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DISSERTATION

VEHICLE EMISSIONS TESTING: FAILURE PROBABILITIES, REPAIR  
INCENTIVES, AND POLICY ASSESSMENT

Submitted by

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In partial fulfillment of the requirements

For the Degree of Doctor of Philosophy

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Fort Collins, Colorado

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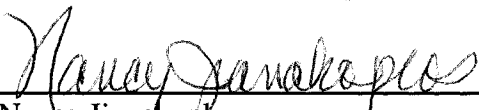
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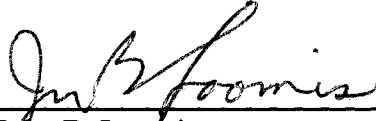
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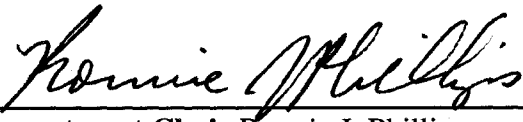
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## ABSTRACT OF DISSERTATION

### VEHICLE EMISSIONS TESTING: FAILURE PROBABILITIES, REPAIR INCENTIVES, AND POLICY ASSESSMENT

The Environmental Protection Agency (EPA) entrusted with mobile emissions attainment has enacted rules in the form of regulations on automobile manufacturers complemented with periodic emissions inspection. The aim of I/M programs is to ensure that vehicles operating in I/M regions have functioning emissions control equipment. This is accomplished in a periodic inspection test, which involves tailpipe emissions measurements and a visual check for missing, broken, or tampered-with emissions control equipment.

This dissertation has three related components with focus on vehicles emissions testing. The first of which, deals with estimated vehicles failure probabilities given vehicle characteristics, firm types, and firm's characteristics, using Fort Collins, Colorado, emissions inspection results in 2000 and 2002. I provide evidence of some discretion exercised among different firm types and firm organizational structure.

The second part compares the effectiveness of emissions related repairs among competitive based emissions testing and command and control emissions testing facilities. Using emissions inspection test results for Fort Collins, Colorado, and Kenosha, Wisconsin, to represent the decentralized and centralized testing

respectively, I show that emissions related repairs are more effective under centralized than decentralized configurations. This is attributed to the nature of both programs.

The third component deals with an evaluation of inspection and maintenance programs in terms of efficiency and equity. I found that inspection and maintenance regulations have been successful in reducing emissions coming from newer vehicles but have been inefficient in terms of high administration costs and enticing motorists to repair and maintain their vehicles. I also found that the program place a particular burden on low income motorists. Also, I explored other proposals to correct for the deficiencies of inspection and maintenance programs, I found new vehicles sales tax and annual registration fee proposal is a suitable complementary tool to current program setting in order to lessen the problem of mobile emissions and achieve the goals of efficiency and equity.

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# Chapter One

## Introduction

## 1. Introduction

Recognizing that mobile emissions are a source for smog problems in major metropolitan regions in the late 1950s, policies were instituted in the form of regulations on auto makers. Over time, the combination of regulations on auto manufacturers, on-board diagnostic equipment and tighter emissions standards have generally produced vehicles that are more fuel efficient and emit 70 percent less nitrogen oxide and 80 to 90 percent fewer hydrocarbons over their lifetime than their uncontrolled counterparts of the 1960s (Lawson 1995). But these combined efforts did not reduce aggregate mobile emissions for a number of reasons. First, new vehicles comprise a small fraction of a region's entire fleet. Second, the increases in the number of vehicles and miles traveled have cancelled out the effects of improvements in vehicle technology and fuel efficiency. Third, emissions control systems do not always perform as designed over the full life of the vehicle. Routine aging and deterioration, poor maintenance, and emissions control tampering increase vehicle emissions.

Recognizing that motorists' inclination to neglect vehicle maintenance combined with the intensity of the smog problem, in 1983 the Clean Air Act was amended to include regulations requiring a periodic inspection test in 64 regions in the U.S. that were violating ambient air quality standards. To achieve the goal of reducing aggregate mobile emissions, regulations in non-attainment areas were drafted that primarily rely on periodic lane testing. Lane testing involves two components, the first is measuring emissions coming from vehicle's tail pipe, and

the second is a visual check to missing or altered emissions control equipments. These are termed inspection and maintenance (I/M) programs. The intention of these programs is to certify vehicles that are in compliance and find vehicles that are not, and require owners to repair them. Further, states were encouraged and empowered by the establishment of the Environmental Protection Agency (EPA) to take an active role in reducing emissions levels by establishing State Implemented Plans (SIPs). The intention of the SIP program has been to provide states with federal funds for highway construction if the state achieved emissions reduction goals. The U.S. EPA has oversight and development responsibility for its I/M program, which is implemented by state agencies.

The Clean Air Act amendment of 1990 relaxed some aspects of the inspection and maintenance program in 1990. Among these changes is the establishment of two types of programs: the basic inspection and the enhanced emissions inspection I/M programs. The basic program is carried out in moderately polluted areas, and the enhanced program is implemented in high non-attainment regions. Lane testing, under both program types, typically involves exhaust tests measuring carbon monoxide (CO) and hydrocarbons (HC) and sometimes nitrogen oxide (NOx) emissions. I/M tests also include a visual inspection of the components controlling evaporative and exhaust emissions and may include a functional gas-cap test and a pressure test of the evaporative emissions-control systems.

To motivate vehicle owners to comply with this policy, vehicle registration hinges on emissions testing results. For vehicles that are clean, vehicle registration is generally associated with little inconvenience. For those vehicles that are not in

compliance, motorists are required to fix the faulty part of their vehicle's emissions component controls and have the vehicle re-inspected before it can be registered. State sponsored and state independent studies have found that the actual enhancements in air quality are below the predicted emissions reductions. These studies conclude that fuel efficiency and vehicle emissions technological improvements alone are not sufficient to improve air quality.

While I/M programs are generally regarded as a valuable tool in curbing mobile emissions, I/M programs have been criticized on three grounds. First, I/M programs have failed to provide motorists with incentives to minimize their vehicle's emissions. Drivers only need to pass a periodically scheduled emissions inspection test without regard to improving their vehicles' in-use emissions conditions. These motivation failures were discovered among vehicles operating in both the basic and the enhanced I/M programs. Motorists' incentives to improve their vehicles' in-use emissions come from the fact that I/M programs put little emphasis on vehicle maintenance. Therefore, it seems reasonable to suggest that vehicle owners, when faced with getting their vehicles registered, usually try to do so at minimal costs. It is likely that this problem rises in the basic programs where emission inspection and repairs are offered by private firms. Thus, these private firms, if they are to remain competitive, need to provide cheap certification. This is the focus of chapter 2 of this study.

Chapter 2 describes this investigation of the relationship of failure probabilities to vehicle characteristics, different firm types and their attributes. The results of this study show that there are discrepancies in testing practices among firms with

different attributes. This is true for firms that are franchised and firms with commissioned labor. Both attributes tend to decrease vehicle failure probabilities in the emissions component test. Also, firms with a single owner appear to have reduced failure probabilities in the visual check. Mechanics at these firms carry out basic maintenance for these vehicles such as spark plug change, oil and filter change, battery test, and wiring replacement before the inspection test. These actions reduce emissions inspection test failures and generate passing results, but that does not guarantee clean cars for the whole year. Therefore, if the goal of lane testing in the study area, Fort Collins, Colorado, is emissions reductions from polluting vehicles, then this undermines emissions reduction goal. Even though individual mechanics do not consider that their actions have a detrimental impact on aggregate mobile emissions and the environment, regulators emphasize that these actions make I/M programs less effective.

A second criticism of the inspection and maintenance program is that many I/M test procedures do not account for real world driving conditions such as acceleration and deceleration cycles, and thus vehicles passing the emissions test in the basic program may still be high emitters under real world driving conditions. This is emphasized by many scholars as one of the disadvantages of the basic program since it only tests vehicles' emissions in the idle mode, as opposed to enhanced lane testing, which simulates driving conditions. Also, it is argued by researchers that the enhanced programs have generally produced better maintained vehicles and more effective emissions components repairs when compared to the basic program. These issues are the emphasis of the third chapter of this study.

The third chapter examines two related issues: the first is comparing motorists' motivations toward maintenance and emissions-related repairs in the basic and the enhanced programs. This comparison was done relying on Bin's (2003) analysis in which he tested the associated failure probabilities with different vehicle characteristics, using Portland, Oregon, inspection test results.

Using emissions inspection results from Fort Collins, Colorado, to represent the basic program and results from Kenosha, Wisconsin, to represent the enhanced program for the two inspection cycles of 2000 and 2002, the third chapter compares failure probabilities between the two program configurations. The results of the third chapter show that vehicles inspected under the enhanced program are better maintained and repairs conducted on failed vehicles generally have been effective. The reasons for this finding are related to how the enhanced I/M programs are set up. This includes the fact that inspection and repair facilities are separate entities; inspectors at emissions inspection stations are state employees, and the inspection is done at a state facility; and the vehicle emissions repair work is offered by state-certified technicians in the private sector. Usually, repair shops are not in close proximity to the testing site in Kenosha, which forces vehicle owners to make multiple trips between the inspection site and repair facilities, especially if a vehicle fails on its second attempt.<sup>1</sup> Because of the separation between testing and repair in the enhanced I/M program, combined with the annoyance of multiple trips, vehicle owners are likely to be motivated to acquire a permanent fix for their vehicle's emissions related problems.

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<sup>1</sup> In the literature, this is referred to as the "ping-pong" effect.

The second related issue examined in the third chapter surrounds the stringency of the enhanced program compared to the basic I/M program. Because the enhanced I/M programs are implemented in high non-attainment regions, the year model standards are tighter compared to the cut points of the basic program. Scholars have asserted that the probability of vehicles failing their inspection test is higher when tested under tighter cut point standards (Kukawka 1999). However, the results of this study could not generalize these results to include two inspection cycles. Nevertheless, it is found that under tighter cut points, vehicles experience higher failure rates compared to the standards of the basic lane testing within one testing cycle. Therefore, if regulators' aim is air quality enhancement, then stringent regulation will achieve better results.

The third criticism of the I/M programs is that these programs have inefficiently used society's resources. This is the emphasis of the fourth chapter of this study. This criticism is based on two aspects of the I/M program. The first is the divergence between expected and actual emissions reductions. This aspect has been highly publicized by some researchers to the effect that I/M programs are generally regarded as inefficient tools to curb mobile emissions. Expected aggregate mobile emissions are usually calculated using the MOBILE (Mobile Source Emissions Factor) model. The MOBILE model assumes that all similar age vehicles have similar emissions levels and that all failed vehicles receive effective repairs. Numerous studies have demonstrated that these two assumptions are flawed. Researchers have shown that the generalization that all similar age vehicles have similar emissions levels is fallible. They have demonstrated that the distribution of

vehicles' emissions is highly skewed with a minority of vehicles producing the majority of emissions. In the same manner, motorists are not alike in terms of their mobility, behavior, income, or, most importantly, their incentives toward regular maintenance applications. Therefore, the basis for quantifying expected emissions reduction is invalid.

NRC (2001) has emphasized that the assumption of lasting emissions repairs contributes to the unrealized aggregate emissions reductions. NRC (2001) asserts that repairing faulty emissions components only solves short-run emissions problems for two reasons. The first is the high repair cost, and second is the absence of correlation between repair expenditures and change in emissions readings between pre-and post-repairs. High-repair expenditures do not guarantee low emissions levels compared to pre-repair emissions levels. Therefore, Green (1997), Stephens et al (1997), and Klein and Koskenoja (2002) assert that I/M program procedures to quantify air quality improvements lack a reality check between the MOBILE model's predicted emissions reductions and the actual reductions. Moreover, the lack of emphasis on vehicle maintenance and reliance on motorists' goodwill for periodic maintenance contribute to the ineffectiveness of lane testing policies.

The second aspect discussed in the fourth chapter is the issue surrounding the presence of high administration costs that make the I/M program inefficient. Quantifying administration costs has been under dispute by regulators and various research groups (Portney (1990), Khan (1994), Spenser (1994), and Small and Kazimi (1995). The lack of precise standard measurements of administration costs

has caused scholars to come up with diverse ways to quantify the cost of I/M programs. This aspect hindered this study's ability to carry out an acceptable comparison between I/M program costs and benefits, a procedure that is important in analyzing I/M program efficiency. Nevertheless, this study was able to establish a consensus among different researchers' findings. This consensus is restricted to some policies I/M enforcement agencies practice to control for emissions coming from passenger vehicles and light trucks. These include the policy of bringing the marginally emitting vehicles into compliance because they have private and social costs that outweigh the social benefits.

Also, given the established pattern of vehicle emissions as being highly skewed, subjecting all vehicles to the test is regarded by scholars as an inefficient policy, especially when motorists' time cost is included. Scholars agree that the persistent high failure rate problems among older vehicles are not properly addressed. These problem vehicles have a high cost for society for two reasons. The first is the pollution level they exert on the environment, and the second is the unequal burden that would be placed on low income motorists to bring these vehicles into compliance with year model cut points. It is argued that subsidizing repairs for those vehicles is not only efficient but it is also an equitable solution. In addition, the lack of emphasis on vehicle maintenance has high costs given that maintenance without dispute could generate benefits to motorists, society, and the environment that outweigh the cost.

To correct for motorists' incentives and high administration costs, this study explored proposals that focus on either replacing or complementing current I/M programs. This chapter analyzed each proposal based on equity and efficiency objectives. This study shows that a measure complementary to current lane inspection policies would be best suited to correct for program deficiencies and to internalize the negative externality associated with vehicle use.

The recommended policy is the institution of a new vehicle sales tax and annual registration fees that reflect the environmental impact of vehicles and thus increase the marginal cost of driving. This method is not only more efficient than other proposals and enhances current emissions inspection registration base, it is also a progressive approach to addressing mobile emissions reductions. In the absence of a reminder about the actual cost of driving, motorists tend to have little regard for vehicle usage. A new vehicle sales tax and annual registration fees conceivably could be tailored to encourage owning vehicles that are more fuel efficient, switching to alternative modes of transportation, and at the same time establishing a sustainable mobility trend.

## Chapter Two

### Failure Probabilities

## 2.1 Introduction

Among the goals of the Clean Air Act and its amendments is to control aggregate mobile emissions. The Environmental Protection Agency (EPA) which is entrusted with mobile emissions attainment has enacted rules in the form of regulations on automobile manufacturers complemented with periodic emissions inspection. The periodic emissions inspection consists of two parts, the tailpipe check and visual inspection of under-hood components. The emissions component is set up so that vehicles need to have emissions levels measured by emissions coming out of the vehicle's tailpipe equal to or lower than model year standards. The visual component includes examining the under-hood components to make sure that there are no missing/broken or misadjusted engine parts and that emissions control equipment has not been tampered with. The goal of the development and installation of On-Board Diagnostic (OBD) equipment in modern vehicles is to minimize any discrepancy that might occur in the visual component test. The OBD signals the vehicle owner/inspector if there are any malfunctioning emissions or engine components by flashing a light connected to the engine part.

Regulations have been successful in lessening the rate of emissions increase (Menz 2002). This is partially attributed to the new improvements in automobile technologies which result in producing vehicles with lower emissions during their normal use compared to earlier models (Menz 2002). Pressing auto manufacturers to comply with new emissions standards has only partly addressed the mobile emissions problem because new vehicles comprise a small fraction of an entire vehicle fleet. Miller et al. (1985), Lawson (1995), Green (1997), and Wenzel and

Sawyer (1998) believe that the I/M program has generated only modest results compared to the predicted reductions.

The authors cited in this chapter have stressed that Inspection and Maintenance (I/M) regulations have had only a limited impact on enhancing ambient air quality. They conclude that the majority of mobile emissions are generated from a few high-polluting vehicles (Lawson 1995). Lawson believed that lane testing, with its current settings, does not align motorists' and inspectors' incentives with I/M regulations' goals. Emissions inspection tests should fail vehicles that are above year-model emissions standards. For I/M policies to be effective, failed vehicles need to be re-tested, preferably after needed repairs are applied. It is believed that the current lane testing leaves room for fraudulent behavior by testing inspectors and mechanics or by motorists. Actions to reduce vehicle failure probability undermine I/M program goals but establish a favorable reputation among consumers for a testing firm (Hubbard 1995). These problems are especially manifested in I/M regions where the inspection test is administered by private firms (NRC 2001).

Motorists acquire emissions inspection tests biannually as part of their vehicle registrations in decentralized I/M testing. Generally, consumers prefer to pass the test in the least costly way. Some motorists, however, are indifferent to emissions outcomes, and their choice of testing sites is usually not directly associated with cost minimization. These consumers might have new vehicles and probably acquire emissions test services at their new car dealerships. The majority of consumers,

though, are sensitive to emissions results, and their choice of testing sites is dictated by the operating conditions of their vehicles and their likelihood of failure.

This research contributes to the body of literature addressing vehicle characteristics that make a vehicle more likely to fail the inspection test using Fort Collins, Colorado, inspection test results. These include vehicle type, transmission style, age, odometer reading, and engine size. The results provide evidence regarding the probability of failure for various sets of vehicle characteristics. This study also tests for any possible discrepancies in implementing the inspection test administered by various testing station types in either or both parts of the test.

Each inspection firm type is tied to a certain organizational structure. Firms are grouped into five categories: quick-lube shops, independent garages, service stations, new car dealers, and used car dealers. Inspectors at different firm types might behave differently and might signal certain differences in how they conduct their inspections. Estimating failure probabilities at a given firm type provides evidence about whether discretionary actions occur among different firm types in one or both parts of the test. This analysis is extended to establish a link between the predicted failure probability and certain firm attributes - franchise, full-service stations, and use of commissioned labor. In addition, this study examines whether there are any changes in failure probabilities associated with mode of ownership, changes in ownership, and if there have been any changes in testing practices over time among different firm types.

## 2.2 Literature Review

Some earlier work by scholars addressed the initial goals of the I/M programs. These goals of the I/M programs were: controlling emissions, increasing vehicle fuel efficiency, and introducing safety features to vehicles.<sup>2</sup> Therefore, studies have been carried out that emphasize these issues. Although the work of Lave (1981) centers more precisely on the social cost of introducing safety features into vehicles, his analysis is nevertheless relevant to this study since he makes an argument that ties vehicle's engine size (weight) with emissions levels. He modeled the trade-offs among the program's goals: safety, emissions levels, and fuel economy. He claimed that I/M regulations, in an attempt to increase safety feature in automobiles, had actually increased vehicles' weight and emissions levels. He added that the additional weight increased fuel consumption and increased total vehicle emissions. He argued that in order to achieve greater fuel economy, either weight must be reduced, thus reducing safety, or vehicles' engines must be readjusted, thus increasing vehicles' emissions. As a result, efforts to increase vehicle safety features had the effect of increasing vehicle weight and total emissions. This demonstrates the ongoing conflict between vehicle weight and emissions reduction goals in vehicle engineering at a time when the auto industry did not achieve the improvement of both emissions levels and safety features.

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<sup>2</sup> Safety features include seatbelts, dual breaking systems, energy-absorbing steering column, improved door latches, high-penetration-resistance windshield glass, side door beams, head restraint, and improved bumpers (Lave 1981).

Since the inception of the I/M program, data have been amassed that could be used for motor vehicle profiling. Vehicle profiling involves selecting vehicles that are likely to have malfunctioning emissions control equipment based on vehicle characteristics. This method is recommended by the NRC (2001) as an efficient approach instead of the blanket approach of testing all vehicles. Also, this is the emphasis of White (1982), Kahn (1996), and Bin (2003). While White addressed the tradeoff among different vehicle features and emissions levels, Kahn and Bin tied emissions levels to certain vehicle classes and attributes.

Using Denver, Colorado, emissions data for lane testing, White (1982) modeled actual emissions measurements of hydrocarbons (HC), carbon monoxide, (CO), and nitrogen oxides (NO<sub>x</sub>) as a function of engine size, mileage, number of carburetor barrels, the presence of full injection, transmission type, and vehicle model. He did not include vehicle age since he claimed that the coefficient on vehicle age was not statistically significant. He asserted that the odometer measure is a more precise description of vehicle condition than age in an ordinary-least-squares regression. He found that the emissions levels of HC and CO increase significantly with mileage but that NO<sub>x</sub> emissions do not increase significantly. He observed that bigger engine size has a modest influence on HC emissions but has a larger impact on CO and NO<sub>x</sub>. He also established that the number of carburetor barrels increases HC and CO emissions but decreases NO<sub>x</sub> emissions. He also found that manual transmission increases HC emissions and has little effect on CO emissions, but decreases NO<sub>x</sub> emissions. Given the earlier vehicles' technology – carbureted

engines – vehicle emissions seem to pose a challenge for both I/M officials and auto makers.

The new fuel injection design systems prevailed over some aspects of the carbureted engines and solved many problematic engine design features found in earlier vehicle models. New vehicle technology improvements have generated cars that require little maintenance compared to earlier models. Nevertheless, these new vehicles require periodic maintenance. Motorists, lack of inclination, by and large, to periodically maintain their vehicles presents I/M officials with a set of problems; among them is the frequent breakdown of emissions control equipment. Ideally, inspection test results can signal initial engine deterioration, and motorists should implement proper repairs. But the compiled data on pre- and post-inspection tests suggest that failed vehicles receive meaningless repairs. Therefore, the predicted benefits of the I/M program are undermined. Researchers' efforts took on a different tone than earlier work; their focus was to determine vehicles' characteristics that are likely to increase the probability of failing their inspection test.

In an attempt to evaluate the benefits of I/M regulations, Kahn (1996) modeled HC emissions as a function of vehicle characteristics. He used two cross-sectional data bases on individual vehicles (from California and Illinois) and illustrated that the profiling method is an efficient way to identify high-polluting vehicles. The dependent variable in his model is the log of HC emissions, and the independent variables include vehicle mileage, number of cylinders, engine cubic centimeter displacement (engine size), and vehicle model year and make. His results suggest

that 4-cylinder engine vehicles have a higher probability of failure compared to 6- and 8-cylinder engine vehicles. The failure probabilities of the 8-cylinder engines declined sharply. He also tested HC failure probabilities for domestic versus imported vehicles and found that imported vehicles are less likely to fail their inspection test. He reasoned that foreign vehicle producers face differential emissions regulatory intensity, which is attributed to less effective lobbying by foreign manufacturers compared to domestic auto makers. He also compared failure probabilities among domestic vehicle makers and found that Chrysler vehicles are less likely to fail than General Motors and Ford vehicles. He attributed this finding to the fact that Chrysler has the smallest market share of the three and has the least amount of bargaining power in negotiating with the federal government to minimize its regulatory burden.

Bin (2003) advocated that if regulators would aim at a particular vehicle year model, vehicle class, or engine size, I/M programs would become more efficient than current lane testing practices. Utilizing emissions data from Portland, Oregon, he quantified the failure probabilities that are associated with certain vehicle attributes. He estimated logit equations for the likelihood of carbon monoxide and hydrocarbon emissions violations given a set of vehicle characteristics. The dependent variables for the regression analyses are binary variables that indicate HC and CO emissions failures. His explanatory variables are vehicle age, engine size, odometer reading, number of cylinders, vehicle class, fuel injection mechanism, presence of air pump, and whether the vehicle is imported or not. He found that vehicle age, engine size, and mileage all play a significant role in

determining lane testing results, as do vehicle make and class. He recommended that if vehicles are at least ten years old, with engine size smaller than 2000 cc and an odometer reading over 100,000 miles, these vehicles would be good candidates for selective emissions testing. He claimed that this method is a more appropriate and efficient method than testing all fleet vehicles.

Enforcement of and compliance with an I/M program ensure that vehicle owners bring vehicles to an inspection site to get tested and then get repairs and retests if they fail. Enforcement also ensures that stations perform proper inspection and repairs, and that certifications of compliance are not fraudulently obtained. Those are some of the most critical elements of the program as well as the most difficult ones. If enforcement mechanisms are not effective, then motorists faced with the cost of repairs will simply not get tested or will fraudulently comply. This defeats the purpose of the I/M program. Testing clean cars does not provide any benefits; only repairing or removing high-emitting vehicles reduces fleet-wide emissions (NRC 2001).

Enforcement is important because there is evidence that motorists, testing personnel, and technicians have found many ways to avoid compliance with I/M programs. Decentralized programs have come under particular scrutiny because it is argued that they present ample opportunities for testing fraud; this is addressed by Ando et al. (1999), Kukawka (1999), and Hubbard (1995 and 2002).

In an attempt to quantify the costs associated with emissions component repairs, Ando et al. (1999) empirically explored whether the observed vehicle characteristics influence the likelihood that a failed vehicle passes the re-inspection

test in Arizona. Their sample did not include the entire fleet, but rather it consisted only of vehicles that failed the inspection test only. Their analysis was done using a probit equation in which the dependent variable is a dummy variable that equals 1 if the vehicle passes the re-test and 0 otherwise. The independent variables are vehicle characteristics that include vehicle type, vehicle age, and vehicle emissions levels of HC, CO, and NOx in their first emissions test. Among other things, their results indicate that the likelihood of failures increases with vehicles classified as trucks and with vehicle age. They found that older vehicles are more likely to fail the re-test and linger in the program area without being fixed. Also, they concluded that if vehicles failed the initial test by a wide margin (HC and CO emissions), then these vehicles were more likely to have final tests that were failures.

Kukawka (1999) carried out a study with a premise that tighter emissions cut points are more likely to produce lasting repairs.<sup>3</sup> Based on statistical tabulations for passenger-type vehicles, he concluded, among other things, that the most frequent emissions problems spring from a breakdown in several engine components. These include air-fuel pumps, catalytic converters, ignition timing, and oxygen sensors. He claimed that these problems could have been avoided if emissions cut points had been tighter. Such cut points would yield failing vehicles rather than letting them pass at the margin over the years. He added that the above problems might eventually lead to marginal failures in emissions testing, and if these vehicles did not receive the proper remedy, then they would probably become high-polluting vehicles. These breakdowns are mostly likely to occur in older vehicles, vehicles with high odometer reading, vehicles equipped with manual

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<sup>3</sup> Cut points refer to emissions standards given vehicle year model.

transmission, and smaller engine size vehicles. He emphasized that the importance of tighter emissions cut points is that this measure leads to failure by a wide margin. He emphasized that this will discourage quick fix procedures used to bring problem vehicles into compliance. Quick fixes entail one or a combination of the following: cleaning the vehicle's tailpipe, battery check, oil and filter change, and spark plug replacement.

Hubbard (1995) found evidence for such incentives in California's I/M program. Hubbard found that consumers are able to provide incentives to station technicians, who then apply quick fixes. He emphasized that motorists therefore shop around to find stations most likely to respond to incentives. Hubbard compared failure probabilities at testing firms using Fresno emissions data to failure probabilities for vehicles tested by roadside pull-overs by state inspectors. He found that the failure rate of emissions tests administered by state officials were as much as double the failure rates at independent garages, service stations, and smog check specialists. He found that inspectors in the emissions testing program in Fresno forgo potential short-run gains from emissions-related repairs. He concluded that mechanics lower failure probabilities by carrying out minor engine adjustments, preconditioning vehicles, and being more lenient on subjective parts of the inspection test. Hubbard interprets the inspectors' behavior as behavior that enhances or establishes a reputation with the customers.

It was shown by Hubbard (2002) that reputational incentives depend critically on relationships between a consumer's decision and his or her previous experiences. Using a panel data set from Fresno, California, he illustrated that consumers are 30

percent more likely to return to a firm where they previously passed emissions inspection than to one where they previously failed. As a consequence, Hubbard (2002) found that firms have strong reputational incentives to supply passing inspections. Using the revealed preference approach, Hubbard (2002) concluded that a single inspection outcome strongly influences consumers' beliefs about individual firms. He used consumers' choices to infer how different factors (price of emissions inspection, failure rate, type of firm, etc.) influence their choice. By comparing how failure rates matter relative to the emissions inspection price, he was able to infer how much differences in failure rate affect expected repair on average.<sup>4</sup> For example, if a \$10 difference in price has the same effect on consumers' choice as a 10 percentage point difference in failure rate, then he could conclude that a 10 percentage point failure rate difference influences expected repairs by \$10.

Since Hubbard (2002) analyzed the impact of the emissions testing price on demand for emissions testing, it is the intention of this study to extend Hubbard's work on estimated failure probabilities by looking at given vehicle characteristics, firm type, and different firm attributes. This study uses Fort Collins, Colorado, inspection results for 2000 and 2002. The inspection fee in Fort Collins is regulated at \$24.25.

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<sup>4</sup> Based on telephone conversation with Thomas Hubbard (2003).

## 2.3 Analytical Framework

### 2.3.1 Firm

Emissions inspection firms have different organizational structures and offer different goods and services. In Fort Collins, Colorado, the different types of inspection shops are: quick-lube shops, service stations, independent garages, new car dealerships, and used car dealers. Quick-lube shops specialize in oil and filter changes in addition to emissions testing. Service stations carry out similar checks as quick-lube shops, but also conduct light vehicle repairs like tire rotation, spark plugs and muffler changes. In addition, service stations perform some light electrical wiring adjustments. Independent garages generally perform what service stations accomplish, but they also specialize in vehicle mechanical failures. Moreover, some independent garages specialize in hot-rod vehicles. New car dealers specialize mainly in selling new vehicles and some of them, as part of their vehicle sales promotion, offer free oil and filter changes and free emissions testing for the duration of the buyer's ownership of the vehicle. Most new car dealerships have garages where they conduct the services that independent garages offer. Used car dealerships sell used vehicles; part of the purchase of a used vehicle includes a test of its emissions control systems. These used dealerships usually do not offer any mechanical or repair services associated with the sale of the vehicle.

According to an interview survey carried out in 2003, different firm types have diverse organizational structures that include different hierarchies and compensation schemes within firm types.<sup>5</sup> Hierarchical setups differ between franchised facilities and other firms. In a franchised firm, the owner/manager usually hires workers who perform specific tasks. In service stations and independent garages, the owner/manager usually is the mechanic and could be the emissions inspector. This person hires labor to help around the shop. The compensation schemes differ between franchised firms and others. In Fort Collins, there are service stations that are franchised and non-franchised; most of them are not franchised and most mechanics' pay rates are based on commissioned salaries. Half of the independent garages are franchised and the other half are not. All franchised independent stations pay flat rates to their mechanics, and almost half of those that are not franchised pay a flat rate; the other half offers a commissioned salary. These characteristics are not directly apparent to consumers.

Some other firms' characteristics that might imply a consumer-friendly environment are the following: can consumers leave their vehicles to be repaired; do consumers need an appointment; and is there a facility to complete the repairs if the vehicle fails the emissions inspection? These attributes can be observed by consumers.<sup>6</sup> This study treats all firms' characteristics as fixed over long time

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<sup>5</sup> Survey questions are provided in Appendix A. An additional question was asked in a telephone survey on January, 2004, which states "how long have you been operating the Fort Collins area."

<sup>6</sup> Responses to survey questions are presented in appendix B.

horizons and exogenous with respect to the decisions of individual inspectors and consumers.<sup>7</sup>

### 2.3.2 Consumer

Consumers choose an emissions testing station in order to pass their emissions inspection in the least costly way. Some may have preferences for a particular firm (for example, their vehicle's new car dealer or a friendly mechanic) that would be unrelated to cost. The cost of obtaining a passing inspection includes the inspection price and time and travel costs. It also includes all costs associated with failing an inspection; i.e., repair costs.<sup>8</sup> Repair costs are zero when vehicles pass the inspection and are positive when they fail.

Consumers might infer the type of testing station and its organizational structure from dealing with mechanics and inspectors. They also might infer a firm's type by relying on their experience in dealing with different firm types, but most importantly, they infer this information from their knowledge of their vehicle's performance and their vehicle's last inspection outcome. If vehicles fail an emissions test when their owners expect their vehicles to pass it, the consumers might infer that inspectors are not acting in their best interest and accordingly may not demand this service from this firm in the future. On the other hand, if vehicle owners expect their vehicles to fail an emissions test, these owners tend to go to

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<sup>7</sup> In a personal interview with an owner of one of the independent garages, he explained that the emissions testing fee does not cover the cost of emissions equipment; they recover their costs by offering other services.

<sup>8</sup> In Fort Collins, if the vehicle fails its emissions test, it can be retested free of charge if the retest is done within ten days of the original test date at the same testing station.

firms with which they have a previous working relationship. Based on consumers' expectations and observations, consumers may infer the type of discretion exercised by inspectors. Consumers may also realize inspectors discretion based on the experience of other consumers. That can translate to the form of reputation.

