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First Biennial Evaluation of the Atlanta Enhanced Vehicle Inspection/Maintenance Program

Submitted to:

Marlin R. Gottschalk, Ph.D.
Mobile and Area Sources Program Manager
Air Protection Branch
Environmental Protection
Division
Georgia Department of Natural Resources

Submitted by:

Leisha DeHart-Davis, Ph.D.
Elizabeth Corley
Michael O. Rodgers, Ph.D.
Air Quality Laboratory
School of Civil and Environmental Engineering

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I. INTRODUCTION

This report evaluates the effectiveness of the enhanced inspection/maintenance (I/M) program of the Atlanta 13-county ozone nonattainment area during its first two years of operation. The evaluation methodology is the same used to rate the effectiveness of the 1994 Atlanta basic I/M program: the emissions differences observed in inspected and uninspected Georgia vehicles are compared with the same emissions differences predicted by the U.S. Environmental Protection Agency MOBILE model (Rodgers, et al, submitted). That comparison yields a ratio that represents actual effectiveness as a percentage of ideal effectiveness.

The report is divided into five sections. This first section provides background on federal vehicle emissions testing requirements, outlines the history of I/M programs in Atlanta, and profiles Atlanta's current enhanced I/M program design. The second section describes the components of the evaluation, including onroad vehicle emission data, model-predicted emission factors, and the formula that uses this data to estimate I/M effectiveness. The third section outlines the analytical results, including descriptive statistics, the results of a semi-logarithmic regression model, and estimates of enhanced I/M program effectiveness. The fourth section discusses the results and the fifth section summarizes our conclusions.

A. Evolution of Automobile Inspection/Maintenance Programs

The 1977 Clean Air Act Amendments required states not complying with federal air quality standards for ozone and carbon monoxide to establish vehicle inspection/maintenance (I/M) programs. The inspection process, which applied to light-duty vehicles of a certain age, involved (and still involves) testing a vehicle's tailpipe emissions to determine the effectiveness of its emission controls.[1] The test was performed while the vehicle idled and measured the concentration of carbon monoxide and hydrocarbons. Motorists were required to repair failed vehicles, comprising the maintenance component of the program. Vehicles with repair costs above a set amount, typically $50, qualified for a waiver, which is an exemption from further repair and testing.

[1] The model year vehicles subject to testing vary across I/M programs.

Motorist compliance was typically verified by police through the presence of a vehicle windshield sticker, which motorists received after passing the test, or through the vehicle registration process, for which an emissions certificate was required. Inspections were provided by decentralized test-and-repair networks, which allowed service stations and automotive repair shops to perform emissions tests and repair failed vehicles, or by centralized test-only networks, in which a limited number of centrally operated facilities performed testing as the sole service.

In the late 1980s, with Clean Air Act reauthorization looming ahead in 1990, experts were attributing over half the ozone-causing emissions and nearly all the carbon monoxide pollution in U.S. cities to the automobile. The Environmental Protection Agency (EPA) responded to this assertion by citing improper testing and poor quality control in decentralized test-and-repair programs, the most common program design. EPA believed that improper testing sometimes stemmed from an inherent conflict-of-interest in test-and-repair programs: emissions inspectors might be tempted to falsely fail a vehicle for the repair business or falsely pass a regular customer's vehicle or a vehicle that did not pass after repairs. Decentralized test-and-repair networks also have a greater number of geographically dispersed test stations that operated independently of one another. As a result, EPA asserted, it was more difficult for administering agencies to ensure that test technicians were properly trained and that tests were competently and honestly performed.

These shortcomings led Congress to expand the requirements for automobile inspection/maintenance programs in the Clean Air Act Amendments of 1990 (CAAA). The CAAA creates two I/M program types, basic and enhanced. Basic I/M programs apply to moderate and marginal ozone nonattainment areas with existing I/M programs. Basic I/M programs require light-duty vehicles of a certain age to be inspected using a simple idle test. Enhanced programs apply to serious, severe and extreme ozone nonattainment areas with urbanized populations of 200,000 or more and to all metropolitan statistical areas with a population of 100,000 or more in the Northeast Ozone Transport Region. Enhanced areas must use improved test technologies and test procedures; conduct centralized testing, unless the state demonstrates that decentralized testing is equally effective; inspect cars annually, unless a state demonstrates that less frequent testing is equally effective;[2] and deny vehicle registration to motorists who fail to comply with inspection requirements.

