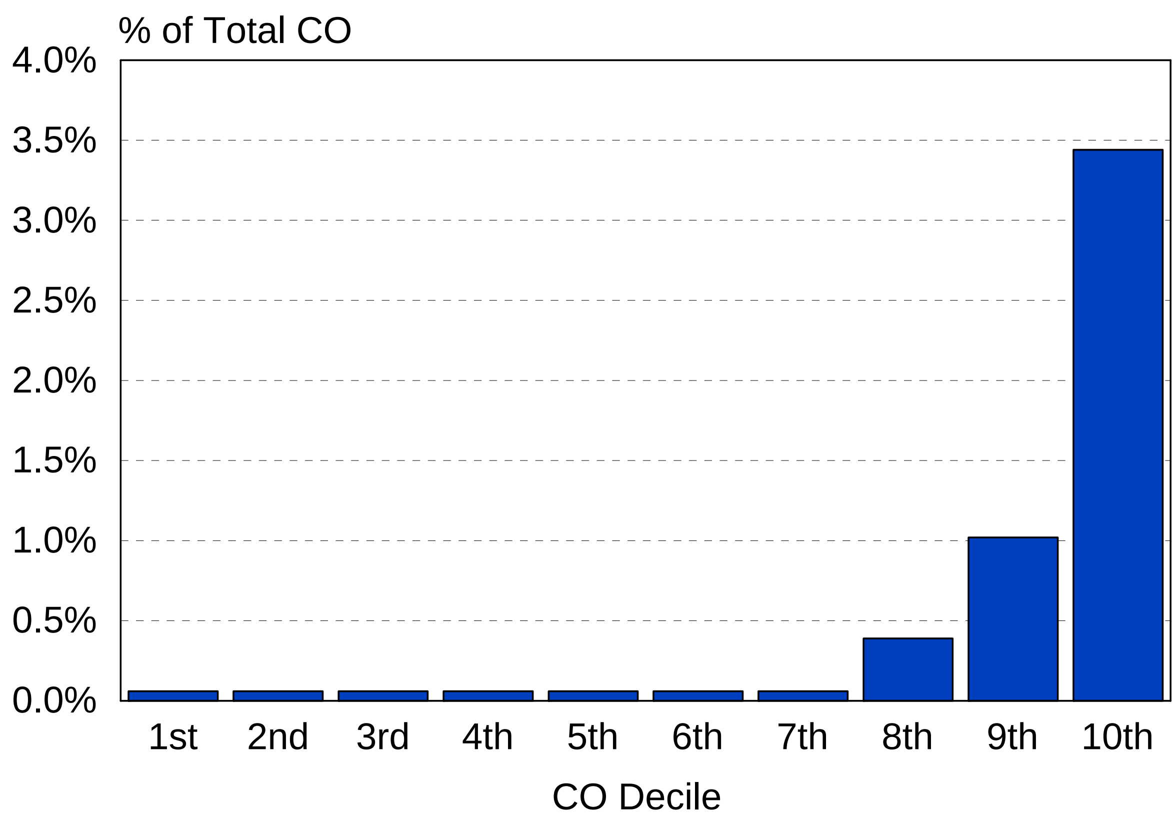
[36] Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report."

[37] Douglas R. Lawson, "The Costs of "M" in I/M--Reflections on Inspection/Maintenance Programs," *Journal of the Air & Waste Management Association*, Volume 45, June 1995, pp. 465–475.

[38] Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report."

While the prime target for I/M—the small number of extreme emitters—has grown ever more clear, traditional I/M program requirements still focus on testing all vehicles, rather than only testing those that we have reason to believe are operating in an extremely polluting manner.

Figure 3: Emission Characteristics of the Automobile Fleet



3. A Formula for Perverse Incentives.

This failure of effectiveness in traditional I/M programs has been attributed to several technical phenomena, including inconsistent behavior of automobile emission control systems and post-test deterioration of emission control systems or emission control system repairs. Others argue, however, that the biggest obstacles to success of traditional I/M programs are behavioral, resulting from the misguided incentives inherent in a system that revolves around the necessity of passing an annual (or biennial) test. Such programs generate incentives to “pass the test,” they do not create behavioral incentives for motorists to maintain clean cars year-round. As Charles Lave, an economist at the University of California, Irvine, puts it: “Such periodic testing is akin to a program that tries to “control” drunken driving by scheduling drivers for a breathalyzer test every two years."[39] Traditional I/M programs also create incentives for fraudulent actions on the part of emission-test facility personnel, and for tampering.[40]

Consider the incentives that motorists have faced under traditional I/M programs. They knew they'd face only an annual or biennial inspection and that there was a limit to how much money they might expend for repairs. They knew when the test was going to be, and they knew that they did't have to worry about any intervening inspections. Little save their own conscience motivated them to perform repairs until just before inspection time. In fact, a natural inclination to minimize expenditures on transportation favored putting off nspections and maintenance as long as possible—right up until the test date, at which time economic incentives favored finding a mechanic who could perform low-cost repairs to allow the car to pass the test.

Mechanics and test-center owners also faced perverse incentives under traditional I/M programs in which they needed to provide quick and cheap certificates if they were to remain competitive. In the worst cases, this incentive led to cheating: Audits of repair facilities show that a small percentage of shops specialized in providing fraudulent certificates or "quick fixes" that got the car past the test without making any meaningful repairs.[41]

4. No Reality Check.

Much of the data regarding I/M effectiveness was gathered fortuitously through an EPA program (begun in 1978) which actually was intended only to determine the rates and types of tampering and fuel switching prevailing after the 1977 amendments to the federal Clean Air Act. Other researchers re-analyzed this data in order to ask questions about I/M program effectiveness by program type, technology type, etc. Unfortunately, EPA's nationwide tampering surveys ended in 1992, sharply curtailing our ability to continue tracking I/M programs with regard to effectiveness and efficiency.

a) Summary of efficiency considerations

In sum, I/M program efficiency has been sabotaged by a misguided focus on universal testing of cars in a hunt that included even very low emitters, despite an inability to guarantee improved performance of these cars through repair. Through their infrequent test regimen, traditional I/M programs create perverse incentives for motorists and mechanics, with no mechanism in place to validate I/M program performance on a continuing basis. Despite all of these uncertainties, EPA has traditioanlly spell out detailed I/M program requirements, holding state programs answerable to complex computer models which define the technology to be used in testing, the required frequency of testing, the population to be tested, and the certification procedures for repair facilities.[42]

B. Fairness

As recent events in California and elsewhere have demonstrated, fairness matters—perhaps as much as efficiency issues. For example, fairness issues have come to the fore in the I/M debate in the aftermath of California's implementation of "Smog Check II," a compromise program worked out between the EPA and the state of California.