### **2.3.3 Data**

The data set is made up of 43,923 observations – 21,235 for vehicles that received their emissions inspections in Fort Collins, Colorado, between August and November 2000, and 22,688 for vehicles that had their emissions tested between August and November 2002. The reason for choosing 2000 and 2002 is that an emission testing in Fort Collins is based on an idle test that requires vehicles to be tested every two years except for two classes of vehicles in which inspection is required every year. These exceptions are diesel-powered engine vehicles and 1981 and older model years. Diesel vehicles require the treadmill test and not the idle test. Therefore, these vehicles are not part of the data set provided to the author by the EPA. As for 1981-year and older vehicles, this study followed Hubbard's (2002) study by including these vehicles as part of both testing cycles

This data set of all individuals who obtained their emissions inspection during this time at one of 31 testing stations in this city.<sup>9</sup> This group of firms is located in a corridor that is approximately 4.6 by 6.7 miles. Included with each observation

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<sup>9</sup> There were seven other testing stations operating in the Fort Collins area. Two testing stations were out of business in 2002 and thus were not available for an interview. The other five testing stations had no duplicate records for both 2000 and 2002. This may suggest either that they did not offer an emissions test in 2000 or 2002, or that they discontinued this line of business in 2002.

are vehicle identification number (vin), test date and time, firm identification number, vehicle characteristics, and inspection results. Vehicle characteristics include auto make and model year, odometer reading, transmission, and vehicle weight.<sup>10</sup> There is no information about consumer characteristics other than the characteristics of their vehicle and where they purchased their inspection. Table 2.1 provides a first look at the data.

Tables 2.1 Results for both years		
Type of Results	Frequency	Percentage
Abort	777	1.8
Fail	6468	14.7
Pass	36628	83.4
Waiver	50	0.1
Total	43923	100

The total number of inspections performed between August and November of 2000 plus those performed in the same months of 2002 was 43,923. As Table 2.1 shows, 0.1 percent of the outcomes were waivers and 1.8 percent were aborts.<sup>11</sup> Eliminating these observations from the data set, the number of vehicles that were observed passing or failing in 2000 and in 2002 are 20,912 and 22,184, respectively. Failure rates for 2000 and 2002 emissions data are 16.1 and 13.1 percent, respectively. Table 2.2 contains data for individual firms – their identification number, their firm types, their market share, and their respective failure rates for both years.

<sup>10</sup> Appendix C displays data set definitions.

<sup>11</sup> “Abort” is aborting the testing during the operation of emissions testing and “waiver” applies to those vehicles that failed emissions testing after proper repair was done. In Fort Collins, the waiver sets in after the vehicle owner has spent \$250 for emissions related expenses for the idle test.

No.	Market Share in 2000	Failure Rate in 2000	Market Share in 2002	Failure Rate in 2002	Firm Type
1	0.183	0.174	0.155	0.133	Quick-lube Shop
2	0.163	0.230	0.176	0.181	Service Station
3	0.073	0.176	0.086	0.146	Service Station
4	0.062	0.124	0.068	0.109	Service Station
5	0.060	0.144	0.065	0.133	Service Station
6	0.047	0.159	0.045	0.124	Service Station
7	0.042	0.043	0.044	0.061	New Car Dealer
8	0.038	0.186	0.036	0.172	Independent Garage
9	0.033	0.202	0.034	0.186	Independent Garage
10	0.033	0.079	0.035	0.024	New Car Dealer
11	0.027	0.175	0.030	0.177	Independent Garage
12	0.022	0.071	0.024	0.032	New Car Dealer
13	0.020	0.087	0.024	0.031	New Car Dealer
14	0.019	0.050	0.011	0.044	New Car Dealer
15	0.018	0.056	0.022	0.047	New Car Dealer
16	0.016	0.153	0.018	0.145	Service Station
17	0.016	0.221	0.009	0.184	Independent Garage
18	0.015	0.170	0.014	0.159	Independent Garage
19	0.014	0.199	0.011	0.226	Used Car Dealer
20	0.013	0.069	0.012	0.026	New Car Dealer
21	0.010	0.169	0.013	0.163	Service Station
22	0.010	0.146	0.012	0.120	Independent Garage
23	0.010	0.238	0.007	0.193	Independent Garage
24	0.010	0.233	0.005	0.157	Independent Garage
25	0.009	0.074	0.008	0.038	New Car Dealer
26	0.009	0.187	0.009	0.154	Independent Garage
27	0.009	0.198	0.008	0.145	Independent Garage
28	0.006	0.215	0.007	0.133	Independent Garage
29	0.005	0.219	0.004	0.089	Independent Garage
30	0.004	0.093	0.003	0.097	New Car Dealer
31	0.004	0.060	0.004	0.012	New Car Dealer

In the data set, there is one quick-lube shop and one used car dealership, seven service stations, twelve independent garages, and ten new car dealerships. Fifteen of the firms had a higher market share in 2000 than in 2002, two firms had matched market shares in both 2000 and 2002, and fourteen firms had a lower market share in 2000 than in 2002. Except for firms number 7, 11, 19, and 30, all firms

experienced higher failure rates in 2000 when compared to 2002 data.

Additionally, Table 2.2 demonstrates that some inspection stations have high (low) market share despite relatively high (low) failure rates, which indicates that other firm characteristics must affect consumer choice.

Firms' characteristics may have an impact on consumers' choice since price competition does not exist in Fort Collins. Some characteristics are observable, but others are less observable to consumers. Among the observable characteristics are friendliness, a space to sit and watch television, courtesy drop-off and pick-up, if consumers need an appointment, and if consumers can leave their vehicles for an emissions test and/or repair; also, if the shop has facilities to complete repairs and if they are a place for one-stop emissions testing and repairs. Consumers may demand a certain firm type based on their knowledge of their vehicles' condition. If consumers know their vehicles will pass the test, they might demand firms that do not have facilities to carry out repairs, and might go to a quick-lube shop for their test. However, if consumers know their vehicles will fail the test, then they might look for shops that have facilities to conduct repairs.

Some firm characteristics are less observable but make a difference in the repair bill, and consequently might influence the consumer's choice, such as franchised facility, mechanics' compensation scheme, and full service station. Full service stations may be referred to shops that are able to carry out emissions related repairs as oppose to facilities for only emissions testing. Consumers might have some knowledge about their vehicle's condition by relying on the previous inspection outcome. If their vehicles previously failed an inspection test, then attribute like

“full service shop” becomes more observable for those consumers. Thus, they might seek services from testing shops that have the capacity to conduct repairs within a day or so. Table 2.3 presents a tabulation of firms’ responses to survey questions, and the failure rates associated with these attributes.

	Survey Questions	No	Response (in percent)	Failure Rate	Yes	Response (in percent)	Failure Rate
Observable	Facility to complete repair on site	6	19.35	0.162	25	80.65	0.12
	Can consumers leave their vehicles	5	16.13	0.168	26	83.87	0.12
	Do consumers need an appointment	25	80.65	0.150	6	19.35	0.088
Less Observable	Change in ownership	23	74.19	0.146	8	25.81	0.143
	Full service station	2	6.45	0.152	29	93.55	0.144
	Franchised	22	70.97	0.156	9	29.03	0.124
	Mode of Ownership - No for single owner - Yes for others	13	41.94	0.154	18	58.06	0.114
	Mechanics pay rate - No for flat rate - Yes for commissioned	13	41.94	0.154	18	58.06	0.123

For consumers’ convenience, data from Table 2.3 show that 81 percent of the firms are able to conduct repairs on the spot, 84 percent let consumers leave their vehicles to be repaired, and 81 percent of the firms are walk-in facilities. From Table 2.3, we see that 74 percent of the firms in Fort Collins have had the same owner since they were established. Additionally, 94 percent of the firms classify themselves as full service stations and 29 percent are affiliated with a mother company. With regard to mode of ownership, about 58 percent of firms have more

than one owner and 42 percent of the firms are sole proprietorships. Mechanics' pay system is a criterion that might influence the motivation of inspectors and mechanics at the emissions testing station; 58 percent are commissioned workers versus 42 percent earn a flat rate.

Generally speaking, certain firm types possess certain associated characteristics. The combined effect of these characteristics might appeal to some consumers. Therefore, when consumers demand emissions testing they may evaluate firm type as a whole and not base their decision on a single attribute. Table 2.4 displays market share and the associated failure rates for each firm type for both 2000 and 2002.

Firm Type	Market Share in 2000	Failure Rate in 2000	Market Share in 2002	Failure Rate in 2002
Quick lube Shop	0.183	0.174	0.155	0.133
Independent Garage	0.186	0.195	0.175	0.167
Service Station	0.432	0.182	0.471	0.150
New Car Dealer	0.185	0.064	0.188	0.040
Used Car Dealer	0.014	0.199	0.011	0.226

Table 2.4 shows that the ranking of market share in 2000 is a little different from that in 2002, but the service station firm type has the highest market share for both years. While independent garages and new car dealer firm types have approximately equal market share in 2000, in 2002 the new car dealer firm type has a higher market share than independent garages. In 2000 and 2002, the quick-lube

shop and used car dealer firm types are ranked fourth and fifth, respectively, in market share.

Contrasting the pattern of market share and failure rates shows that the quick-lube shop and independent garage firm types have higher market share and both are associated with higher failure rates in 2000. In 2002, both have lower market shares and they both have lower associated failure rates. Service station and new car dealership firm type percentages display the opposite pattern. In 2000, when they experienced lower market share, the associated failure rates were high compared to 2002, and when they have high market share in 2002, they have lower associated failure rates compared to 2000. The used car dealer firm type has its own pattern, with higher market share in 2000 compared to 2002. The associated failure rate in 2000 is lower than that in 2002.

## 2.4 Empirical Analysis

### *Failure Probability Model*

The object is to estimate the relationship between probability of failure and various observed vehicle and firm characteristics using the standard binary logit model. With the logit formulation, the natural logarithm of the odds of failure is assumed to be a linear function of the explanatory variables.

$$\ln\left(\frac{P(F_{ij} = 1)}{1 - P(F_{ij} = 1)}\right) = L_{ij} = \beta_0 + \beta_1 Z_j + \beta_2 N_j + \beta_3 S_j + \beta_4 T_j + \beta_5 O_j + \beta_6 R_j + \beta_7 M_j + \beta_8 V_{ij} + \zeta_{ij}$$

where  $F_{ij}$  is a binary variable that is equal to 1 for a failed emissions test and 0 for a pass, so  $P(F_{ij} = 1)$  is the probability of failure and  $P(F_{ij} = 0)$  is the probability of a pass.  $Z_j$  represents a vector of dummy variables for testing firm type—quick-lube shops, independent garages, service stations, and new car dealers. The used car dealer is the base case for firm type.  $N_j$  is a dummy variable that equals 1 for a franchised firm and 0 otherwise. Some testing stations are franchised and others are not; this variable compares testing practices among franchised versus non-franchised facilities. This will allow the current study to furnish some grounds for determining whether there is a difference in pass/fail rate related to motivations dictated by different organizational structures of the testing station. It seems likely that failure rates would be higher in the franchised than the non-franchised testing stations, other things equal. This argument can be supported by the fact that franchises are better organized, have better equipment, and have a procedure code to follow. If the franchise was involved in manipulating results and was caught, it

would be not only subject to citation by the EPA inspectors but also subject to the possible loss of its franchise.

This study tests if there are variations in results between “full service stations” and “emissions-only testing stations.” This study introduces the dummy variable,  $S_j$ , equal to 1 for full service station and 0 for shops that are only emissions testing stations. This study hypothesizes that there is a higher probability of failure at full service facilities – in this case, due to mechanics’ perverse incentives.

$T_j$  represents how long a firm has been operating in the Fort Collins area where it is measured in number of years as of 2002.

Quite often, customers observe “new ownership” or “under new management” signs. Marketing literature argues that such signs have an impact on attracting new customers. This study use  $O_j$  to represent any change in ownership. This binary variable is equal to 1 if there has been a change in ownership since it was established and 0 if the station has had the same owner over its years of operation.

Among the questions that the survey collected, one is “whether mechanics at the testing station in Fort Collins are paid as a function of work completed or not.” This is an important variable that will reflect the motivations of inspectors to help vehicles pass or fail. The dummy variable  $R_j$  equals 1 if mechanics’ pay is a function of work completed and 0 if the pay scale is a flat rate.  $M_i$  is a dummy variable that equals one if the testing facility has one owner, and zero otherwise. Employee management is different in the presence of more than one owner. This study hypothesizes that facilities under one owner tend to have consistent testing policies. And finally,  $V_{ij}$  represents vehicle characteristics – vehicle age,

odometer reading, and vehicle type and transmission – tested at firm  $j$ .  $\zeta_{ij}$  is an error term.

Because  $(F_{ij})$  is a binary variable, it could be 1 or 0 depending on whether a vehicle failed or passed its inspection test. The logistic function will take the following form:  $P_{ij} = \frac{1}{1 + e^{-L_{ij}}}$  where  $L_{ij}$  is given in the equation above. It is the probability of consumer  $i$  getting emissions testing at station  $j$  and failing the emissions test. The above equation is the cumulative logistic distribution function that satisfies the two requirements; as  $L_i \rightarrow +\infty, e^{-L_i}$  tends to 0 and as  $L_i \rightarrow -\infty, e^{-L_i}$  increases indefinitely, thus,  $L_i$  ranges from  $-\infty$  to  $+\infty$  when  $P_i$  ranges between 0 and 1.

To estimate  $P_{ij}$ , this study refers to the sample collected from the Environmental Protection Agency (EPA) in Denver, Colorado. Each observation represents, among others, data on the inspection result for each vehicle between August and November for 2000 and 2002. The study will denote the number of vehicles that were observed to have emissions testing for the two years 2000 and 2002 as  $N_i$ , and denote the number of vehicles that failed during these two years as  $n_i$ .

$\hat{P}_i = \frac{n_i}{N_i}$  is the estimated failure rate and  $1 - \hat{P}_i$  is the estimated passing rate

among all vehicles that went through inspection during the stated period. Thus,

$\frac{\hat{P}_i}{1 - \hat{P}_i}$  is the odds of failing – the ratio of the probability of a failure to the

probability of a pass. Therefore, the estimated logit is:

$$\hat{L}_i = \ln\left(\frac{\hat{P}_i}{1-\hat{P}_i}\right) = \hat{\beta}_1 Z_j + \hat{\beta}_2 N_j + \hat{\beta}_3 S_j + \hat{\beta}_4 T_j + \hat{\beta}_5 O_j + \hat{\beta}_6 R_j + \hat{\beta}_7 M_j + \hat{\beta}_8 V_{ij}$$

The interpretation of  $\beta$ s are somewhat different from OLS. Usually, the estimator's value indicates the change in the value of the dependent variable for a unit change in the independent variable. This interpretation should be applied given that regressors are continuous variables but not dichotomous, as in the case of dummy variables. This study obtains the relative change in mean dependent variable by taking the antilog (to base  $e$ ) of the estimated coefficient and subtracting 1 from it, as suggested by Gujarati (1995, 525-526).

## 2.5 Results

The data set contains variables that were recorded at the time of inspection. They fall into three categories: identification, vehicle condition, and test results. Identification includes vehicle identification number and firm-assigned station number. The date and time of the test are also part of the identification. Additionally, the data set includes vehicle year-model, odometer readings, size of engine, vehicle type (truck or passenger), and whether the vehicle has manual or automatic transmission.

The emissions test is comprised of two parts: emissions readings and visual check components. Vehicle emissions are measured as emissions coming from the tailpipe, and include readings of carbon monoxide (CO) in percentage of total exhaust emissions and hydrocarbon (HC) and carbon dioxide (CO<sub>2</sub>) in parts per million. The emissions component has three parts; initial readings (IDLE 1), conditioning (emissions level while the engine is running at 2500 rotations per minute-RPM), and final emissions reading (IDLE 2). Any pre-inspection repair is not part of the vehicle's records.<sup>12</sup>

The second part of the test is a visual check component (under-hood inspection). This includes checking the engine lights and whether any parts of the emissions control equipment (gas cap, catalytic converter, air pump, etc) are broken, missing, or altered.

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<sup>12</sup> In Colorado, it is required by law that inspectors warm up the vehicle first.

## 2.5.1 General Results

### Data comparison

Table 2.5 presents means for the whole market sample and by station type.<sup>13</sup>

Table 2.5 Sample Mean for whole Market and by Station Type						
Variable	Market	Quick-lube shops	Independent garages	Service stations	New car dealer	Used car dealer
N	43,096	7284	7764	19473	8036	539
Share		0.1690	0.1802	0.4519	0.1865	0.0125
<b>Emissions Failure Rate:</b>						
- Overall	13.588	14.58	16.73	15.39	4.89	19.67
- Emission Component	13.275	14.31	16.51	14.96	4.75	18.92
- Visual Component	0.699	0.47	0.75	0.92	0.27	1.48
<b>Vehicle Characteristics:</b>						
- Engine size (Liters)	3.615	3.266	3.533	3.806	3.581	3.107
- Vehicle age (Years)	9.998	11.110	12.210	10.640	5.260	10.550
- Truck (vehicle type-percent)	39.540	39.670	43.700	38.600	38.170	32.280
- Automatic Transmission (percent)	64.050	60.590	58.590	63.520	74.020	59.930
- Odometer Reading (Miles)	88634.587	92,328.70	98,011.99	92,551.58	65,388.18	108,705.94
- HC emissions (Parts Per Million)	123.601	135.950	151.800	137.710	50.380	132.420
- CO emissions (% of total Emissions)	0.434	0.465	0.587	0.483	0.136	0.478
- CO2 emissions (Parts Per Million)	13.109	12.919	12.784	12.915	14.067	13.108
- Idle Speed (rpm)	810.920	810.900	842.490	816.280	765.940	833.390

The first part of the table presents a comparison between failure means of the overall test results, emissions component, and the visual check outcomes for the whole market and by station types. Because a vehicle could fail the inspection test by failing one or both parts of the test, the combined failure percentage of emissions and the visual check may be greater than the overall failure percentage.<sup>14</sup> The used car dealer firm type has the highest mean on the overall and on the emissions

<sup>13</sup> Quick-lube shops and used car dealers are comprised of one firm each; therefore, the characteristics of this station type reflect that station only.

<sup>14</sup> It is found that there are there are 167 vehicles in the sample market failed both tests - emissions and visual check components; 14 vehicles at quick-lube, 41 at independent garage, 97 at service station, 11 at new car dealer, and 4 at used car dealer firm types.

component failure rates. New car dealers score the lowest failure means. Quick-lube shops, independent garages, and service stations have higher than market means for the overall and emissions component failures.

Contrasting means on vehicle characteristics are found in the second part of Table 2.5. Vehicle odometer readings for the used car dealer firm type are the highest in the market, which explains their associated higher failure rates. Quick-lube shops and service stations share, approximately, equal means for vehicle age, odometer reading, and emissions failure mean, but the failure rate in the visual part at the quick-lube shops is lower than service stations. This could indicate that inspectors at quick-lube shops are less likely to be thorough in the under-hood component. New car dealers have the lowest means on vehicle odometer reading, vehicle age, and HC and CO emissions, which is consistent with their line of business.

Service stations seems to serve above-market “engine size” mean vehicles, and used car dealers, on average, serve vehicles with smaller engine sizes: 3.806 and 3.107 liters, respectively. While engine size mean vehicles classified as trucks are the highest at independent garages, used car dealers attract passenger vehicle owners more than they do truck owners. New car dealers have a higher mean value for vehicles with automatic transmissions than that of the market; used car dealers and independent garages serve vehicles (on average) with a lower-than-market automatic transmission mean. The independent garage firm type seems to have the highest HC and CO mean emissions readings.

Table 2.6 presents sample means firm characteristics by station type. While quick-lube shop and used car dealer firm types consist of one firm each, service stations consist of seven firms, the new car dealer category has ten firms, and twelve testing stations are classified as independent garages.

Table 2.6 Average Across Firms						
	Market	Quick-lube shops	Independent garages	Service stations	New car dealer	Used car dealer
Number of Firms in Each Type		1	12	7	10	1
Firm Characteristics:						
- Years in Business (Number of Years)	20.020	20.000	26.420	14.860	27.300	6.000
- Change in ownership*	0.335	1.000	0.250	0.143	0.300	0.000
- Full Service Station*	0.766	0.000	1.000	0.857	1.000	1.000
- Franchised*	0.348	0.000	0.083	0.571	0.400	0.000
- Single Owner	0.740	1.000	0.500	0.857	0.500	0.000
- Mechanics on Commission *	0.349	0.000	0.750	0.143	0.800	0.000
* Change in ownership is a dummy variable = 1 if there was any change in ownership since firm was established and 0 otherwise.						
Full service station is dummy variable =1 if the firm can fix the defective component and 0 otherwise.						
Franchised is dummy variable =1 if the firm is franchised and 0 otherwise.						
Mechanics on commission is dummy variable =1 if mechanics' pay scheme is part of job completed and 0 otherwise.						

Quick-lube firm type have had change in owners, are not considered full service station and not franchised, have single owner, and mechanics are not commissioned. Approximately 25 percent of the independent garages experienced a change of ownership since their establishment, and they are all classified as full service stations. About 8.3 percent are franchised, 50 percent have a single owner, and most of their mechanics are compensated as a function of work done. Service stations experienced little change in ownership, and most are classified as full service stations. A little more than half of them are franchised. By and large, they are sole proprietorships and their mechanics earn hourly wages.

The new car dealer firm type experienced a 30 percent change in ownership. These dealers are considered full service stations, 40 percent of them are franchised, 50 percent have a single owner, and their mechanics are 80 percent commissioned labor. The used car dealership firm type did not experience changes in ownership. These firms are considered full service stations and are not franchised. Used car dealer firm type, have more than one owner, and the mechanics are paid an hourly wage.

### ***Logit Coefficient***

Tables 2.7, 2.8, and 2.9 present the outcome of three logit analyses. The dependent variable is the overall emissions, emissions component, and visual component check results, respectively. The dependent variable in each specification takes on the value of 1 to represent a fail result and 0 otherwise.

**Table 2.7**  
**Parameter Estimates - Overall Inspection Logit**

Dependent Variable: Overall Inspection Result				
Number of Observations: 43,096				
Overall Failure Rate in Sample: 14.545%				
Log of Likelihood Function: -32,580.64				
Log-Likelihood Ratio (16 df) = 140.156				
		Coefficient	Standard Error	T-statistic
	Constant	-2.590*	0.142	-18.24
Vehicle Characteristics	Engine size	-.039*	0.011	-3.55
	Vehicle age	.075*	0.002	37.50
	Truck	.102*	0.034	3.00
	Automatic transmission	-.220*	0.032	-6.875
	Odometer	4.548**	2.343	1.94
Firm Characteristics	Years in Business	.04*	0.019	2.11
	Change in ownership	0.039	0.065	0.60
	Full Service Station	0.084	0.077	1.09
	Franchised	-.160*	0.042	-3.81
	Single owner	.162*	0.049	3.31
	Mechanics on commission	-.082	0.064	-1.28
Firm Type	Quick-lube shops	-.496*	0.177	-2.8
	Independent garages	-.315*	0.146	-2.16
	Services stations	-.314*	0.129	-2.43
	New car dealer	-1.007*	0.153	-6.58

\* Significant at 0.05 level, \*\* Significant at .1 level

**Table 2.8**  
**Parameter Estimates - Emission Component Logit**

Dependent Variable: Emission Component Result  
 Number of Observations: 43,096  
 Emissions Failure Rate in Sample: 13.275%  
 Log of Likelihood Function: -30,614.494  
 Likelihood Ratio (16 df) = 188.481

		Coefficient	Standard Error	T-statistic
	Constant	-2.755*	0.148	-18.61
Vehicle Characteristics	Engine size	-.039*	0.011	-3.55
	Vehicle age	0.078*	0.002	39.00
	Truck	0.081*	0.035	2.30
	Automatic transmission	-.268*	0.033	-8.12
	Odometer	4.624**	2.399	1.93
Firm Characteristics	Years in Business	-.006	0.02	-.3
	Change in ownership	-.015	0.068	-.22
	Full Service Station	0.118	0.082	1.44
	Franchised	-.255*	0.044	-5.80
	Single owner	0.187*	0.051	3.67
	Mechanics on commission	-.166*	0.066	-2.52
Firm Type	Quick-lube shops	-.363**	0.185	-1.96
	Independent garages	-.192	0.152	-1.26
	Services stations	-.242	0.134	-1.81
	New car dealer	-.831*	0.16	-5.82

\* Significant at 0.05 level, \*\* Significant at .1 level

Table 2.9 Parameter Estimates - Visual check Component Logit				
Dependent Variable: Visual Check Component Result				
Number of Observations: 43,096				
Visual Failure Rate in Sample: .699%				
Log of Likelihood Function: -4,601.736				
Likelihood Ratio (16 df) = 74.04				
		Coefficient	Standard Error	T-statistic
	Constant	-4.409*	0.493	-8.94
Vehicle Characteristics	Engine size	-.020	0.036	-0.56
	Vehicle age	-.033*	0.009	-3.67
	Truck	-.029	0.116	-0.25
	Automatic transmission	-.066	0.11	-0.60
	Odometer	2.776	6.354	0.44
Firm Characteristics	Years in Business	0.033	0.067	0.49
	Change in ownership	0.515*	0.194	2.65
	Full Service Station	-0.017	0.239	-0.07
	Franchised	0.611*	0.148	4.13
	Single owner	-0.369*	0.17	-2.17
	Mechanics on commission	0.876*	0.216	4.06
Firm Type	Quick-lube shops	-0.326	0.61	-0.53
	Independent garages	-0.562	0.52	-1.08
	Services stations	-0.087	0.476	-0.18
	New car dealer	-2.255*	0.557	-4.05
* Significant at 0.05 level				

Parameter estimates for vehicle characteristics are displayed in the first part of Tables 2.7, 2.8, and 2.9. While coefficients in Tables 2.7 and 2.8 on engine size and vehicle age, truck, and automatic transmission variables are significant at the .05 level, odometer coefficient is significant at the .1 level, and coefficients on vehicle characteristics in those two Tables retained their signs. Coefficients on vehicle characteristics in Tables 2.7 and 2.8 indicate that bigger engine size and vehicles equipped with automatic transmission reduce the log-odds of failure, and that older vehicles, truck-type vehicles, and high odometer readings increase the

log-odds of failure. In Table 2.9, the only significant coefficient is on vehicle age; and it experienced a sign change from positive to negative.<sup>15</sup>

The second parts of Tables 2.7, 2.8 and 2.9 present coefficient estimates for firm characteristics. In the overall specification, years in business, being franchised, and single owner variables are significant. While older firms and single owner coefficients tend to increase the log-odds of failure, franchised coefficient decreases the log-odds of failure. In the emissions component logit (Table 2.8), franchised, single-owner, and mechanics on commission coefficients are significant; franchised and commissioned labor tend to decrease the log-odds of failure, and single ownership tends to increase the log-odds of failure. In the visual component test, change in ownership, franchised, single ownership, and mechanics on commissioned coefficients are significant; while change in ownership, franchised, and commissioned labor increase the log-odds of failure, single ownership decrease the log-odds of failure.

The third parts of Tables 2.7, 2.8, and 2.9 present coefficients on all firm type dummies, and used car dealer serves as the reference group. While coefficients on quick-lube shops, independent garages, service stations, and new car dealers are significant at the .05 level in the overall specification (Table 2.7), in the emissions component (Table 2.8) only new car dealer is significant at the .05 level; quick-lube shops' coefficient is significant at the .1 level. In the visual component logit (Table 2.9), only the new car dealer dummy is significant. Coefficient signs in all three

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<sup>15</sup> Negative coefficient on vehicle age in the visual specification means that it reduce the log-odds of failure, this is not explained.

specifications are negative on all firm type dummies, which indicate the reduction in log-odds of failures compared to used car dealership firm type.

## 2.5.2 Failure Probabilities Estimation

### *Vehicle Characteristics*

To better understand the magnitude associated with the coefficients seen in Table 2.7, further treatment is required. The variables associated with vehicle condition are either binary (truck and type of transmission) or continuous (engine size, vehicle age, and odometer reading). The percentage point change in the estimated failure probabilities associated with binary vehicle characteristics given that all other independent variables are held at their sample mean value is calculated by subtracting the estimated failure probability when the variable equals 1 from that when it equals 0.<sup>16</sup> This is done using logit coefficients in Table 2.7 and the variables' corresponding market means. The results are displayed in Table 2.10.

Truck	7.654
Automatic Transmission	-3.163

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<sup>16</sup> This procedure was implemented by Hubbard (1995).

Vehicles classified as truck have increased failure probability by 7.654 percentage points compared to passenger cars, holding all other variables at their mean values. That may be due to the fact that trucks bear loads beyond their net weight, which makes the engine work more, and the engine deteriorates at a faster rate. Therefore, higher emissions levels leads to higher estimated failure probabilities.

Also, vehicles experience a decrease in estimated failure probabilities by 3.163 percentage points if they are equipped with automatic transmission, holding other variables at their mean values. A vehicle with an automatic transmission cycles once every complete stop that the vehicle makes as opposed to a manual transmission, which cycles three to four times depending on gear shifts. So, vehicles with automatic transmissions experience less tear and wear on the engine, and that could explain why vehicles with automatic transmissions have lower estimated failure rates than those with manual transmissions.<sup>17</sup>

Table 2.11 presents the predicted failure probabilities at different percentiles for the continuous variable.

	<b>vehicle age</b>	<b>Failure Rate</b>	<b>Odometer</b>	<b>Failure Rate</b>	<b>Engine size</b>	<b>Failure Rate</b>
10th	2	2.20797	23900	2.39195	1.7	0.433445642
25th	4	2.56529	47176	13.25204	2.1	0.426736387
50th	8	3.46278	81488	25.20507	3	0.412017823
75th	13	5.03830	121739	32.56194	4.2	0.393179715
90th	19	7.90161	160311	36.51953	5.6	0.372287724
75th - 25th		2.4730		19.3099		-0.0336

<sup>17</sup> It may also suggest that vehicle owners with manual transmission mis-shift the gears, which results in more wear and tear on the engine.

These predicted probabilities are found by holding all independent variables at their sample mean values using the overall logit specification. The estimated failure probability for vehicle age is found by placing the vehicle age in different percentiles along with the vehicle age coefficient, holding all other independent variables at their mean values. Also, the estimated failure probability for odometer reading is found by placing the odometer readings in different percentiles along with the odometer coefficient, holding all other independent variables at their mean values. In addition, the predicted failure probabilities for engine size are found by placing engine size in different percentiles along with the engine size coefficient, holding all other independent variables at their mean values. From this table, it is evident that vehicle odometer reading has a greater influence on failure rates than vehicle age.

Holding all other variables at mean values, the probability of failure increases by about 1.06 percentage points moving from four to eight years, by 2.4 percentage points moving from four to thirteen years, and by 5.3 percentage point moving from four to nineteen years. In contrast, differences in odometer readings are associated with relatively larger differences in failure probabilities; there is approximately a 12 percentage point difference moving from the 25<sup>th</sup> to the 50<sup>th</sup> percentile, a 19 percentage point difference moving from the 25<sup>th</sup> to the 75<sup>th</sup> percentile, and a 23 percentage point difference moving from the 25<sup>th</sup> to the 90<sup>th</sup> percentile.

### *Type of Firms*

Comparing the coefficient on dummies related to firm type in Tables 2.7, 2.8, and 2.9 reveals differences in coefficient significance and magnitude compared to the used car dealer firm type.<sup>18</sup> All firm type dummy coefficients are negative and significant in the overall specification found in Table 2.7. New car dealers have the largest impact on reducing the log-odds of failures in the overall specification. Firm type dummy coefficients in the emissions component logit (Table 2.8) present different outcomes. The quick-lube dummy coefficient is significant at the .1 level, and the new car dealer dummy coefficient has a lower impact on reducing the log-odds of failing the emissions component test compared to the overall logit. In the visual check component logit (Table 2.9), vehicles that are only tested at new car dealers tend to have lower log-odds of failures.

