

Repair Avoidance and Evaluating Inspection and Maintenance Programs

DONALD H. STEDMAN AND
GARY A. BISHOP*

University of Denver, Denver, Colorado 80208-2436

ROBERT S. SLOTT

71 Hawes Avenue, Hyannis, Massachusetts 02601

On-road remote sensing measurements of vehicle carbon monoxide (CO) emissions in Denver, CO, have discovered vehicles that, after failing a state inspection and maintenance (I/M) test, are avoiding repair through sales to individuals who register them outside the program but still drive the vehicles in the I/M area. This reduces the emissions benefits from the program and makes it difficult to analyze program benefits by comparing the emissions of eligible vehicles with ineligible vehicles since the program is increasing the emissions of the ineligible vehicles. On-road emissions measurements of CO collected in 1995/1996 after the first year of Colorado's new centralized biennial I/M program showed a pattern of high emitting vehicles, which were unable to pass the new test, being moved out of the program but not out of the area. We predicted that if this were the case the observed pattern would disappear for CO data collected 1 year later. New measurements made in 1996/1997 confirmed this prediction.

Introduction

Motor vehicle inspection and maintenance (I/M) programs aim to reduce on-road emissions by inducing motorists to take better care of their vehicles and to repair their vehicles if they fail a test (1, 2). However some failed vehicles never pass being registered to a location where the test is not required, and some broken vehicles may pass a test without effective repair (3, 4). The latter situation may occur due to overt motorist behavior, such as taking their vehicle on a hard drive immediately prior to the test (5) or repetitively taking the test hoping to achieve a pass due to emission or test variability (6).

When the State of Colorado imposed a new enhanced biennial IM240 program in 1995, the opportunity arose to compare the on-road emissions of vehicles that had undergone the new enhanced I/M test with a socioeconomically matched control group of those that had not been tested but had foregone 1 year of the previous Colorado annual decentralized idle test. The new enhanced I/M test was required of all 1983–1993 odd-model-year vehicles and any 1994 vehicles purchased new before October 1, 1994, registered in the six-county metro Denver I/M program area. The legislation also required commuters who lived outside

* Corresponding author phone: (303)871-2584; fax: (303)871-2587; e-mail: gbishop@du.edu.

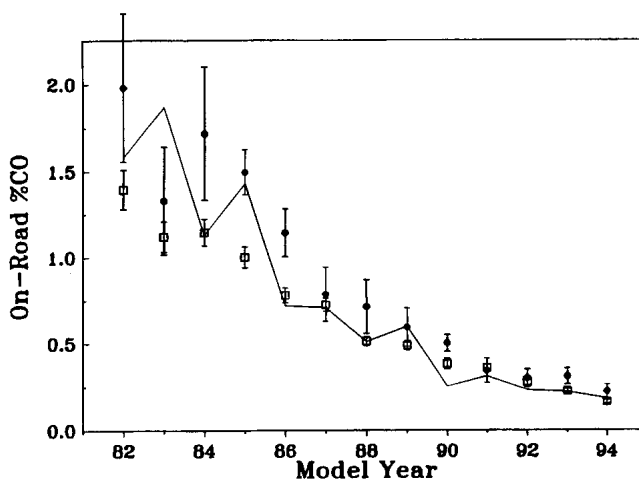


FIGURE 1. Fleet averaged on-road CO emissions collected at 6th and I-25 in Denver, CO. I/M ineligible (●) and eligible (□) vehicles (as defined by Colorado DMV) measured in December/January of 1996/1997; errors bars define the standard error of the mean of the five measurement days. The solid line shows the ineligible vehicle data collected in 1995/1996 (7). These data show that the state's I/M program increases the emissions of ineligible vehicles.

the I/M program area but drove in the area to subject themselves to I/M testing.