Information on the poor efficiency of traditional I/M programs has rarely reached the attention of the public (much less motivated them to take action). However, fairness concerns immediately arouse public attention. For example, the fairness ramifications of California's Smog Check II were used by several northern California radio talk show hosts to mobilize large protests against the program. In part, what sparked the protests seems to be some of the very program elements that could lead to greater I/M program effectiveness, including increases in repair cost limits, and a focus on very polluting vehicles.

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39 Patrick Bedard, "Still Smoggy After All These Years," *Car and Driver*, April 1995, p. 107.

40 Gary A. Bishop, Donald H. Stedman and Lowell Ashbaugh, "Motor Vehicle Emissions Variability," Technical Paper, *Journal of the Air And Waste Management Association*, Volume 46, July 1996. See also Jerry Aroesty, et al. "Restructuring Smog Check: A Policy Synthesis (Draft)," Rand Corporation, Santa Monica, CA, October 1994, p. 7.

41 Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report."

42 Lynn Scarlett, "Vehicle Inspection and Maintenance: Comments on Current Federal Regulations," Testimony Presented to U.S. House of Representatives Committee on Commerce, Subcommittee on Oversight and Investigations, Reason Foundation Testimony No. 2, Los Angeles, CA, June, 1995.

California has been at the forefront of efforts to reform I/M in a way that shifts the incentive structure faced by motorists to promote ongoing vehicle maintenance. The California hybrid I/M program incorporates a number of features intended to make it more efficient and equitable. The program eliminated waivers for extremely high-emitting vehicles. It raised repair cost limits and instituted "between test" monitoring via a remote-sensing program. Its emphasis on shifting the inconvenience of centralized, IM240 testing onto only those vehicles that are likely to be high emitters may be one of the most important changes, despite its not-inconsiderable problems.

While EPA's preferred program featured annual testing of all cars at a small number of high-tech, test-only facilities, the California program only tests 15 percent of the California vehicle fleet this way, while the remaining 85 percent can be tested at either centralized test-only facilities or decentralized test-and-repair facilities. And to further refine the focus of the program on finding the highest-emitting vehicles, the 15 percent of vehicles required to go to test-only facilities are mostly (all but a two percent random sample) vehicles that have a high probability of being high-emitters, such as:

- High mileage fleet vehicles;
- Vehicles for hire;
- Vehicles identified as high emitters by test/repair stations;
- Vehicles identified as likely high emitters by remote sensing;
- Vehicles previously identified as high emitters;
- Tampered vehicles; and
- Vehicles targeted through the high-emitter profile.

But demonstrations held on the Capitol steps in Sacramento showed that the public's perception of Smog Check II differed strongly from that of planners and legislators, with the biggest sore spots involving issues of fairness, rather than efficiency.

Waving signs saying "First you took our guns, now you want our cars," and "USA not USSR," protesters objected to the prospect of high-cost vehicle repairs; the seemingly careless and motorist-unfriendly way that Smog Check II was implemented; and the possibility that their car might become ineligible for registration, or even, through a much-exaggerated legal loophole, subject to impoundment.[43] While some of these objections had merit, especially those involving careless program initiation, technical glitches that failed certain types of new, perfectly functioning vehicles, and excessively tight cutpoints for others, many objections were either based on misconceptions of the program or were in direct contradiction with what the public has repeatedly said it wants—cleaner air and a robust Smog Check program. The matter of repair costs and their impact on low-income motorists is a complex one. On the one hand, motorists have often emphasized the importance of personal responsibility for vehicle repairs. On the other hand, when confronted with potential economic hardship, the idea that individual motorists were to be held truly responsible for expensive repairs to their vehicle in response to Smog Check test failure seemed to strike many of the protesters as intrinsically unfair. This inconsistency could pose a problem more intractable than the formidable obstacles attached to technological improvement.

1. Inappropriate Assumptions of Motorist / Automobile Uniformity.

The biggest inequity of traditional I/M programs is that they treat all cars and motorists essentially alike. Yet cars are not alike in terms of their pollution, and all motorists are not alike in terms of their mobility needs, behavior or income. Certain classes of automobiles are, in fact, extremely unlikely to be significant emitters. Some motorists might drive an older car that produces more pollution per mile than a newer car, but they might drive it much less, or at off-peak hours when their somewhat higher comparative emission level is also relatively less significant. Despite these obvious differences in car and motorist behavior, most programs require that all motorists must still go through the inconvenience and expense (in terms of time and money) of taking their car in for testing. This inconvenience becomes even more burdensome under EPA's initially proposed enhanced I/M, in which a far smaller number of testing stations spread thinly over large urban areas were to test huge numbers of cars. When Colorado implemented enhanced I/M, wait times were as long as an hour, after a lengthy commute to the test-only facilities which, for property-value considerations, were located in suburban communities, rather than the more densely populated urban centers.[44] And unlike the older test-and-repair shops, motorists could not simply drop their car off for testing, but rather,

[43] Subsequent legislation, California Assembly Bill 2515, closed this loophole by clearly prohibiting any sort of confiscation.

[44] Personal conversation, Doug Lawson.

had to sit and wait in their car. While the wait time was eventually cut down (mainly by dint of creating "shorter" versions of the required 240 second test protocol), the distance and compulsory attendance problems remain.