Under the assumption that unobserved vehicle condition is independent of type of firm, differences in logit coefficients on the firm-type dummies indicate differences in how inspectors conduct inspections compared to the used car dealer firm type.<sup>19</sup> Using dummy coefficients from Table 2.7, one can estimate the probability of failure holding all variables at their sample mean value and assigning 1 for a station type and 0 for all other firm type dummies. The above procedure is repeated for coefficients in Tables 2.8 and 2.9, and is repeated for all station types.

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<sup>18</sup> Since used car dealer firm type is used as a reference group.

<sup>19</sup> This assumption is based on Hubbard's (1997) finding. In a two-stage procedure, he first estimated an equation over the entire sample for each firm type where the firm-type dummy is the dependent variable. In the second stage, he used the predicted firm type in order to remove the bias (if any) from the correlation between firm type and the unobserved vehicle characteristics. He compared his finding to the results estimated using maximum likelihood estimation and found that the results are the same under both techniques.

To find estimated failure probabilities for used car dealer firm type, coefficients on all firm dummy types are assigned 0. The results are presented in Table 2.12. The first, second, and, third columns correspond to parameter estimates in Tables 2.7, 2.8, and 2.9, respectively.

<b>Stations</b>	<b>Overall Failure</b>	<b>Emission Component Failure</b>	<b>Visual Check Failure</b>
Quick-lube shops	14.10391	12.52152	0.77523
Independent garage	17.70129	15.60300	1.31028
Service Stations	16.04879	13.96707	1.37959
New car dealer	4.91540	2.71720	0.36733
Used car dealer	20.74450	17.21603	1.56163

Table 2.12 presents estimated failure probabilities by firm type for the overall, emissions component, and the visual component tests holding other variables at their mean values. What this table shows is comparison of the estimated failure probabilities for the average vehicle's characteristics when tested at each firm type. For example, if the average vehicle was tested at the quick-lube shop firm type, its predicted failure probabilities would be 14.10, 12.52, and .78 percent in the overall, emissions, and visual tests, respectively. If it was tested at the independent garage firm type, its predicted failure probabilities would be 18, 16, and 1.3 percent in the overall, emissions and visual check, respectively. As for service station firm type, this vehicle has predicted failure probabilities of 16, 14, and 1.4 percent of failing the overall, emissions, and visual tests, respectively. For new car dealer firm type, this vehicle has estimated failure probabilities of 5, 3, and .36 percent in the overall,

emissions, and visual test respectively. The used car dealer firm type has 21, 17, and 1.6 percent estimated probabilities that it will fail the overall, emissions, and visual test, respectively.

### *Firms' Characteristics*

Vehicle owners' choose a firm at which they believe they can motivate inspectors to act in their best interest, or they choose based on their belief of a firm's organizational arrangements. These arrangements may indicate certain behaviors practiced by inspectors and mechanics. Firm characteristics that are tested are: change in ownership, full service stations, franchised, mode of ownership, employees' compensation scheme, and the duration in which the firm is operating in the Fort Collins area. The above differences among different firm types reflect the differences in the incentives that firms' observed and unobserved characteristics provide their inspectors.

Failure probabilities associated with change in ownership are estimated by assigning 1 to the change in ownership logit coefficient and then subtracting it from the failure probabilities estimated with 0, holding other firm characteristics at their market mean values.<sup>20</sup> This method can be carried out to find estimated failure probabilities for other binary firm characteristics – full service station, franchised, single owner, and commissioned labor variables. Results of this procedure are displayed in Table 2.13.

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<sup>20</sup> This procedure was implemented by Hubbard (1995).

<b>Station Characteristic</b>	<b>Overall Failure</b>	<b>Emission Component Failure</b>	<b>Visual Check Failure</b>
Change in ownership	0.0361	-0.0104	0.0328
Full Service station	0.0757	0.0795	-0.0009
Franchised	-0.1439	-0.1709	0.0382
Single owner	0.1437	0.1244	-0.0227
Commissioned labor	-0.0746	-0.1126	0.0599

A change in ownership sign may send a signal that implies a policy change in emissions testing practices. This may draw new consumers or it might simply entice unsatisfied consumers to demand their services. Change in ownership variable for the three logit specifications in Table 2.13 shows that firms that experienced change in ownership tend to be more lenient in the emissions test than firms that did not experience a change in ownership. In the visual check, firms that experienced a change in ownership tend to increase the estimated failure probabilities compared to firms that did not experience change in ownership.

Full service stations are firms that offer to fix emissions component defects in case of emissions test failures. These services range from replacement of air pump and fuel filter to mechanical breakdown of the catalytic converter, or simply the installation of new exhaust gas recirculator (EGR), and oxygen sensor. From Table 2.13, the estimated failure probabilities indicate that mechanics at firms of the full service station firm type tend to have a reduced estimated failure probability in the visual check test compared to firms that did not have facilities to carry out repairs. Also, in the emissions test, it is clear that firms classified as full service stations did

not exercise discretion in reducing failure probabilities compared to firms classified as non full service facilities.

In most franchised testing facilities, inspection practices are governed by the mother company's policies and franchising license renewal depends on the firm's performance. Therefore, the results in Table 2.13 point to some discretion exercised by mechanics in the emissions component compared to non-franchised facilities. This could imply that the mechanic might conduct some kind of routine engine checkup before implementing the inspection test. In the visual check, the data indicate that the change in failure probabilities is positive compared to non-franchised firms.

Inspection procedures under one owner, as opposed to multiple owners, tend to be consistent over all services, and the policies governing the test might be parallel to some objective that is not necessarily the same as the I/M regulators'. The owner of the shop might be the certified inspector or the technician, or both. Also, a single owner might have a different attitude in regard to developing some kind of rapport with the customers. It seems from the results in Table 2.13 that the changed failure probabilities in the visual component imply that there is a reduced estimated failure probability compared to facilities that have multiple owners. In the emissions component test, there is an increase in failure probabilities with single owner compared to multiple owner firms.

A firm's compensation scheme sends different signals to their employees. If the employees are paid as an hourly rate, this might suggest that the inspectors' decisions on how to implement the test are irrelevant to their take-home income. If

the labor is commissioned, this might entail that their paycheck is a function of jobs completed. Therefore, the motivation behind testing procedures lies with the inspector/mechanic, and this individual may choose to implement or disregard certain aspects of the testing in order to increase his or her take-home income. The results presented in Table 2.13 shows that commissioned labor tends to be more lenient in the emissions component test, thus decreasing failure probabilities compared to non-commissioned labor. In the visual component there is an increase in estimated failure probabilities compared to non-commissioned labor.

To find firm type estimated failure probabilities that are associated with different firm ages, one can use the overall logit specification in Table 2.7 with their corresponding firm type mean values. To estimate failure probabilities at different time periods (5, 10, 15, 20, 25, and 30 years) one can insert these different ages for “Years in Business” in the equation for each firm type. The results are presented in Table 2.14.

<b>Years in Business</b>	<b>Quick-lube Shops</b>	<b>Independent Garages</b>	<b>Service Stations</b>	<b>New Car Dealer</b>	<b>Used Car Dealer</b>
5	-0.0023	-0.0246	0.0041	0.0103	0.0007
10	-0.0052	-0.0324	0.0026	0.0103	-0.0015
15	-0.0086	-0.0419	0.0009	0.0102	-0.0042
20	-0.0129	-0.0535	-0.0012	0.0102	-0.0074
25	-0.0181	-0.0677	-0.0038	0.0101	-0.0114
30	-0.0244	-0.0851	-0.0070	0.0100	-0.0163

Evaluating the percentage-point change in failure probabilities for all five firm types at different firm ages implies the existence of different inspection test practices over firms' ages; independent garage and quick-lube shop firm types have higher value of reduced failure probabilities than service stations, new car dealer, and used car dealer firm types.

Comparing the percentage point change between station age of 5 and 20 for all firm types, there is a reduction in percentage-point change for quick-lube firm type by 1.06 percent. For the independent garage firm type there is a reduction by 2.9 percent; for the service station firm type there is a reduction by .5 percent; for the new car dealer firm type there is a reduction by .012; and for the used car dealer firm type there is a reduction by .008. The highest change is at the independent garage firm type and the lowest is at the used car dealer firm type.

The differences in inspectors' behavior that is associated with differences in firm characteristics may reflect the possibility that some consumers choose firms because of certain aspects of a firm that are appealing that were not picked up in the data set. For example, consumers with older vehicles attending independent garages and service stations are likely to know that if they pay the \$40 fix-it fee before the emissions test, their vehicle will likely to pass the test. In short, there is likely some self-selection in these markets. In this case, consumers are presenting mechanics with a strong incentive to act in their best interest. Having stated the above, one needs to note that this may not be, necessarily, a bad arrangement, given that the vehicle receives some basic maintenance check and later passes. The car is thus running cleaner post-test than it ran per-test. These actions taken by vehicle

owners and implemented by mechanics are ways to counter the effect of high repair costs associated with emissions failures.

## 2.6 Conclusions

Emissions inspection test ought to provide consumers with information about the operating conditions of their vehicles. If the vehicle failed the emissions component test, then there is a clear indication that emissions levels are above year model standards. All tailpipe emissions failures are the result of incomplete fuel combustion. This could result from a number of issues: among them are broken fuel injection timing, foul spark plug, weak battery, soiled oil filter, and broken recirculation valve. If the vehicle failed its inspection test based on the visual component, then possible causes would include broken muffler, missing (or defective) air pump, missing fuel filter restrictor cap, broken catalytic converter, and closed crankcase ventilation system. This alludes to the operating condition of the vehicles. Motorists need not to be mechanics to know these details, but when their vehicles fail, in most cases, the mechanic could provide them with the proper remedy to fix the faulty component(s).

In addition to vehicles' operating conditions, more obvious vehicle characteristics like vehicle class, transmissions type, odometer reading, vehicle age, and engine size all are an indication of the status of the vehicle. Consumers equipped with information about their vehicles could choose an inspection site that is more or less compatible with the condition of their vehicle. For example, motorists with new vehicles probably seek services at quick-lube shops, whereas motorists with older vehicles tend to have their vehicles inspected at independent

garages or service stations. This may be the case so that their vehicle could be fixed and possibly retested by the same mechanic, if the vehicle failed the initial test.<sup>21</sup>

Inspection sites could be a range of types depending on services offered. They could be either just an inspection site or a firm that combines testing and repair. Testing sites in Fort Collins, Colorado, could be quick-lube shops, service garages, independent garages, new car dealers, and used car dealers. Quick-lube shops specialize mainly in oil and filter changes in addition to emissions testing. Service shops perform similar tasks as quick-lube shops, but they also conduct light vehicle fixing like tire rotation, replacing spark plugs, and muffler changes. In addition, service stations carry out some light electrical wiring adjustments. Independent garages generally perform what service stations accomplish, but they also specialize in vehicle mechanical failures. New car dealers specialize mainly in selling new vehicles and some of them, as part of their vehicle sales promotion, offer their customer free oil and filter changes but others offer an additional free emissions testing for the duration of the buyer's ownership of the vehicle. Used car dealerships buy used vehicles; part of the purchase of a used vehicle includes a test of its emissions control system.

Other than motorists with new vehicles, vehicle owners, equipped with knowledge about their vehicles' operating conditions, would most probably select a testing site based on how they think the inspection test is carried out. Given the firm type, there are a myriad of organizational structures that dictate how the inspection test is done. These include whether the facility is franchised or not, whether it is a full service stations or not, the type of employee compensation

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<sup>21</sup> In that case, vehicle owners do not need to pay an additional fee for retest.

scheme, if there has been change in ownership, mode of ownership, and how long the firm has been operating in the Fort Collins area. Therefore, vehicle owners choose a testing site that might help them pass the inspection test. This study's goals are to determine failure probabilities that are associated with different vehicle characteristics, different firm types, and different firm attributes.

This study shows that there is a clear indication that vehicles that are classified as trucks tend to have increased in failure probabilities, and vehicles with an automatic transmission have reduced failure probabilities. However, vehicle classification and transmissions type are not the only determinants of vehicle condition. This study shows that vehicle mileage is more important than vehicle age in determining failure probabilities. Engine size, on the other hand, has a small impact in determining failure probabilities.

Consumers equipped with knowledge about their vehicle may choose a firm that may reduce the failure probabilities of their vehicles. For reasons mentioned above, I/M regulators would like the inspection test to be administered without any discretion. However, this study shows that there is an obvious variation in conduct across firm types in both parts of the inspection test. Controlling for vehicle characteristics, vehicles are least likely to fail the emissions component test at a new car dealer firm type than at a quick-lube shop, independent garage, service station, and used car dealer firm types. Comparing the failure probabilities among quick-lube shop, independent garage, and service station firm types reveals that vehicles are more likely to fail the emissions component at the independent garage firm type than at service stations and quick-lube shops, and least likely to fail the

visual check at quick-lube shops than at independent garage and service station firms. This indicates that there are obvious differences in conduct among different firm types in both parts of the test. Moreover, firm types in general have different organizational structures that embody certain attributes like product pricing and how inspections are done, which dictate firms' failure rates.

How inspectors choose to carry out an inspection is governed by a firm's institutional characteristics. These include full service station, franchised facility, and whether the labor is commissioned. Additionally, change in ownership, whether the firm is a sole proprietorship, and how long the firm has been operating in Fort Collins are all part of the organizational character that governs some aspects of how the inspection test is implemented.

Controlling for vehicle characteristics, estimated failure rates tend to be lower at franchised facilities in the emissions test than at non-franchised sites, but has an increase in failure probability in the visual check compared to non-franchised facilities. This motivates consumers with older vehicles to find a better match between firm type and their vehicles, especially if there is a chance that their vehicles will the emissions component test.

In addition, facilities with a single owner as opposed to multiple owners tend to have reduced failure probabilities in the visual check test as opposed to firms with multiple owners. Firms with single owners have an increase in failure probabilities in the emissions component for single owner firms compared to multiple owners.

Commissioned labor tends to decrease failure probabilities compared to non-commissioned labor in the emission component test. This may be a result of practices like conducting quick maintenance before testing. This leads to the belief that inspectors and mechanics forego short-run gains for emissions-related repairs in favor of a longstanding good reputation. In the visual check, commissioned labor increased failure probabilities compared to non-commissioned labor. Also, firms that experienced change in ownership tend to increase failure probabilities in the visual check component compared to firms that did not experience a change in ownership. Testing stations might develop testing practices with firm age. The data show that failure probabilities for independent garages and quick-lube shop firm types experienced decrease in estimated failure probabilities.

This research highlighted some of the obstacles that hinder the improvements in air quality that might be attained from I/M programs. As stated earlier, this might be the result of nonalignment of goals among I/M officials and testing site owners/inspectors. A better method would be to educate inspectors about their significant role in combating mobile emissions. This might be done through educating inspectors during their certification process. It would imply exposing the inspectors to the side effects of vehicles' excessive emissions and the impact of these emissions on the environment. In such settings, an ethical climate can be set so that inspectors in a given I/M program area have uniform policies in implementing inspection tests, and their behavior is consistent. This process empowers individual inspectors toward the stated objective of the I/M program while at the same time allowing them the discretion to exercise their mechanical

expertise toward emissions reductions. This approach would compel inspectors to be part of the solution rather than being part of the problem. A tax rebate system could be set up to entice firms to comply with the testing procedures.

## Chapter Three

### Repair Incentives

### 3.1 Introduction

The Clean Air Act Amendment of 1990 relaxed some aspects of inspection and maintenance (I/M) programs and it called for the Environmental Protection Agency (EPA) to establish performance standards for two programs, the basic and enhanced I/M programs (NRC 2001). Under these guidelines, areas with moderate pollution are permitted to implement a “basic” I/M program. This consists of stationary tailpipe testing of emissions with no load, and is referred to as the idle test. Locales considered “serious” non-attainment areas for ozone control must implement the “enhanced” I/M program, and is referred to as IM240.<sup>22</sup>

I/M programs, under both program types, require that all passenger vehicles (cars and light trucks) undergo periodic testing to determine whether their emission-control systems are functioning well. An inspection test may be annual, biennial, or upon sale of the vehicle, depending on program configuration. Implementing inspection tests can range from a relatively simple and inexpensive tailpipe testing to more complex and expensive dynamometer testing. In the basic I/M program, the inspection test is allowed to be carried out by private testing stations; the enhanced I/M program should be administered by state inspectors.

Analysts have known for some time that the problems with the I/M program transcend technological issues. They involve the most fundamental ideas behind the I/M program, including assumptions that all similar-age vehicles are equally likely to pollute; that emissions component repairs will necessarily reduce

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<sup>22</sup> Source://[www.coax.net/croe/cr0594.htm](http://www.coax.net/croe/cr0594.htm)

emissions level; and that behavioral incentives are less important than technological standard-setting.

In addition to these technical and conceptual flaws, increasing attention is being given to the misguided incentives created by the basic I/M programs. Rather than creating incentives for motorists to maintain their vehicle's emissions systems, basic I/M programs create an incentive to "pass the test" at minimal cost while placing less emphasis on the durability of emissions repair. Incentives to beat the system are manifested in fraudulent tampering behavior by mechanics and motorists. These observations support the contention that the basic program has led to inadequate vehicle repairs.

Under the basic I/M program, mechanics and test station owners are faced with perverse incentives, in which they need to provide cheap certificates if they are to remain competitive. In the worst cases, these incentives lead to cheating. Audits of repair facilities show that, a small percentage of shops specialize in providing certificates or "quick-fixes" that enable a vehicle to pass the emissions test without undergoing any meaningful repairs (Green 1997).

In general, researchers have asserted that the enhanced I/M programs have achieved substantial reduction in mobile emissions coming from high-emitting vehicles compared to the basic I/M program. They attribute this trend to the program's stringent cut points, the way the inspection is done, the fact that the test is administered by state inspectors, or a combination of the above. It is the intention of this study to analyze this assertion.

Using emissions inspection data for two cities in the two different program types (the basic and the enhanced), the study was able to find expected HC and CO emissions failure probabilities. To infer lasting emissions component repairs, one needs to compare expected failure probabilities of vehicles in one testing cycle to the next testing cycle. The testing cycles used in this study are from August through November of 2000 and 2002. The cities that were chosen are Fort Collins, Colorado, and Kenosha, Wisconsin, to represent the basic I/M program and the enhanced I/M program configurations, respectively. Using logit analysis, one can find estimated failure probabilities by placing mean values of vehicle characteristics and emissions results into their corresponding logit coefficients.

To substantiate that the enhanced program, in general, produces emissions reductions in high-emitting vehicles, one need to compare estimated failure probabilities using each city's mean values along with the estimated logit coefficients of the other city. This establishes that emissions reductions and durability of emissions repairs are attributable to stringent cut points.

This study is organized as follow: section 2.2 presents a literature review on comparative studies of the performance of both programs in regard to effective emissions repairs and emissions reductions for both program types. Section 2.3 is a description of both program types, the technical aspects of emissions testing, and discussion of each city's demographics. Section 2.4 is the empirical section which includes two parts -- model specification and a description of emissions and vehicles characteristics for each city. Section 2.5 displays the results and a discussion of those results. Section 2.6 is the conclusion section.

### 3.2 Literature Review

An important aspect of any periodic emissions inspection program is to ensure that the vehicle still has a functional emissions control systems. Vehicles failure of emissions testing could be attributed to one or more piece of failed engine emissions control or evaporative control equipment. Thus, when a vehicle fails emissions testing, it should be repaired.<sup>23</sup> These types of problems probably are avoidable with periodic maintenance. Vehicles also fail inspection tests if one of the emissions component controls is missing in the visual check. Vehicle emissions testing by any technique does nothing by itself to improve air quality. The air only benefits when a failed vehicle is properly repaired.

Repairing failed vehicles involves time and monetary costs. The monetary costs can range from tens to hundreds of dollars depending on the faulty component. Numerous scholars have found that repair expenditures bear little relation to effective repairs. Harrington and McConnell (1999a) compiled data from various studies on average repair expenditures and the average vehicle's emissions before and after repair. This data is displayed in Table 3.1.

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<sup>23</sup> Failure can occur for many reasons, ranging from faulty spark plugs to broken catalysts, missing or damaged gas cap, and faulty exhaust gas recirculation.

<b>Table 3.1 Comparison of EPA Repair Effectiveness Assumption with Results of Non-EPA Empirical Studies</b>				
	Number of Vehicles	Average Cost	Average emissions <sup>a</sup>	
			Before repair <sup>b</sup>	After repair <sup>b</sup>
<b>EPA Repair Dataset (FTP)</b>	266	-		
HC			3.13	1.24
CO			44.8	12.7
NOx			-	-
<b>California I/M Review Committee (1993)</b>	681	\$89.55		
HC			4.94	3.7
CO			48.4	41.4
NOx			2.12	1.89
<b>Sun Company (Cebula 1994)</b>	155	\$338.55		
HC			4.83	1.55
CO			69.2	17
NOx			2.9	2.02
<b>Total Petroleum (Lodder and Live 1994)</b>	103	\$390.21		
HC			3.66	2.48
CO			45.64	33.38
NOx			-	-
<b>California I/M Pilot Project FTP (Patel et al. 1996)</b>	199	\$305.50		
HC			3.34	1.65
CO			35.9	20.8
NOx			2.05	1.23
<b>Arizona Enhanced I/M (Ando et al. 1999)</b>	5909	\$199		
HC			2.69	1.7
CO			40.4	25.7
NOx			3.14	2.24
<b>a All emission measurements were made with FTP, except for Arizona I/M, which used the IM240 test</b>				
<b>b Emissions are measured in g/mi</b>				
<b>Source: Harrington and McConnell (1999a)</b>				

Harrington and McConnell (1999a) illustrate that repair expenditures have a minute relationship to emissions reductions from failed vehicles. From Table 3.1, one can compare the percentage decrease in average emissions among different studies and their corresponding average costs. At a cost of \$89.55, there is a 25 percent reduction of HC emissions under the California I/M review committee study compared to 67 percent under the Sun Company at an average cost of \$338.55; 32 percent under Total Petroleum at an average cost of \$390.21; 50 percent under I/M Pilot Project FTP at an average cost of \$305.50; and 37 percent under the Arizona Enhanced I/M at an average cost of \$199 for HC emissions reduction. Also, comparing the average CO emissions reductions for Total Petroleum and Arizona Enhanced I/M, there are 27 and 36 percent average reductions at costs \$390.21 and \$199, respectively. Using this criterion, higher average cost did poorly when compared to lower average repair expenditures.

Motorists' expectations of high repair costs for emissions-related problems have been emphasized by researchers and regulators. This expectation is attributed to the lower benefits achieved from existing I&M programs. Consumers will most likely try to reduce high repair costs when given alternative options because of their experiences with vehicle engineering repair or repairs offered by their mechanics. Therefore, tampering or fraud by mechanics or motorist is a continual problem for I/M programs (centralized and decentralized alike).<sup>24</sup> These problems are the focal

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<sup>24</sup> Tampering can be illustrated by disconnecting the catalytic converter in the exhaust for increased circulation, thus better performance (faster car). Fraud can be illustrated by recycling the exhaust gas back into the combustion chamber. Although this procedure is not sustainable for more than 5 minutes, it will yield cleaner tailpipe emissions.

point of interest to some researchers and legislators. Attempts to mitigate tampering and fraud have been explored and tested.

Tampering, as defined by the EPA, is based on observations of disconnection, missing, and obviously modified emissions control devices and provide the clearest indication of the extent to which motorists and/or mechanics are deliberately trying to defeat emissions control systems. As an example, vehicle owners may remove the catalytic agent from converters in an effort to increase exhaust efficiency and therefore performance. With this procedure, HC flowing out of the combustion chamber is not broken down to H<sub>2</sub>O and CO<sub>2</sub>. Tampering has been emphasized by scholars as one of the major causes that undermine the achievement of I/M program goals. According to Lawson (1993)

It is clear that I/M programs, regardless of the (program) type, have not made much progress toward reducing the occurrence of tampering, one of the causes of high emissions from mobile sources (Lawson 1993, 1568)

Fraud is an action taken by technicians and motorists to help the vehicle pass emissions testing by adjusting emissions control devices to reflect a cleaner vehicle. Helping the car pass the emissions test is important for 1986 vehicles and older. With carburetor technology, it is a matter of adjusting the level of O<sub>2</sub> and fuel mixture to give the right emissions levels.

Given current practices in many states of not charging for a retest, motorists may repeat the test indefinitely; there is no way of determining at each visit to the testing station whether any serious repair attempts have been made. Harrington and

McConnell (1999a) examined IM240 data for Arizona. Their findings suggest that this method is being employed on occasion, because there are vehicles that have appeared for testing more than five times.<sup>25</sup>

A number of studies have shown that some vehicles have reductions that last a very short time. Lawson (1993) observed that many high-emitting vehicles stopped at random roadside pullovers had either passed their emissions test in the previous 90 days or went on to pass their emissions test in the following 90 days. This finding suggests that some repairs were of short duration and were done simply to pass the test. Wenzel (1998) illustrates reduction in repair effectiveness over time. His contentions are supported by the statistics available; 40 percent of vehicles that failed in the first I/M testing cycle failed in the next I/M testing cycle, compared to 7 percent of the vehicles that passes the first I/M testing cycle.

The IMRC study (2000) found, using change-of-ownership data that approximately 20 percent of vehicles that failed, then later passed, would have failed again immediately after the test. Nevertheless, the IMRC study found that 80 percent of the vehicles appeared to have received lasting repairs and displayed emissions reductions for NO<sub>x</sub> that extended at least a year. For HC emissions, the deterioration of those benefits began after nine months. The IMRC study was not able to look beyond a year after repair.

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<sup>25</sup> Profiles of emissions of a single vehicle over time show enormous variation in emissions depending on many vehicle characteristics, including speed, acceleration, and whether the vehicle is in "cold start" mode (Harrington and McConnell, 1999a). Vehicle owners recognizing these differences drive them for multiple trips to emissions testing station, hoping to get the right emissions composition in each attempt.

McClintock (1999) found in Colorado, using remote-sensing data, which a significant amount of the emissions reductions estimated from data obtained in the inspection lane, was lost within one month of the final test. Also, Wenzel (in press) found in Arizona that half of on-road benefits disappear after one year and that 40 percent of the vehicles that fail in one I&M cycle fail again in the next cycle. Moreover, Rajan (1996) found in a California study that, on average, vehicle emissions of the repaired vehicles returned to their original level after two years. There is also evidence that some emissions reductions last for much longer periods.

Existing programs provide most consumers with little incentive to maintain their vehicles; rather they are motivated to pass periodically scheduled emissions inspections. This leads consumers to fulfill I&M requirements without improving their vehicle's "in-use" emission conditions (Hubbard, 1997b).<sup>26</sup>

Even when an emissions-related repair is conducted by a professional certified technician, the repair is not guaranteed to generate a "clean car." As reported by NRC (2001), this problem is illustrated in an "emission related repair" study commissioned by the California I/M Review Committee for which a large "undercover car" investigation took place. This inquiry sent a sample of nearly 5,000 vehicles to random inspection stations in various California cities in order to evaluate the Smog Check program in its vicinity. The nearly 700 vehicles failing the initial test were then followed through the program until they received a Smog Check certificate. Improvements in these vehicles were compared against before-

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<sup>26</sup> According to Hubbard (1997b), in order to provide consumers with incentives that will improve vehicle "in-use" conditions, regulators should implement nonscheduled emissions testing.

and-after emissions tests on each vehicle. The results showed that over half the vehicles actually had higher emissions after repair than before.

In summary, there appears to be a distribution of duration of repairs to vehicles that do have emissions reductions as a result of I&M. The distribution ranges from a matter of days to several years. There is a need to study the factors that influence how long repairs last-- for instance, how different I&M program configurations (centralized versus decentralized) might affect repair durability.

Some researchers have sought to analyze repair effectiveness by comparing estimated failure probabilities of different program types, among them Bovee (2003). Bovee analyzed the impact of the transition of I/M programs from the basic (decentralized) to the enhanced IM240 (centralized) in southern Wisconsin in 1995. He concludes that the program not only realized a 24 percent reduction in HC emissions, it is also credited for identifying high-emitting vehicles. He adds that centralized programs are also credited for improving repair effectiveness compared to decentralized programs. Concurring with Bovee (2003)'s findings, the EPA concluded that centralized programs have, generally, produced greater benefits in terms of emissions reductions than decentralized programs (EPA 1992).

Bin (2003) relied on logit analysis to identify vehicles that are more likely to be high polluters and fail the test. Using emissions-testing data from Portland, Oregon, he estimated logit equations for the likelihood of carbon monoxide and hydrocarbon emissions violations given a particular set of vehicle characteristics. He modeled a vehicle's emissions data as a function of the vehicle's age, odometer reading, make, model, engine size, type of transmission, and number of cylinders within one

emission testing cycle. His aim was to identify vehicles with certain emissions data and vehicle characteristics that are more likely to fail. His results indicate that vehicle age, engine size, and odometer reading all play a significant role in determining the probability of emissions test failure.

Bin's method paved the way for this study. This study analyzes the estimated HC and CO failure probabilities given vehicles' characteristics for two cities, Fort Collins, Colorado, and Kenosha, Wisconsin. Given the argument that centralized testing programs, generally produce durable emissions repairs compared to the basic program, this study tests this assertion. Using data for two testing cycle years, 2000 and 2002 this study compares the estimated failure probabilities for both cities in the stated testing cycles. Also, because centralized I/M programs have stringent cut points compared to decentralized programs, this study exchanges the CO and HC logits coefficients for the alternate city's mean values.

### 3.3 Analytical Framework

This section includes a description of both program types, some technical aspects of each program type, and statistics on both cities.

#### 3.3.1 Program Types

##### 3.3.1.1 The Basic I/M Program (Idle Test)

According to the NRC (2001) report, the idle test is a steady-state unloaded test using a tailpipe probe to measure directly the concentrations of CO, and HC emissions, and CO<sub>2</sub> in exhaust emissions from idling vehicles.<sup>27</sup> A high-idle test, in which engine speed is manually increased to ~2,500 rotations per minute (rpm), is sometimes performed in addition to the natural, or “low-idle,” test. In all cases, there is no load applied to the engine. NO<sub>x</sub> concentrations are not usually measured as part of idle tests because NO<sub>x</sub> emissions are low if the engine is not under a load. The emissions test duration is set to last for 30 seconds.

The emissions component has three parts -- initial readings (IDLE 1), conditioning (emissions level while the engine is running at 2500 rpm for 30 seconds), and final emissions reading (IDLE 2). In the basic program, vehicles fail emissions tests when they have above standard emissions for their year model for either or both HC and CO emissions after conditioning (IDLE 2 readings.) In

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<sup>27</sup> High CO<sub>2</sub> levels indicate that high percentage of fuel is properly broken down and burned.

decentralized emissions testing, vehicles fail inspection tests if *either* or both HC and CO emissions are above standard. The idle test involves vehicle emissions identified by readings of carbon monoxide (CO) in percentage of total exhaust emissions and hydrocarbon (HC) in parts per million.

Emissions testing in decentralized programs are usually offered by state-independent testing facilities. Some of these facilities have testing and repairs, others have only testing. In order for the basic I/M programs to improve air quality, vehicles for which emissions-related repairs would be effective must fail inspections, and after failing must be repaired such that emissions are low. Elements of traditional I/M programs provide incentives designed to achieve these goals. These threaten to punish motorists if they do not participate, and to punish inspectors and firms if inspectors improperly carry out inspections.

#### **3.3.1.2 The Centralized I/M Program (IM240)**

According to the NRC (2001), the IM240 is a transient, loaded-mode emissions test. “Loaded-mode” refers to the fact that the test is run on a treadmill-like device called a dynamometer, which simulates driving with the engine in gear. The test measures the mass of emissions collected over a 240-seconds, 2-mile driving cycle. “Transient” refers to the fact that the car drives under a load that varies from second to second during the inspection test.

In centralized emissions testing, the failing criterion is based on combination of emissions violations -- HC and NO<sub>x</sub>, or CO and NO<sub>x</sub>, or both HC and CO or either HC or CO emissions. HC, CO, and NO<sub>x</sub> emissions coming out of the exhaust pipe are read as grams per mile.

The emissions inspection test is done at a centralized testing facility and the test is administered by state inspectors. Therefore, in centralized programs, consumers may not choose among firms. In programs using computerized analyzers, software limits the discretion inspectors can exercise. Regulators also attempt to set inspection procedures and performance standards such that only vehicles whose emissions are low during normal use can pass. If successful, these measures limit motorists' decisions regarding which repairs to purchase after their vehicles fail, given that they wish to satisfy I/M requirements (Hubbard, 1997b).<sup>28</sup>

Failing the visual check constitutes failing the inspection test under both program types even if the vehicle has below-emissions vehicle year model cut points.