On-road measurements were carried out at the end of the program's first year (1995/1996) and showed excellent fleet average correlation by model year (MY) with the State's IM240 emissions for CO, HC, and NO (7). On-road CO emissions were found to have decreased in the odd-model-year vehicles by $6 \pm 2\%$ as compared to the untested even-model-year eligible vehicles (7). This can be taken as a measure of the improvement arising from the new I/M program in its first year. No decrease in HC or NO emissions was seen. Vehicles not subject to the new I/M test (as determined by Colorado DMV records) were also driving by this remote sensing site. The CO emissions of these ineligible vehicles showed a surprising and opposite pattern. The CO emissions of the odd-model-year ineligible vehicles were $32 \pm 10\%$ higher than the average of the adjacent even-model-year ineligible vehicles (solid line Figure 1). We found a positive correlation ($r^2 = 0.77$) between the increased odd MY emissions and the I/M program failure rates increasing with older MY. We proposed that the new I/M program was inducing a movement of higher emitting, odd MY vehicles to outside the required testing area (7) and that if this proposal were correct the pattern would disappear if measured 1 year later.

Results and Discussion

This paper reports on a second series of measurements made (5 days, 35 148 valid vehicle CO measurements that contained 1550 ineligible vehicles) at the same location central to the Denver I/M area (the exit ramp from northbound I-25 to westbound US6). Figure 1 shows 1996/1997 average CO emissions by MY for vehicles not required by the Department of Motor Vehicles to submit to any Colorado I/M test (●) as compared to vehicles eligible for the Colorado enhanced IM240 I/M program (□). The plotted errors are standard errors of the means calculated using the daily averages as independent samples. The solid line repeats the 1995/1996

average CO emissions for the I/M ineligible vehicles showing the large odd/even alternation. Figure 1 shows that for the ineligible vehicles the previous odd/even alternation has disappeared, as predicted (7). Subtracting the first year ineligible average CO emissions by model year from those in the second year produces a well-defined alternation, indicating that the second year of the new I/M program induced higher average CO emissions among the even-model-year ineligible vehicles. The odd MY vehicles have also experienced a slight increase in emissions as would be expected with their increase in age by 1 year. There is now no statistically significant odd/even MY difference (using a paired Student's *t* test at the 95% confidence level).

The previous work found a 12% difference between the average on-road CO emissions of the ineligible vehicles as compared to the I/M eligible vehicles. As expected, this has grown to a $23 \pm 2\%$ difference (weighted average %CO of 0.64 ± 0.04 for the ineligible vehicles vs 0.49 ± 0.02 for the eligible vehicles). If the emissions of ineligible vehicles driving in the area of required I/M are increased as a result of the I/M program, then an estimate of the effectiveness of an I/M program made by comparing emissions from eligible and ineligible vehicles (8–10) will lead to an overestimate of the program benefit.

We searched for evidence that the emissions export is due to vehicle owners relocating vehicles out of the area to a second address, the so-called "summer cottage" effect (7). Unfortunately, change of address records are not standardized in Colorado, and attempts to find vehicles from within our data sets that have changed county of registration, but not owners, were unsuccessful. However, more than 50% of the ineligible vehicles measured were registered in counties with more than a 1.5-h commute to Denver.

A second process by which the I/M program can increase emissions of ineligible vehicles is the sale of vehicles that need emissions repairs to residents of the out-lying areas. In 1996, Colorado's enhanced I/M program reported 651 773 completed vehicle tests when counted by unique VIN. Of these, 41 762 vehicles apparently left the testing center with a "FAILING" overall test result. However only 34 381 of those vehicles have records indicating compliance with the program. On the basis of monthly averages for these missing vehicles, 600–700 of the 7381 missing vehicles would be expected to show up with passing scores in the next year's data. Thus, in 1996 16–17% of the vehicles that fail their initial test disappear from the system. This result has also been reported in Vancouver, Canada, where 15.7% of the failing vehicles were reported to have no subsequent passing record (11). Where do the Colorado vehicles go? The data suggest that some of them end up registered in the out-lying counties around Denver and are used to commute back into the program area without proper emission repairs.

We combined MY 1982/1994 records from our 1995/1996 and 1996/1997 on-road measurements. There were 2694 (average model year 1989.5) ineligible vehicles, and of these, 707 vehicles had a record of being tested by the enhanced I/M program (average model year 1989.7). The failure rate for these vehicles was 9.7% (four had aborted test records) as compared to a 6.4% failure rate for all of the 1996 enhanced tests. Of the ones that failed the test, we found 33 vehicles that have no passing records.