To account for suspected weaknesses in decentralized programs, EPA applied a 50 percent discount to emission reduction credits estimated from such programs. This discount represented half the credit that could be earned by an equivalent test in a centralized network. The November 1992 federal I/M regulations specifying the discount was followed by a heated public debate, led by states, disputing the empirical foundation for the discount and calling for its repeal. The adverse reaction by states laid the groundwork for the 1995 National Highway System Designation Act, which revoked the automatic 50% credit discount of emission reductions from decentralized I/M programs. The federal legislation required a state-by-state analysis of I/M credits, made in "good faith" and "based in fact." This good faith estimate contains two components. The first component is a qualitative interim evaluation that assesses the differences in testing performance between test-only and test-and-repair stations. The second component is a final quantitative evaluation which determines the I/M emission reduction credit.

The first evaluation component of the Atlanta enhanced I/M program was submitted to EPA in June 1999 (Georgia Institute of Technology, 1999). The second evaluation component is the focus of this report.

B. History of Atlanta Inspection/Maintenance Programs

In 1981, the Georgia Air Quality Act established the state's first I/M program, covering four ozone nonattainment area counties totaling more than 200,000 registered vehicles.[3] The program was implemented through a decentralized test-and-repair network which allowed repair shops, service stations and automobile dealers to perform emission inspections and emissions-related repairs. Testing was originally required for the latest ten model year vehicles, but was expanded in 1986 to include the latest twelve model years. To receive an emissions compliance certificate, cars were required to pass an idle emissions test and an inspection of the catalyst, air pump and fuel inlet restrictor for

[2]While the CAAA legislation emphasized annual testing, most enhanced I/M programs conduct biennial inspections to defray higher inspection fees that result from more costly advanced testing technologies.

[3] 1979 Georgia Air Quality Act, 68-2501, et seq.).

evidence of tampering. Owners of failing cars that would have cost more than $50 to repair qualified for a waiver and an emissions certificate, so long as any repairs made resulted in some reduction in emissions. Owners of cars that failed the tampering inspection were required to obtain repairs to bring their emissions into compliance regardless of cost.

In response to the 1990 Clean Air Act Amendments (CAAA), the Georgia legislature revisited emissions testing in 1992.[4] This legislation enabled the Georgia Department of Natural Resources (GDNR) to upgrade Georgia's I/M program and bring it into compliance with the 1990 CAAA and current federal regulations. Specifically, the new legislation allowed GDNR to require advanced testing technology and improved inspection procedures; raise the $10 testing fee to a maximum $25; expand testing from four counties to the entire 13-county Atlanta ozone nonattainment area[5]; and increase the minimum waiver amount from $50 to $450 plus a consumer price index adjustment, as mandated by the 1990 CAAA[6]. The legislation also authorized GDNR to hire a contractor to perform testing, but effectively prohibited the agency to exclude other businesses from emissions testing.

In Fall 1993, GDNR promulgated regulations creating a centralized test-only IM240 network that also allowed for independent stations to perform inspections. In March 1994, after mounting testing industry concern that centralization would economically damage small testing businesses and produce long motorist waiting lines, GDNR announced its decision to delay selecting a contractor and re-evaluate its options for implementing enhanced I/M.

At that time, EPA was considering allowing states to use RG240, a lower cost repair grade emissions analysis system that would facilitate the entry of independent stations into the testing business. A survey of Atlanta emissions testing stations indicated

[4] 1992 Georgia Air Quality Act, Article 2: Motor Vehicle Emissions Inspection and Maintenance Act (OCGA Section 12-9-40 et seq.).

[5] The basic I/M program area included Cobb, Fulton, Gwinnett and DeKalb counties. The enhanced I/M program area includes these counties plus Cherokee, Clayton, Coweta, Douglas, Fayette, Henry, Forsyth, Paulding, and Rockdale.