2. Unfunded Mandates for Garage Operators.

Still another fairness issue that has surfaced recently involves the large number of small businesses which have had to respond to the shifting technological requirements of I/M programs. Attempts to improve traditional I/M programs have led to changing requirements for complex equipment which, often, cannot be acquired as a simple upgrade to previously owned equipment. Such requirements for the purchase and use of specific types of increasingly expensive equipment often pose a challenge for small test-and-repair facilities. In other states, such as Colorado and Arizona (which simply accepted EPA's proposed I/M program) this investment in equipment happens infrequently, with relatively long time periods for recouping the investment in dynamometer equipment through I/M fees. In California, however, attempts to make I/M more efficient and fair to the bulk of motorists has created an inequitable situation for repair shop operators. The prospects of more rapidly shifting clean air standards and the prospect of sinking large amounts of money into technology that may never pay for itself create a dilemma for repair shop owners who can't be assured of recouping the costs of the last instrument investment before they're required to implement a new one. This problem threatens to create a situation of de facto centralized testing by simply driving independent test-and-repair shops out of business through an ever-shifting set of technology mandates.

Even in regions that simply implement EPA's enhanced I/M protocols, the situation is tricky. High financial burdens on existing test and repair centers may lead many of them to avoid purchasing new, expensive test equipment, and to apply instead for re-certification as repair-only facilities. This trend raises the specter of centralized I/M testing becoming the only test facilities available, even where state regulators may have intended to maintain some test-and-repair facilities. A more flexible I/M methodology would allow for incremental modifications and some equipment flexibility.

a) Summary of Fairness Considerations

The central tenet of traditional I/M programs is also the central inequity—a focus on annual testing of all cars in the face of strong evidence that most motorists are driving comparatively clean cars that are not contributing disproportionately to our urban pollution problems. Another inequity embodied in traditional I/M programs is imposition of unfunded mandates on existing auto repair shops to comply with state-imposed protocols and to use costly, state-selected equipment that changes on an unpredictable basis unrelated to the economic pressures of the industry. Even programs that do focus on extreme emitters, regardless of the technology used to identify them, face fairness problems—they have given too little attention to public education and to finding methods to reconcile the interests of lower-income motorists while preserving the concept of individual accountability for disproportionate contributions to urban air pollution represented by high-mileage, extreme-emitting vehicles.

V. Recommendations for Reforming Inspection and Maintenance Programs

Traditional I/M programs have been neither efficient nor fair. They do not produce incentives for motorists to drive cleaner cars, and they have not produced substantially cleaner air in the areas they serve even after attempts at reform. They have also inconvenienced the majority of motorists who drive clean cars.

And yet, there is still a need for: 1) motorists to perform necessary emission-system maintenance, 2) for some mechanism that can tell a motorist when emission-system service is necessary, and 3) some mechanism that can insure that such maintenance is being performed. With sufficient reforms, I/M can fulfill these needs. Such a program is an important component of automobility since it links personal freedom to drive with personal responsibility for preventing harms to others in the process of driving.

A. Focus on the Detection of Extreme-Emitters and Erecting a Clean-Screen

A fairer emission-control system for automobiles would focus only on those who are operating their vehicles in a manner which harms others—i.e., by operating the small percentage of cars putting out extreme amounts of emissions. In this regard, even the California I/M program, which goes farther in its efforts to identify these extreme-emitters, may need further revisions.

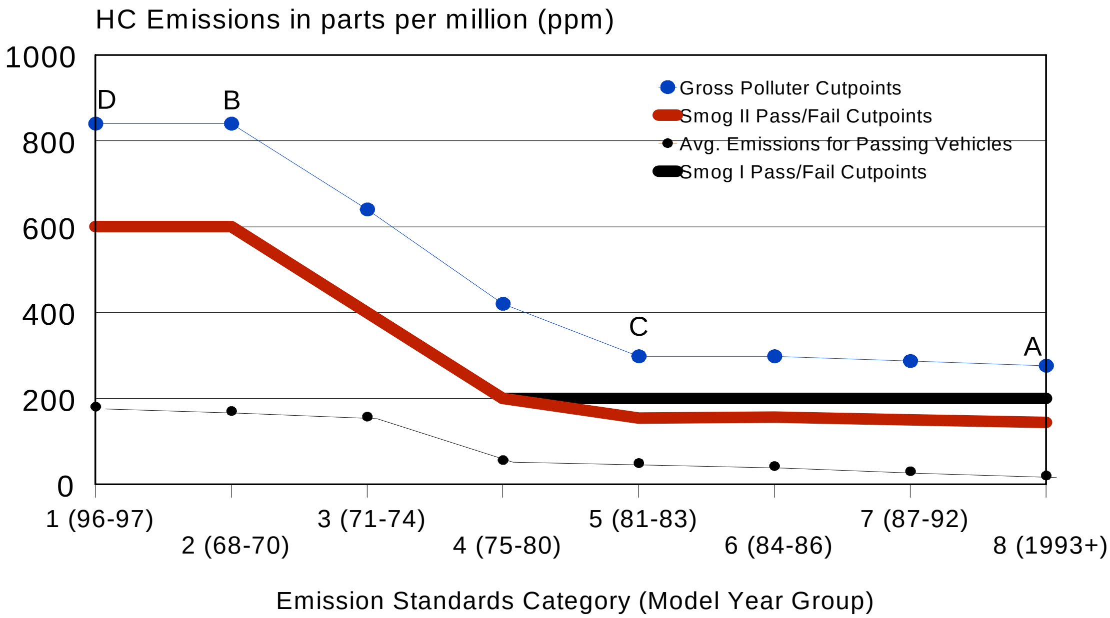
Currently, cars in California classified as "gross polluters" are identified on a self-referential basis—that is, classification as a "gross polluter" rests on a demonstration that a car is emitting at some level higher than the original manufacturer's specifications for that specific type of car. Yet this definition has little relation to the more important distinction of which cars are contributing a disproportionate amount of emissions to the total on-road emissions inventory.