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<sup>28</sup> According to Hubbard (1997b), regularly scheduled emission inspections failed to enhance ambient air quality. The reasons given by Bin (2003) are (1) the number of vehicles on the road and the number of miles driven per vehicle has increased substantially, and (2) most vehicle emission control systems begin to function improperly while the vehicles are still being driven. Recognizing this in-use emissions problem, Congress, as part of the 1990 Clean Air Act Amendment, required that I&M programs be updated. Accordingly, many states adopted new I&M test procedures such as remote sensing emissions tests.

### 3.3.2 Technical Aspects

The emissions test is applicable to all vehicle owners who live, work, or go to school for 90 days or more each year in any program area. The frequency of the emissions test depends on the model year; 1981 and older vehicles must be tested annually, 1982 and newer vehicles must be tested every two years in the basic program and every year in the enhanced program, and vehicles newer than 2000 are exempt from the testing requirements for the first four years, or until change of ownership.<sup>29</sup> According to NRC (2001), the emissions test includes:

- Tailpipe emissions of carbon monoxide (CO) and hydrocarbons (HC) are measured. Nitrogen oxide (NOx) emissions are not measured in the idle test but are measured in the IM240).
- Visual inspection of emissions control systems (under-hood component), includes:
  - ⇒ oxygen sensor
  - ⇒ check engine light
  - ⇒ catalytic converter
  - ⇒ leaded fuel inlet restrictor
  - ⇒ air injector system
  - ⇒ evaporative canister systems
- Inspection for visible smoke coming from the engine.

The emissions limits for 1982 and newer passenger vehicles are listed in Table 3.2.

For both Kenosha and Fort Collins, there is a decreasing pattern in emissions cut points for newer vehicles; emissions inspection test becomes more stringent for new model vehicles.

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<sup>29</sup> <http://fcgov.com/airquality/emissions-testing.php>

<b>Kenosha*</b>	<b>Model Years</b>	<b>Hydrocarbons (grams/mile)</b>	<b>Carbon Monoxide (grams/mile)</b>	<b>Oxides of Nitrogen (grams/mile)</b>
	1996 and newer	0.6	10	1.5
	1994-1995	0.8	15	2
	1987-1993	0.8	15	2
	1983-1986	2	30	3
	1981-1982	2	60	3
	1980	2	60	4
	1977-1979	3	65	4
	1975-1976	3	65	6
	1973-1974	7	120	6
	1968-1972	7	120	7
<b>Fort Collins**</b>	<b>Model Years</b>	<b>Hydrocarbons (parts/million)</b>	<b>Carbon Monoxide (percent of emission)</b>	
	1989 and newer	220	1.2	
	1988-1980	400	1.5	
	1979	400	2	
	1978-1977	400	3	
	1975-1976	600	3.5	
	1974-1971	1000	4.5	
	1970 and earlier	1000	5.5	
* Source: Wisconsin Vehicle Inspection Program; NR 485.04				
** Source: Motor Vehicle Emissions Inspection Program - Colorado AIR program-Regulation No. 11				

In the tailpipe measurements, emissions analyzers determine the composition of vehicles' exhaust. In the visual check, inspectors determine the condition of the relevant equipment. Vehicles satisfy I/M requirements when they pass both parts of the inspection. Vehicles pass inspection if they satisfy performance standards for tailpipe measurement of hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NOx), and a combination of technological and performance standards on the visual checks. Vehicles that fail their inspections generally must be re-inspected, possibly after repairs. However, if expensive repairs are necessary for vehicles to pass, waivers may relieve the vehicle owners of I/M requirements. The cost threshold beyond which waivers apply generally differs with a vehicle's model year. It also

varies across states. Cost limits apply to all vehicles regardless of whether they failed the idle test or the I/M 240 test.<sup>30</sup> However, these limits do not apply if the vehicle failed for reasons of visible smoke or missing emissions control equipment. Waivers are issued to vehicles that continue to fail the emissions test even after appropriate repairs have been made with receipt verification that rounds of repairs were attempted. According to NRC (2001), for an owner to be eligible for a waiver, all items on the following checklist must apply:

- The vehicle has failed the emissions test two or more times.
- Engine parameters are set to manufacturer's specifications.
- The vehicle did not fail for visible smoke or missing emissions control equipment (the repair spending limits do not apply to vehicles that smoke or are in tampered condition).

All repair receipts and Vehicle Inspection Reports (VIR) must be presented to the state waiver inspector.

### **3.3.3 City Statistics**

Fort Collins is a unique city with its geographical location, service sector, and demographic composition, and is not easily comparable with too many other cities, especially given its growth rate. The growth rate is due to the high tech firms operating in and around the city that attract talent by offering higher income to people from around the country. A comparable city to Fort Collins that has a centralized program is Kenosha, Wisconsin.

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<sup>30</sup> <http://www.aircarecolorado.com/vfails.htm>

One important criterion was used to select a comparable city to Fort Collins is median household income. This is an important factor because it determines the amount of disposable income a typical household has in terms of vehicle repair money. Median household income refers to the sum of all income in a given household and is higher in Fort Collins by 5 percent than in Kenosha. Another statistic that was gathered is income per capita, which refers to the average earnings per worker in the labor force. Kenosha has 13 percent lower income per capita than Fort Collins. Table 3.3 illustrates that the city of Fort Collins has a larger population, smaller family size, and younger residents than Kenosha.

	Fort Collins	Kenosha
Population	118,652	90,362
Income per capita	\$22,133	\$19,578
Median household income	\$44,459	\$41,907
People per household	3.01	3.13
Median age	28.4	32.4
Source: <a href="http://www.nationmaster.com/encyclopedia">www.nationmaster.com/encyclopedia</a>		

This study used data on emissions testing for Fort Collins and Kenosha to represent decentralized and centralized I&M program configurations, respectively. Using vehicle identification numbers (VIN), this study was able to match observations about vehicles' emissions for the testing cycles August-November 2000 and 2002. Because inspections are required when vehicles change owners, a vehicle's inspection cycle may shift so that its next scheduled inspection falls two years after the ownership change. This study was able to eliminate vehicles that had

a different owner within two testing cycles. This is a necessary procedure that will allow this study to interpret “same vehicle” as “same consumer” or “same household” when the matching between the two years is done. Also, this procedure allowed the study to omit observations in which vehicles were previously inspected outside the cities of Fort Collins or Kenosha. While in Fort Collins there is a total of 5,216 vehicles that have a matched VIN, Kenosha has 2,051 observations. Although Kenosha has 3,959 vehicles with matched VINs, but due to errors in entering the odometer reading at the time of the test, there are 2,051 useable observations.<sup>31</sup>

The data set includes vehicle identification, characteristics, and emissions results. Vehicle characteristics include vehicle age and type, odometer reading, engine size, and transmission type. The vehicle inspection test includes two components, the emissions and the visual (under-hood) components. The emphasis of this study is on the emissions component test.

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<sup>31</sup> Vehicles that have discrepancies in data recording total 1,908; odometer readings for these vehicles in 2002 were recorded the same as 2000 and in most cases lower than odometer readings for 2000.

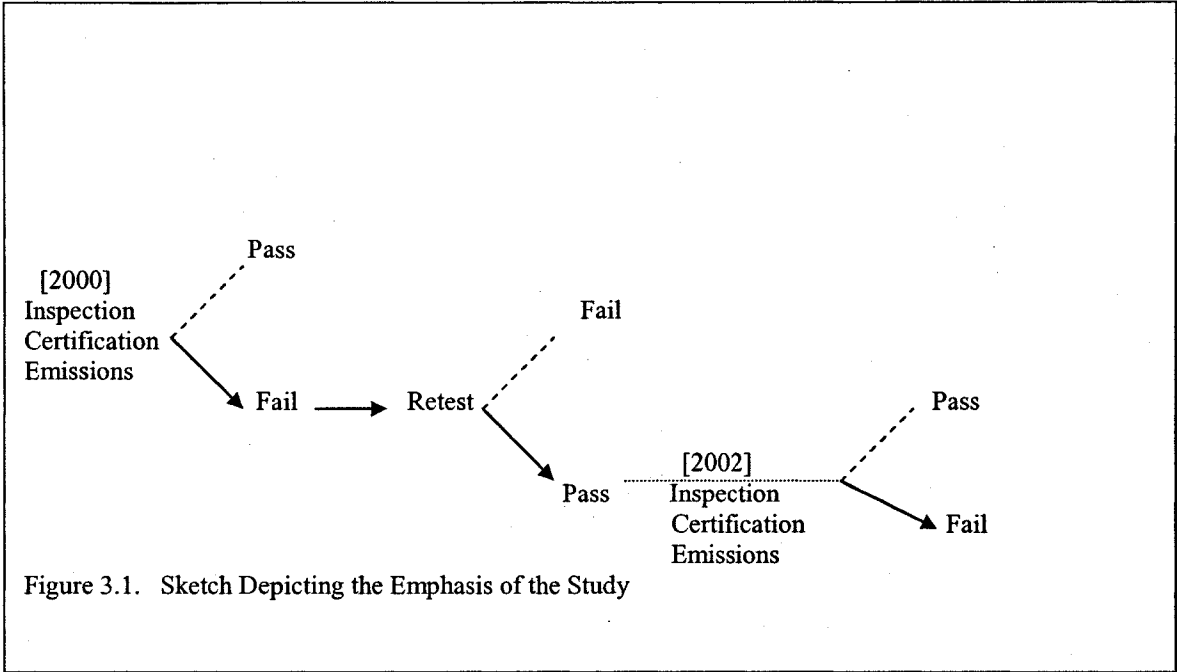
## 3.4 Empirical Framework

### *3.4.1 Model Specifications*

Bin (2003) investigated the characteristics and emissions results that cause vehicles to fail emissions inspection at emissions inspection scheduled programs. The two dependent variables for the logit regression analysis that Bin (2003) constructed are CO and HC emissions results. The dependent variables are binary indicators of vehicles' emissions test failures; they equal one if there are HC or CO failures and zero otherwise. The independent variables are: age of the vehicle, size of the engine, odometer reading, number of cylinders, fuel injection, the presence of an air pump, vehicle transmission property, whether the vehicle is a truck or passenger vehicle, and if the vehicle is imported. His findings indicated that vehicle age, engine size, and odometer readings all play a significant role in determining I/M test results, as do a vehicle's make and class.

His conclusions are no surprise to any technician working in an automobile repair shop. As a matter of fact, any experienced technician can forecast with accuracy a vehicle's probability of failing its emissions test depending on the vehicle's age, make, model, and odometer readings. Bin's (2003) contribution is not in his results but rather in his method, which will be the platform for this study. This study investigates two research questions: first, what is the behavior of consumers' choices with regard to their purchase of emissions-related repairs under both program types?

Vehicle owners who attempt to purchase emissions inspection certificates can either pass or fail. If the vehicle passes its emissions inspection test, then it is in compliance with EPA emissions standards; if the vehicle fails, then it is not in compliance. Motorists can purchase a permanent fix to solve the emissions problem or they can purchase a quick-fix solution. If a quick fix is purchased, then the probability that the vehicle will fail the emissions test in two years is high. The focus is on the estimated failure probabilities for vehicles that failed emissions inspections and then passed in 2000, and on the vehicles that failed the emissions test in 2002. In Figure 3.1, the arrowed bold lines illustrate the above scenario.



The HC and CO emissions readings of the reinspection results for the year 2000 and the HC and CO emissions readings of the first emissions inspection test in 2002 are the dependent variable for this study's logit regression model. To compare repair effectiveness, one needs to compare the estimated failure probabilities evaluated at mean vehicle characteristics with pass results in 2000 to the estimated failure probabilities evaluated at mean vehicle characteristics with fail results in 2002. This will allow this study to test the hypothesis that vehicles in Kenosha got permanent repairs in 2000 compared to Fort Collins.

For the study's second research question, the study tests different program type cut points in determining failure probabilities. One needs to compare the rate of change of the estimated failure probabilities evaluated at mean values for each logit coefficient for each city along with the estimated failure probabilities using alternate coefficients. This will help to test the hypothesis that the stringent cut points of the enhanced program, in Kenosha, increase the estimated failure probabilities and the looser standards of the basic program in Fort Collins decrease the estimated failure probabilities.

Bin (2003) used logit regressions to examine the likelihood of CO and HC emissions violations given a set of vehicle characteristics. He assumed that the probability of emissions test failures depend on a set of vehicle characteristics according to the following logistic cumulative distribution function:

$$P(F = 1) = \Lambda(\beta'X) = \frac{\exp(\beta'X)}{[1 + \exp(\beta'X)]}$$

Where  $P(F=1)$  is the probability that the vehicle fails the emission test given a vector of vehicle characteristics,  $X$ , and  $\Lambda$  represents the logistic cumulative distribution function. The parameters,  $\beta$ s, are estimated by the method of maximum likelihood. Unlike the linear regression model, the parameter estimates are interpreted as the rate of change in the log-odds of test failure as vehicle characteristics change. Therefore, the marginal effects of the vehicle's characteristics on the probability of test failure are calculated as follows (Greene 1997):

$$\frac{\partial P}{\partial x_i} = \Lambda(\beta'x_i)[1 - \Lambda(\beta'x_i)]\beta$$

The marginal effects are evaluated at the means of the characteristics. For carbon monoxide and hydrocarbon emission violations, two alternative specifications will be estimated to detect collinearity among the vehicle's characteristics. In particular, regressions will be estimated with variables for number of cylinders and odometer reading excluded, and then compared to the estimates with these variables included.

### ***3.4.2 Emissions and Vehicle Characteristic Data***

Tables 3.4 and 3.5 display vehicle and emissions means for Fort Collins in 2000 and in 2002, and Tables 3.6 and 3.7 exhibit Kenosha vehicles and emissions means for 2000 and 2002, respectively.

(1)	(2)	(3)	(4)	(5)
Variable Name	Definition	Total (N=5,216)	Pass (N=5,145)*	Fail (N=71)**
HC	Hydrocarbon measured by parts per million after conditioning	77.54 (124.371)	72.5 (102.048)	442.10 (500.449)
CO	Carbon monoxide measured by the percent of total volume of emission gas after conditioning	.2415 (.7081)	.2279 (.66102)	1.2251 (2.06115)
Vehicle age	Model year subtracted from 2000	9.29 (6.361)	9.24 (6.361)	12.85 (5.274)
Odometer reading	Vehicle odometer reading in thousands of miles	80.317 (50.644.72)	79.906 (50.497)	110.116 (52.721)
Engine size	Engine size measured by liters	3.518 (3.1715)	3.521 (3.1874)	3.304 (1.6529)
Cylinders	Vehicle number of cylinders	5.65 (1.584)	5.65 (1.578)	5.69 (1.961)
Transmission	=1 if automatic transmission; =0 otherwise	.6463 (.47817)	.6484 (.47752)	.4930 (.50351)
Vehicle type	=1 if passenger vehicle; =0 otherwise	.5798 (.49365)	.5810 (.49345)	.5638 (.49631)
HC violation	=1 if vehicle has HC violation; =0 otherwise	.0736 (.26118)	.0661 (.24845)	.6197 (.48891)
CO violation	=1 if vehicle has CO violation; =0 otherwise	.0489 (.21565)	.0420 (.20057)	.5493 (.50111)

\* This is the number of vehicles that had "pass" as a final result in 2000 that *include* vehicles failed on their first and even second attempts then passed

\*\* This is the number of vehicles that had "fail" result in 2000

**Table 3.5  
Fort Collins-Variable definitions, means and standard deviation for 2002**

(1)	(2)	(3)	(4)	(5)
Variable Name	Definition	Total (N=5,216)	Pass (N=4,597)*	Fail (N=619)**
HC	Hydrocarbon measured by parts per million after conditioning	105.01 (200.287)	70.44 (97.786)	361.74 (438.740)
CO	Carbon monoxide measured by the percent of total volume of emission gas after conditioning	.3721 (1.03907)	.2211 (.62235)	1.4933 (2.19127)
Vehicle age	Model year subtracted from 2002	11.29 (6.357)	10.96 (6.377)	13.76 (5.633)
Odometer reading	Vehicle odometer reading in thousands of miles	96.385 (57.140)	94.335 (55.723)	111.613 (64.783)
Engine size	Engine size measured by liters	3.428 (2.0325)	3.406 (1.7753)	3.593 (3.3749)
Cylinders	Vehicle number of cylinders	5.64 (1.580)	5.63 (1.574)	5.71 (1.626)
Transmission	=1 if automatic transmission; =0 otherwise	.6526 (.47619)	.6637 (.47250)	.5703 (.49544)
Vehicle type	=1 if passenger vehicle; =0 otherwise	.6005 (.48985)	.6054 (.48882)	.5638 (.49631)
HC violation	=1 if vehicle has HC violation; =0 otherwise	.1262 (.33205)	.0635 (.24392)	.5913 (.49200)
CO violation	=1 if vehicle has CO violation; =0 otherwise	.1116 (.31488)	.0452 (.20787)	.6042 (.48942)

\* This is the number of vehicles that had "pass" as an initial result in 2002

\*\* This is the number of vehicles that had "fail" as an initial result in 2002

**Table 3.6**  
**Kenosha-Variable definitions, means and standard deviation for 2000**

(1)	(2)	(3)	(4)	(5)
Variable Name	Definition	Total (N=2,051)	Pass (N=2,004)*	Fail (N=47)**
HC	Hydrocarbon measured by grams per mile	0.783 (1.457)	.789 (1.473)	.537 (.432)
CO	Carbon monoxide measured by grams per mile	8.678 (19.685)	8.729 (19.884)	6.514 (6.858)
Vehicle age	Model year subtracted from 2000	8.47 (3.786)	8.43 (3.781)	10.49 (3.482)
Odometer reading	Vehicle odometer reading in thousands of miles	70.80 (39.185)	70.83 (39.219)	69.49 (38.21)
Engine size	Engine size measured by liters	3.506 (1.745)	3.505 (1.755)	3.543 (1.261)
Cylinders	Vehicle number of cylinders	5.83 (1.465)	5.82 (1.466)	6.00 (1.445)
Transmission	=1 if automatic transmission; =0 otherwise	.903 (.296)	.903 (.296)	.894 (.312)
Vehicle type	=1 if passenger vehicle; =0 otherwise	.619 (.486)	.620 (.485)	.575 (.499)
HC violation	=1 if vehicle has HC violation; =0 otherwise	.164 (.370)	.166 (.372)	.064 (.247)
CO violation	=1 if vehicle has CO violation; =0 otherwise	.048 (.213)	.048 (.214)	.043 (.204)

\* This is the number of vehicles that had "pass" as a final result in 2000 that *include* vehicles failed on their first and even second attempts then passed  
\*\* This is the number of vehicles that had "fail" result in 2000

(1)	(2)	(3)	(4)	(5)
Variable Name	Definition	Total (N=2,051)	Pass (N=1,663)*	Fail (N=388)**
HC	Hydrocarbon measured by grams per mile	1.145 1.660)	1.154 (1.723)	1.11 (1.362)
CO	Carbon monoxide measured by grams per mile	12.586 (23.168)	12.29 (22.47)	13.858 (25.944)
Vehicle age	Model year subtracted from 2002	10.48 (3.785)	10.02 (3.659)	12.42 (3.704)
Odometer reading	Vehicle odometer reading in thousands of miles	122.8 (51.043)	122.2 (48.212)	125.38 (61.730)
Engine size	Engine size measured by liters	3.482 (2.095)	3.468 (1.83)	3.545 (2.981)
Cylinders	Vehicle number of cylinders	5.77 (1.476)	5.76 (1.494)	5.80 (1.395)
Transmission	=1 if automatic transmission; =0 otherwise	.848 (.359)	.845 (.368)	.8634 (.344)
Vehicle type	=1 if passenger vehicle; =0 otherwise	.604 (.489)	.609 (.488)	.583 (.494)
HC violation	=1 if vehicle has HC violation; =0 otherwise	.257 (.437)	.262 (.439)	.24 (.427)
CO violation	=1 if vehicle has CO violation; =0 otherwise	.081 (.273)	.079 (.270)	.088 (.283)

\* This is the number of vehicles that had "pass" as an initial result in 2002  
\*\* This is the number of vehicles that had "fail" as an initial result in 2002

Variable names and definitions are displayed in the first two columns of Tables 3.4, 3.5, 3.6, and 3.7. The third columns of Tables 3.4, 3.5, 3.6 and 3.7 present variable means and their standard deviations for the matched vehicles and is referred to as the whole market mean. Column 4 of Tables 3.4 and 3.6 displays information about vehicles that have a pass on their *final* test results in 2000. That includes vehicles that have failed their initial inspection and later passed, as well as vehicles that have a pass result on their initial inspection test in 2000. There are 5,145 and 2,004 vehicles from Fort Collins and Kenosha, respectively. Column five of Tables 3.4 and 3.6 includes vehicles that failed the test in 2000. In Fort Collins there are 71 vehicles and there are 47 vehicles, in Kenosha. There is no information in the data

set about these vehicles passing at a later date in 2000. Thus, this study considers these results as a *final* test result for the specified period.

Column 4 of Tables 3.5 and 3.7 illustrates mean values on vehicles that have pass results on their *initial* inspection in 2002. There are 4,597 and 1,663 such vehicles in Fort Collins and Kenosha, respectively. Column 5 of Tables 3.5 and 3.7 consists of data description of vehicles that have fail results on their *initial* inspection results in 2002. There are 619 such vehicles in Fort Collins and 388 in Kenosha.

From the above, the failing rate in 2000 in Fort Collins and Kenosha is 1.36 and 2.29 percent respectively, and failing rate in 2002 is 11.87 percent in Fort Collins and 18.92 percent for the city of Kenosha. It is obvious that the failure rates between 2000 and 2002 in Kenosha is higher than in Fort Collins; it is 0.93 percent and 7.05 percent point differences, respectively. What follow is a description of the data in Fort Collins (Tables 3.4 and 3.5) preceded by a description of the data for the city of Kenosha (Tables 3.6 and 3.7).

### ***Fort Collins***

Column 3 of Tables 3.4 and 3.5 displays market mean values for 2000 and 2002 respectively. The HC emissions are measured in parts per million and emission for CO is measured in percent of total volume. The violations in 2002 are higher than those in 2000, probably because the sample of 2000 includes repaired vehicles to

reflect lower emissions. This can be seen in a higher percentage of passes in 2000 than in 2002; 98.6 versus 88 percent, respectively.

The mean value for HC emissions in 2000 is much lower than that for 2002; 77.54 versus 105.01, respectively. The mean value for CO emissions for vehicles that were tested in 2000 is .2415 as opposed to .3721 in 2002. The mean vehicle age in 2000 is 9.29 years and that for 2002 is 11.29 years (because vehicles are two years older). Odometer readings are approximately 16,000 miles higher in 2002.<sup>32</sup>

Vehicle characteristics like engine size, number of cylinders, transmission and vehicle type should *not* be different for market mean values for 2000 and 2002 since that data set covers exactly the same vehicles for both years. But according to market mean values on the stated vehicle characteristics, in both Tables 3.4 and 3.5 for the city of Fort Collins, they are different. This could be due to human error in entering the data at the time of the test. The market mean engine size is approximately 3.5 liters, and the market mean number of cylinders is 5.6. About 64 percent of vehicles have automatic transmission and there are 58 percent passenger-type vehicles in the whole market sample. In 2002, there are 65 and 60 percent of vehicles with automatic transmission and passenger vehicle type, respectively.

The HC and CO violations are dummy variables that equal one if the vehicle has above model year standard emissions for HC and CO and zero otherwise. In 2000 about 7 and 5 percent of vehicles had HC and CO violations, and in 2002 about 13 and 11 percent of vehicles had HC and CO violations, respectively. These percentages are displayed in Table 3.8 and will be discussed later.<sup>33</sup>

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<sup>32</sup> Odometer readings were divided by 1000 to reflect the same unit as in the Kenosha data.

<sup>33</sup> There are 200 vehicles that received pass results with violations in either CO and HC emissions;

Table 3.8 Percent of HC and CO Failures				
City	2000		2002	
	HC Failure	CO Failure	HC Failure	CO Failure
Fort Collins	7.4	4.9	12.6	11.2
Kenosha	16.4	4.8	25.7	8.1

HC failure is dummy variable equal 1 if vehicles' emissions above HC standard and zero otherwise.  
CO failure is dummy variable equal 1 if vehicles' emissions above CO standard and zero otherwise.

From column 4 of Tables 3.4 and 3.5, it can be seen that the mean emissions for HC and CO are higher (but not by much) for 2000 than for 2002. Mean vehicle age for 2000 and 2002 is 9.24 and 10.96 years, respectively, and odometer reading in 2002 is up by 18 percent. Mean engine size for passed vehicles in 2000 is higher than that in 2002; 3.521 versus 3.406. The number of cylinders is approximately equal in 2000 and in 2002; 5.65 and 5.63, respectively. Approximately 65 percent of vehicles in 2000 and 66 percent of vehicles in 2002 that passed emissions inspection have automatic transmission. Percentages of vehicles that passed inspection and are passenger-type vehicles are about 58 percent in 2000 and 61 percent in 2002. About 6.61 and 6.35 percent of vehicles that passed inspection have HC violations in 2000 and 2002, respectively. About 4.2 percent of vehicles that passed in 2000 and 4.52 percent in 2002 have CO violations.

In column 5 of Table 3.4, although the number of vehicles is small (71 vehicles), HC emissions mean value for 2000 is very high (442.10) compared to market means in 2000 and in 2002. This is because some of the vehicles that

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55 and 145 vehicles with CO and HC violations respectively.

continue to fail their emissions test in 2000 will probably fail it again and are considered high-polluter vehicles. The mean value for HC emissions in 2002 is 361.74, a smaller number than in 2000. This is probably because the high-polluting vehicles' mean emissions are spread over a larger number of vehicles and not just the high-polluters, as was the case in 2000. Mean values for CO emissions in 2000 and 2002 are 1.2251 and 1.4933, respectively; both above their market mean values.

Vehicle age and odometer means (column 5 of Tables 3.4 and 3.5) for both 2000 and 2002 are higher than their market mean values in both years. Vehicles that failed in 2002 have a larger engine size and larger number of cylinders compared to 2000. While the percentage of vehicles that failed in 2002 with automatic transmissions is higher in 2002 than 2000, percentages of passenger-type vehicles are equal for both years. Contrasting the HC and CO emissions violation dummies, about 62 and 59 percent of vehicles have HC violations in 2000 and 2002 and approximately 55 and 60 percent of vehicles have above-standard emissions for CO in 2000 and in 2002 respectively.

### ***Kenosha***

The HC and CO emissions are measured in grams per mile. Cut points vary with vehicle year model, as illustrated in Table 3.2. As in Fort Collins, market means for HC and CO emissions are higher in 2002 than in 2000. Vehicles in Kenosha are two years older in 2002, the same pattern as in Fort Collins vehicles. Market mean value on odometer reading is changed by 52,000 miles in 2002 (column three of Tables 3.6 and 3.7). Compared to the Fort Collins odometer

reading mean increase, Kenosha is higher by 36,000 miles. Probably this is because Kenosha is 30 miles away from Milwaukee and 40 miles from Chicago, and it could be that many Kenosha residents commute to these big cities on a regular basis.

Market means for vehicle characteristics like engine size, number of cylinders, transmission type, and vehicle type on the market mean values should not change from 2000 to 2002. This could be due to human error in entering the data at the time of the test; such error exists in the Fort Collins data as well. The market mean engine size in Kenosha is 3.506 and 3.482 liters in 2000 and 2002, respectively. The number of cylinders for Kenosha in 2000 and 2002 is 5.83 and 5.77, respectively. The percentage of vehicles that have automatic transmission is 90.3 percent in 2000 and 84.8 percent in 2002. Passenger-type vehicles are 61.9 and 60.4 percent in 2000 and 2002, respectively.

The percentages of vehicles that have HC emissions violation for the whole market are 16.4 and 25.7 percent in 2000 and 2002, and CO emissions violation, 4.8 and 8.1 percent in 2000 and 2002, respectively.

Column 4 in Tables 3.6 and 3.7 show that mean values on HC and CO emissions are higher in 2002 than in 2000 for vehicles with pass inspection results. Vehicles are approximately two years older in 2002 and odometer reading mean is up by 51,370 miles in 2002. Mean engine size and the mean number of cylinders in 2000 and 2002 are approximately equal. About 90.3 percent of vehicles have automatic transmission in 2000 and 84.5 percent in 2002, and the percentage of passenger-type vehicles is higher in 2000; 62 versus 60.9 percent. The percent of vehicles that have HC and CO emissions violations is 16.6 and 4.8 percent in 2000,

and that on HC and CO emissions violations in 2002 is 26.2 and 7.9 percent, respectively.

From column five of Tables 3.6 and 3.7, it can be seen that means for HC and CO emissions in 2000 are higher than those for 2002 for fail inspection test results. Vehicles are approximately 2 years older in 2002 and odometer reading mean is higher in 2002 than in 2000 by 80 percent. It is worth mentioning that vehicle age for both 2000 and 2002 fail test results is 2 years older than market mean vehicle age. Engine size is approximately equal for 2000 and 2002; number of cylinders is 6 cylinders in 2000 and 5.8 in 2002. The percentage of vehicles with an automatic transmission is higher in 2000 and the percent of passenger-type vehicles is higher in 2002. Vehicle percentages with HC and CO emissions violations are higher in 2002 than in 2000.

From the above description of the data, it is apparent that the behavior of emissions violation and vehicle characteristics are similar between the chosen cities and between years. Generally speaking, vehicles that failed in 2002 tend to have higher HC and CO emissions and are older. As mentioned in section 2.3, centralized and decentralized programs not only differ in cut points (as illustrated in Table 3.2), they also differ in their failing criteria. In Fort Collins, vehicles fail emission testing if *either* or both HC or CO emissions are above the standard; in Kenosha, the failing criterion is based on a combination of emissions violations; HC and NO<sub>x</sub>, or CO and NO<sub>x</sub>, or both HC and CO emissions or either HC or CO emissions. Failing the visual check component will fail the vehicle in the test under both program types. Therefore, vehicles with pass inspection results will still suffer

from one form or another of emissions violations, or, in the case of failing the visual check, the vehicle does or does not have emissions failures.

Table 3.8 Percent of HC and CO Failures				
City	2000		2002	
	HC Failure	CO Failure	HC Failure	CO Failure
Fort Collins	7.4	4.9	12.6	11.2
Kenosha	16.4	4.8	25.7	8.1

HC failure is dummy variable equal 1 if vehicles' emissions above HC standard and zero otherwise.  
CO failure is dummy variable equal 1 if vehicles' emissions above CO standard and zero otherwise.

Table 3.8 illustrates the percentages of HC and CO failure rates for both Fort Collins and Kenosha in 2000 and in 2002 for the whole market. They are computed using dummy variables that equal one if vehicles have above HC and CO emissions cut points and zero otherwise. Contrasting failure rates between Fort Collins and Kenosha show that there are two consistent patterns in HC and CO failure rates. The first pattern is failure rates across time, and the second is among different emissions failure categories for both cities.

The first pattern recognized is the higher failure rate data in 2002 for both HC and CO emissions for both cities. HC emissions failure rates in Fort Collins are 7.4 and 12.6 percent in 2000 and 2002, and 16.4 versus 25.7 percent in 2000 and 2002 respectively, in Kenosha. This corresponds to higher failure rates in 2002 than in 2000 for both cities. Also, comparing CO emissions failure rates in 2000 and 2002, the failure rate is 4.9 and 11.2 percent for Fort Collins. In Kenosha, it is 4.8 versus 8.1 in 2000 and 2002, respectively.

The second pattern is realized when comparing Fort Collins and Kenosha failures. HC emissions failures for both 2000 and 2002 are higher for Kenosha than for Fort Collins. While CO emissions failure is approximately the same in 2000 for both cities, CO emissions failure is higher in Fort Collins than Kenosha in 2002. The higher HC emissions failures in Kenosha are explained by tighter standards. Higher CO emissions failures in Fort Collins could be explained by vehicle age.