[6] The transition to a $450 waiver limit was implemented by GDNR in phases. The limit was $200 for the first three years of the program and increased to $450 plus CPI on January 1, 2000.

that several hundred would invest in the $40,000 equipment to remain as inspection providers. In response to EPA's flexibility and empirical evidence that there would be sufficient suppliers to serve the Atlanta fleet, GDNR issued new regulations in 1994 calling for RG240 testing. The agency also distributed a new request for proposal (RFP) for a centrally managed network combining both centralized IM240 and decentralized RG240 testing.

The regulatory landscape shifted dramatically in 1995, when EPA approved California's plan to allow Acceleration Simulation Mode testing, a less stringent test than RG240, within a "hybrid" network of test-only and test-and-repair stations. In response, GDNR withdrew its request for RG240/IM240 proposals. After an extensive review of "Guidance of I/M Flexibility Options and Emission Reduction Credits" (February 1995), the document that formalized EPA's decision criteria for California's program acceptance, GDNR proposed to implement a decentralized I/M program featuring ASM and two-speed idle testing by both test-only and test-and-repair stations. In December 1995, GDNR issued an RFP for a contractor to manage the new program. After receipt and review of three bids, GDNR awarded the contract to MCI Telecommunications, Inc. in May 1996, with a program start date of October 1996.

C. The Atlanta Enhanced I/M Program

Table I chronicles the history of I/M programs in Atlanta, GA. The Atlanta enhanced I/M program received limited implementation in October 1996[7], with emission inspections required only for those vehicles migrating to the Atlanta I/M program area. The new program commenced in January 1997, with biennial emissions testing required of all vehicles from the 1975 model year to three years of age.[8] The new program also spanned

[7] October 1996 was chosen as the soonest possible start-up date after the previous basic I/M program, which operated during a January-to-April vehicle registration "season." Vehicle registration is now conducted year-round in Georgia, as is enhanced emissions testing.

[8] Three significant changes have recently been made to the Atlanta enhanced I/M program. The waiver limit increased in January 2000 to $608, which represents $450 plus the consumer price index. In 2001, testing frequency changed from biennial to annual; the requirement to inspect back to 1975 model years was replaced with the requirement to inspect the latest 25 model years; and the exemption of the two newest two model years was changed to exempt the newest three model years.

the 13-county nonattainment area, incorporating nine new counties that were not subject to the previous basic I/M program. Vehicles were inspected using the two-speed idle (TSI) testing procedure, which measures emissions under idle and a 2500 RPM engine speed.[9] Vehicles that failed emissions testing were required to be brought into compliance by repair, whereas repairs beyond $200 that showed emissions improvement were eligible for a waiver from further testing.

In October 1998, the program began to require vehicles over six years of age to undergo the more rigorous Acceleration Simulation Mode (ASM) testing. (ASM testing was originally slated for October 1997. However, manufacturers' problems with the testing software resulted in a one-year delay until the technology difficulties could be resolved.) The primary difference between ASM and TSI testing is the approximation of real-world driving conditions, i.e., placing the engine under load. While the emissions inspector depresses the accelerator to achieve 25 miles per hour (MPH), ASM testing places the vehicle's drive wheels on a treadmill-like dynamometer that applies an actual load on the vehicle engine.[10] The latter approach is more representative of actual driving conditions than an idle test.

Covered vehicles in the 13-county ozone nonattainment area must show proof of a passing emissions inspection, a waiver, or proof that they qualify for an exemption in order to register their vehicle. Exemptions are granted to business and military personnel and college students with vehicles temporarily located in other states and senior citizens (over 65) that own vehicles older than ten years that they drive less than 5,000 miles per year.

II. I/M PROGRAM EVALUATION COMPONENTS

This evaluation of the Atlanta enhanced I/M program involves comparing the onroad emissions differences observed in inspected and uninspected vehicles with the same emissions differences predicted by the TECH5 subcomponent of the MOBILE5b

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[9] This procedure contrasts with the testing procedure of basic I/M programs that measure emissions while vehicles idle.

[10] This ASM test places a load that is generated using 25 percent of the maximum acceleration of the Federal Test Procedure.

emissions model of the U.S. Environmental Protection Agency. The TECH5-predicted emissions difference represents the goal of the I/M program, a reasonable assumption given that states use the model to generate the emission reduction credit received for automobile emissions testing programs. The emissions difference observed in onroad inspected and uninspected vehicles is assumed to reflect I/M program performance.