Figures 4 and 5show the thresholds for a car's passing or failing the BAR-90 two-speed test, and also show the thresholds for defining a car as a "gross polluter."[45]

Examination of these figures shows how the self-referential nature of the current definition results in progressively cleaner cars being equally labeled as "gross polluters" despite the fact that a post-1993 "gross polluter" (see point "A" on figures 4 & 5) might be emitting only one-third the emissions of an early-1970s "gross polluter" (see point "B" on figures 4 & 5). In fact, cars less than 20 years old that fail I/M badly enough to be called "gross polluters" still produce only about half the emissions of a pre-1975 "gross polluter." Worse yet, a post-1980 car can be designated a "gross polluter" despite having emission levels far lower than late 1960's cars that pass the test (see points "C" & "D" on Figures 4 & 5) Despite the disparity in emission levels, "gross polluter" vehicles must all be repaired and retested in order to win certification. Yet as Lawson has shown, some vehicles at their self-referential "gross polluter" levels of emission performance might actually pollute more after repair procedures, even when those repairs are performed by highly trained mechanics specialized in the repair of emission control systems.[46]

Figure 4: HC 2500 RPM Emissions for Passenger Cars

A Comparison of Emission Standards



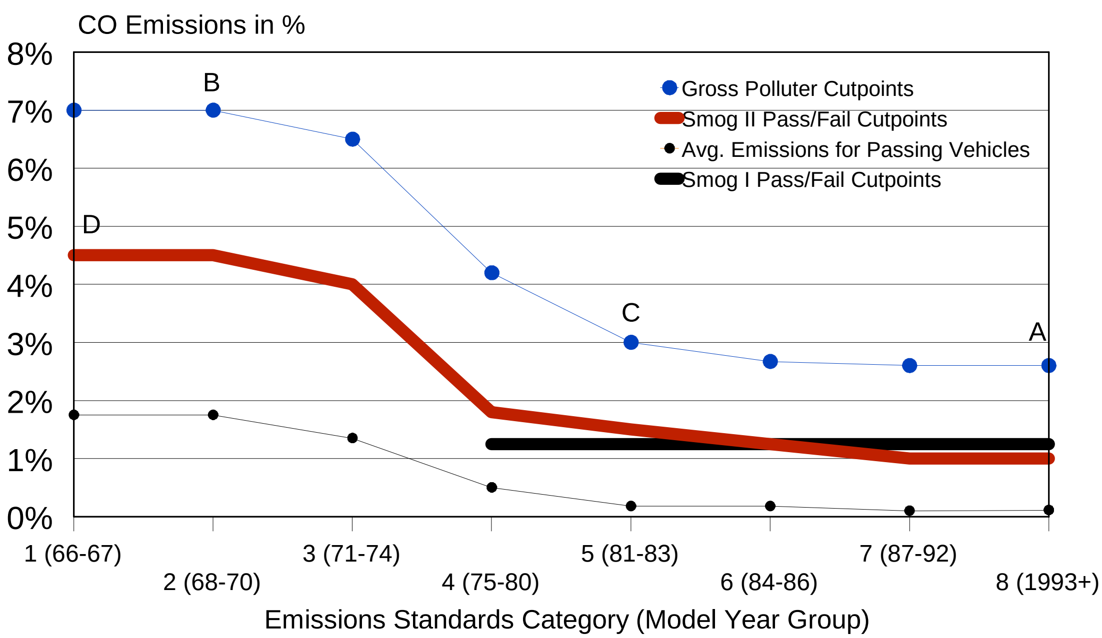
HC 2500 RPM emission standards were added with the BAR-90 ET software update for some of these categories.

[45] Information provided from BAR by fax.

[46] Douglas R. Lawson, et al., "Effectiveness of U.S. Motor Vehicle Inspection/Maintenance Programs, 1985–1992, Final Report."

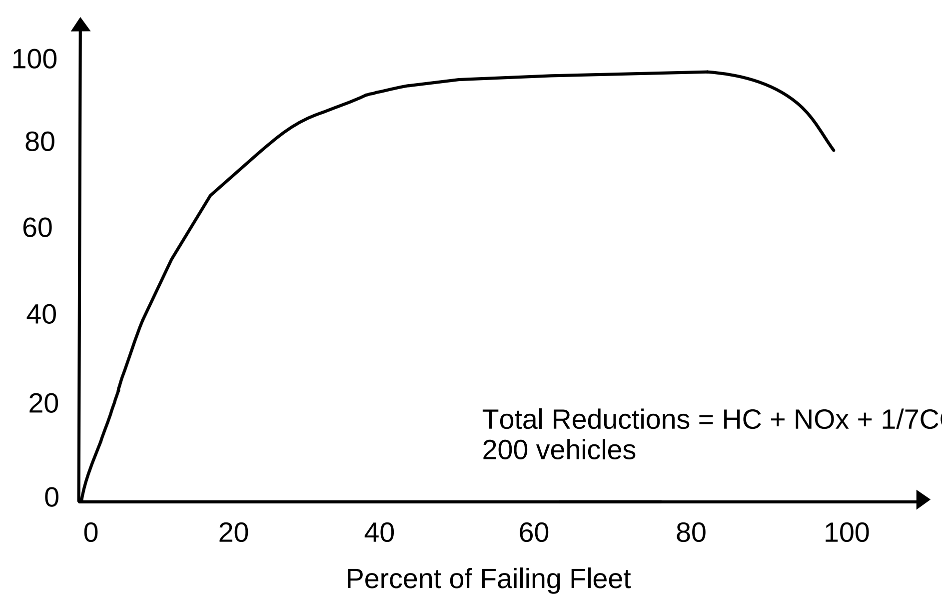
Figure 5: CO 2500 RPM Emissions for Passenger Cars

A Comparison of Emission Standards



HC 2500 RPM emission standards were added with the BAR-90 ET software update for some of these categories.

Figure 6: El Monte Data Set "Total" Emission Reductions



The current self-referential definition results in far lower cost-effectiveness than would a standard based on repairing those vehicles which produce the majority of emissions—extreme-emitters—and those vehicles that are probably reparable, or at least reparable enough to justify the expenditure of resources.