Mean age of failed vehicles in Fort Collins in 2000 is 12.85 years and in 2002, 13.76 years; the mean age of failed vehicles in Kenosha in 2000 is 10.49 years and in 2002, 12.42 years. Fort Collins has an older fleet than Kenosha, which is the result of climate factor, humidity. Vehicles in Kenosha have a rust factor that plays an important role in retiring vehicles early. This factor does not exist in Fort Collins; therefore, the fleet in Fort Collins has a large proportion of “old beaters.”<sup>34</sup> In Fort Collins, vehicles’ long life, combined with a low maintenance level, mean that HC and CO emissions become a problem because older vehicles will have frequent mechanical failures and more breakdowns. Fixing old vehicles could add years to the life of a vehicle, but does not alter vehicle’s age or alter the rate at which vehicle’s conditions deteriorate. Adding to this problem, if older vehicles receive “patching” repairs, this could accelerate the decline in their condition, which might result in more emissions. This could be avoided if proper maintenance and effective repairs were applied.

HC emissions are the result of bad spark plugs, poor ignition wiring, and/or a weak battery. CO emissions are due to mechanical wear which results in poor air circulation and an improper air/gas mixture. Both emissions problems come about

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<sup>34</sup> As explained by a car mechanic.

from the combination of aging vehicles and poor maintenance over the life of the vehicles. As vehicles age, the deterioration in driving condition takes on an accelerated rate. This could explain why vehicles have higher CO emissions failure rates in 2002 in Fort Collins than in Kenosha.

## 3.5 Results

This section has two parts, the first of which has an analysis that was done to check for multi-collinearity among vehicles characteristics. The second part consists of an interpretation of logit analysis coefficients and their impact on the likelihood of HC and CO emissions failures. This includes a discussion on inferences about consumers' incentives toward emissions-related repairs in Fort Collins and Kenosha. It also includes inferences regarding the effect of each program's cut points on the likelihood of failures.

### *3.5.1 Testing for Multi-Collinearity*

Although the presence of collinearity does not undermine the model, it does cause a substantial decrease in the predictability power and it also increases the standard error of coefficients of highly collinear variables (Achen 1982). It should be noted that large variances of the estimated regression coefficients may exist even if there is no multi-collinearity, either because the explanatory variables have a small dispersion or because  $\sigma^2$  itself is large (Kemanta 1986, pp 438.)

To test for collinearity among vehicle characteristics, logit analysis was conducted. The dependent variables are dummy variables for HC and CO emissions for which the dummy variable on HC emissions equals one if the vehicle has above HC emissions standard and zero otherwise. The dummy variable on CO emissions equals one if the vehicle's emissions are above CO emissions standard

and zero otherwise. For each HC and CO emissions violation, two alternative specifications are estimated to detect multi-collinearity among vehicle characteristics. In particular, regressions are estimated with variables for “number of cylinders” and “odometer reading” excluded, and then compared to the estimates with these variables included. The reason for choosing these variables is that it is expected that “engine size” and “number of cylinders” will go side by side, as well as “odometer reading” and “vehicle age.” This procedure was implemented by Bin 2003.

Eight logit models were estimated for both cities for both HC and CO emissions violations, and results are presented in Tables 3.9 and 3.10 for Fort Collins and Kenosha, respectively.

Table 3.9								
Logit estimates for vehicle emissions test failure - Fort Collins								
Variable	2000				2002			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	-2.808*	-4.003*	-3.973*	-4.689*	-2.363*	-3.657*	-3.305*	-3.867*
	(.152)	(.293)	(.199)	(.354)	(.137)	(.243)	(.148)	(.255)
Vehicle age	.020*	.009	.093*	.090*	.016*	.009	.089*	.089*
	(.008)	(.009)	(.009)	(.009)	(.006)	(.007)	(.006)	(.007)
Passenger	.087	.280*	.075	-.003	.108	.246*	.083	.093
	(.111)	(.124)	(.139)	(.151)	(.092)	(.099)	(.098)	(.106)
Engine size	.012	-.006	-.001	-.017	.064*	.035	.047*	.046*
	(.014)	(.022)	(.026)	(.041)	(.020)	(.020)	(.018)	(.020)
Automatic	-.022	-.177	.006	-.053	-.081	-.183	-.193*	-.183
	(.113)	(.126)	(.140)	(.155)	(.091)	(.101)	(.096)	(.107)
Number of cylinders		.178*		.094		.166*		.039
		(.046)		(.062)		(.038)		(.040)
Odometer		.004*		.003*		.005*		.003*
		(.001)		(.001)		(.001)		(.001)
Log-Likelihood function	-2,734.742	-2,706.545	-1,911.550	-1,902.646	-3,932.227	-3,866.904	-3,420.077	-3,399.830
Log-Likelihood ratio	56.394		17.808		130.646		40.494	
Notes:								
Number of observations 5,216, Standard error in parenthesis, * Significant at .05								

	2000				2002			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	HC failure	HC failure	CO failure	CO failure	HC failure	HC failure	CO failure	CO failure
Constant	-1.963*	-3.731*	-3.819*	-6.523*	-2.127*	-3.000*	-3.476*	-5.475*
	(.293)	(.370)	(.447)	(.662)	(.270)	(.334)	(.389)	(.530)
Vehicle age	-.006	-.008	.015	.013	.009	.007	.012	.011
	(.016)	(.016)	(.026)	(.026)	(.014)	(.014)	(.021)	(.021)
Passenger	.726*	.768*	1.001*	1.178*	1.167*	1.127*	1.217*	1.423*
	(.151)	(.146)	(.264)	(.284)	(.131)	(.126)	(.215)	(.212)
Engine size	.136*	.002	.085*	-.084	.268*	.077	.117*	.040
	(.053)	(.043)	(.038)	(.206)	(.048)	(.060)	(.053)	(.028)
Automatic	-.647*	-.679*	-.344	-.542	-.852*	-.837*	-.409	-.623*
	(.191)	(.199)	(.334)	(.356)	(.141)	(.143)	(.218)	(.229)
Number of cylinders		.226*		.430*		.174*		.295*
		(.057)		(.174)		(.059)		(.064)
Odometer		.012*		.011*		.004*		.004*
		(.002)		(.003)		(.001)		(.001)
Log-Likelihood function	-1,795.862	-1,719.171	-768.620	-730.641	-2,226.931	-2,203.776	-1,106.091	-1,076.468
Log-Likelihood ratio	153.382		75.958		46.31		59.246	
Notes:								
Number of observations 3,959, Standard error in parenthesis, * Significant at .05								

Columns 1, 2, 3, and 4 of Tables 3.9 and 3.10 display model specification for 2000 data and columns 5, 6, 7, and 8 of Tables 3.9 and 3.10 include logit model coefficients for 2002 data. Columns 1, 3, 5, and 7 of Tables 3.9 and 3.10 are logit models with the excluded variables, and columns 2, 4, 6, and 8 of Tables 3.9 and 3.10 are logit models with variables included.

With the exception of coefficients on engine size for HC failure specifications for Fort Collins in 2000 and coefficients on passenger-type and automatic transmission dummy variables for CO emissions failures for Fort Collins in 2000 specification, coefficient signs are unchanged across columns. Also, coefficient sign change in the CO failure specification in 2000 for Kenosha is unchanged.

The magnitude of coefficients effect differ slightly for both “included and excluded” variables specifications. Also, similarly to Bin 2003, some coefficients on variables became significant and others became insignificant for both the

included and excluded variable specifications. This is most obvious in the Fort Collins logits. The coefficient on vehicle age for both 2000 and 2002 in HC failure models is significant in the excluded variable specifications. In addition, engine size in the HC failure logit is significant only in 2002 with the excluded variable specification in Fort Collins. Furthermore, in Fort Collins, coefficient on automatic transmission dummy variable in the CO failure model in 2002 is significant in the excluded variable specification. Also, in Fort Collins, coefficients on passenger-type dummy variable in the HC failure specification for both years are insignificant in the excluded specification. In Kenosha, the engine size coefficient is significant in HC and CO excluded variable specifications for both years. Also, the automatic transmissions dummy variable in the CO failure in 2002 is significant in the included specification. The only coefficient that has both changed sign and significance change is the engine size variable in the CO emissions failure in Kenosha in the 2000 specification; in the excluded specification it is positive and significant, and in the included specification it is negative and insignificant.

From the above discussion it can be seen that even change in coefficient significance it does not preclude the existence of collinearity among vehicle characteristics. Running a correlation to check for an association among vehicles' "odometer reading and age" and "engine size and number of cylinders" for the Fort Collins data revealed that it is .075 and .681 in 2000 and 2002, respectively. The correlation between vehicle "odometer reading and age" and "engine size and number of cylinders" for Kenosha is .152 and .634 in 2000 and 2002, respectively. It is reported that if the correlation is in excess of .8, then multi-collinearity

becomes a serious problem (Gujarati 1995, 335). Thus, results indicate little evidence of collinearity among vehicle characteristics.

The bottom of Tables 3.9 and 3.10 shows the likelihood ratio statistic for testing the joint significance of the two excluded variables. The likelihood ratio is calculated by subtracting the likelihood function of logit specifications of the included variables from the likelihood function with excluded variable specifications multiplied by two. Given the critical chi-square value of 13.28 at the .01 significant level, the joint null hypothesis is rejected for both CO and HC failures models for Fort Collins and Kenosha specifications. Thus, both excluded variables in all specifications have significant impact on the model's predictability power.

### ***3.5.2 Inference about Failure Probabilities***

This section consists of two parts, the first of which is testing consumers' behavior toward emissions related repairs using each city's estimated logits and their respective coefficients. The second part, test the likelihood of failures using each city's coefficients with alternate city's means. This will help draw inferences about programs' standards in determining the estimated failure probabilities.

### *3.5.2.1 Estimating Failure Probabilities*

The estimates of logit analysis presented in Tables 3.9 and 3.10 (columns 2, 4, 6, and 8) indicate differences and similarities in coefficient significance for each of HC and CO logits for each city. Testing for HC failures in Fort Collins (columns 2 and 6 of Table 3.9) in 2000 and 2002 suggests that the likelihood of HC failures increase if the vehicle is a passenger-type vehicle with a large number of cylinders and has high mileage. Thus, in Fort Collins, if vehicles have a combination of being a passenger-type vehicle with a large number of cylinders and is highly driven, it increases the likelihood of HC failures. In addition, in Fort Collins, the likelihood of CO failures increases with vehicle age, and with high mileage in both years in 2000, and vehicle age and high odometer and engine size coefficients for only 2002 (columns 4 and 8). Hence, older and highly driven vehicles with a large engine size have a higher the likelihood for failing the CO emissions test.

The estimates for the city of Kenosha, from Table 3.10 columns 2, 4, 6, and 8, suggest that passenger type, large number of cylinders, and highly driven vehicles increase the likelihood of HC and CO failures for both 2000 and 2002. Automatic transmission reduces the likelihood of HC failure in 2000 and in 2002 and reduces the likelihood of HC and CO failures for 2002.

To test the impact of coefficients on influencing failure probabilities, one needs to evaluate regression equation outputs against their sample means. Using sample means for pass and failure categories from Tables 3.4, 3.5, 3.6, and 3.7, and the coefficients from Tables 3.9 and 3.10, one can compute the magnitude of logit

coefficients on HC and CO failure probabilities for 2000 and 2002 for both cities as implemented by Bin 2003.

Using coefficients in column 2 of Table 3.9 and “pass” sample means (column 4 of Table 3.4), one can compute HC failure probabilities for Fort Collins in 2000. Also, using coefficients from column 4 in Table 3.9 and “pass” sample means (column 4 of Table 3.4), one can compute CO failure probabilities for Fort Collins in 2000. The results of the above two scenarios are 8.09 and 2.68 percent for HC and CO failures, respectively. To compute HC and CO failure probabilities evaluated at “fail” sample means for Fort Collins in 2000, one can use the coefficients in columns 2 and 4 of Table 3.9 using “fail” sample means from column 5 in Table 3.4. The results are 9.15 and 4.07 percent for HC and CO failure probabilities, respectively. To compute HC and CO failure probabilities for Fort Collins in 2002, one can repeat the above process using logit models presented in columns 6 and 8 in Table 3.9, and “pass” and “fail” sample means presented in Table 3.5 (columns 4 and 5). The results of the above eight scenarios are presented in the first two rows of Table 3.11.

<b>Table 3.11</b>					
<b>Probability of failure</b>					
Probability of failure in 2000			Probability of failure in 2002		
<b>Fort Collins</b>					
	HC	CO		HC	CO
(1) Pass means	<b>0.0809</b>	<b>0.0268</b>	Pass means	0.1222	0.0861
(2) Fail means	0.0915	0.0407	Fail means	<b>0.1337</b>	<b>0.1174</b>
<b>Kenosha</b>					
	HC	CO		HC	CO
(3) Pass means	<b>0.1822</b>	<b>0.0812</b>	Pass means	0.2164	0.0525
(4) Fail means	0.1815	0.0820	Fail means	<b>0.2111</b>	<b>0.0513</b>

The first row in Table 3.11 shows HC and CO estimated failure probabilities evaluated at their “pass” sample means for both years 2000 and 2002 for Fort Collins. It is clear that expected failure probabilities for HC and CO are higher in 2002 than in 2000. In Fort Collins, HC and CO failure probabilities evaluated at “pass” sample means in 2002 increased by 4.13 and 5.93, respectively. Also, row 2 of Table 3.11 illustrates that when HC and CO estimated failure probabilities evaluated “fail” sample means, failure probabilities are higher in 2002 than in 2000; they increased by 4.22 and 7.67, respectively.

HC and CO estimated failure probabilities for Kenosha are found using coefficients in Table 3.10 (columns 2, 4, 6, and 8) and evaluated at their sample means of “pass” and “fail” presented in Tables 3.6 and 3.7 for 2000 and 2002, respectively. The results are presented in the bottom half of Table 3.11. From row 3, HC and CO estimated failure probabilities evaluated at “pass” sample means in 2000 are 18.22 and 8.12, respectively. Also, in 2002 HC and CO estimated failure probabilities, evaluated at “pass” sample means, are 21.64 and 5.25, respectively. Kenosha’s estimated failure rates due to CO emissions violation are lower in 2002 than in 2000 when evaluated against “pass” sample means. In addition, row 4 indicates that CO estimated failure probabilities, evaluated at “fail” sample means, are lower in 2002 than in 2000.

### 3.5.2.2 The Impact of Regulations on Estimated Failure Probabilities

In Fort Collins, for vehicles to fail their emissions test, they have to record above standards for either CO or HC emissions, as opposed to Kenosha. Kenosha standards dictate that vehicles fail the test as a result of a combination of pollutant violations. Also, in Fort Collins, the cut points are more lenient than that in Kenosha. To test the differences in both programs on the estimated failure probabilities, one needs to evaluate each city's market mean values against the other city's logit coefficients. Table 3.12 presents the results of this evaluation.

		2000		2002	
		HC	CO	HC	CO
Fort Collins Means	with its respective coefficients	0.081	0.027	0.124	0.089
	with Kenosha coefficients	0.227	0.053	0.224	0.051
Kenosha Means	with its respective coefficients	0.182	0.046	0.216	0.052
	with Fort Collins coefficients	0.081	0.024	0.144	0.090

Using Fort Collins 2000 mean values and the city's respective logit coefficients, it is revealed that the estimated HC and CO failure probabilities are 8.1 and 2.7, respectively. When the expected failure probabilities for Fort Collins are estimated using Kenosha's logit coefficients, it shows that there is an increase in estimated failure probabilities to 22.7 and 5.3 for both HC and CO emissions, respectively. What this means is that if the average vehicle in Fort Collins were tested in Kenosha in 2000, there would be a 180.25 percent increase in failure rates due to

HC emissions violation. Also, if the average vehicle in Fort Collins were tested in 2000 using Kenosha standards, there would be a 96.29 increase in the probability rate that the vehicle would fail its emissions test due to CO emissions violation. The percent of change in estimated failure probabilities for HC and CO emissions violations are presented in Table 3.13.

	2000		2002	
	HC	CO	HC	CO
Fort Collins	180.25%	96.29%	80.65%	-42.70%
Kenosha	-55.49%	-47.83%	-33.33%	73.08%

To evaluate Kenosha's average vehicle characteristics against Fort Collins standards, one needs to estimate failure probabilities for Kenosha's means and its respective logit coefficients and then compare this to the estimated failure probabilities using Kenosha's means and Fort Collins logit coefficients. Table 3.12 presents this analysis. HC and CO failure probabilities using Kenosha's means and its respective coefficients for 2000 are 18.2 and 4.6, respectively. When Kenosha's means are evaluated using Fort Collins logit coefficients, there is a decrease in the estimated HC and CO failure probabilities; 8.1 and 2.4, respectively. What this demonstrates is that if the average vehicle in Kenosha is tested using Fort Collins standards, there will be an expected decrease in HC and CO failure probabilities by 55.49 and 47.83 percent, respectively. This is presented in Table 3.13. This means

that Kenosha's stricter standards in 2000, if applied to Fort Collins vehicles, would increase the likelihood of failure. And if Fort Collins cut points were implemented in Kenosha in 2000, this would decrease the likelihood of failure. This supports researchers' finding that vehicles in states with more lenient standards will have reduced failure rates

Tables 3.12 and 3.13 reveal that the average car in Fort Collins will experience an increase in HC estimated failure probability rate by 80.65 percent in 2002. Also, the average car in Kenosha would have a decrease in estimated HC failure probability by 33.33 percent if tested in Fort Collins in 2002.

The decrease in estimated CO failure probabilities for Fort Collins using Kenosha's logit coefficients, and the increase in estimated CO failure probabilities for Kenosha using Fort Collins logit coefficients is probably explained by the differences in odometer reading means for Fort Collins and Kenosha. Kenosha's mean odometer reading between 2000 and 2002 increased by 52,000 (73.4 percent) as opposed to Fort Collins readings, which increased by 16,000 miles (20 percent). This could explain the decrease in the rate of change in estimated failure probability of the average Fort Collins vehicle using Kenosha's coefficients and the increase in the rate of change in the estimated failure probabilities of the average Kenosha vehicles using Fort Collins coefficients for the CO logit in 2002. As stated earlier, CO emissions failure is probably due to serious mechanical failures and vehicles with high mileage are prone to higher failures in emissions controls. Therefore, when the average vehicle from Kenosha is tested in Fort Collins, its higher mileage will increase the change in failure probability rates.

### 3.5.2.3 The Impact of the Initial Test Result in Determining Likelihood of Failure

It is reported by Wenzel (1998) that 40 percent of the vehicles that failed their inspection test failed their emissions test in the next testing cycle. Table 3.14 provides comparable results.

	Fort Collins	Kenosha
Initial fail 2000 and initial fail 2002	36.4	21.3
Initial pass 2000 and initial fail 2002	8.8	11.3

From the data sample in Fort Collins, Colorado and Kenosha, Wisconsin, Table 3.14 shows that 36.4 percent of the vehicles that received initial fail results in 2000 failed their test in 2002, in Fort Collins. In Kenosha this percentage is lower; 21.3 percent. This implies that vehicles in Fort Collins that experienced initial fail in 2000 have 58.52 percentage points failure rate in 2002 compared to Kenosha. As for those vehicles with initial pass result in 2000 and then failed in 2002 it is lower in Fort Collins compared to Kenosha, 8.8 and 11.3 percent, respectively. This is probably because Kenosha's mean mileage in 2002 increased by 73.45 percent compared to 2000 mileage. In Fort Collins mean mileage increased in 2002 by only 20 percent compared to 2000 mileage; vehicles in Kenosha are driven more in the sample provided. Therefore, with increased mileage more tear and wear takes place and thus probably failing more vehicles in Kenosha compared to Fort Collins. That could explain the higher failure rate in Kenosha's vehicles compared to Fort Collins

when assessing vehicles with “initial pass result” in 2000 with initial failure rate in 2002.

To determine the likelihood of failure in the presence of initial failure in 2000, a binary variable was introduced into HC and CO logits for the data set in 2002. This dummy variable equals 1 if the vehicle experiences initial fail in 2000 and 0 otherwise. I/M regulators postulate that if vehicles failed emissions testing, they need to be fixed before being retested. If repairs were effective then this will reduce their likelihood of failure in current and future years. Therefore, the introduction of this dummy variable is to test whether these repairs were lasting or not for those vehicles that failed in 2000. If repairs were lasting in one program as oppose to another then the coefficient magnetite of this dummy variable on the likelihood of failure is expected to be lower than otherwise. Using 2002 data for both cities, the results of the logistic regressions presented in Table 3.15 with a dummy for initial fail in 2000 included.

Variable	2002		2002	
	Fort Collins		Kenosha	
	HC failure	CO failure	HC failure	CO failure
Constant	-3.466*	-5.591*	-3.007*	-5.476*
	(.305)	(.410)	(.335)	(.531)
Vehicle age	-.06*	.083*	.006	.011
	(.010)	(.010)	(.014)	(.021)
Passenger	.008	.051	1.127*	1.424*
	(.129)	(.171)	(.126)	(.212)
Engine size	.043**	.044**	.078	.040
	(.023)	(.025)	(.06)	(.028)
Automatic	-.391*	-.361*	-.834*	-.621*
	(.131)	(.178)	(.143)	(.229)
Number of cylinders	.105*	.156*	.175*	.296*
	(.048)	(.063)	(.059)	(.064)
Odometer	3.4223	1.461	.004*	.004*
	(8.099)	(1.025)	(.001)	(.001)
Initial 2000 fail dummy	1.365*	1.210*	.287	.233
	(.132)	(.168)	(.378)	(.591)
Log Likelihood function	-2,463.775	-1,472.467	-2,203.218	-1,076.320
Log-Likelihood ratio (8 df)	143.114	183.460	136.388	76.546
Notes:				
Dependent variables in the HC and CO logit specifications are HC and CO failure dummies respectively.				
Number of observation for Fort Collins and Kenosha are 5216 and 2,051 respectively.				
Standard error in parenthesis, * Significant at .05 ** Significant at .1				

Coefficients on “initial 2000 fail” dummy variables in the HC and CO logits in Fort Collins is significant; in Fort Collins, there is approximately 1.4 and 1.2 increase in the likelihood of failures if vehicles experienced initial fail compared to vehicles that did not, due to HC or CO violations, respectively.

In Kenosha the coefficients on this variable are not significantly different from zero in both logit specifications. This suggests that initial failures in 2000 in Kenosha do not determine likelihood of failures in 2002. And it may suggests that

repairs for vehicles that experienced initial fails in Kenosha received proper repairs as oppose to quick-fixes. This is supported by the significance of initial fail in 2000 dummy variable in both HC and CO logit and it increases the likelihood of HC and CO emissions failures in Fort Collins compared to Kenosha.

To test for equal means in the two independent distributions, one need to specify the null hypothesis that the true “initial 2000 fail” dummy coefficients are the same for Fort Collins and Kenosha. To do so, one can subtract Kenosha coefficient on “initial 2000 fail” dummy variable from Fort Collins coefficient on “initial 200 fail” dummy variables then divide the difference by the square root of the sum of the estimated variance of Fort Collins plus the estimated variance of Kenosha coefficient for both HC and CO logits. This is demonstrated in the

following: 
$$\frac{(\beta_{failed\ 2000-FortCollins} - \beta_{failed\ 2000-Kenosha})}{\sqrt{(Var\ \beta_{failed\ 2000-FortCollins} + Var\ \beta_{failed\ 2000-Kenosha})}}$$
. With a one-tailed test

accepting the alternative hypothesis implies the true Fort Collins coefficients are larger than the true Kenosha coefficients in both HC and CO logits.

From the above equation, it was found that this ratio to be 2.6924 for HC logit and 1.590 for CO logit. This ratio has a statistic that has a student’s *t* distribution. The degrees of freedom are the sum of the number of observations for both Fort Collins and Kenosha minus 2; that is 7,265. With one sided, 1 percent significance level the student’s *t* critical value is 2.326. Thus, one can reject the null hypothesis that the true “initial 2000 fail” dummies for HC specifications (Fort Collins and Kenosha) are the same. With one-sided 10 percent significance level of student’s *t* critical value is 1.282, therefore one can reject the null hypothesis that the true

“initial 2000 fail” dummies for CO specifications (Fort Collins and Kenosha) are the same.

With statistically significant coefficients on “initial 2000 fail” dummy variables in Fort Collins logits combined with evidence of random sample distribution between Fort Collins and Kenosha, one can state that there is strong evidence that repairs in Kenosha are more durable than in Fort Collins for vehicles that failed their initial inspection test in 2000.

To find estimated failure probabilities one can use sample mean vehicle characteristics in 2002 (column 3 of Tables 3.5 and 3.7) along with HC and CO coefficients (Table 3.15) and subtract the estimated failure probabilities when the “initial 2000 fail” dummy equals 1 from that when it equals to 0. This procedure is implemented for both Fort Collins and Kenosha and both logit specifications. The results are displayed in Table 3.16.

<b>Table 3.16</b>		
<b>Increases in Estimated Failure Probabilities in 2002</b>		
	HC	CO
Fort Collins	0.489657	0.450299
Kenosha	0.231262	0.257988

From Table 3.16, it is obvious that Fort Collins vehicles in 2002 have higher predicted failure probabilities when compared to Kenosha, when vehicles have initial fail result in 2000. Fort Collins vehicles have increased in estimated failure probability, in 2002, due to HC violation compared to CO violation, if initial fail in

2000 is detected. Kenosha vehicles on the other hand have increased in estimated failure probability in 2002 due to CO violation compared to HC violation, if vehicles experienced initial fail in 2000.

Differences in failing criteria indicate differences in vehicles' conditions. As mentioned earlier in the study that HC violation results probably from low maintenance, while a probable cause for CO violation is serious mechanical wear and tear. Given that vehicles in Kenosha are driven more (than Fort Collins) between inspection cycles, then it is expected that higher estimated failures are due to CO violation, compared to HC violation. On the other hand, vehicles in Fort Collins have higher probability of failing the emissions test due to HC violation when compared to CO violation. Therefore, this could indicate that not only failed vehicles in Fort Collins, in 2000, have less effective repairs (when compared to Kenosha) but also they are less maintained during inspection test cycles.

### 3.6 Conclusions

The Environmental Protection Agency (EPA) is charged with enforcing I/M regulations in states with poor air quality. The implementation of these regulations takes place on the state level. Reflecting different pollution levels, program configurations differ among cities to coincide with their level of ambient air quality. The basic I/M program operates in jurisdictions classified as medium non-attainment air quality areas, and the enhanced program is instituted in regions with serious pollution problems.

Emissions inspection tests in the enhanced programs are offered by state agencies and repairs are conducted at certified privately owned repair shops; this is referred to as a centralized program. In the basic program, emissions testing is carried out by private garages that are equipped with the proper emissions testing equipment. This is referred to as a decentralized program. In both program configurations, vehicles' emissions and inspections involve a periodic emission testing to detect vehicles that are not in compliance with year model emissions standards.

Repairing a failed vehicle is a very important aspect of the effectiveness of I/M programs. Repairs are considered proper when failed vehicles' emissions are below program cut points after repairs. They are considered improper repairs when quick-fixes are done only so that vehicles will pass the test. In this study, an evaluation of repair effectiveness and the effect of different program standards were compared in

two program configurations-- centralized (Kenosha, Wisconsin) and decentralized (Fort Collins, Colorado).

The effect of program cut points was tested first by using each city's fitted logit model to predict probability of failure for both a vehicle with that city's average vehicle characteristics and a vehicle with the other city's average vehicle characteristics.

While it is true that if the average Fort Collins vehicle was tested for HC and CO emissions in 2000 and HC in 2002 using Kenosha's coefficients, the estimated failure probabilities would increase, there is a decrease in estimated CO failure probability in 2002. By the same token, the average Kenosha vehicle, if tested in Fort Collins for HC and CO emissions in 2000 and HC emissions in 2002 using Fort Collins cut points, would have a reduced estimated failure probability, but would experience an increase in CO failure probability in 2002. Probably the increase in the estimated CO failure probability, in 2002, of Kenosha vehicles using Fort Collins standards is because the average Kenosha vehicle experienced a greater increase in miles traveled than did the average Fort Collins vehicle. Apart from this latter finding, more stringent cut points increased estimated failure probabilities for the average vehicle in Fort Collins and the more lenient standards of Fort Collins decreased the estimated failure probabilities of the average Kenosha vehicle.

Also, this study tested the hypothesis that centralized I/M programs generally achieve better repair effectiveness. According to I/M regulations if vehicles fail the inspection test, they need to be re-tested presumably after being fixed. I/M regulators prefer a permanent fix for defective emissions components rather than a

quick-fix. To compare the effectiveness of repairs that were presumably carried out in 2000 for failed vehicles among the two program configurations, one needs to assess vehicle failure probabilities in 2002 given the results of each vehicle's initial inspection in 2000. To do so, one needs to create a binary variable that takes a value of 1 if the vehicle experienced initial fail in 2000, and 0 otherwise. Four logistic specifications were estimated for 2002 for both cities and for both HC and CO failures. Results in Table 3.16 show differences in failure probabilities if vehicles failed the initial inspection test in 2000, and therefore differences in 2000 repair effectiveness between the two programs.

From Table 3.16 one can infer that if Fort Collins vehicles experienced initial failure in 2000, there will be an increase in their 2002 failure probabilities by approximately 49 and 45 percent due to HC and CO violations respectively. Therefore if vehicles in Fort Collins failed the inspection test on their first attempt in 2000, they have a greater increase in their probability of failing the 2002 HC test than in their probability of failing the 2002 CO test.

In Kenosha, vehicles that experienced initial failure in 2000 will have increased failure probabilities of approximately 23 and 26 percent due to HC and CO violations respectively. Therefore, if vehicles in Kenosha failed the 2000 inspection test on their first attempt, the increase in failure probabilities for 2002 is greater for the CO emissions test than for HC emissions test.

Inspection failures due to HC emissions violation can be reduced by conducting proper and periodic vehicle maintenance. Those include periodic oil and filter change, replacing spark plugs, checking on ignition wiring, and battery tests. These

simple tasks can reduce the likelihood of vehicles failing emissions tests due to HC emissions violations. Comparing the increase in estimated HC failure probabilities for both cities one can infer that Fort Collins vehicles are less well maintained in this testing cycle compared to vehicles in Kenosha.

Vehicles that fail the test due to CO emissions violations are likely to have serious mechanical failure and excessive engine wear and tear. CO emissions are a byproduct of incomplete combustion of fuel. In older and less well-maintained vehicles, the fuel combustion mechanism is not carried out efficiently, thus producing excessive CO emissions.<sup>35</sup> One possible way that vehicle owners can fix their excessive CO emissions problem is by rebuilding the engine. The cost of this approach is approximately \$1,500.<sup>36</sup> Given vehicles' mean age combined with the high cost to fix this problem, to overcome the problem of CO emissions violation, the preferences of vehicle owners will likely be to purchase a quick-fix rather than permanent repairs. Comparing the increase in the CO failure probabilities between Fort Collins and Kenosha, one can infer that vehicle owners in Fort Collins are more likely to obtain quick fix repairs for their CO emissions problems rather than apply a permanent solution, compared to owners in Kenosha.

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<sup>35</sup> Due to excessive wear and tear in the piston head, fluids and gases leak into the cylinder case. Also, there is emissions leakage out of the cylinder wall. The wear of the cylinder wall (case) is caused by an abrasive environment (Erjavec and Scharff 1996).

<sup>36</sup> According to car mechanic estimates.

## Chapter Four

### Policy Assessment

## 4.1 Introduction

Vehicle emissions are a significant source of air pollution problems at the local, regional and national levels in the U.S. Although mobile emissions standards have become much more stringent since 1970, pollution from automobiles continues to contribute the lion's share of total pollution (Menz 2002).

Present regulations rely primarily on new-vehicle emissions standards focused at car makers, complemented by inspection programs for testing vehicles' in-use emissions. The idea behind imposing regulations on automakers rather than individual motorists is that a regulation base program is less costly to implement. The program's enforcement cost, though, has surpassed many initial regulators' estimates. This problem, combined with its ineffectiveness, has received the attention of many scholars.

Currently, emissions testing programs are required only in non-attainment areas and have had marginal success in curbing mobile emissions. The impact of previous and present regulation to entice automakers to produce more fuel-efficient vehicles has clearly contributed to decrease in emissions from new cars. However, setting emissions standards for new vehicles only partially addresses the mobile source pollution problem. This is because the percentage of new vehicles comprises just a portion of the entire fleet (Menz 2002). Moreover, more stringent regulation causes increases in the price of new vehicles compared to older ones. This leads consumers to drive older cars even longer and causes aggregate emissions reductions to occur at a slower rate than anticipated (Gruensprecht 1982).