This section of the report describes the data used in the evaluation. It details the Continuous Atlanta Fleet Evaluation (CAFE), the ongoing remote sensing study of onroad Georgia vehicles that provides, *inter alia,* onroad emissions data of inspected and uninspected vehicles. The TECH5 subroutine of EPA's MOBILE5b emissions model, from which we extracted predicted emission factors for a single cycle of testing, is also discussed. The last section outlines the algorithm that combines data from CAFE and TECH5 to generate effectiveness estimates for the Atlanta enhanced I/M program.

A. Continuous Atlanta Fleet Evaluation

The Continuous Atlanta Fleet Evaluation (CAFE) provides the onroad emissions data used to represent Atlanta enhanced I/M program performance. CAFE uses remote sensing devices to measure annually the emissions of approximately 300,000 in-use vehicles in the 13-county I/M program area, as well as two cities more than 75 miles from Atlanta that do not require automobile emissions testing.[11] The study is an ongoing effort started in 1993 to collect automobile emissions data for assessing a variety of trends, including fleet turnover, emission control deterioration, and socioeconomic impacts of mobile source control strategies.

Remote sensing devices (RSD) enable the unscheduled measurement of tailpipe emissions from vehicles while they are in operation. The advantage of in-use measurement is the ability to observe a vehicle's emissions under typical driving conditions, which cannot be captured in the relatively highly controlled conditions of emissions testing procedures.

RSD measures the emissions of passing vehicles remotely and unobtrusively so motorists are minimally aware of the equipment and do not alter their natural driving

[11] Augusta is located 136 miles east of Atlanta, whereas Macon is 76 miles south of Atlanta.

behavior. To that end, the remote sensing instrumentation is housed in a van parked on the roadside along with a videocamera. An infrared light source and its generator are placed on the opposite side of the road or on the median to create a beam of light that traverses the road. When a passing vehicle breaks the beam, it triggers a measurement of hydrocarbons, carbon monoxide, and nitrogen oxides in the exhaust. Simultaneously, a videocamera records the vehicle's license plate, which is automatically scanned into the database of emissions measurements.

After data collection, remote sensing measurements are merged with vehicle registration records using the vehicle license plate. The resulting database allows various characteristics of measured vehicles to be identified, including vehicle identification number,[12] make, model year, and vehicle type. License plates are also linked with inspection/maintenance records to identify vehicles with prior emission inspections.

RSD sampling sites are selected to ensure physically consistent but demographically diverse characteristics. Single straight lines of traffic with an average 35 mile-per-hour velocity are sought to facilitate single vehicle measurements and speeds that maximize measurement opportunities. Driver behavior and driving maneuvers are also observed at each site to ensure that remote sensing measurements would not be biased high by acceleration or low by coasting. Finally, notations are made during the site visits regarding any obvious or suspected diurnal patterns that exist which affect the traffic volume. If distinct variations are found to exist in sites ultimately selected, sampling times are scheduled to account for those diurnal patterns. U.S. Census tract data and traffic count reports inform the selection of different income ranges and land uses.

The remote sensing sites relevant to this study reside within the 13-county Atlanta I/M program area, as well as the Georgia cities of Augusta and Macon. The latter locales do not require emissions testing and thus provide an uninspected vehicle fleet to serve as a control group. These cities were chosen after a review of census data and registration records revealed them to have characteristics – median household income, population

[12] Vehicle identification numbers are 17-digit alphanumeric strings that uniquely identify every vehicle manufactured. When decoded, they provide additional characteristics on vehicles. The VIN-decoded data of particular relevance to this research are vehicle type (car, truck, multi-purpose vehicle, van) and model year.

density, and fleet age -- most similar to Atlanta than three other Georgia cities considered[13].