Classification as an extreme-emitter should be based on the relative contribution to the pollution problem, not through reference to a car's variance from its ideal lowest-emission state.[47] Since marginal emitters may not be repairable and if "repaired," may result in only small total emission reductions, states may wish to consider a program in which any car that is not identified as an extreme-emitter should be considered clean enough, saving the majority of motorists the inconvenience of reporting for scheduled, stationary testing, the default option for any car not clean-screened out of the program. Or, alternatively, only extreme emitters might be categorized as "gross polluters," while other cars operating at emission levels only slightly above their manufacturer's standard would simply fail as "non-compliant vehicles" requiring repair, but not the resultant additional verification requirements attendant upon identification as a "gross polluter." There is, of course, no "bright line" that determines what cars should qualify as extreme-emitters (also called "gross" emitters). In part, setting the extreme-emitter cut-off point would depend upon how much emission reductions one was attempting to achieve and which universe of cars were likely to actually be repairable. Also, such cut-offs might be revised over time as cars become cleaner and cleaner, should continued mobile-source emission-reductions be necessary.

The technology already exists to allow such a refinement in focus. Remote-sensing technology that permits a car's emissions to be measured "on the fly" using roadside sensing equipment has been developed and extensively tested, and while the technology isn't necessarily ready to entirely supplant stationary testing of suspected extreme-emitters, it is clearly ready for use in distinguishing between clean cars and extreme-emitters, and it can make such determinations cheaply and efficiently.[48] Other technologies that allow for greater motorist empowerment and even better discrimination between relatively clean cars and extreme-emitters also exist, or are in advanced stages of development. Early forms of on-board diagnostic systems (OBD) such as exhaust-gas oxygen sensors are already standard on new automobiles, giving motorists the ability to detect and repair many emission-system malfunctions as soon as they occur.

Concerns have been raised over the ability of remote-sensing to give good "coverage": that is, to "scan" enough passing vehicles to insure that the vast majority of extreme-emitters are detected, or, in a clean-screen scenario, to insure that enough clean vehicles would be scanned to allow the screening to benefit motorists. But evidence gathered in a pilot study of remote-sensing equipment conducted in Sacramento should mitigate such concerns. In a study using several remote sensing units for about two months, 45 percent of the entire Sacramento metropolitan area vehicle population was measured at least once by the remote sensors. The implication of this pilot study is that even a single RSD unit operating every day for a year would test about 250,000 cars, compared to one IM240 unit's ability to test only 19,000 cars if operated for 60 hours each week, for 52 weeks of the year, at a rate of six cars per hour.[49]

Incorporating remote sensing into I/M programs as a clean screen (and preliminary extreme-emitter spotter) would dramatically increase the program's ability to evolve in response to:

- Changing vehicle fleet composition;
- Changing automobile emission levels over vehicle lifecycles;
- Changing emission-control technologies;
- Changing emission-testing technologies;

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47 As will be discussed later in the paper, there are other factors involved beyond simple "emissions/mile" determinations, including comparative use levels, pollution levels in the region of use, and the time of day that the car is used as well.

48 Gary A. Bishop, et al., "A Cost-Effectiveness Study of Carbon Monoxide Emissions Reduction Utilizing Remote Sensing," *Journal of the Air and Waste management Association*, July 1993, pp. 978–988; Joel Schwartz, "Clarification of Misconceptions Regarding the Sacramento RSD Pilot Program," a report prepared for the California I/M Review Committee, Sacramento, CA, March, 1995; and Douglas R. Lawson et. al, "Program for the Use of Remote Sensing Devices to Detect High-Emitting Vehicles, Final Report," Desert Research Institute, Reno Nevada, April 1996.

49 Joel Schwartz, "Clarification of Misconceptions Regarding the Sacramento RSD Pilot Program," a report prepared for the California I/M Review Committee, March, 1995.

- Changing motorist responses to clean-air incentives;
- Changing composition of vehicle fuels and fuel types.

In addition, as emission-control technology improves, a greater share of the remaining emissions may come from an ever smaller number of high emitters. Remote sensors are relatively inexpensive, and are produced by private companies competing to produce higher-quality and lower-cost units. Upgraded units that are more sensitive and accurate can be incrementally introduced at relatively low cost to replace older technology models. Also, if pollutants rise or fall differentially (e.g., CO falls, but NOx does not) or some pollutants turn out to be more damaging to health than others (such as ozone or small particles), remote-sensing technology can be adapted to respond to changing ambient pollution levels, automobile-emission characteristics and motorist driving and maintenance behavior than conventional I/M tests could.

In implementing a program using frequent but invisible remote sensing, certain infrastructure questions will have to be addressed. Remote-sensor siting will be one issue that requires careful consideration. In the city of Los Angeles Remote Sensing Pilot Project, sensor siting was found to be a non-trivial challenge. Physical requirements for sensor placement included:

- Sufficient traffic volume;
- Sufficient roadway length;
- Acceptable traffic congestion due to lane closures;
- Sufficient median area in roadways for the remote-sensing equipment; and possibly
- Sufficient area to conduct BAR90 and/or IM240 confirmation tests within a quarter-mile of the remote-sensing test area.

The report states that even in a city the size of Los Angeles: "In some planning areas of the city there were no sites which met both the physical requirements and the population cross section goals in the study."[50] Those goals, essentially designed to assure that the tested population is representative of the overall vehicle fleet, would be the same in any broader implementation of remote sensing as a means of automobile emission monitoring. If such systems are to have a miles-traveled component, questions regarding the method of mileage validation arise, with potential infrastructure ramifications invoked depending upon the proposed data-collection methods.

B. Address the Economic-Hardship Problem

Any program designed to actually repair cars will raise serious fairness concerns involving repair costs, since high-emitters are often owned by those of limited means. Such motorists, in many cases, have little choice (in the economic sense) but to drive vehicles with high-emission characteristics.[51]

In a study conducted for the City of Los Angeles, Nelson Sorbo and Ed Palen of Hughes Environmental Systems, Inc., makers of remote-sensing equipment, examined the socioeconomic characteristics of high emitters identified during a study of remote-sensing feasibility. They found that:[52]

- The average income of drivers of high-emitting vehicles was significantly less than that of motorists driving low-emitting vehicle. ($18, 365 vs. $36,508);
- 32 percent of the high-emitting vehicle drivers had an annual family income of less than $10,000. Only 13 percent of the low-emitting vehicle drivers had such low family income levels;
- 74 percent of the high-emitting vehicle drivers had a per capita income of less than $10,000. Only 37 percent of the low-emitting drivers had such low per capita income;
- 76 percent of high-emitting vehicle drivers felt that money was the major reason for not tuning up the vehicle.