It is becoming increasingly clear to researchers that the combined effect of technological advances and regulation will not be sufficient to control mobile emissions. The difficulty of managing mobile emissions as opposed to stationary-source emissions rests on four points; first, the fact that cars have an entrenched role in the modern lifestyle. This aspect makes controlling for mobile emissions difficult. Second, mobile emissions result from a large number of vehicles, each of which emits a negligible amount of pollution (Menz 2002). Third, despite stricter new vehicles' standards in place, the factory-controlled emissions performance diminishes during normal vehicle use. These problems are even greater when vehicles are not maintained. This is one major emphasis of researchers for the ineffectiveness of inspection and maintenance (I/M) programs (Green 1997).<sup>37</sup> Fourth, emissions tend to be concentrated in a relatively small number of gross polluters. These high emitters contribute to at least half of the mobile emissions problem (Lawson 1995 and Klein and Koskenoja 2002).

The significant number of problems associated with the command and control approach has caused economists, environmentalists, and regulators alike to investigate other means to control for air pollution. Scholars vary in their views on how to solve for existing programs' deficiencies. Some advocate initiatives to complement the present I/M program. Others consider replacing lane testing with incentive-compatible market-based systems.

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<sup>37</sup> Throughout this study the term "I/M program" is used generally as a cover term for all various I/M programs that presently exist in the U.S.

This study examines proposals that seek to complement present I/M programs. It also considers proposals that attempt to substitute the command and control approach with market-based instruments. These proposed techniques tackle two problems: high administrative costs associated with I/M regulation and motorists' incentives towards maintenance and effective repairs.

This study is organized as follows: the first section addresses the technological and legislative background of mobile emissions control. It explores the evolution of automotive technology, accompanied by milestones in U.S. regulations to control for vehicles' emissions.

The second section is an assessment of present I/M regulation in terms of efficiency and equity. The *efficiency* of I/M program is explored using two criteria. The first of these is the effectiveness of I/M programs in controlling/reducing mobile emissions. The second criterion used in evaluating program efficiency relies on cost and benefit analysis. Program *equity* valuations investigate several aspects that contribute to the program's inequitable side effects.

The third section explores proposals by researchers for overcoming program the high administrative cost. These include remote sensing, the Coase approach, and accelerated vehicle retirement proposals. Other proposals address motorists' incentives in regard to maintenance and emissions repair purchases. These are emissions fees and tighter cut-point proposals. There is also a discussion of omnibus proposals that consist of gasoline tax, pay-at-the-pump, vehicle mile travel, and new vehicle sales tax and annual registration fees proposals. The

intention of these bundled proposals is directed at increasing the variable cost of driving.

The fourth section is an analysis of the aforementioned proposals on the grounds of efficiency and fairness. This analysis is associated with critiques (if any) with regard to their potential to solve the programs' deficiencies. The criticism also addresses technical matters and implementation.

The last section is the conclusions and recommendations section. This section summarizes the program's dilemmas and provides recommendations about fixing current problems. Also in this section there is a discussion of the most efficient and equitable proposal that this study finds would solve current I/M programs' shortcomings.

## 4.2 Background

### **Technical aspect of vehicles and legislation background**

Automobile manufacturers have been working toward emission reduction since the early 1950s, when hydrocarbons from mobile emissions were found to be the cause of smog in Los Angeles.<sup>38</sup> The federal government's interest in controlling mobile emission, developed around the same time. This momentum became visible in the law when, in late 1959, California established the first standard for mobile emissions. In 1967, the Federal Clean Air Act was amended to provide for federal standards that apply to vehicle emissions.

According to Erjavec and Scharff (1996), the first sources of emissions to be brought under control were emissions expelled from the crankcase under normal combustion. Positive crankcase ventilation systems (PCV) to route vapors back to the engine intake manifold were developed and incorporated in 1961 vehicles and light trucks sold in California.<sup>39</sup> These systems were installed on all vehicles nationwide beginning with the 1963 vehicle models.

Control of unburned hydrocarbons (HC) and carbon monoxide (CO) in the engine exhaust was the next major development. An air injection reactor (AIR) system was built into vehicles and light trucks sold in California in 1966 (Erjavec and Scharff 1996). Other systems, including the controlled combustion system

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<sup>38</sup> Hydrocarbons are volatile compounds that are a precursor to forming smog (Khan 1996).

<sup>39</sup> The PCV system removes pollutants generated by the piston bowl in the crankcase and then recirculates them into the induction systems.

(CCS), were developed and used nation wide in 1968.<sup>40</sup> That was followed by further improvements in combustion mechanisms to reduce HC and CO emissions.

The 1970 law introduced many modifications to the existing Clean Air Act, among them initiating a strong federal role in air pollution policy. This was accomplished by establishing air quality goals and, for the most part, granted state agencies great latitude in meeting these goals (Harrington and McConnell et al. 1996a). Also, the Clean Air Act Amendment of 1970 established minimum ambient air quality levels for counties violating air standards. These regions are required to achieve cleaner air standards regardless of costs (Kahn 1996). The intention of this was to put further pressure on automobile companies whose products contributed to smog accumulation. Regulating escaped fuel vapor from the gasoline tank and the carburetor float bowl occurred during the 1970s. This is achieved by introducing evaporative control systems.<sup>41</sup> These systems were first installed in 1970 model vehicles sold in California and in most domestically made vehicles beginning with 1971 models (Erjavec and Scharff 1996). Beginning with the 1975 model year, passenger vehicles and light trucks have been equipped with catalytic converters. The converter provides a mean of oxidizing CO and HC emissions in the engine exhaust, a process that lowers the amount of pollutants.

The Clean Air Act Amendments of 1977 required states to implement emissions testing programs to all counties not in attainment of the required ozone and carbon monoxide levels by 1982. This was a nationwide mandate. At the same time, it

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<sup>40</sup> Engine modification systems improve combustion and reduce HC and CO in the exhaust. That includes a heated primary air system, air/fuel control change, engine breathing refinements, and some spark timing control.

<sup>41</sup> Exhaust gas re circulating systems reduce NOx by diluting the air/fuel mixtures with some exhaust gas, which has not burned.

required that all vehicles sold in the U.S. be equipped with emissions control systems. White (1982) estimates that the emissions control investment needed to allow 1981 year models to meet federal emissions standards added \$1,500 to a vehicle's sticker price. Vehicle manufacturers have stressed the cost of compliance and have lobbied Congress for relief (Kahn 1996).

Although fuel injection technology has been around since 1920, it was not until 1980 that some car manufacturers began to replace carburetors with fuel injection systems. Fuel injection usually involves spraying or injecting fuel directly into the engine intake manifold. This process, especially when it is electronically controlled, has several major advantages over carbureted systems. These include improved drivability under all conditions, improved fuel control, and, most importantly, decreased exhaust emissions and an increase in engine efficiency and power. Since the 1995 model year cars, all U.S. manufactured vehicles are equipped with electronic fuel injection systems, as required by law.

The Clean Air Act Amendment of 1990 relaxed some aspects of inspection and maintenance (I/M) programs and it called for the Environmental Protection Agency (EPA) to establish performance standards for two programs, the basic and enhanced I/M programs (NRC 2001). Under these guidelines, areas with moderate pollution are permitted to implement a "basic" I/M program. This consists of stationary tailpipe testing of emissions at different engine speeds with no load, with the testing carried out every two years. Locales considered "serious" non-attainment areas for ozone must implement the "enhanced" I/M program. This test requires annual testing for all vehicles at centralized facilities equipped with dynamometers, on

which vehicles are tested using a simulated driving protocol. The emissions standards for this type of program are associated with tighter cut points than the decentralized program. According to the 1990 Clean Air Act amendments, the EPA designated 98 areas as failing federal ozone standards. In terms of the severity of the smog problem, the EPA classified 43 areas as marginal/barely over the federal standards, 31 as moderate, 14 as serious, and 9 as severe. One area, Los Angeles, was classified as extreme.<sup>42</sup>

To combat emissions from new vehicles, the EPA has required manufacturers of 1996 and newer model year vehicles to add sensors and computers cumulatively called OBD (on-board diagnostic). These systems are designed to illuminate the “check engine” light if an emission problem is diagnosed by the computer. The OBD system is supposed to encourage early preventive maintenance and a lower vehicle usage deterioration rate is predicted.

A major leap in automobile technology occurred with the development of computerized engine control. By 1997, all vehicles manufactured and sold in the United States are required to have computerized control systems. This system is responsible for lower vehicles’ emissions in modern cars. The achievement in emissions reduction is done by controlling the air/fuel mixture by compensating when vehicles start cold. Accordingly, it enables engines to make rapid changes to match changes in temperature, load, and speed (Erjavec and Scharff 1996). As many authors have noted, I/M programs appear to have served their designed purpose – the reduction of emissions from new vehicles. Consequently, I/M

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<sup>42</sup> Source://www.coax.net/croe/cr0594.htm

programs have been effective in forcing the automobile industry to make more fuel-efficient vehicles.

Beyond on-board emissions control devices, one of the most important developments for lower emission levels has been the availability and use of unleaded gasoline. Beginning with 1971, vehicles have been designed to operate on unleaded fuels (Erjavec and Scharff 1996.) Removing lead from gasoline brought some immediate benefits. It eliminated the emission of lead particles from vehicles' exhaust. It also prevented lead deposit formulation in the combustion chambers (which tend to increase HC emissions) and had the side effect of increasing spark plug life.

Fuel economy regulation is relevant when studying vehicle emissions because emissions per mile of driving are equal to emissions per gallon multiplied by gallon per mile (Kahn 1996). Fuel economy has been regulated through the CAFE (Corporate Average Fuel Economy) standards. Car makers have an incentive to achieve lower emissions by increasing fuel economy (Kovalsky 2003). Increased fuel economy offers car makers a double payoff because it decreases the likelihood that they will have to pay CAFE fines and increases the likelihood that they will meet the emissions per mile standards (Ayres 1998). This policy increased the average new vehicle fuel economy from about 15 to 27.5 miles per gallon in 1985 (Ayres 1998).

The federal government and some states implemented requirements for the use of newly developed cleaner fuels, and certain non-attainment areas are required to sell only "cleaner" gasoline to motorists. For example, specially formulated fuel

has been provided in Denver, Colorado, during winter seasons in an attempt to reduce its CO emissions problem (Menz 2002).

Present government goals call for a 98 percent reduction of unburned HC, a 97 percent reduction in CO, and a 90 percent reduction of NO<sub>x</sub> compared to pre-controlled vehicles. Further developments in EPA regulations imposed on automobile manufacturers include that, beginning in 1997, they need to have two percent of their fleet produce zero emissions. This has led to the development of hybrid electric vehicles(HEV). In this regard, Ayres (1998) claims that alternative fuel programs or zero percent emissions vehicles receive one of the largest federal subsidies. These vehicles have no emissions during normal use.<sup>43</sup> A negative aspect, though, is that these vehicles could emit greater green house gas emissions especially if vehicles are charged by using electricity from a coal-fired power plant, than gasoline vehicles. As stated by Lava et al. (1995) "...electrical cars are a means of switching the location of the environmental discharges." Beginning with 2000, each automaker introduced concept vehicles - the Daimler Chrysler ESX3, the Ford Prodigy, and the General Motors Precept - at a subsidy of \$1.5 billion (Menz 2002). In regard to zero emission vehicles, federal policies are still in their

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<sup>43</sup> Hybrid electric vehicle technologies have been available since 1960s powering astronauts to various off world missions. It is the concept behind FreedomCAR and the fuel is hydrogen base. Hydrogen can be produced from a wide variety of domestic resources using several technologies using fuel cells that harness the chemical energy of hydrogen to generate electricity without combustion or pollution. The big challenge is the cost of this technology. Currently, fuel cells are up to ten times more expensive than internal combustion engines. The biggest advantage is this technology has the potential to reduce greenhouse emissions from transportation alone by more than 500 million metric tons by 2040. Source [http://www.eere.energy.gov/vehiclesandfuels/program\\_areas/freedomcar/index.shtml](http://www.eere.energy.gov/vehiclesandfuels/program_areas/freedomcar/index.shtml). This vehicle technology is available from several manufacturers including hybrid versions of the Chevy Silverado, GMC Sierra, Dodge Ram Pickup, Ford Escape, Honda Accord, Lexus RX 400 and the Toyota Highlander. Source: [http://www.polk.com/news/releases/2004\\_0422.asp](http://www.polk.com/news/releases/2004_0422.asp).

infancy stages and are not fully developed to counter challenges associated with these new vehicles' technologies.

### 4.3 Assessment of I/M Regulations

In our society, no one disputes the need for cleaner air. It is also a culturally accepted norm, as determined, by actual survey data (Harrington and McConnell 1996a). Clean air is a public good and motorists derive private benefits from vehicle use. The side effect of vehicle use is pollution in the form of mobile emissions. The ecosystem has the capacity to generate cleaner air if the rate of pollution accumulation is less than the rate of photosynthesis.<sup>44</sup> This eco-dynamic is disrupted when aggregate emissions are greater than what our ecosystem can process. A consequence of this eco-disequilibrium is the accumulation of smog (Stern 1976). Scholars have shown that mobile emissions are the major source of smog accumulation in most metropolitan areas.<sup>45</sup> Smog is a mixture of pollutants, principally ground-level ozone, produced by chemical reactions in the air involving smog-forming chemicals.<sup>46</sup> A major portion of smog-formers comes from burning petroleum-based fuels such as gasoline. Smog can harm health, damage the environment and cause poor visibility. Major smog occurrences are often linked to heavy motor vehicle traffic, sunshine, high temperatures and calm winds, or temperature inversion.<sup>47</sup> The major component of smog is ozone.<sup>48</sup>

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<sup>44</sup><http://www.life.uiuc.edu/plantbio/wimovac>

<sup>45</sup><http://www.ce.berkeley.edu/sustainability/archive/2002Presentations/files/Oct15.ppt>

<sup>46</sup>[www.smallbiz-enviroweb.org/compliance/glossary.html](http://www.smallbiz-enviroweb.org/compliance/glossary.html)

<sup>47</sup>[www.smallbiz-enviroweb.org/compliance/glossary.html](http://www.smallbiz-enviroweb.org/compliance/glossary.html)

<sup>48</sup> Ozone is a form of molecular oxygen that consists of three oxygen atoms linked together. Ozone in the upper atmosphere (the “ozone layer”) occurs naturally and protects life on earth by filtering out ultraviolet radiation from the sun. But ozone at ground level is a noxious pollutant (EPA 400-F-92-006.)

Because clean air is a public good and clean air perception is an acceptable norm, the government has a duty to regulate the negative externality associated with vehicle use. Therefore, in the mid part of the last century, government agencies created regulations to contain the smog problem and to minimize the side effects of normal vehicle use. What follows is an evaluation of present I/M regulations in terms of efficiency and equity criteria as described by different scholars.

#### **4.3.1 Evaluation of I/M Regulation on Ground of Efficiency**

In the absence of a market mechanism to control pollution, command and control emerged as a suitable strategy. Society's perception is that a regulatory body is an efficient way to minimize mobile emissions as opposed to private solutions. As a requisite for efficiency evaluation, one needs to test for effectiveness of I/M regulations in terms of reducing mobile emissions. Consequently the first section of this efficiency evaluation will explore various studies to determine the program's effectiveness.

In the public finance context, efficiency requires cost minimization associated with net benefit maximization levels of output. Therefore, a necessary step in efficiency assessment is to recognize costs and benefits of the attained reductions. Accordingly, the second part of this efficiency investigation will survey various reports on costs and benefits of the achieved reductions.

### **a) Effectiveness of Present I/M Programs**

Over time, I/M programs have received some mixed reviews. Some analysts claim that they have been highly effective in reducing aggregate emissions, yet others assert they have not been very effective. Independent and state-sponsored evaluations show that emissions reductions are modestly successful when compared to predicted reductions. The reductions are from zero to about one-half percent (NRC 2001). Their benchmark comparison models are the Mobile Source Emission Factor (MOBILE) and the California Air Research Board Emissions Factor (EMFAC) models.<sup>49</sup> These models' predicted reductions are important because they serve as part of the basis for formatting emissions reduction credits within state-implemented plans.<sup>50</sup>

In the hope of achieving overall mobile emission reductions in the U.S., there have been several amendments to the original Clean Air Act established in the 1950s. These adjustments were imposed on automakers in the form of restrictions on vehicles' technologies. Also, these amendments were imposed on state, county and city municipalities to entice authorities to be more regimented in their approach to emissions controls. When evaluating the effectiveness of inspection and maintenance programs as well as EPA restrictions, one needs to consider the possibility of mobile emissions reductions in the absence of these programs. The second step is to address whether the program has generated enough incentives for vehicle maintenance as a result of I/M programs than there would be without such

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<sup>49</sup> Source:<http://www.mindfully.org/Air/Vehicle-Emissions-Inspection-NAS-26ju101.htm>.

<sup>50</sup> SIPS describe the strategies that regions in non-compliance with National Ambient Air Quality Standards (NAAQS) use to come into compliance.

programs in place. And the third criterion is to assess emissions inventories throughout different program areas and through different time periods.

### ***Emissions Reductions Attributable to I/M Regulation***

Currently, to control mobile emissions new vehicles sold in the U.S. must be equipped with sophisticated emissions control equipment. Included in the mandate are a three-way catalytic converter and an exhaust gas recirculation system. Electronic control modules that regulate fuel/air mixture and fuel injection rates and the installation of OBD signals for maintenance checks are also part of the mandate. These technologies have done a great deal to control emissions and are evident in new cars' emissions levels. A new vehicle or light truck produces 96 percent less CO and HC, and 90 percent less NO<sub>x</sub>, than vehicles of the 1960s (White 1982). A critique of OBD by Stedman (2002) reasons that states, claiming to have a larger portion of their fleet equipped with these technologies, have the potential to declare inflated credit for emissions reduction through the State Implemented Plans program.<sup>51</sup>

Emissions regulation has, without dispute, prompted a change in the automobile industry that has pushed technological innovation to produce vehicles that have fewer side effects in use. In this regard, Portner (1991) asserts that improvements in automotive technology are partially attributable to more stringent environmental regulations over time. According to Portner, without such regulations in place,

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<sup>51</sup> State Implemented Plans (SIP) are programs that establish regional planning based on population density and mobile emissions. Counties with high SIP credits can claim federal funds for highway projects.

vehicle manufacturers would not have made the effort to reduce excessive emissions. Others, like Jaffe and Palmer (1997), find that lagged environmental compliance expenditures have a significant effect on R&D spending. Therefore, regulations have had a long-term impact rather than immediate benefits.

White (1982), in his quest to determine whether vehicle emission reductions are a result of change in vehicle characteristics or is attributed to I/M regulations, analyzes Denver, Colorado, emissions data. In order to predict the emissions reductions that would have occurred in the absence of regulations, he estimates emissions models from vehicle characteristics for the pre-1968 model years. He uses estimated coefficients along with average vehicle characteristics for model years covered by regulations. He concludes that current regulations have achieved substantial reductions in mobile pollutant emissions. To quantify emissions reductions, Kahn (1994) models how aggregate emissions would evolve in the absence of emissions testing using Florida emissions data. He finds evidence that emissions testing programs have reduced median yearly smog by 6 percent.

Bovee (2003) analyzes the impact of the transition of I/M programs from the basic (decentralized) to the enhanced IM240 (centralized) in southern Wisconsin in 1995. He concludes that the program not only realized a 24 percent reduction in HC emissions, it is also credited for identifying high-emitting vehicles. He adds that centralized programs are also credited for improving repair effectiveness compared to decentralized program. It was shown earlier in this study that the probability of failed vehicles passing a retest is higher under centralized programs

than in decentralized lane testing.<sup>52</sup> Owners of failed vehicles in centralized configurations receive detailed test results including diagnostic information. In addition, motorists receive a report that provides statistics on the success of individual repair facilities in emission component repairs to pass the retest. Perhaps this setup is what makes centralized I/M testing facilities yield effective repairs. Concurring with Bovee's (2003) findings, the EPA concluded that centralized programs have, generally, produced greater benefits in terms of emissions reductions than decentralized programs (EPA 1992).

One problem associated with decentralized programs is ill-informed mechanics (Green 1997). To overcome this situation, under the new I/M program's guidelines, mechanics and technicians working on emissions control equipment must go through mandatory training programs. Informed mechanics is the focus of Kukawka's (1999) study. He assesses the impact of educating technicians on emissions reduction. He attributes reductions of 80 to 87 percent in HC emissions and 87 to 92 percent in CO emissions to the training program that exists in southern Wisconsin.

Evaluation studies done by different scholars have come to different conclusions in regard to the effectiveness of I/M programs. This could be attributable to the way the data was gathered, or the way they conducted such comparisons, or it could be due to the estimation method used. According to the NRC (2001) there are three methods for measuring emissions reductions: the reference method, the step method and the comprehensive method. The reference method compares emissions by model year measured by the test program with those

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<sup>52</sup> Chapter 3 of this study

of a reference program. That entails comparing fleets from different areas that have the same I/M program configuration. The step method involves testing emissions of random samples of vehicles tested under specific program configurations and comparing emissions to vehicles yet to be tested. An example of this approach is the roadside pullover. In the comprehensive method, vehicles are split into groups according to their test results and then the emissions of these vehicles are followed over time using periodic inspection test data. Even with these guidelines, there exist disagreements among researchers as to the best method of contrasting different research results.

Miller et al. (1985) investigate the method of sequential testing on vehicle emissions certification. Sequential testing involves gathering data on lane emissions results of failed vehicles and then comparing them to emissions results after the needed repairs are applied. The quantified emissions reductions are the differences between these two data sets, as prescribed by the EPA. For the EPA, this procedure is currently implemented by regulators; it allows them to quantify aggregate fleet emissions reductions. The EPA also uses this method to make inferences regarding the number of miles driven within a program area. This procedure establishes a pattern between number of miles driven and aggregate fleet emissions.

To test the EPA's method in quantifying the benefits of I/M programs, Miller et al. (1985) assembled data on new vehicles and vehicles with significant mileage in order to determine how engine deterioration affects auto emissions. Contrary to the EPA methods, Miller et al. find that a vehicle's miles driven are a critical

component, but not the only criterion that determines vehicles' conditions. They also reason that, vehicle miles traveled alone is not a suitable proxy for overall fleet condition and it also does not provide a correct approximation for aggregate fleet emissions. There are special vehicle attributes concerning engine class, regular maintenance and, most importantly, lasting emissions components repairs, that all determine fleet emissions. Therefore, Miller et al. refute the method implemented by the EPA for aggregate mobile emissions assessments. Studies by Lawson (1995), Green (1997), Wenzel and Sawyer (1998), and Stedman (2002) using remote sensing and random roadside pullover data concur with Miller et al.'s conclusion. They find that emissions levels of vehicles post-emission repairs revert to their pre-repair status. These studies explain that implemented repairs for those failed vehicles have had only a temporarily effect on emissions level reductions; a natural outcome resulting from aging, deterioration, and poor maintenance. They add that one cannot assume that repairs for those vehicles would permanently enhance the functioning of their emissions controls. They conclude that quantifying benefits by the EPA based on emissions levels before and after repairs is not valid.

Summarizing the above researchers' findings, this study finds I/M regulations to be effective in controlling the rate of mobile emissions increase emitted by *new* vehicles; an obvious result form regular update policies on automakers. Also, this study finds centralized programs to be more effective than the decentralized configuration. This could be due to either tighter standards or to the fact that centralized programs have more rigorous policies with regard to lane testing administered by state inspectors. Moreover, this study finds methods implemented

by the EPA to quantify emission reduction to be fallible. This conclusion rest on the EPA's erroneous assumption that repairing failed vehicles generates lasting effects. Effective repairs and regular vehicle maintenance are the emphasis in many scholars' works. They reason that program officials' assumption of motorists' incentives toward those two issues undermine the I/M program's ineffectiveness. This finding is examined next.

### *Incentives Issues*

One of the most important new sections of the 1990 amendments to the Clean Air Act directed the EPA to develop an enhanced I/M program to overcome the apparent inadequacies of the first-generation I/M programs. However, Ando et al. (1999) add that the focus of these efforts were concentrated more on "inspection" than on "maintenance." Lawson (1995) in his study "the cost of 'M' in I/M" confirms that program officials devoted resources to the inspection aspect of the program with little focus on vehicle maintenance. The lack of an effective policy for vehicle maintenance is a significant failure of the program (Stedman 2002). Beaton et al. (1995) find vehicle exhaust emissions measurements show that most vehicles, when properly maintained, contribute less to mobile emissions than poorly maintained vehicles. They reason that, although poor maintenance correlates with increasing vehicle age, different states of maintenance among vehicles of a given model year far outweigh the average age factor. They conclude:

[T]hat regulatory policies based on a computer model that targets all vehicles equally, without recognizing the overriding importance of individual maintenance, may not be cost-effective or may be ineffective.

Green (1997) stated that these programs set up incentives to “pass the test” but they do not create behavior incentives for motorists to maintain clean vehicles year-round. Green quotes Charles Lave, an economist at the University of California, Irvine,

Such periodic testing is akin to a program that tries to “control” drunken driving by scheduling drivers for a breath-analyzer test every two years.

Hubbard (1997) also concludes that existing I/M programs provide consumers’ incentives to fix their vehicles so as to pass periodically scheduled emissions tests. This leads consumers to fulfill test requirements without improving their in-use vehicle’s emissions conditions. These actions are done through quick fixes for their failed vehicles in order to pass the retest.

Miller et al. (1985) assert that maintenance application could signify vehicles condition and could influence vehicles’ emissions results. The difficulty with vehicle maintenance is that there are no mandatory tools to coerce motorists to provide periodic maintenance. Therefore, it is up to motorists’ good will to perform maintenance and purchase lasting repairs. Accompanied this trend is the fact that testing stations’ credentials, in basic I/M programs, are important to vehicle owners. Thus, mechanics will probably act in the best interest of their customers (Hubbard 1997). To stress this idea, it was shown earlier in this study that inspectors and

mechanics in decentralized programs exercise discretion in helping vehicles pass emissions tests.<sup>53</sup>

A common mistake regulators fall into is making the assumption that all similar-age vehicles are equally likely to pollute. In fact, studies show that the distribution of vehicles' emissions is highly skewed, with a minority of vehicles producing the majority of emissions (Green 1997). Green also adds that a vehicle's age is positively but weakly correlated with emissions levels. Klein and Koskenoja (2002) argue that 10 percent of vehicles are gross polluters that generate over 50 percent of the on-road CO and HC emissions. Another study, by Lawson (1995), proclaims the dirtiest 10 percent of the fleet produces 77 percent of the HC emission. Even with these discrepancies in researchers' results, one can infer that the relatively few gross emitters contribute to an ever-larger fraction of overall mobile emissions. These common consensuses among studies, the skewness in mobile emissions, have generally contributed to I/M programs' ineffectiveness. Stephens et al. (1997) establish through regression analysis that there is a strong correlation between high emitters and model year rather than vehicle age;  $r^2$  of 0.96. Therefore, they suggest the possibility that vehicle model year is slightly more important than vehicle age in determining high emitter frequencies. They explain that some year models manufactured in the U.S. are more prone to have defective parts than others. These studies suggest that the program would be more efficient if program officials concentrated their efforts on the high polluters for particular vehicle models regardless of their age.

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<sup>53</sup> Chapter 2 of this study

With advances in automotive technology, many researchers are skeptical of the policy-makers' assumptions about the universal pursuit of marginally emitting vehicles.<sup>54</sup> Under this assumption, the program forces all vehicles and light trucks in its jurisdiction to be tested. Thus, vehicles are guilty of pollution until tested. According to Lawson (1993), roughly 80 percent of those vehicles that fail do not have emissions much above cut-point standards. Spencer (1994) notes that, mechanics find these marginal emitters difficult to fix. He also remarks that half of the marginal emitters showed an increase in pollutants after repairs. This raises obvious question about whether it was worth the effort to fix them in the first place. In this respect, the I/M program is inflicting unnecessary costs on all motorists. Analysts state that this assumption contributes to the program's inefficient policies.

Stephens et al. (1997) agree with this conclusion. To evaluate the effectiveness of I/M programs, they compared the emissions from 1982 and 1983 passenger cars through the Michigan Road Study (MRS). The selection of these two model years is important because 1982-year models are not part of the I/M program whereas 1983 passenger cars are. They found that CO emissions were significantly lower for the 1983 than for the 1982 vehicles. However, they also found that for passenger cars registered outside the I/M region, emissions were not significantly different between the 1982 and 1983 model year passenger cars.

Lawson et al. (1996) provide evidence that both centralized and decentralized program types do not induce motorists to improve their vehicles' in-use emissions conditions. Their study analyzes data from surveys taken by the EPA in many regions between 1985 and 1992. In these surveys, EPA staff pulled over vehicles as

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<sup>54</sup> Marginal emitters are vehicles with emissions levels are slightly above cut-point year models.

they were being driven. When drivers consented, staff members performed emissions inspections. After controlling for vehicle age and odometer readings, they concluded that the fraction of high emitters was only slightly higher in states without I/M programs than in those with an I/M program in place. In addition, neither the fraction of high emitters nor tampering rates differed much regardless whether vehicles were in states where centralized or decentralized inspection is implemented. Lawson et al. (1996) also add that motorists' inclination for effective repairs is affected by high repair costs.

Repair cost has a big impact on vehicle owners' behavior; it determines the durability of repairs that vehicles receive. This is another aspect of the I/M program that has not been fully addressed by regulators. In fact, information on vehicle repairs, including costs and parts repaired, are self-reported by vehicle owners and not verified by test inspectors. Ando et al. (1999) argue that many rounds of repairs, for a given vehicle, have been reported as zero costs. They explain that zero or trivial costs can occur, since nominal costs may include home repairs by do-it-yourself mechanics. Zero repair costs could be the result of repairs done at home depending on the opportunity cost of the owner's time and the benefits received from these repairs. Ando et al. (1999) add that reported zero repair costs could, also, indicate missing data or repairs under warranty.

The EPA argues that proper vehicle repairs may yield benefits through improved fuel efficiency: the estimated improvement on average is 12.6 percent (EPA 1992). Using the same method as the EPA, Ando et al. (1999) estimated the effect of fuel economy changes among failed vehicles in Arizona, and found that

the estimated fuel economy improvements to be much smaller than EPA estimates—about 3.5 percent. In this regard, Ayres (1998) asserts the increase in miles-traveled has largely offsets the effect of improved in fuel economy vehicles. Thus increase in miles traveled compensated negatively for more fuel efficient vehicles. But others advocate that, overall on-road emissions are diminishing even as miles traveled increased (Menz 2003). This is verified by the fact that modern vehicles are low emitting when new and generally they remain that way for many years with minimal maintenance.

From the above findings, one needs to ask why estimates from various simulation models differ in air quality assessments. The reason could be that simulation models assume that vehicles have an equal deterioration rate, of vehicles' emissions components, regardless of whether individual vehicles receive repairs. This assumption implies that repairs permanently improve vehicles' emissions conditions relative to what they would be without repairs. This is an unrealistic assumption because it is known in the repair and auto industries that one can only do so much to fix older cars. For older vehicles, improvements in emission conditions could be only attained by engine rebuilding. The wear and tear on older vehicles is not eliminated by regular maintenance. It may reduce the deterioration rate, but it does little to reverse the age factor.<sup>55</sup> Therefore, if repairs have only temporary effects, this assumption leads one to overstate the environmental benefits and, therefore, overestimate the effectiveness of I/M programs.

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<sup>55</sup> According to interview with a car mechanic in Fort Collins, Colorado, 2003.

Based on the evidence thus gathered, this study finds I/M program to be ineffective in addressing motorist incentives toward proper repairs and vehicle maintenance. In addition, it has an inefficient policy by targeting the marginally emitting vehicles. Since the social and private costs of fixing these vehicles outweigh the social and private benefits. Also, the program lacks guidelines that prescribe procedures to find and fix high polluters. Despite these deficiencies, I/M regulation was – and still is – perceived (by both regulators and researchers) as a key element in any attempt to reduce vehicle emissions to improve air quality in polluted urban areas (Henderson 1996). This assertion is evident in the discussion on emissions inventories.