B. TECH5 Subcomponent of the MOBILE5b Emissions Model

Model-predicted emissions differences in inspected and uninspected vehicles were generated using the TECH5 subroutine of MOBILE5b, EPA's computer model for estimating emission factors for mobile sources. Most states use MOBILE5b to estimate emission reductions due to I/M programs. TECH5 generates general emissions information which is then tailored by MOBILE5b to the characteristics of the program being evaluated (e.g., fleet distribution and annual mileage data). We used the TECH5 subroutine to alter a major assumption of the MOBILE5b model: that inspected vehicles have been tested regularly since their introduction into the fleet as new vehicles. Two features of the Atlanta enhanced I/M program make this assumption problematic. First, enhanced emissions testing had been in place for only one full cycle (two years) in 1998, the evaluation year. Second, vehicles registered in the nine Atlanta counties not covered under the previous basic I/M program are brand new to emissions testing. Given these characteristics, the use of MOBILE5b emission factors would significantly overestimate expected program effectiveness. To make predicted emission factors reflect current program characteristics, we extracted from TECH5 predicted emission factors from vehicles that had undergone a single enhanced emissions test in a biennial two-speed idle testing program. (See Appendix A for an overview of the TECH5 component of MOBILE5b.)

C. Evaluation Algorithm

We estimated Atlanta enhanced I/M program effectiveness by comparing EPA model-predicted emission differences with observed emission differences in inspected and uninspected vehicles. The comparison yields a percentage that represents the proportion

[13] Savannah, Athens, and Rome were also considered as potential control areas. Athens and Rome feature lower median household incomes and population densities than do Macon and Augusta. Savannah was ruled out based on its travel distance from Atlanta – 226 miles and 4 hours – which rendered the cost of remote sensing research in this locale prohibitive.

of expected emission reductions actually achieved by the program. The formula for estimating I/M effectiveness is as follows:

$$\text{Effectiveness}=\frac{\sum_{ij}[(O_{n_{ij}}-O_{m_{ij}})/O_{n_{ij}}](P_{n_{ij}})(C_{ij})(VMT_{ij})}{\sum_{ij}(P_{n_{ij}}-P_{m_{ij}})(C_{ij})(VMT_{ij})}$$

where:

- O_m and O_n are the average onroad CO emissions observed for a particular model year and vehicle type for I/M program and non-program vehicles, respectively;
- P_m and P_n are the model-estimated emission factors for I/M program and non-program vehicles for a given model year a vehicle type;
- C_{ij} is the fraction of the Atlanta fleet of that model year and vehicle type observed by CAFE; and
- VMT_{ij} is the average annual vehicle-miles-traveled by model year and vehicle type in the I/M program area.

The formula normalizes predicted and observed emissions differences in I/M program and non-I/M program vehicles by model year to the onroad fleet fraction and average annual mileage of that model year. This exercise enables the different units of measurement between onroad and predicted emissions – exhaust CO percentage versus grams per mile of carbon monoxide -- to be put in ratio form.

III. ANALYSIS

This section reports the results of evaluating the Atlanta enhanced I/M program during its first two years of operation, during which time two-speed idle testing was the dominant inspection procedure for subject vehicles. The evaluation uses remote sensing emissions data collected in 1998 and emission factors predicted for the 1998 fleet by the TECH5 component of EPA's MOBILE5b model. The 1998 calendar year represents the end of the first full cycle of enhanced two-speed idle testing, by which time all odd and even model year vehicles should have been inspected.

The data are restricted in several ways. First, only 1981 to 1996 model year vehicles are included in the analysis. While the Atlanta enhanced I/M program inspected back to the 1975 model year during 1998, TECH5 fails to provide emission factors prior to 1981. Furthermore, few pre-1981 vehicles were observed onroad in 1998, making statistical conclusions questionable for this segment of the vehicle population. The 1997 and 1998 model years are not included since these vehicles were exempt from testing in 1998.

The second data restriction is the use of only vehicles registered in the nine counties of the I/M program area not covered by the previous basic emissions testing program. As discussed previously, the TECH5 emission factors are based on a fleet that has undergone a single-cycle of enhanced emissions testing. Vehicles registered in the previous four-county basic I/M area do not qualify as newly tested because they were subject to emissions testing fourteen years prior to enhanced I/M program implementation. Furthermore, there is no mechanism for extracting from TECH5 the incremental effectiveness of enhanced testing on a fleet previously subject to basic I/M testing. Consequently, nine-county vehicles offer the emissions data most comparable to the TECH5 factors.