The authors state that:

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50 Nelson Sorbo and Ed Palen, "City of Los Angeles Remote Sensing Pilot Project," p. 38.

51 Nelson Sorbo and Ed Palen, "City of Los Angeles Remote Sensing Pilot Project," pp. 116–120.

52 Nelson Sorbo and Ed Palen, "City of Los Angeles Remote Sensing Pilot Project," pp. xiii–xiv.

Based on the sample of drivers and vehicles studied in the Los Angeles pilot study, a significant relationship was found to exist between vehicle tampering and both vehicle age and per capita income, with tampering increasing as per capita income decreased and vehicle age increased…over half of all high-emitting vehicles showed signs of tampering.

As California's protests showed, such issues must be addressed in a way which the public views as equitable. A range of options is available to help minimize the inequities caused by virtually any change in existing governmental programs, especially transportation-related programs that consume a major share of low-income household annual income.

But this is tricky: subsidizing vehicle repair poses "moral hazard" problems, and actually may weaken the effectiveness of direct emission-charging schemes that states might implement. For example, instituting a system of subsidized auto repair would probably lead to generally higher rates for vehicle repair, as virtually all third-party pay systems have in the past. Also, program administration costs could mount as more motorists apply for assistance, requiring verification of economic need and appropriate use of whatever form of subsidy is given out. Subsidized repair would also create a perverse incentive for those who are marginally poor and who, by allowing their car's emission system to degrade far enough, can then qualify for free tune-ups and repair. Such systems invariably lead to fraud as people seek to gain free repairs of car systems that they have neglected or that are only tangentially related to emissions.

Several approaches to this problem have been proposed, but few have been explored in any systematic way. Programs that extend the time allowed to pay off repair costs could address many economic equity concerns while still putting the primary responsibility for driving a clean car where it belongs, with the vehicle owner.
Alternately, private companies might advance repair funds for repair of high-emitting vehicles in exchange for some form of tradable emission reduction credit that could be used as an offset for more-expensive, less-effective incremental reductions on mobile or stationary sources of the same pollutants. Precedent for this approach can be seen in Hughes Aircraft Company's program of employee remote sensing and subsidized repair, which was used to gain credit against emission reductions required under the now defunct Rule 1501.[53]

C. Allow for Flexible and Economic Use of Appropriate Technologies

Efficiency considerations go beyond the question of simple effectiveness, and also refer to getting the most "bang for the buck" spent on using I/M as an emissions control strategy. One of the most important changes to increase I/M system efficiency lies in reversing what EPA originally proposed as a central component of enhanced I/M: the requirement for extensive use of expensive, loaded transient tests with failure criteria designed to fail cars that may be only marginally out of compliance and which might be impossible to adjust to reduce emissions at a reasonable cost. An efficient testing system would find cars with high levels of reducible emissions first, leaving marginal emissions of questionable reparability for last. It should favor spending money on repair, rather than testing, and thus should go with the cheapest test that meets accuracy requirements, rather than going with a more expensive test that does not outperform less-expensive tests at finding high-emitters. Both BAR90 and remote-sending systems appear to offer such alternatives, *if the focus is on extremely dirty vehicles and only on HC and CO emissions.*

Given that there is little difference in performance between centralized and decentralized I/M, in dynamometer or idle-test protocols for purposes of identifying extremely "dirty" cars, and in the relationship between the facility where the car is tested and the facility where the car is repaired, logic would dictate that the cheapest of these alternatives would be preferable. This may vary by circumstance and over time. Some stations may find dynamometers to be preferable, since they can be used for many different purposes. Others may prefer idle tests.

The various testing methods differ in their effectiveness at identifying various pollutants. For example, I/M 240 shows good ability to measure NOx, where, to date, remote-sensing is limited in its ability to directly measure NOx emissions. In some cases, dynamometer testing may be the best method for the task at hand, such as in post-repair certification of cars classified as extreme-emitters through another test type.

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53 The author consulted with Hughes over the question of determining "equivalency," for the purpose of equating remote-sensing-gained emission reductions with the emission reductions claimed to be produced by increased levels of ridesharing.

Efficiency also dictates avoiding needless spending and needless effort. EPA's enhanced I/M structure requires tests for "evaporative emissions," pollutants that come off of the heated surface of the engine, or out of leaking engine seals, rather than out of the tailpipe. EPA estimates that evaporative hydrocarbon emissions account for 50 percent of all hydrocarbon emissions, but this oversimplifies the problem. Several studies have shown that the distribution of evaporative emissions is as highly skewed (if not more highly) than the distribution of tailpipe emissions.[54] Other researchers studied "hot soak" evaporative emissions (emissions that evaporate after a car's engine turned off) and observed that only 20 percent of the study vehicles were responsible for 80 percent of the observed evaporative emissions.[55] Also, requirements that a "purge test" be performed on vehicles that fail the evaporative emission test may cause damage to engines that could exacerbate the problem and raise the cost of repair. A more efficient strategy would involve holding back such a costly test until it was clearly indicated, such as after identification of a vehicle as being a high tailpipe emitter, and therefore suspect in terms of maintenance history.

D. Create Mechanisms to Assess and Improve I/M Program Performance

Existing I/M programs were enacted without provision for performance measurement. While attributing specific reductions in air pollution to an individual component of a region's air quality control program may be impossible, there are other ways to check the performance of an individual component. In the case of I/M programs, this could be accomplished by instituting random checks of emission control systems, performed voluntarily and non-punitively upon a statistically significant cross-section of in-use vehicles. Such testing could be funded, as it was in the past, through Smog Check or other vehicle fees, which should cover the testing of 2,000 - 4,000 vehicles per year.[56]

E. Identify and Remove Legislative Obstacles

The federal Clean Air Act requires that some states implement prescribed I/M programs. These required programs consume a considerable portion of the state's resources available for addressing automobile emission problems, thereby slowing down the development and testing of alternative control regimes.