These 33 vehicles are older (average MY 1986 vs 1989.5) and higher emitting (average on-road %CO of 2.03 vs 0.59) than the rest of the ineligible fleet. These vehicles were also four times more likely to have a test record indicating no valid registration (dealer owned or ownership change) at the time of its emission test (5.4% of the ineligible vehicles with

test information had no valid registration as compared to 1.4% for all vehicles in the I/M program).

The 33 vehicles do not explain all of the emission differences observed. They do illustrate by example one mechanism whereby vehicle emissions are exported out of the program but not out of the area. Other factors such as private vehicle sales (which could skip the emissions test before sales) and the registration of vehicles to second residences outside the program by their owners are still potential contributors. Thus, the new Colorado I/M program, which was intended to influence human behavior, actually does so but not in the intended manner. Since these "repair avoiding" vehicles continue to operate inside the I/M program area, this will adversely impact the actual effectiveness of a region's I/M program. This information supports our previous contention that the Colorado I/M program benefit should be discounted to a $4 \pm 2\%$ benefit in on-road CO emissions reduction at our measurement site (7). The results are identical if the %CO readings are converted (12) to fuel-specific mass emissions (g/gal of fuel).

This study reinforces the conclusion that on-road I/M program evaluation should be carried out when half the eligible fleet have been tested. Then a fully matched control group is available. It also shows that in-program/out-of-program on-road emission differences can only be used as evidence for the upper limit of claimed program benefits. The EPA/ECOS recommended method of I/M program evaluation (13) apparently will not detect repair avoidance either by this method or by vehicles that fail and then never reappear to pass.

Literature Cited

- (1) EPA I/M Briefing Book: *Everything you ever wanted to know about inspection and maintenance*; U.S. Environmental Protection Agency, Office of Air and Radiation; U.S. Government Printing Office: Washington, DC, 1995; EPA-AA-EPSP-IM-94-1226.
- (2) *High Tech I/M Test Procedures*. U.S. Environmental Protection Agency, Office of Air and Radiation; U.S. Government Printing Office: Washington, DC, 1996; EPA-AA-RSPD-IM-96-1.
- (3) Lawson, D. R. *J. Air Waste Manage. Assoc.* **1993**, *43*, 1567–1575.
- (4) Lawson, D. R. *J. Air Waste Manage. Assoc.* **1994**, *44*, 426.
- (5) Gourley, D. Was it Hot Enough. *Air Care Repair*, Vol. 3; Vancouver, 1996.
- (6) Bishop, G. A.; Stedman, D. H.; Ashbaugh, L. *J. Air Waste Manage. Assoc.* **1996**, *46*, 667–675.
- (7) Stedman, D. H.; Bishop, G. A.; Aldrete, P.; Slott, R. S. *Environ. Sci. Technol.* **1997**, *31*, 927–931.
- (8) Radian Corp. *Colorado automobile inspection and readjustment program performance audit*; Prepared for the Colorado Office of State Auditor, Denver, CO, 1992.
- (9) Zhang, Y.; Stedman, D. H.; Bishop, G. A.; Beaton, S. P.; Guenther, P. L. *Environ. Sci. Technol.* **1996**, *30*, 1445–1450.
- (10) DeHart-Davis, L.; Rodgers, M. O. Linking Scientific Data and Public Policy: Evaluating Inspection/Maintenance Programs using Remote Sensing Data. Presented to the Association for Public Policy Analysis and Management, Pittsburgh, PA, Nov. 1996.
- (11) Stewart, S. J.; Gourley, D. I. *AirCare Technical Review of the AirCare Program: Program Year Three*; British Columbia Ministry of Transportation and Highways and Insurance Corporation of British Columbia: Vancouver, 1996.
- (12) Bishop, G. A.; Stedman, D. H. *Acc. Chem. Res.* **1996**, *29*, 489–495.
- (13) Steib, J. Memo to ECOS/STAPPA NHA I/M workgroup members. July 11, 1996.

Received for review December 18, 1997. Revised manuscript received February 17, 1998. Accepted March 19, 1998.

ES9711019