A. Data Overview

The remote sensing data used by this evaluation were collected at thirty-nine (39) Atlanta I/M program area sites and eight non-program area sites in Augusta and Macon.[14] Measurements in the I/M program were conducted from January to December 1998, while non-program area measurements were collected over nine days in March, October and December. Temperature at the non-program area sites averaged 58 degrees Fahrenheit, in comparison with sixty-four degrees Fahrenheit at the nine-county I/M program sites.

CAFE collected 15,790 measurements from 14,741 nine-county vehicles with a 1997 or 1998 inspection. Fifty-eight percent of these vehicles (n=8,508) received 1997 inspections, where as forty-two percent (n=6,233) received 1998 inspections. In the non-program areas, 11,698 measurements were collected from 10,363 vehicles registered in the counties comprising Augusta and Macon. In each case, multiple carbon monoxide measurements from unique vehicles were averaged to obtain a single CO value.

[14] I/M program area measurements span thirteen counties that comprise the ozone nonattainment area: Cherokee, Clayton, Cobb, Coweta, DeKalb, Douglas, Fayette, Fulton, Gwinnett, Henry, Forsyth, Paulding, and Rockdale. Non-I/M program measurements include Bibb, Richmond and Columbia counties.

B. Examining Onroad Emissions Over Time

Because biennial I/M programs test only half of the eligible vehicles in each year, it is possible to compare the onroad emissions of inspected and uninspected model years over time to determine the impact of this schedule. Specifically, as inspected vehicles accumulate over the twelve month test cycle, the onroad emissions difference between the inspected and uninspected model years should increase. This expectation is based on the increased probability over time that remote sensing will measure a vehicle that has been inspected, as well as the emissions impact of having a higher proportion of the onroad fleet subject to inspection and repair.

Figure 1, which plots the ratio of the average emissions of uninspected to inspected model years of Atlanta vehicles, indicates that the expectation is largely met. The ratio of odd to even model year emissions hovers at 1 during the third and fourth quarters of 1996, during which time only a small number of vehicles newly registering in the Atlanta 13-county ozone nonattainment area were required to be inspected.[15] The even/uninspected-odd/inspected ratio increases over the first three quarters of 1997, reaching 111 percent during the third quarter and declining slightly to 110 percent in the fourth quarter. The ratio dips below 1 during the first quarter of 1998, when even model years are just beginning to be inspected and odd model years receive a testing reprieve. By third quarter and fourth quarters of 1998, the ratios return to 110 percent.

C. Modeling Onroad Emissions

Before generating effectiveness estimates for the Atlanta enhanced I/M program, we modeled onroad carbon monoxide tailpipe emissions as a function of model year, vehicle type (light-duty car versus truck), temperature at the measurement site, and I/M area registration status. A semi-logarithmic regression model, which takes the natural logarithm of the dependent variable CO, was used to counter the nonnormal and heteroskedastic residuals generated by a nontransformed linear regression model. Given the presence of negative and zero CO values, we added 0.58 to all CO readings to transform the lowest negative reading (-0.57) a positive value. This tactic enabled us to

[15] Even though all new vehicle registrants regardless of model year were inspected from October to December 1996, we use the even-odd model year ratio to maintain continuity of the analysis into the 1997 inspection year.

retain data that would have been lost from the mathematical impossibility of taking the natural logarithm of a negative or zero value.

Vehicle age and type are contained in the model to account for the influence of age and the differential emission standards to which cars and trucks have been built. Temperature is included as a way to control for possible seasonal effects between the Atlanta and Augusta/Macon sampling areas that could confound our results. Finally, I/M area registration status is a dummy variable coded "0" for vehicles registered in the nine-county Atlanta I/M area or "1" for vehicles registered in the non-program Augusta-Macon area.

The semi-logarithmic model explains nearly 14 percent of the variance in transformed CO readings (Table IIA). Vehicle age has the most statistically significant effect ($p=0.002$), with an estimated 6 percent increase in CO emissions for every one-year increase in vehicle age (Table IIB). Inspection status has the next strongest influence, with vehicles registered in the nine Atlanta I/M counties having 16 percent lower emissions than those registered in Augusta and Macon. Vehicle type is also a significant CO influence, with light-duty trucks having CO emissions 4% higher than passenger cars. Finally, each additional degree in temperature yields a small but statistically significant increase in emissions.