EPA has announced its flexibility in helping states meet clean air standards. However, that flexibility has been limited to date.

Nonetheless, some progress has been made. The National Highway System Designation Act of 1995 imposed a moratorium on mandatory test-only IM240 programs, and further, allowed states to propose an interim I/M program and required that, "The administrator [of EPA] shall approve the program if the proposed credits reflect good faith estimates by the State and the revision is otherwise in compliance with such Act [Clean Air Act]."[57] This act also removed one of the more contentious aspects of the EPA I/M guidelines, called the "50 percent discount," which essentially established EPA's preferred program as a sort of gold standard, and gave any proposed alternative program only half as much credit for producing reduced emissions, though EPA had not demonstrated any solid empirical basis for such an assumption.

Because of these revisions, California was able to enact a hybrid I/M program that incorporates a number of positive features, testing only 15 percent of the California vehicle fleet annually at test-only stations, while the remaining 85 percent can be tested at either centralized test-only facilities or decentralized test-and-repair facilities.

But additional reforms are necessary. Rather than relying on EPA's continued flexibility to permit innovative programs such as California's, the detailed requirements for enhanced I/M—Section 182 [c] [3] of the Clean Air Act[58]—should be amended to allow nonattainment areas to use whatever methods they believe will best produce attainment

54 Robert M. Reuter, et al., "Sources of Vehicles Emissions in Three Day Diurnal SHED Tests—Auto/Oil Air Quality Improvement Research Program," SAE Technical Paper Series, #941965, The Engineering Society for Advancing Mobility Land Sea Air and Space International (SAE), Warrendale, PA, October, 1994.

55 David J. Brookes, Steven L. Baldus, et al., "Real World Hot Soak Evaporative Emissions—A Pilot Study," SAE Technical Paper Series, 951007, The Engineering Society for Advancing Mobility Land Sea Air and Space, International (SAE), February–March 1995.

56 Personal communication, Doug Lawson, University of Colorado, Denver.

57 National Highway System Designation Act of 1995 Conference Report, Senate Bill 440, November 1995.

58 *Clean Air Act Amendments,* Public Law No. 101-549, 104 Stat. 2399, 1990.

with federal clean air standards while meeting the other concerns of their locality. These reforms are essential if alternative emission-control strategies are to be pursued quickly in a context of limited governmental resources. The current system of auto emission control is flawed by perverse incentives, and those flaws center around I/M. Currently, EPA decides what programs are adequate to meet provisions of the 1990 Clean Air Act amendments.

If EPA is unwilling to use its own authority to facilitate the implementation of an optimized auto emission control system, legislation should be introduced to amend sections 172 [b] [2], 182 [a] [2] and 182 [c] [3]of the Clean Air Act in order to give states the power to determine what role, if any, I/M programs with scheduled testing of all cars have in an optimized clean-air plan for their own state's non-compliance areas.

F. Look Beyond the I/M Paradigm

While much can be done to render I/M an effective component of an optimized auto emission-control program, inspection and maintenance programs should not and need not dominate the other vital components of a comprehensive emission-control regimen. Like good health care, good auto care would involve much more than what we have now: a system of infrequent and easily falsified checkups with a few transportation control measures of dubious merit thrown in for good measure.

The incentive structure for both motorists and vehicle-repair facilities needs significant revision, introducing real-time performance assessment, personal responsibility for keeping cars clean, and incentives to operate cars in an environmentally responsible manner.

The best incentives would be those which reward continual maintenance of auto emission control systems, penalizing motorists who drive cars with dysfunctional emission control systems (and test facilities that facilitate such behavior), and providing incentives for driving the cleanest car that people can afford to drive.

While an improved I/M program can address some of these issues, particularly using a clean-screen / extreme-emitter focus, the incentive issue could be addressed at an even more direct level, through a system primarily based on remote sensors or on-board diagnostic systems linked to an automobile emission-fee regime. That is, each car would fall into a given emission class, based upon manufacturer's data for that vehicle's make and model year, as validated by remote-sensing or other readings. Motorists might pay these emission fees in a number of ways, including, for example, fees based on miles-traveled, or at-the-pump direct emission charges. Cleaner gasoline cars and cars using cleaner fuels would pay considerably lower emission fees than older, conventional-gasoline, higher-emitting vehicles.

Motorists detected as high polluters by a remote sensor might be reclassified as an "uncontrolled vehicle" and would receive a notification of projected registration fees for the following year based upon that category. Repair of the vehicle would allow for reclassification into its normal category with no penalty for the motorist, if repairs are done within, say, 60 days of the notification.

An emission-charge system would not only be efficient and effective, as we have seen from a myriad of other pricing systems, it would be a step toward greater fairness as drivers are eventually required to pay for the impacts they produce in closer and closer proportion to the scale of those impacts. It addresses a question that I/M cannot, such as the trade-off between owning an older, higher emission car that one drives sparingly, versus owning a newer, much cleaner car that one drives constantly. Such a system could also automatically evolve as emission profiles fed into the pricing system as change emission-control systems age over time.

But there are other aspects to driving in an environmentally responsible manner than the simple question of minimizing emissions, and, in the near term, even driving clean cars might not be enough to reduce air emissions to target levels. Clean cars today are very clean, but they still produce emissions, and a certain percentage of vehicles have broken emission-control systems and high emissions. Under conditions of extreme traffic congestion, these emissions can produce air-quality impacts at local and regional levels which result in unhealthful air quality.