### *Emissions Inventories*

An emission inventory is an accounting of the amount of air pollutants discharged into the atmosphere. It is generally characterized by the following factors:<sup>56</sup>

- the chemical or physical identity of the pollutants included,
- the geographic area covered,
- the institutional entities covered,
- the time period over which emissions are estimated, and
- the types of activities that cause emissions.

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<sup>56</sup> <http://library.thinkquest.org/04apr/01194/global.htm>

The emissions inventory is one technique used by state agencies to assess the level of pollutants released into the air from various sources. The ultimate goal of these procedures is to identify sources that result in violations of ambient air quality standards. Also, it is used to identify the accumulation of pollutants that cause the depletion of the ozone layer and exploring the greenhouse effect.<sup>57</sup>

Moreover, emissions inventories serve as a benchmark comparison tool to assess the effect of I/M regulations on ambient air quality. The mobile sources inventory includes highway vehicles such as passenger cars, light-duty and heavy-

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<sup>57</sup>The earth has a natural greenhouse effect due to trace amounts of H<sub>2</sub>O and CO<sub>2</sub> that naturally occur. The enhanced greenhouse effect refers to the augmentation of these natural gases by human activities. <http://zebu.uoregon.edu/1998/es202/113.html> Therefore, some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Certain human activities, however, add to the levels of most of these naturally occurring gases: *Carbon dioxide* is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned. *Methane* is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock. *Nitrous oxide* is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels. Very powerful greenhouse gases that are not naturally occurring include *hydrofluorocarbons* (HFCs), *perfluorocarbons* (PFCs), and *sulfur hexafluoride* (SF 6), which are generated in a variety of industrial processes. Each greenhouse gas differs in its ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbent. Methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. Often, estimates of greenhouse gas emissions are presented in units of millions of metric tons of carbon equivalents (MMTCE), which weights each gas by its GWP value, or Global Warming Potential <http://library.thinkquest.org/04apr/01194/global.htm> . One needs to add, that the greenhouse effect is a necessary phenomenon that keeps all earth's heat from escaping to the outer atmosphere. Without the natural greenhouse effect it is certain that we would all be lost. Temperatures on earth would be much lower than they are now, and the existence of life on this planet would not be possible. The global average temperature would drop precipitously 33 degrees from its current 15° to -18°C. The earth would become an ice planet. However, too many greenhouse gases in earth's atmosphere could increase the greenhouse effect. This could result in an increase in mean global temperatures as well as changes in precipitation patterns. <http://www.solcomhouse.com/globalwarming.htm>. Fossil fuels burned to run cars and trucks, heat homes and businesses, and power factories are responsible for about 98% of U.S. carbon dioxide emissions, 24% of methane emissions, and 18% of nitrous oxide emissions. Increased agriculture, deforestation, landfills, industrial production, and mining also contribute a significant share of emissions. In 1997, the United States emitted about one-fifth of total global greenhouse gases. <http://yosemite.epa.gov/oar/globalwarming.nsf/content/Climate.html>.

duty trucks, and motorcycles using gasoline and diesel fuels (NRC 2001). These emissions inventories differ by seasons and by geographical areas.<sup>58</sup> The differences in seasons for smog accumulation are attributed to how each pollutant reacts in different temperatures. Differences in geographical location are important because location is related to latitude, wind, and population density.<sup>59</sup> Consequently, emissions inventories provide another frame of reference for development of air quality strategies. To account for the above goals, numerous studies present their findings as either a revelation of pollution sources or to imply the success of certain approaches. Yet others confine their findings to using the data to validate present I/M policies.

An assessment done by the Northern Front Range Air Quality board (at Colorado State University) concludes that mobile sources produce 58 percent of NO<sub>x</sub>, 53 percent of HC, and 94 percent of CO emissions.<sup>60</sup> Their results also indicate that vehicles in the northern Colorado fleet in cold weather produce nearly as many emissions as those produced by the few high emitters in the fleet. In addition, when new vehicles are running under hot stabilization conditions, their direct emissions contribute to only 3 percent of the total emissions inventories. Another presumption reached is that high-emitting vehicles produce emissions more than 100 times greater than the new technology vehicles.

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<sup>58</sup> <http://www.colorado.edu/cuenviornmentalcenter/energy/projects/emissions/inventory.html>

<sup>59</sup> <http://www.colorado.edu/cuenviornmentalcenter/energy/projects/emissions/inventory.html>

<sup>60</sup> <http://www.nfraqs.colostate.edu/nfraqs/Files/Final/Rep2Gov.pdf>

The Bay Area Air Quality Management District confirms that emissions inventories, resulting from mobile sources increase with population and gasoline consumption. In the summer, there is an increase in smog accumulation resulting from HC emissions, and in the winter, CO emission concentration peaks.<sup>61</sup>

A comparison study was conducted by authorities in the South Coast Air Basin in California, to evaluate HC emissions inventory between 1970 and 1990. They concluded that half or more of the current HC emissions are from mobile sources and that mobile emissions comprise a greater fraction of the current emissions inventory than previously predicted.<sup>62</sup>

A carbon monoxide emissions inventory was the focus of a study done by the University of Colorado at Boulder.<sup>63</sup> Their aim was to assess the relationship between emissions reductions and electricity use in and around the campus area. Their calculations show that CO emission decreased by 5.2 percent over ten years. This is correlated with an increase in electricity use, an increasing pattern of 4-5 percent every year. Given the alarming annual percentage that fossil fuel combustion contributes to pollution, campus officials switched from traditional fuel consumption to more environmentally friendly energy sources.<sup>64</sup> One question if this method needs to be further explored for future emissions planning and reduction.

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<sup>61</sup> [http://www.baagmd.gov/pln/emission\\_inventory.asp](http://www.baagmd.gov/pln/emission_inventory.asp)

<sup>62</sup> <http://www.aqmd.gov/matesiidf/matestoc.htm>

<sup>63</sup> <http://www.colorado.edu/cuenvironmentalcenter/energy/projects/emissions/inventory.html>

<sup>64</sup> About 98 percent of CO emitted in the U.S. is attributed to fossil fuel combustion.

A study done by the Utah Division of Air Quality that compared yearly inventories to previous inventories confirms that on average, pollutants from vehicle emissions have a decreasing pattern over time, which coincides with more stringent regulations on vehicle emissions.<sup>65</sup>

Beyond regional emissions reductions, a study done by Menz (2002) summarizes mobile emissions patterns from 1970 through 1999 and concludes that, except for NOx emission, HC, CO, and SOx emissions fell from 1970 to 1999 nationwide. He notes this decreased pattern coincides with the development of I/M regulations over the years.

From the above, one can concede that mobile emissions programs have generally created not only a decrease in the rate of emissions increase, but, in some areas, a decrease in total mobile emissions. This occurred despite the increase of miles traveled and the combination of Americans' desire for larger vehicles and economic growth.

Few people dispute the need to seek reductions in mobile source emissions as part of society's quest for clean air. However, what many people question is how these reductions are achieved, and at what cost. For an air quality policy such as an I/M program to be considered efficient at any level, one has to first demonstrate cost effectiveness at some level. This issue is addressed next.

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<sup>65</sup> <http://www.airquality.utah.gov/PLANNING/into.htm>

## **b) Costs and Benefits of I/M Regulations**

Since 1981, cost and benefit analysis is mandated to be carried out to analyze the impact of any regulation. Executive Order 12291, issued by President Ronald Reagan, states that

In promulgating new regulation, reviewing existing regulations, and developing legislative proposals concerning regulation, all agencies, to the extent permitted by law shall adhere to the following requirements: ...b) Regulatory action shall not be undertaken unless the potential benefits to society for the regulation outweigh the potential costs to society.

This executive order lacks explicit guidelines for conducting such analysis; it fails to lay out precise definitions of benefits and costs. In the absence of such criteria, one might infer that the executive order mandates an interpretation of costs and benefits consistent with applied welfare economics.

An increasing number of researchers are measuring the gains of I/M programs in terms of benefits and costs rather than simply in terms of pollution abatement. As a follow up they also question how the program might be redesigned to achieve greater benefits at lower costs. But scholars do not agree on unified ways and units with which to quantify social and private costs and benefits. This is recognized in Silberston's (1995) discussion. He asserts that public funding assessments do not capture all relevant elements. Accordingly, quantifying external costs and benefits have been underestimated. This is clear in government agencies' estimations; they fall into the trap of underestimating the social costs and benefit of these regulations. Hence, authors vary in their assessment analysis, and this is evident in their

discussions. Table 4.1 present a summary of the documented costs and benefits of the I/M program.

Study	I/M Program Costs		I/M Program Benefits		
	Costs	Cost/Ton	Emissions Reductions	Benefits	Benefits/Ton
Portney (1990)	- Annual \$30 Billion required by the Clean Air Act - Annual Compliance Expenditure \$9-12 Billion - Annual Alternative Fuel Provisions \$3 Billion - Annual New Vehicle Technology \$5 Billion	N/A	N/A	\$5 - \$4.0 Billion - Annual Agricultural Benefits \$1 Billion - Annual Reduction Damage to Forest and Improve Visibility - Annual Reduction of Concentration of Carcinogenus - Annual Added Benefits of Clean Air	N/A
Khan (1994)	- Motorist Time 60 Million hours	N/A	N/A	N/A	N/A
Spenser (1994)	- Motorists' Time Cost \$2.4 Billion	N/A	N/A	N/A	N/A
Arizona Program (from 1999-2003)	- Total cost \$408,000 - Repair Lasting One Year \$456/Vehicle - Repair Lasting Two Years \$684/Vehicle	\$1,367 Per Ton	300 Tons Per Year	N/A	N/A
California Smog Program	N/A	\$5,317 Per Ton	207, 273 Tons in 2002	N/A	N/A
Small and Kazimi (1995) assessing California Smog Program	N/A	N/A	N/A	N/A	\$20,000 Per Ton of HC Reduction
Cost of Repair NRC (2001):	- Arizona \$120 Per Vehicle - California \$128 Per Vehicle - Colorado \$118 to \$250 Per Vehicle	N/A	- From California 55 tons of HC and NOx Reduction Per Day - From Colorado 8-17 Percent CO Reduction	N/A	N/A

An important component of compliance costs of vehicles' air-pollution control has been non-pecuniary; a decline in vehicle performance. In the literature this is referred to as drivability and it has been analyzed by Bresnahan and Yao (1985). They modeled valuations of drivability, cold starts, and other performance disadvantages associated with emissions controls. They find that two opposing forces affect the costs of compliance over time. Stricter regulations increase compliance costs, but the improvement in technology reduces the cost of compliance. Their assessment suggests that initial regulations were overly ambitious and poorly planned, but probably created a pattern of costs that started very high and fell as cost-effective technology replaced stop-gap technology. They explain that, given the large decrease in incremental compliance costs, it appears that the pace of innovation brought on by early ambitious standards increased society's overall costs from mobile-source emissions control substantially. It is also evident to the authors that the incremental social costs of the more recent standards are more often overestimated than currently perceived. Thus, costs associated with the early standards are underestimated, while those associated with later standards are overestimated by regulators.

Portney's (1990) view is that the most important environmental status amended by the 101<sup>st</sup> Congress has compliance costs of approximately \$90 billion. Of those, \$30 billion is required by the Clean Air Act. He claims in order to curb pollution by 2005 in moderately polluted metropolitan areas, a round of regulations requires the installation of specific technology. This includes vapor recovery equipment on gasoline pumps in all passenger vehicles and light trucks. In highly polluted areas,

the amendment additionally requires plans to limit vehicle use. It is reported by Portney that the Office of Technology Assessments (OTA) quantified enforcement cost to be \$9 to 12 billion annually. The added cost for vehicle emission technology ranges from \$100 to \$600 per vehicle (an extra \$5 billion annually). He claims that there is double annual spending for air pollution control in the United States at the federal and state levels.

A second round of overall emissions regulations required the implementation of "clean air fuels" programs that require the use of formulated gasoline, methanol or ethanol. The compliance expenditure for use of alternate fuels is \$3 billion annually. Therefore, the total annual new expenditures range from \$19 to \$22 billion (Portney 1990).

To quantify costs, individuals view private costs in terms of explicit monies paid to bring their vehicle into compliance with I/M regulation. This includes fees paid and repair costs, neglecting the time costs. Spencer (1994) states that emissions testing time in California consumed more than 100 million hours of motorists' time and has estimated cost of \$2.4 billion since 1984. To stress the importance of time costs, Kahn (1994) claims the U.S. fleet consisted roughly of 120 million vehicles and 60 million trucks in 1992. He assumes that, if one-third of these vehicles are tested each year, the program cost motorists 60 million hours of time. The time to travel to testing stations and testing times are costs that can be monetized in terms of lost wages. He argues that when policy-makers neglect these costs, a program's costs are underestimated.

With reference to social enforcement costs, most federal assessments are calculated in terms of private compliance expenditures (Hazilla and Kopp 1990). Motorists bear the time and travel costs of taking their vehicles to a test facility. They also endure the expense of diagnosing emission test failures, and the cost of re-testing those that need to be repaired. The costs of pollution control equipment repairs in order to bring their vehicles into compliance are costs carried by motorists as well (Menz 2002). Therefore, there exists a divergence between private compliance expenditure and social enforcement costs. These discrepancies have been empirically observed by Hazilla and Kopp (1990). In an attempt to refute the method implemented by government agencies in social cost valuations, they modeled the U.S. economy in a general equilibrium model. Their model encompasses both static and intertemporal behavioral adjustments. They conclude that private expenditures are not suitable proxies for social cost approximations.

To assert the above point, Wenzel (2001) carried out an empirical study with a focus on compliance costs of marginal emitter vehicles. He claims that devoting programs resources to bringing marginal emitters into compliance contributes to inefficient program practices. Wenzel quantified costs endured by government agencies in Colorado to be \$300 per identified IM240 failure.<sup>66</sup> The motorist's cost to bring low-emitting vehicles into compliance is \$400 per identified failure. Consequently, there is a divergence between private compliance expenditures and federal enforcement costs. Wenzel adds that fixing marginal failed vehicles will not

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<sup>66</sup> This is high estimates but considering that only 6 percent of the vehicles tested fail the IM240 in the Colorado Front Range IM240 program.

generate great social benefits but could enhance drivability. Enhanced social benefits are quantified in reduced aggregate fleet emissions.

To implement the 1990 amended regulation, officials in Pima County, Arizona, instituted a subsidy repair program for failed vehicles. They found that, on average, repairs reduced individual vehicle emissions by 82 percent. The repairs were state mandated for 1,000 older high-emitting vehicles. Eligible vehicles were cars that failed the state emission test within the past 60 days and were 12 years of age or older. They had to be titled in Arizona, registered for at least the last 12 months in Arizona and in good working condition. In addition, the owner should be willing to participate and pay a co-payment of \$150. Repairs were covered up to \$550. According to the program manager, the merit behind this program is that it provides an alternative to quick-fix repairs. Program officials in Pima County declare the average cost of repair at the time of the study to be \$456 per vehicle. They also established the cost per ton of emissions reduction at \$1,367 based on repairs lasting two years and \$684 based on repairs lasting one year. A total of 330 tons of air pollution has been eliminated at a total cost of \$408,000.<sup>67</sup> The social cost amounts to \$1,360 per ton of emissions reduction. It is reported by NRC (2001) that repairs of ongoing I/M programs in Arizona and California show very similar estimates of average repair costs: average repair costs in California are \$128 per vehicle and in Arizona they are \$120 per vehicle. In addition, it was reported that in 1999 Colorado's repair costs ranged from \$118-\$250 depending on program type and testing configuration (NRC 2001.)

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<sup>67</sup> <http://www.deq.co.pima.az.us/air/newsrealase/V2R210.31.01.htm>

The Smog program in California accounts for different costs of emissions reductions. Smog Check program officials note the program generated HC and NOx reduction of 207,273 tons in 2002. The cost of these reductions is higher than the Pima county cost amounting to \$5,317 per ton.<sup>68</sup> Considering benefits reaped by the public, one needs to ask if such benefits justify the costs incurred. This is a subjective valuation that depends on regulators, researchers, and local jurisdiction appeal.

While researchers differ regarding whether the emissions controls are stringent or not stringent enough, most people support the notion that health damage is not an acceptable by product of vehicle use (Green 1997). A study by Small and Kazimi (1995) summarized existing studies of benefits of I/M programs. They provide average estimates of benefits for the stringent California program to be \$20,000 per ton of HC emissions reduction. These estimates are high because they include substantial mortality reductions resulting from air pollution. Contrasting the cost of the California Smog Check program and its quantified benefits, it is clear that the Smog Check program generated greater benefits for California residents. These benefits are reductions of 55 tons of each of the HC and NOx pollutant per day. Unfortunately, other program areas are not subject to massive research impeded by funding, thus curtailing efforts to quantify benefits. Therefore, this study cannot generalize the efficiency of other regions, but it can allude to the general benefits of I/M regulations. These benefits can be seen on three levels; benefits to the environment, to policy-makers, and to motorists.

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<sup>68</sup> [http://www.imreview.ca.gov/presentations/bar\\_20040127.htm](http://www.imreview.ca.gov/presentations/bar_20040127.htm)

A vehicle emissions program by any technique does nothing by itself to improve air quality. The air benefits when a failed vehicle is repaired or scrapped. Social benefits of stringent emissions requirements include reduced asthma attacks, chest pain, and other adverse health effects that would result from reduced ozone concentrations. Total monetized social benefits would amount to \$.5 to \$4 billion annually, and agricultural benefits could range up to \$18 billion annually (Portney 1990). Other benefits include reduced damage to forests, improved visibility, and reduction in the ambient concentration of benzene, butadiene and other carcinogens. These benefits range from \$4 to \$12 billion per year (Portney 1990). Table 4.1 summarizes the above costs and benefits.

I/M lane testing have a profound impact in terms of benefits perceived by government agencies. Inspection (and therefore registration) provides information about an aging fleet. This considerable amount of data provides program regulators with an accurate representation of vehicles' conditions in their jurisdictions. This understanding could be used to tailor I/M programs to fit a given local district. This is evident in the California Smog Check program.

Periodic inspections provide an update about a vehicle's emissions status that individuals can use to draw inferences about their vehicle's conditions (Hubbard 2002). Individuals see few private benefits of the "maintenance" aspect of the program neglecting the profound effects of well-maintained vehicles, which arguably prolong the vehicle's life and enhance drivability. Because of the disparity between private and social benefits, program benefits are seldom appreciated by individuals. Nevertheless, a general consensus among scholars

affirms that I/M regulations are responsible for controlling the rate of mobile emissions increases.

Based on the evidence presented, one could conclude that, despite the ineffectiveness of some policies associated with lane testing, these programs have generated benefits for society and motorists alike. A more efficient approach would be to concentrate a program's efforts on repairing high-polluting vehicles- just as in the Arizona study. It was evident from the Pima county study that despite the high cost of curbing mobile source pollution, the benefits that residents received outweigh the cost. Also, the policy of the "universal pursuit of marginal emitters" is not efficient because the benefits generated are incrementally small. A more appropriate expenditure would be to concentrate on educating motorists regarding maintenance. That public education can be successful is evident in the recycling programs that exist in the United States.

#### 4.3.2 Evaluation of Present I/M Regulations in Terms of Equity

Our current tax structure is progressive in nature, which leads one to examine the “vertical” equity notion. This is emphasized in most scholars’ work. Vertical equity entails distributing burdens fairly among individuals with different abilities to pay (Rosen 1998). The areas for which the program is deemed unfair by researchers are in practices such as their policies regarding to high polluters, the treatment of all vehicles and motorist as being equal, and the high repair costs. Also, there are equity issues raised by scholars in regard to emissions testing stations and the increase in new vehicle prices.

##### *High Emitter’s Policies*

Studies demonstrate that a small malfunctioning fraction of the U.S. fleet contributes a substantial portion of the overall mobile emissions. Typically, less than 10 percent of the fleet contributes more than 50 percent of the emissions. For any given pollutant, emissions reduction is skewed; a relatively small share of vehicles failing I/M tests contribute a large proportion of total excess emissions.

Research that combines data for vehicle ownership (high-emitter frequency) and income levels suggests a strong link between low household income and the likelihood of owning a high-emitting vehicle (Green 1997). Studies have also shown that between 10 and 27 percent of vehicles that fail an I/M test never pass the retest (Green 1997). Their exact fate has not been well documented, although some have been found to be still in operation in I/M areas in some states more than

a year after their last test.<sup>69</sup> Also, NRC (2001) reports that those gross emitters are more likely to be found among older vehicles. In addition, the probability of gross emissions increases for cars that have had multiple owners and whose current owners can not afford the necessary maintenance and repair costs. Thus, increased emphasis on gross emitters might increasingly impact low income motorists. Moreover, vehicles tested at I/M stations in relatively low-income areas have consistently higher emissions than the same models tested at stations in relatively high income areas (Harrington and McConnell 1999a). This assertion demonstrates that in-use emissions are sensitive to vehicle maintenance, and that some vehicle models are more sensitive to maintenance practices than others.<sup>70</sup>

California legislators sought to shift their program to become more incentive compatible in order to promote ongoing vehicle maintenance. The Smog Check program in California concentrates on extreme emitters in an attempt to focus on problem vehicles, which led to significant inequity ramifications and public disapproval. The California program tests only 15 percent of their fleet at a small number of high-tech, test-only facilities; the remaining 85 percent are tested at either centralized test-only or decentralized test-and-repair facilities (Green 1997). Usually, the 15 percent are vehicles that have a high probability of being high emitters (Wenzel and Sawyer 1998).

The California program, which is more stringent than the rest of the nation, involved the elimination of waivers for extremely high emitting vehicles, increased repair cost limit waivers and “between tests” monitoring. But demonstrations held

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<sup>69</sup> <http://enduse.lbl.gov/Projects/vehicles/Evaluation.html>

<sup>70</sup> <http://enduse.lbl.gov/Projects/vehicles/AverageEmissions.html>

in Sacramento showed that the public's perception of Smog-Check differed strongly from that of planners and legislators, with the biggest sore spots involving the fairness issue rather than efficiency.

### *All Vehicles and Motorists Are Alike*

The fundamental tenet of environmental law, the polluter pay principle, is violated when all vehicle owners pay fees for emissions testing in order for officials to find a few high polluters. The biggest inequity of I/M program is the treatment of all vehicles and motorist as essentially alike (Green 1997). Vehicles 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 vehicles are, in fact, extremely unlikely to be significant emitters.<sup>71</sup> Also, some motorists might drive an older vehicle that produces more pollution per mile than a newer vehicle, but they might drive it much less, or at off-peak hours when its higher emissions level is relatively less significant (Green 1997). Despite these obvious differences in vehicles and motorists' behavior, most programs require that all motorists must go through the inconvenience and expense (in terms of time and money) of taking their vehicles for periodic testing.

The blanket approach to testing is regarded as unfair in Bin's (2003) study. He tests, in a selective sampling in Portland, Oregon, vehicle characteristics that would suggest probable high polluters that would consequently fail emissions testing. His results indicate that vehicle age, combined with engine size and odometer readings,

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<sup>71</sup> <http://www.coax.net/croe/cr0594.htm>

all play a significant role in determining the probability of a vehicle of being a high polluter. He proposes that state agencies implement a more efficient selective measure in emissions testing, and concentrate on vehicles with selective characteristics. Bin's (2003) finding, although an efficient way to address high polluters, has serious political opposition regarding fairness to low income motorists, unless his recommended method is accompanied with a repair subsidy program.

Stedman (2002) points to the current Colorado program that has unfair treatment of vehicle owners, the four-year exemption for new cars. Another unfair aspect of Colorado program is testing of so called "classic" vehicles. Vehicles that are more than 25 years of age are effectively exempt from emissions testing regardless of their annual mileage accumulation and actual emissions levels. The current registration-based test it takes no account of the fact that some new service vehicles, such as taxis and delivery vans, drive between 30,000 and 70,000 miles per year and are thus more likely to deteriorate and begin producing high emissions before their exemption is up. These vehicles experience a disproportionate number of emissions equipment failures by reason of their high annual mileage (Green 1997).

### ***Repair Costs***

The matter of high repair costs and their impact on low income motorists is a complex issue. On the one hand, individuals and scholars have often emphasized the importance of personal responsibility for vehicle repairs. On the other hand,

when confronted with potential hardship, the idea that low-income motorists should be held truly responsible for expensive repairs seems unfair to people.

Ando et al. (1999) addressed the relationship between the probability that vehicles fail their initial inspection given model year vehicles and the average reported and imputed costs of repairs. They also tie the above relationship to the average income of vehicle owners. They confirm that the expected costs show substantial variation across model years, primarily because of differences in expected failure probability. The expected repair costs are very high for older vehicles, and these vehicles are more likely to be held by low income households. They recommended lowering waiver limits for low income households.

Yet another study, by Kukawka (1999), finds that to effectively repair failed vehicles, waiver levels must increase. This would make the program more successful in bringing a significant number of waived vehicles into compliance.<sup>72</sup> He bases his finding on the fact that older vehicles, when they fail, probably may have a malfunction of emissions processing attributed to wear in the catalytic converter. In this case, catalyst replacement is necessary to achieve a high retest pass rate. The cost of this replacement puts the total repair cost well in excess of the waiver limit, so the repair is most often declined in favor of a waiver.

To address high repair costs and their impact on low income motorists, Green (1997) states that California instituted a subsidy program that transfers a small portion of the responsibility away from vehicle owners. Under such programs, low income motorists facing high repair bill qualify for “co-pay” from the state to

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<sup>72</sup> Waiver limits in most state programs are below the cost of many repairs that would likely to be needed to achieve year model cut points compliance.

complete repairs. Vehicle owners have to qualify for repair assistance with eligibility determined by income of \$27,000 or less for a family of four. The eligible vehicle owner has to pay \$250 and then would qualify for a subsidy of the remainder of the repair bill. The funds for the subsidy come from a smog impact fee levied on vehicles bought and registered in California. As of May, 1999, the California subsidy program downgraded their co-pay from \$250 to \$75.<sup>73</sup> This aspect brought about an equitable solution to a much debated issue—high repair costs.

### ***Emissions and Inspection Shops***

Still another fairness issue that has surfaced recently involves the large number of smaller businesses that have had to respond to changing technological requirements of I/M programs. The attempt to improve traditional I/M programs has changed requirements for complex equipment that cannot be acquired as a simple upgrade to previously owned equipment. The requirements for new technologies call for increasingly expensive equipment, which often poses a challenge for smaller test-and-repair facilities. As was discussed by emission and repair shop owners in Fort Collins, Colorado, the cost of implementing the updated technology is from \$100,000 to \$125,000. Another problem that was mentioned is how to avoid losses while working in a regulated price system. The owners added that they are not allowed to raise prices to reflect these rising costs. In the presence

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[http://64.233.179.104/search?q=cache:sEQVT\\_TuSC4J:www.smogcheck.ca.gov/ftp/scapdf/sca699.pdf+emissions+in+California+%22co-pay%22&hl=en](http://64.233.179.104/search?q=cache:sEQVT_TuSC4J:www.smogcheck.ca.gov/ftp/scapdf/sca699.pdf+emissions+in+California+%22co-pay%22&hl=en)

of frequent technological updates, shop owners face rising production costs. The result is a profit crunch. Harrington et al. (1996a) explain that, in decentralized programs where the emissions inspection fee is regulated, independent garages are faced with two opposing decisions: how to price their other lines of business while keeping costs to motorists low, and earning revenue.

Moreover, “regulating emission price” is a move that many states are proposing to implement. A recent price capping in Pennsylvania created outcry from the automotive emission businesses. Price capping is different from regulating emissions testing charges. A regulated fee is a standard price that does not increase or decrease. Price capping refers to a range of emission fees that service stations can charge consumers. The issue of whether to cap the amount that service station owners can charge or to let a free market system take effect has serious equity issues.<sup>74</sup> The emissions business owners’ problems are magnified by the cost of keeping two sets of equipments for emissions testing- one set to test older vehicles that still use dynamometer testing and another set for OBD testing on 1996 vintages and newer.<sup>75</sup> Another problem associated with these technologies is the cost of maintaining the equipment.<sup>76</sup> Green (1997) asserts these problems threaten to create a situation of de facto centralized testing. He reasons that this will happen by driving independent test-and-repair shops out of business through an ever-shifting set of technology mandates.

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<sup>74</sup> <http://www.motorage.com/motorage/article/articleDetail.jsp?id=96326>

<sup>75</sup> <http://www.motorage.com/motorage/article/articleDetail.jsp?id=96326>

<sup>76</sup> <http://www.motorage.com/motorage/article/articleDetail.jsp?id=96326>

### *New Vehicles' Prices*

Scholars advocate that centralized clean air regulation should be implemented only if it reduces the transaction costs of reaching a uniform standard, and if it permits a different and more socially beneficial uniform standard than would occur if states acted. Discussion by Harrington et al. (1996b) asserts that uniform policy will not deliver equitable outcome in terms of new vehicles' prices. The uniform higher standard in one region may end up spreading costs of vehicles sold everywhere in the country. White (1982) estimates that the emissions control investment needed to allow 1981 makes to meet federal emission standards of the 1977 amendment added \$1,500 to a vehicle's sticker price. Therefore, motorists who live in non-polluted areas end up paying for the cost of stricter air quality standards. This is evident in Abele's (2004) study. According to his data, he asserts that tighter emissions standards have had a significant and direct impact on new vehicles' prices. Nonetheless, he finds that despite relatively costly regulated emissions controls, income levels have kept pace with new vehicle prices. One might add that enhanced safety features contribute to higher prices for new vehicles as well.

Based on the above discussion, the I/M program as it presently exist is not considered fair for a number of reasons. The first is related to the nature of emissions distribution; the majority of emissions are generated from a minority of older vehicles owned by low income motorists. A policy reform to subsidize repair of older vehicles would be efficient and equitable.

Second, the blanket approach regards all similar age-vehicles as likely to have same emissions status. A better approach is to emphasize on periodic maintenance since it minimize the deterioration rate of emissions equipments.

Third, the policy of the pursuit of the marginal emitters is not equitable, since the cost of fixing marginal emitting vehicles does not generate profound social benefits. Finally the program is unfair because of the impact of frequent technological changes have on repair shops. This is especially true for the basic I/M lane testing.

## 4.4 Proposals

The existing gap between potential and actual emissions reductions has initiated a series of studies to discover ways to overcome this disparity. Research groups center their critique on two main issues, high administrative costs and motorists' incentives toward maintenance and repairs. They claim these two aspects have undermined present I/M policies. Scholars propose diverse methods and techniques to correct for I/M deficiencies. All mobile source emissions reduction proposals ought to be carefully examined in order to evaluate actual environmental benefits while keeping costs to businesses, individuals, and the public as low as possible.

This section explores two different kinds of proposals. The first set of proposals includes remote sensing, the Coase approach, and accelerated vehicle retirement proposals. The aim of these proposals is to reduce the high administrative costs. The second set has the intention to influence motorists' incentives. These include emission fees, and tighter cut-points proposals. Finally there is a discussion on some other omnibus of techniques. The objective of these techniques is to increase the variable cost of driving.

#### **4.4.1 Proposals to Combat High Administrative Costs**

According to the literature, programs' administrative costs are largely for designing and implementing lane testing. Embedded in these costs are enforcement and compliance costs. Scholars use the terms enforcement, compliance, and administrative costs interchangeably. Some research groups narrow their analysis to a particular cost, but others use costs in a looser sense. This rather flexible terminology is found throughout this study.

Researchers proclaim that high administrative costs are the result of planning, coordination and monitoring costs. Others attribute high costs to regulation monitoring, motorists repair avoidance, and to the rigid system of non-transferability of emission reduction credits. This section describes proposals from proponents of both beliefs.

#### ***Remote Sensing***

Remote sensing is emissions monitoring technology that allows a large number of vehicles emissions be read during driving, determining vehicles' in-use emissions. Remote sensing works by transmitting an infrared beam to a receptor on the other side of the road about a foot above the surface. When a vehicle passes the sensor and its exhaust trail cuts the beam, the device determines concentration and ratios of CO and particles of HC emissions. Through the use of stoichiometric principles and assumptions about the composition of the fuel, these ratios are then converted to grams of pollutant per gallon of fuel burned. If the vehicle's fuel

economy is known, the emissions readings can be further converted to grams per mile. At the same time the sensor is making an emission measurement, a camera is taking a snapshot of the vehicle's license plate. This process allows emission readings to be linked to other vehicle characteristics in a database maintained by the state's department of motor vehicles. Most researchers advocate using remote sensing along with the existing programs to provide a key reform to scheduled inspection programs (Lawson et al. 1996), Spencer (1992), and (Hubbard 1997). Others assert that replacing I/M program with remote sensing would bring about an efficient outcome (Harrington and McConnell 1999a), (Stedman 2002), (Green 1997), and (Klein and Koskenoha 2003).