D. Results

Before reporting effectiveness estimates for the TSI component of the Atlanta enhanced I/M program, we examined a few trends in the data. The inspected Atlanta and uninspected Augusta-Macon vehicle fleets have comparable model year distributions, although the inspected Atlanta fleet is slightly newer than the uninspected Augusta-Macon fleet (Figure 2). Another comparison of model year distributions, this time between vehicles present in the 1998 I/M records and those measured onroad by 1998 CAFE, also yield similar distributions (Figure 3). However, the onroad fleet is generally newer than the inspection roster, an expected result given that newer vehicles tend to be driven more frequently, and more miles per year, than older vehicles and thus are more likely to be measured onroad.

To further investigate the comparability of the inspected and uninspected fleets, we compared 1997 onroad emissions data from Augusta[16] and uninspected nine-county Atlanta vehicles. Because the nine counties were not covered under the previous testing program, the emissions of uninspected vehicles registered in the nine-county area should resemble those of the untested Augusta vehicle fleet. Figures 4-6 reveal that the two vehicle fleets have statistically similar emissions. The exceptions to this pattern are the 1981, 1982, and 1984 model years, in which the Augusta fleet has higher emissions than the nine-county fleet. A second issue of comparability is between the Augusta and Macon fleets, which serve as a combined reference fleet for vehicles in the Atlanta nine-county area. A comparison of 1998 onroad data between the two areas (Figure 7) indicates statistically similar emission profiles.

Figure 8 compares the ratio of uninspected to inspected car emissions measured onroad versus those predicted by TECH5. The TECH5 ratios form an oscillating pattern that corresponds with the 1998 biennial testing schedule: the ratios are higher for even model years (which were last tested in 1998) and lower for odd model years (which were last tested in 1997). The onroad emission ratios also oscillate by even and odd model years, although a distinguishing pattern emerges. The onroad emission ratios fall short of the predicted emission ratios mostly in the off-cycle odd model years, whereas onroad emission ratios are similar to or exceed predicted emission ratios for even model years.[17] This pattern suggests that post-inspection emissions deteriorate more rapidly than anticipated by the TECH5 model. Similar patterns are seen for trucks (Figure 9), except there are fewer instances of the observed emissions ratio being higher or near to the predicted ratio for even model years.

The effectiveness estimates for cars and trucks in the Atlanta enhanced I/M program are laid out in Tables III and IV. But first, let us review the methodology for generating the estimates. We calculate the emissions difference in inspected and uninspected cars and trucks by model year and then weight those differences to that

[16] The Continuous Atlanta Fleet Evaluation only conducted remote sensing in Augusta during 1997, thus we have no Macon measurements to include in this analysis.

[17] The onroad emissions ratio for 1981 cars run contrary to expectations, with higher inspected than noninspected vehicle emissions. This is mostly likely due to small sample size for this model year (n=110).

model year's annual average mileage and fleet fraction. The exercise is undertaken separately for predicted emissions factors and onroad emissions data. The weighted emissions differences in each category are then summed over all model years. The weighted value based on onroad emissions data becomes the numerator, whereas the weight value based on predicted emission factors becomes the denominator. Dividing the numerator by the denominator yields the percentage of expected emissions differences actually achieved in inspected and uninspected vehicles.

The results of this exercise indicate that the Atlanta enhanced I/M program captures 83 percent of the emission reductions predicted for cars and 77 percent of the emission reductions predicted for trucks. The 1994 evaluation of Atlanta's basic I/M program generated a similar pattern, with higher effectiveness for cars and lower effectiveness for trucks. Specifically, the basic I/M program was estimated to be nearly twice as effective for cars (196 percent) and only 63 percent as effective for trucks as predicted by MOBILE5a. While these evaluations use the same methodology to generate results, they are evaluating different I/M program designs and using a different mobile emissions model to estimate I/M effectiveness (Table VI).

IV. DISCUSSION

A fair reporting of these results requires examining sources of underestimation and overestimation bias (Table VI). The greatest risk of overestimating program effectiveness results from our inability to control for mileage differences between the I/M and non-I/M program areas. If Augusta and Macon vehicles have higher annual mileage than Atlanta vehicles, then the lower emissions in the Atlanta I/M area may reflect a lower rate of emission control deterioration than that of these nonprogram vehicles. However, similarities in the 1997 emission profiles of onroad Augusta and untested Atlanta nine-county vehicles makes this less likely. And while Macon data were not available for the 1997 emissions comparison with untested nine-county vehicles, Augusta and Macon vehicles have statistically similar 1998 emissions, thus making a higher-mileage Macon fleet unlikely.