As much research and experience has indicated, traffic congestion can be reduced in an efficient and equitable manner using appropriate variants of congestion pricing, in which time-varied roadway tolls are used to reduce demand for peak-period access to crowded facilities. In a landmark study performed for the California Air Resources Board's

Statewide Working Group on Market-based Transportation Control Measures, the authors studied the potential impact of a range of pricing structures for California's urban roadway system.[59] Table 3 shows the predicted reduction in vehicle miles traveled, vehicle trips, travel time, fuel consumption, air emissions and predicted revenue flows resulting from the imposition of an average congestion fee of $0.15 per mile for Los Angeles, San Diego, Sacramento, and San Francisco as based on expected roadway usage in the year 2010.

Congestion pricing, however, must be accomplished in ways that take into account the transportation consumer's needs and wants through responsive transportation-system management. Large potential revenue sources such as those shown in Table 4 present a powerful temptation to governmental entities at all levels that find themselves increasingly low on funds to use congestion fees to supplement, rather than to displace existing taxes and fees paid by motorists. And congestion pricing is not the only way to reduce congestion. Increased capacity can also reduce congestion, as it has during the evolution of our transportation system.

Table 4: Analysis Results for Congestion Pricing (2010)[60*]

Region	Bay Area	Sacramento	San Diego	South Coast
Average Price	$0.13	$0.06	$0.09	$0.19
VMT	(2.8%)	(1.5%)	(1.7%)	(3.3%)
Trips	(2.7%)	(1.4%)	(1.6%)	(3.1%)
Time	(8.2%)	(4.8%)	(5.4%)	(9.7%)
Fuel/CO2	(8.3%)	(4.8%)	(5.4%)	(9.6%)
ROG	(6.9%)	(3.7%)	(4.2%)	(8.1%)
CO	(6.9%)	(3.9%)	(4.3%)	(7.9%)
NOx	(3.2%)	(1.7%)	(2.0%)	(3.6%)
Annual Revenue	2,274	443	896	7,343

Notes: Revenues expressed in millions of dollars per year; VMT denotes weekday vehicle-miles traveled; trips are weekday vehicle-trips; time is weekday vehicle-hours of travel; fuel is daily gallons of gasoline/diesel; CO2 is daily tons of carbon dioxide; ROG is daily tons of reactive organic hydrocarbons; CO is daily tons of carbon monoxide; and Nox is daily tons of oxides of nitrogen.

VI. CONCLUSION

While great progress has been made in reducing both stationary and mobile-source pollution, the road to meeting health-based air pollution standards has been a rocky one, and there is still some distance to travel. We have to ensure, as we continue to clean up the air, that we reduce the harm in this environmental arena without simply transforming it into some other kind of harm, including the economic harm that can result from misguided air pollution-reduction policy. Simply moving harm from one sphere of life to another is not a worthwhile goal of public policy—eliminating harm or reducing it is.

While we strive to bring auto emissions down, we should also keep in mind that such efforts will impact many people's lives: automobile use constitutes a positive value for the 87 percent of American households who choose auto-

59 Greig Harvey, Elizabeth Deakin, Randall Pozdena and Geoffrey Yarema, "Transportation Pricing Strategies for California: An Assessment of Congestion, Emissions, Energy and Equity Impacts," California Environmental Protection Agency, Air Resources Board Research Division, Draft Final Report, Sacramento, CA, June 1995.

60 The congestion pricing strategy analyzed here assumes that prices would be assessed on a per mile basis everywhere that congeston appears in the highway network, including on arterials and collector streets as necessary. A technology for electronic toll collection would be required. Roadway message signs or in-vehicle readouts would provide information about tolls on upcoming segments, likely as part of a broader highway information system. Prices would not vary minute-by-minute, but would be set to reflect average conditions on each highway link during each period of the day, perhaps with seasonal adjustments. The results shown here are based on a reduction of congestion to level-of-service D/E, defined as a volume-to-capacity ratio of .9. Note that travelers would continue to experience some delay under this criterion, but that greater reductions in volume might not be justifiable in economic terms.

mobiles for their primary mode of transportation.[61] Mass transit systems, still favored by many planners and regulators despite increasing evidence of their lack of consumer appeal and economic viability, have been unable to lure drivers out of their cars. Nor have drivers been deterred by increasing congestion on roadways, demonstrating the depth to which they value their automobility.[62]

Traditional I/M programs—a linchpin measure in the automobile-emission-reduction framework of national clean-air policy—are inefficient and inequitable. Even reformed I/M programs face an uphill battle to gain public acceptability and overcome infrastructural challenges.

The challenge of reducing mobile-source emissions without compromising people's mobility will require new ways of thinking, since established methodologies are reaching the limits of their effectiveness. Increasingly, the remaining problems will require innovative, flexible, and responsive approaches which use more finely tailored tools than those available to central planners. Such tools might include the expanded use of market incentives and market forces, two methods which promise greater efficiency and fairness than our historically centralized command-and-control methodologies.

ABOUT THE AUTHOR

Kenneth Green, D.Env. is Environmental Studies Director and a Senior Policy Analyst at the Reason Foundation. Dr. Green has published two previous studies on the linkage between transportation and air quality: "Looking Beyond ECO," and "Defending Automobility," and directed studies on electric vehicles and on roadway finance reform. Dr. Green serves on the California Department of Transportation Advisory Committee and also on the REACH Commission, a task force sponsored by the Federal Highway Administration and the Southern California Association of Governments to design pricing approaches for roadways in the South Coast Air Basin.

[61] United States Department of Transportation, 1990 National Personal Transportation Survey, Table 4.24, "Number of Person Trips by MSA size and Mode of Transportation," 1990 NPTS, pp. 4–47, Washington D.C., U.S. Government Printing Office.

[62] Charles Lave, "It Wasn't Supposed to Turn Out Like This: Federal Subsidies and Declining Transit Productivity," *Access*, University of California Transportation Center, Issue No. 5, Fall 1994, pp. 21–25, Berkeley CA; Thomas A. Rubin and James E. Moore II, *Ten Transit Myths: Misperceptions About Rail Transit in Los Angeles and the Nation*, Reason Foundation Policy Study No. 218, November 1996; and Thomas A. Rubin and James E. Moore II, *Why Rail Will Fail: An Analysis of the Los Angeles County Metropolitan Authority's Long Range Plan,* Reason Foundation Policy Study No. 209, July 1996.