Another potential source of overestimation comes from temperature differences in the Atlanta and Augusta/Macon remote sensing sites. While these areas share a generally temperate climate, remote sensing took place in the cooler months of March, October and December for the Augusta/Macon fleet and year-round in 1998 for the Atlanta fleet. As a result, the average Augusta/Macon site temperature is a full six degrees Fahrenheit cooler than the Atlanta site temperatures. Given that cooler temperatures can increase CO readings by reducing engine operating temperature, there exists the possibility that temperature is driving some of the emissions differences between the inspected and uninspected fleets. The results of the semi-logarithmic regression model dispute this assertion, however. Even when temperature differences are considered, Augusta and Macon vehicles have 16 percent higher emissions than Atlanta vehicles. Furthermore, temperature exerts a negligible, albeit statistically significant, *positive* influence on CO emissions in the presence of vehicle type and age, and inspection status.

The primary risk to underestimating Atlanta enhanced I/M program effectiveness derives from the use of vehicles inspected in 1997 and in 1998. Obviously, most vehicles inspected in 1997 have a longer time lag between their last inspection and the first remote sensing reading than 1998-inspected vehicles. To illustrate, 133 days (just over four months) is the average time lag between 1998-inspected vehicles and their first remote sensing measurement. By comparison 466 days (about sixteen months) typically distance a 1997-inspected vehicle and its first 1998 remote sensing measurement.

To distinguish effectiveness in current versus prior year testing, Tables VIIa-b and VIIIa-b evaluate even and odd model-year vehicles separately. Even-year cars appear to be 113 percent as effective as predicted by TECH5, while even-year trucks are 94 percent as effective as predicted. By contrast, odd-year cars are 46 percent as effective as predicted and odd-year trucks are 56 percent as effective as predicted. Considering the 70-30 percent split between cars and trucks in the inspected fleet, as well as the average time lag between emissions inspection and RSD measurement for even and odd model year vehicles, it appears that the Atlanta enhanced I/M program has a four-month effectiveness of 107 percent (combining the car-truck effectivenesses for even model year vehicles) and a sixteen-month effectiveness of 49 percent (combining car-truck effectiveness for odd model-year vehicles). Effectiveness differences between inspection cycles may be due to deterioration, repair experience (as repair technicians become adept at diagnosing and treating emission failures), and testing competency (as inspectors improve at identifying emission failures for repair).

Another source of potential underestimation comes from the timing of the evaluation. The 1998 inspection year represents the second year of the first full biennial cycle of TSI testing in the Atlanta enhanced I/M program. For those stations new to emissions testing and repair, the first two years of enhanced TSI testing may have carried a learning curve not accounted for in the repair efficiency rates of the MOBILE5b model. Furthermore, the introduction of ASM testing in October 1998 and the requirement to inspect vehicles for nitrogen oxide emissions (NOx) will trigger a second learning curve for repair shops. This timing could delay program maturity until 2001, when the repair community will have had two full years of ASM testing and four full years of TSI testing.

V. CONCLUSIONS

Determining the exact effectiveness of any I/M program is a metaphysical impossibility. Such a determination would require comparing vehicle fleets completely identical in all characteristics relevant to automobile emissions. In the absence of identical fleets, we evaluated the Atlanta enhanced I/M program by comparing the emissions of new program-area vehicles with vehicles registered in the demographically similar non-I/M areas of Augusta and Macon. The results indicate that Atlanta and Augusta/Macon cars have emissions differences that are 83 percent of that predicted by EPA's TECH5 model, whereas Atlanta and Augusta/Macon trucks have emissions differences 77 percent of model predictions. Considering the relative concentration of cars and trucks in the Atlanta vehicle fleet (70 percent vs. 30 percent[18]), this leads to an overall effectiveness estimate of 81 percent for the Atlanta enhanced I/M program's first two years of operation.

[18] These figures are estimates based on 1997 and 1998 Atlanta enhanced I/M records.