Invented by Donald Stedman of the University of Denver, the remote sensing device has proven to be quite useful in the estimation of average emissions of vehicle populations and subpopulations (Harrington and McConnell 1999a). Compared to current I/M tests, it makes about six million tests per year using six devices (Krause 2001). In contrast with scheduled lane tests, remote sensing has advantages and disadvantages. On the positive side, compared to current scheduled lane testing, the cost per measurement is in cents, and the estimated cost to operate a two-man team is about \$200,000 per year. According to Harrington and McConnell (1999a), with a conservative estimate of 5,000 vehicles per twelve-hour day, the cost is only 15 cents per reading. Therefore, this technology is an efficient method for identifying vehicles in-use emissions, thus overcoming the costs associated with lane testing. They propose replacing I/M testing with network of remote sensing given the cost effectiveness of this technology.

Evidence gathered in a pilot study of remote sensing equipment in Sacramento, California, points out the practical aspects of this technology. Schwartz (1995) observes that a single unit of remote sensing operating every day for a year yields about 250,000 vehicles tested, compared to the IM240 unit, which tests only 19,000 vehicles if operated for 60 hours each week, 52 weeks each year, a test facility would generate a rate of six vehicles per hour. Spencer (1992) suggested employing remote sensing alongside lane testing. He argues that this is necessary to separate emissions test errors that arise from vehicle-specific emissions variations in lane testing.

Green (1997) addressed a number of the changes in information-gathering that could come about with remote sensing. These include changes in vehicle fleet composition and measuring changes in a vehicle's emission levels over its life cycle. Remote sensing could also track down changes in emissions-control technologies and changes in the composition of vehicles' fuel and fuel types.

Among the disadvantages, remote sensing is thought to be inaccurate: the data collection duration is based on seconds compared to several minutes using I/M testing. This technology is also constrained by the number of suitable sites on the road, and it does not measure NO<sub>x</sub> accurately (Harrington and McConnell 1999a). Additionally, in some cases some practical limitations are imposed by the number of vehicles passing the sensor.

Another problem with remote sensing discussed by Hubbard (1997) is that it does not detect vehicles that have high non-tailpipe emissions. Further, this technology does not eliminate all incentives problems: in fact, it can create new

ones. Hubbard (1997) supports his contentions noting that motorists knowing when and where inspections tend to take place devote resources toward avoiding inspection. He adds that remote sensing-based programs would create incentives for vehicle owners to adjust their vehicles so that the device cannot measure their tailpipe emissions well by adjusting the level of their vehicle's tailpipe. In a similar vein, consumers also will have incentives to make their vehicles difficult to identify by making their license plates hard to read (Hubbard 1997).

### *Coase Approach*

A numbers of scholars have addressed the issue of reducing aggregate pollution and program costs using the Coase theorem, among them Harrington and McConnell (1999b). They argue that the present program, since its inception, has been plagued by transaction costs that have drastically raised its cost in a way that limits its efficiency. They claim that only 29 to 36 percent of total program costs are devoted to repair and the rest are transaction costs.

They categorize actions that lead to high transaction costs into three categories: emission monitoring, repair avoidance, and non-transferability of emissions reduction credits. They argue that most of the transaction costs could be attributed to the current assignment of vehicle repair liability to motorists. This is based on the fact that repair costs are heterogeneous given vehicle year model, and repair expenditures bear little relation to emissions reductions. They claim that the program's cost could be reduced substantially by shifting repair responsibility away from motorists. Administrators would focus on I/M performance in terms of aggregate fleet emissions rather individual motorists (Harrington and McConnell 1999b). This would reduce the transaction costs that are devoted to monitoring.

They examine four liability assignment approaches to reduce transaction costs and improve program efficiency. The first is extending liability to auto manufacturers (extended liability). This approach is based on an already established system of warranty coverage by auto manufacturers. This approach requires little modification to the existing I/M program setup. It would entice

automakers to establish a lifetime warranty for a vehicle's emissions components. For example, if a 10 (or 15) year-old vehicle fails emissions testing, the responsibility for fixing the faulty component falls onto the manufacturer. The authors recommend this approach because automakers generate their profits from car sales and they should take responsibility for contributing to a problem that their products are generating.

To reduce transaction costs, Harrington and McConnell (1999b) propose a second approach: a state-sponsored repair subsidy program. This system would shift the financial responsibility of fixing emissions components away from the individual motorist. The aim of this approach is to transfer the liability of repair costs to the state (in the form of subsidizing repair program). This approach is comparable to the current California subsidy program mentioned earlier. Motorists pay a co-pay and the state pays the remainder of the repair bill regardless of the motorists' income. Since periodic lane tests would still be required for all vehicles there would be no discretion in choosing which vehicle to repair; this would be determined entirely by the I/M results. One way this program would work is to use a remote sensing network to identify high emitters. They would be notified immediately by billboard of their emissions status and advised to report to a repair facility within 30 days. These facilities would consist of privately-owned repair shops certified by some authorized body as qualified to conduct emission repairs. At the repair shop, a diagnostician would examine the vehicle and make a decision about whether repairs were cost-effective. Thus, repair subsidies would reduce or eliminate avoidance incentives and would probably make it possible to use less

costly monitoring methods to identify repair candidates. One of the virtues of this system is that it allows a great deal of flexibility in designing mixed systems for sharing the responsibility of repairs between the state and motorists.

A more drastic approach would be assigning liability to firms with experience in vehicle emissions repairs (centralized repair liability for emissions control equipment). This approach is similar to a vast insurance program, and the liability for emissions would be assigned to a third party. These firms should have expertise in vehicle emission repairs: each would be responsible for the emissions of subfleet vehicles. The responsibility for *total* emission in each subfleet could be auctioned off to the lowest bidder, just as public works contracts are. The necessary revenues to pay the contract amounts would come from vehicle registration fee surcharges or new vehicle sales taxes. A firm with a winning bid for a group of vehicles would pay an annual fee based on the amount by which the emissions of the subfleet exceeds the agreed-upon limit. This proposal would reduce monitoring costs and tackle motorists' incentives for avoidance and place the incentives for proper vehicle maintenance on the "right" third party. The third party could be auto manufacturers or new car dealers. This approach is similar to a program in place that is based on trading emissions credits between stationary and non-stationary sources.

The last and most radical approach centers on vehicle ownership with the establishment of a vastly expanded system of vehicle leasing (mandatory leasing). Currently, the vehicle leasing approach is becoming a popular alternative to purchasing vehicles, and requires the separation of vehicle ownership and

possession. Robert Slott (1998) proposes vehicle leasing programs as one of a number of options that could be offered to motorists to shift the responsibility for emissions reduction to other parties. To implement it, Harrington and McConnell (1999b) advocate an expanded system of vehicle leasing that would become the basis for a new system of in-use emissions management. The responsibility for maintaining vehicles and emissions repairs could rest on the vehicles' owners, whether the automaker or some other party. Each leasing firm would pay fees based on the total of emissions expelled by its lessees, as determined by a remote sensing network. Because leasing companies buy vehicles, they would be able, in their purchase decisions, to give automakers proper durability incentives. This approach would include having rental agencies offer a variety of vehicles, new and old, in accordance with individuals' willingness to pay. Motorists could be encouraged to choose a leasing arrangement over outright ownership. The authors propose changes in income tax policy to favor leasing so as to encourage leasing of older vehicles by low income households. Motorists would pay a monthly fee for vehicle usage, similar to the present vehicle rental arrangement.

All four approaches have one objective - to reduce transaction costs by shifting the responsibility of vehicle maintenance and emissions repair away from the vehicles' owners. Harrington and McConnell (1999b) predict that a utility-maximizing motorist would be indifferent to proper emissions repairs; hence, motorist's goodwill would likely be very valuable. They claim implementing any policy should be accompanied by a media campaign that would inform vehicle

owners in regard to clean car policies relying on the successful experience of the way society has embraced recycling.

### *Accelerated Vehicle Retirement (Scrappage)*

A more aggressive approach to reducing vehicle emissions is scrapping vehicles, a program that is becoming attractive to state legislators and regulators alike. The intention of this approach is to complement current I/M lane testing. Scrappage programs accelerate natural vehicle retirement by allowing for the purchase of vehicles from owners – vehicles are then typically crushed into blocks of scrap metal. Given the appealing aspect of this method, for eliminating high emitting vehicles, researchers have conducted empirical and analytical assessment of this proposal.

Legislators, in an attempt to combat mobile emissions, have enacted more stringent regulations and tighter cut points that apply to newer vehicles. To implement the updated regulations, auto manufacturers have devoted resources to seek cleaner vehicles, vehicles that have low in-use emissions. A side effect to more stringent regulation is the increase in new vehicles' prices, a phenomenon that causes low income motorists to hold on to their older vehicles. Therefore, the adoption of more stringent standards has generally been shown to prolong the retention of old vehicles in the fleet (Alberini et al. 1996 and Menz 2002). Tighter new standards have actually increased aggregate emissions in the short run (Gruenspecht 1982).

In an attempt to analyze the impact of regulation and the composition of fleets and new vehicle prices, Grunespecht (1982) modeled the behavior of scrappage. He concludes that scrappage rates for all year models were inversely related to the

real prices of new vehicles. As more regulations are imposed on vehicle makers, the price increases and the scrappage rate decreases. His model highlights the economic interaction among multiple externalities generated by regulations operating in a given program area. For example, if newer vehicles are more fuel efficient than older vehicles, the adoption of more stringent standards (which reduce the replacement rate) works against the goal of reducing aggregate fuel consumption. Therefore, Grunsepecht suggests that, when imposing more stringent emission policies, regulators should promote early retirement by offering compensation that is above the price motorists are willing to accept for vehicle replacement.

Along the same line, Manski and Goldin (1986) modeled individuals' scrappage decisions. They applied their analysis to scrappage rates of entire types and model years of vehicles as a function of market variables such as price and repair costs. This approach allows the determination of average scrappage rates for vehicle cohorts. The authors infer that there is a link between aggregate vehicle scrappage rates, and used and new car prices. As new vehicle prices, increase the scrappage rate decreases. This concurs with Grunespecht (1982) findings.

Dill (2000) reports that vehicles scrapped under a CARB buy-back program and under the Bay Area Air Quality Management District's vehicle buy-back program had a life time expectancy of about three years. Alberini et al. (1996) analyze the results of an experimental vehicle retirement program in Delaware in which owners of pre-1980 vehicles were offered \$500 for their vehicles. They estimated the relationship between the owner's reserved price and the expected vehicle's

remaining life in order to derive the supply curve for emissions reductions. Based on actual I/M data, the supply curve is derived from the consumer's willingness to accept a certain price for his or her vehicle. Their analysis suggests those emissions reductions are a function of the offer made for eligible vehicles in a scrappage program. They observe that an owner's willingness to accept an offer to participate in a scrappage program depends primarily on the vehicles' condition. They conclude that the scrapped vehicles are driven as many miles as the average old vehicles in the fleet, but that the remaining expected life of the scrapped vehicles is lower than previously assumed.

Alberini et al. (1996) maintain that vehicle retirement programs that target high-emitting vehicles are likely to be much more cost effective, with the social costs internalized, if the policy is well designed. They speculate that increasing registration fees based on vehicle age or emission results, taxes, or increased waiver limits, and increased cut points, would likely induce owners to trade in vehicles faster than they would otherwise. These added restrictions bring about voluntary vehicle exchange and produce efficient outcomes because they increase the cost of owning older vehicles. They estimate the cost of scrappage program to be less than \$6,000 per ton of HC reductions. They maintain this method is cost effective compared to other measure to reduce HC emission. These other measures include, the cost of reformulated gasoline is \$3,900 per ton, natural gas vehicles are \$12,000 per ton, and \$30,000 per ton for methanol vehicles (Alberini et al. 1996, 261.)

Most vehicle scrappage programs were instituted in I/M jurisdictions based on trading of emissions credits and were initiated so as to entice polluters to determine cost effective means to reduce air pollution; automakers receive credit when their older vintages retire. Supporters of this proposal recommend, in that same spirit, that credits could be used in lieu of implementing mobile emissions control measures.

Opponents of this program advocate that policy-makers will focus only on a vehicle's age rather than on the vehicle-in-use emissions, which has a detrimental impact on the scrappage rate. Most scrppage programs currently in use are based on the erroneous perception that all old vehicles are high-emitters. An arbitrary scrappage program could be inefficient when retiring old vehicles whose their in-use emissions are low and/or have a high anticipated residual life.

Beaton et al. (1995) argue that scrapping all vehicles older than 1980 and replacing those with vehicles whose average age and emissions match those of the newer part of the fleet would cost \$2.2 billion. Beaton et al. calculate the benefits of this action would amount to a 33 percent reduction in HC emissions and a 42 percent reduction in CO emissions. Stated another way, this is a 15 percent reduction in total HC emissions and a 19 percent reduction in CO emissions per billion dollars spent. This is a costly and inefficient solution, especially if the policy generally targets old vintages without considering a vehicle's actual emissions and residual life. Also, if all vehicles older than 1988 are scrapped, the result would be a 44 and 74 percent reduction in HC and CO emissions, respectively, at a cost of \$17 billion.

The EPA acknowledges that not all old vehicles are dirty vehicles and that many are quite clean. Most scrappage administrators do not make an effort to measure the real emissions of the vehicle involved.<sup>77</sup> A further shortcoming of scrappage programs is that they do not necessarily capture gross polluters; the gross polluter vehicle can be any vehicle that is improperly maintained, by any year, and not just old cars. Those seeking a quick fix through vehicle scrappage programs ignore this reality (Beaton et al. 1995).

#### **4.4.2 Proposals to Influence Motorist's Incentives**

Motorists' incentives refer to three key issues - the first with regard to periodic maintenance for vehicles. Regular maintenance is usually recommended in a vehicle's owner manual. The second incentive involves effective repairs if vehicles fail inspection test. The third key issue involves motorists taking responsibility for their vehicle's condition and the externality they generate. The aim of these proposals is to make lane testing more incentive compatible when compared to the current setup.

##### ***Emission Fees Proposal***

The current rigid I/M policy which relies on registration-based lane testing, has an appealing side; it is used to raise revenue (Harrington et al 1996b). Deviating from command and control policies to combat air pollution, economists

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<sup>77</sup> <http://www.ctccc.org/download/article19.doc>

recommended a reliance on economic incentive policies to lessen pollution and achieve economic efficiency. A more incentive-compatible approach, which is recommended by applied researchers, is to impose users' fees.

Economic efficiency in pollution control is achieved when the marginal cost of pollution control equals the marginal damage caused by pollution source (Baumol and Oates 1998). If the value of damage from pollution is known and emissions from different sources have the same impact on environmental quality, then setting a charge equal to marginal damages will automatically insure environmental targets will be met at minimal social cost (Baumol and Oates 1998). Accordingly, the optimal government policy should be to first to select a target amount of pollution, on the basis of emission inventory, and then to impose a tax rate on emissions necessary to yield good air quality. Harrington et al. (1996b) maintain that such a method would achieve the target pollution level at minimum cost.

To some extent, the first criterion was developed by the Clean Air Act through setting ambient emissions standards. The implementation of this approach, falls onto the EPA in assessing this fee. It is argued that this approach, if well customized to specific program areas, can achieve the desired social output with low administrative and enforcement costs.

Emission fees provide vehicle owners with choice; that aspect is absent from current programs. The rationale behind their proposal is that vehicle owners could respond to emission fees by repairing faulty components effectively, or by scrapping their vehicle altogether.

The emissions fee policy they examined is a two-part fee, when emissions are below model year cut points, motorist pay a low (or zero) fee, and if emissions are over a vehicle's emission standard, higher flat fees are assessed. They argue this proposal has considerable appeal if it is implemented at lower administrative costs, and could generate greater effectiveness compared to rigid regulatory policies.

Relying on Baumol and Oates' (1998) theory of internalizing externality and using simulation model one could compare the net welfare impact of emissions fees to internalize mobile emissions. Their simulation model captures aspects of both the stochastic and behavioral elements of effective emissions repairs. Stochastic elements include the initial true vehicle's emission level and emissions measurement errors. Behavioral elements include lasting vehicle repairs and the mechanic's ability to predict repairs' effectiveness. Even under conditions of uncertainty, regarding emissions repairs effectiveness, when accompanied with a two-part fee and subsidized repairs for low income motorist, they find that objectives of efficiency and equity are achieved. This is accomplished using baseline fees; motorists do not have to pay the fee until emissions exceed year model cut points. Vehicle owners will continue to pay fees until their vehicles are in compliance with year model standard emissions. Hence, motorists have options regarding whether to spend the maximum amount on fees or invest in a combination of test and repairs, depending on which is less expensive.

To reduce the burden of large repair costs on low-income motorists, they recommend allowing caps on total expenditures and offering repair subsidies financed by fees collected from other vehicles. From their simulation model, they

find that the repair ceiling should be equal to fees collected and subsidies paid. This would amount to less than \$100. They advocate that this method, distributing the cost of vehicle repair, is more equitable solution to a problematic issue. They find the monetary values of benefits achieved in terms of reducing emissions are \$10,000 per ton of NO<sub>x</sub> and \$3,000 per ton of HC, a total of 7 tons of HC and NO<sub>x</sub> reduction per year.

This proposal has an important advantage over current I/M programs; it induces motorists with failed vehicles to purchase proper fixes. Hence, emissions from older vehicle are reduced, a critical component that present rigid I/M systems have failed to combat. The drawback, though, is that it does not motivate motorists to regularly maintain their vehicles, a persistent problem that this proposal could not address.

### *Tighter Cut Points Proposal*

Scholars agree that the issue of vehicles' maintenance has undermined I/M goals, and therefore underestimated forecasted emissions reduction. The forecasted emissions reductions are critical component in determining credits claimed by state agencies through the SIP program. Research groups emphasize that the ineffectiveness of I/M polices come from vehicles' in-use emissions conditions. Also, the current system provides vehicle owners and mechanics ample opportunity to "game" the system.

Studies illustrate that gaming has taken a number of forms. There is evidence that vehicles owners have failed to register their vehicles at all, or have registered them at false addresses in jurisdictions without an I/M program. Also, to avoid repairs, vehicle owners have made changes to their vehicles before an emissions test, then undone those changes afterward.

Furthermore, some mechanics argue that vehicle owners have opportunities to make inexpensive repairs that produce clean emissions test that don't last. For example, if a vehicle fails an emissions test, a change of spark plugs may enable the vehicle to pass the retest, but the condition that caused the plugs to foul may be left uncorrected, which will lead to higher emissions later. Additionally, the inconsistency of emissions tests sometimes enables motorists to retake the emissions test without mending their vehicles.

To combat repair and maintenance incentive issues, Ando et al. (1999) offer yet another solution - tightening I/M cut points. They analyze how a change in the emissions rate cut points in Arizona would influence repair-related costs and associated emission-rate reductions, at least for one class of vehicles. In their experiment, they used vehicles from the 1990 and 1991 model years (both model years are associated with similar technologies) to accomplish the same emissions cut points. Arizona cut points are stricter for the 1991 than 1990 model year vehicles, which is why they chose vehicles from these years, to test their hypothesis. They found that initial test failure rates are lower for 1990 than for 1991 vehicles, although failure rates usually increase with vehicle age. This is not surprising because 1991 model year vehicles are subject to lower emissions cut-points. Using a simulation model, they examined the importance of tighter cut points on emissions reductions and failure rates. They compared the actual emissions reduction results and costs for 1991 vehicles with what they would have been if those vehicles had been subjected to 1990 cut points. They assume that vehicles are only repaired if they have emission levels exceeding the 1990 emissions standards. The authors agree that, although tighter cut points achieve emissions reductions they do so at higher costs. These higher costs are measured in terms of increased repair expenses and the inconvenience costs associated with multiple repairs.<sup>78</sup> They quantified the relationship among pollutants in the test results and post-repair emissions rate changes. They found that under looser 1990 cut points, fewer vehicles failed; 1,092 vehicles under looser cut points compared to 1,872 vehicles under tighter cut-points. They computed repair costs to be 60

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<sup>78</sup> Multiple repairs apply to multiple failures due to CO, HC, and NOx violations.

percent higher when tighter cut-points are applied, achieving an increase in emissions reductions of 30 to 40 percent. They maintain that, without considering benefits of fuel economy, about 5,000 weighted tons of reduction could be achieved for approximately \$4.6 million. This would amount to \$920 per ton of emissions reductions. They assert this is roughly 87 percent of emissions reductions under current program at 65 percent of the current costs.

Quantifying emissions reductions of tighter cut points compared to looser ones, Ando et al. found that 43 percent of HC emission, 29 percent of CO and 39 percent of NOx could come from passenger cars. They recommend that future attempts for further emissions reductions would be most effective and would arise from tightening light truck cut points. Further, they found that repairs appear to be most cost-effective for the heavier class of truck, although they make up only of one-quarter of all vehicle types in their repair database.

They concluded that the looser the cut points, the less likely it is that failed vehicles will receive proper repairs. They also determined that tightening cut-points across the board is unlikely to be cost effective. This is based on an empirical evidence that suggests that the proportional increase in cost-effective repair is more than the proportional decrease in emissions reductions with stricter I/M cut points. Conforming to Ando et al., Silberston (1995), in his discussion on urban planning, recommends, among other things, tighter legal limits on emissions for all types of road vehicles to control for lower air quality. Also, as was discussed earlier, Kukawka (1999) agrees that tighter cut points would bring about better vehicle repairs and a reduction in overall emissions levels.

## *Collection of Complementary Techniques*

Other researchers advocate the introduction of complementary measures to improve I/M program effectiveness. These mechanisms are meant to enhance ambient air quality and, most importantly, induce motorists to pay for an already existing pollution problem. Accordingly, the intention of the following proposed techniques is to increase the variable cost of driving through instituting market mechanisms. These are gasoline tax, pay at the pump, vehicle mile travel, and, vehicles sales tax and registration fees proposals. There was little literature that addressed some of these mechanisms.

### *Gasoline Tax*

Since 1950, the variable cost of driving has been decreasing (Ayres 1998). In 1932, the federal government levied a tax on gasoline of 1 cent per gallon--about 6 percent of the price of gasoline at that time--as a way to raise revenue.<sup>79</sup> Currently, the average tax paid on a gallon of gasoline in the U.S. is about 41 cents--or roughly 27 percent of the price (assuming an average retail price of \$1.50). Those 41 cents of tax include average state and local taxes of 22.6 cents.<sup>80</sup> In 2000, the nominal price of gasoline was over five times higher than it had been in 1950, but the real price was lower than in 1950.<sup>81</sup> In Europe, the gasoline tax is between 69 and 77

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<sup>79</sup> <http://www.spea.indian.edu/kenricha/Practice%20File.txt>

<sup>80</sup> <http://www.spea.indian.edu/kenricha/Practice%20File.txt>

<sup>81</sup> <http://www.cbo.gov/showdoc.cfm?index=3991&sequence=1&from=0>

percent of the total gasoline price, so the price of gasoline more accurately reflects environmental costs incurred in its use.<sup>82</sup>

An increase in the federal gasoline tax would require federal legislation, while an increase in state gasoline taxes would require independent action in each state. The latter action would probably be more appropriate because not all states are in violation of ambient air standards.

While gas tax can be used, their environmental effectiveness depends on the quantitative reduction in fuel use in response to increased gas prices, or the price elasticity of demand. The demand for car fuel is typically inelastic, but demand for a particular type of fuel is more responsive to price changes because of greater availability of substitutes (Menz 2002). Thus if overall gasoline use declined only modestly as gas prices increased, taxes might encourage motorists to substitute among different fuels. For example, diesel fuel is typically taxed at a lower rate than gasoline in virtually all European countries. The tax differential has been a factor in causing the use of diesel fuel to increase from 15 percent of the total fuel used in Europe in 1970 to 32 percent in 1999 (Menz 2002). Alternatively, gasoline tax increase might entice motorists to use alternative modes of transportation (Ayres 1998).

A major objection to the gasoline tax concerns equity issues (Ayres 1998). As reported by Ayres (1998), a study by Resources for the Future determined the burden of an increase in the federal gasoline tax by calculating the extra taxes paid

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<sup>82</sup> <http://www.spea.indian.edu/kenricha/Practice%20File.txt>

as a percentage of household income in various demographic groups. The study found that households in the lowest income quintile would face nearly three times the burden of those in the highest quintile. In short, it is regressive in its application.

### ***Pay at the Pump (PATP)***

It is a program that had the intention of providing universal liability insurance coverage. Levying a surcharge on each gallon of gasoline became an appealing proposal to control vehicle emissions.<sup>83</sup> Researchers sought this method as an indirect tool to motivate incentives toward driving more fuel-efficient vehicles. This insurance program would not necessarily generate revenue, but it would change insurance payments from a lump sum to an out-of-pocket expense. Lump sum payments lead to the perception that driving a car is cheaper than it really is because there is no frequent reminder of the actual associated cost.<sup>84</sup> Silbertson (1995) asserts the cost of private transportation should increase because current costs do not reflect damage done to health and the environment. He states:

... to the extent that such external costs are consequently not taken into account in users' travel decisions, transport is today, and for a long time has been, un-priced. This has resulted in a level of transport use that is significantly greater than that which would pertain if there were an equality between the marginal social benefits of transport and marginal social costs... (Silbertson 1995, 1275)

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<sup>83</sup> It was first initiated by Senator Daniel Patrick Moynihan of New York in the late 1960s.

<sup>84</sup> [http://www.fhwa.dot.gov/policy/1999cpr/ch\\_09/cpm09\\_7.htm](http://www.fhwa.dot.gov/policy/1999cpr/ch_09/cpm09_7.htm)

He adds that this method would not only charge for fuel but also would reflect vehicle tax and insurance costs. This makes the cost of driving to be variable instead of fixed. He concludes that this method would make the marginal social cost of vehicle use even more obvious than a high gas tax would (Silbertson 1995).

According to Ayres (1998), in California, pay at the pump plan, surcharges of 30 to 40 cents per gallon would replace the personal injury liability premium.<sup>85</sup> Khazzoom (2000) makes several arguments for PATP, most notably that it would accelerate fleet turnover. The likely reason for his recommendation is that older vehicles are less fuel efficient and require more frequent refueling. Therefore, the surcharge would make refueling more expensive. The idea behind it is to entice vehicle owners to switch to more fuel efficient (unleaded) vehicles or decrease the frequency with which they fuel their vehicles. Most importantly, drivers would switch to alternative modes of travel.

### *Vehicles Miles Traveled (VMT)*

The overall costs of driving include the cost of the vehicle, sales taxes, depreciation, the cost of fuel, fuel taxes, insurance premiums, vehicle registration fees, and, in most areas, the cost of required vehicle inspections. Many of those costs are fixed and do not vary with mileage. Policy-makers can make these costs a stronger function of miles traveled (Ayres 1998). This is important because there is prediction of a 25 percent increase in vehicle miles travel from 1990 to 2010 (Kovalsky 2003). Reducing vehicle miles traveled poses a significant challenge

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<sup>85</sup> Private collision premiums and other fees would be unchanged.

because policy-makers cannot depend on technological improvements alone to control for mobile emissions problems.

Ayres (1998) argues that this method will increase the variable cost of travel and the VMT fee collection will take place at the pump. He explains that this scheme would require “smart card” technology to record mileage and/or fuel consumption, on which fees would be based. He argues that the downside of such a scheme is that measuring vehicle mileage at regular intervals is problematic since drivers may tamper with their odometer. This approach can be refined to overcome the number of transactions involved with the “smart card” and the potential tampering problems (Menz 2002). Relying on the method of metered utility usage, when they register their vehicles on yearly (or biannual) basis, the motorists’s odometer reading would be the component that would determine a vehicle’s usage fees (Walls and Hanson 1996).

Under the assumption of a high correlation between vehicle age and emissions rates, Wells and Henson estimate VMT fees using 1990 California data. They divide total mileage of all passenger vehicles by total registration fees paid by motorists. They find a VMT-based registration fee of 0.94 cents per mile. Wells and Henson argue that a fee that varies by a combination of vehicle age and miles traveled would be much easier to implement compared to current registration fees. Their underlying assumption is held by most present program officials. This method is critiqued by many scholars, though, who claim this is what tainted the I/M program and made it inefficient and inequitable. Also, this method is critiqued

for its regressive approach in the absence of a subsidy program (Walls and Hanson 1996).

### *New Vehicle Sales Tax and Annual Registration Fees*

This proposal has two parts, the first address new vehicles sales tax assessments, and second, re-evaluation of the current annual vehicles registration fees.

Currently, the U.S. imposes a one-time “gas guzzler” tax ranging from \$500 to \$3,850 per vehicle based on fuel consumption rates for inefficient passenger cars and sport utility vehicles.<sup>86</sup> Some states in the U.S. differentiate a vehicle’s registration fees according to the vehicle’s weight, engine size, and/or number of axles (Walls and Henson 1996). These factors do not necessarily reflect a vehicle’s environmental impact (Menz 2004).

In Austria, Germany, and Norway, the annual registration fee depends on the environmental class of the vehicle as determined by the European Union Classification standards (OECD 2001). The annual vehicle registration tax in Germany depends on cylinder capacity, engine power, and emissions rates; low-polluting and high fuel efficiency vehicles are taxed at lower rates (OECD 2001). The “gas guzzler” tax in Germany ranges between \$1,000 and \$7,000 per vehicle (Menz 2002).

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<sup>86</sup> <http://www.epa.gov/otaq/imports/factmnc.htm>

Annual vehicle registration fees are differentiated according to their emissions results. This is a novel concept because it is an assessment in accordance with the vehicle's environmental impact. Wells and Hanson (1996) say that this provides environmental benefits with no net increase in average household tax payments. They emphasize that, in addition to improving efficiency in the market for emissions, this method might produce a "double dividend" by reducing deadweight losses generated by existing taxes. They add that this method constitutes a tax shift rather than a tax increase. They explain that motorists already pay fees and taxes to register their vehicles; under the reform policy, they would simply pay these taxes and fees in a different way. Using California emission data, Wells and Hanson (1996) quantified emissions fees to be 0.46 cents per gram of HC emission. Small and Kazimi (1995) came up with a range of estimates of marginal damages from HC and NO<sub>x</sub> emissions, with an upper end of this range for HCs being 0.45 cents per gram. The estimation of Pigovian tax by both studies is very important because it outlines the foundation for emissions fees assessments. It also provides policy-makers with tools for combating several problems, namely internalizing negative externality associated with vehicle use.

In Germany, there is evidence that the differential tax has achieved environmental objectives: From July 1997 to January 2000, the stock of high emissions vehicles decreased from 6.9 million to 3 million while the number of vehicles meeting the tighter emission standards increased from 6.2 million to nearly 16 million (OECD 2001).

To implement such a program, there exist vast information provided by automakers to the EPA through the new vehicle certification process. This information includes vehicles' horsepower, fuel efficiency, durability, emissions component degradation rate, etc. These characteristics can be passed on to the testing lane to establish basic annual fee assessments (Menz 2002). Along with this strategy, emissions fees can be adapted in accordance with vehicles' emissions status upon annual registration (Menz 2002). If emissions are below year standard cut points, motorists do not pay for violations, but they still pay their vehicle annual registration fees depending on their vehicle's characteristics and their environmental impact (Wells and Hanson 1996).

This process requires little modification to existing I/M programs, and guarantees that the social cost of mobile emissions is rectified. To motorists, this will serve as a reminder of the cost of their vehicle use. This method is implemented successfully in most European countries (Mayeres and Proost 2003).

In the U.S., most of the allocation of vehicle registration currently goes to fund the construction and maintenance of state highways, county roads, and city streets (Wells and Hanson 1996). Silberston (1995) states: "road building is seen as reducing congestion locally, but the gains are often lost quickly in growing traffic as the economy grows."

Mayeres and Proost (2003) demonstrate, using a general equilibrium model analysis, how the efficiency, equity, and acceptability of a reform depend not only on the change in regulations but also on the way the extra tax revenues are used. To

that end, Silbertson (1995) advocates, that resources (tax revenues) should be switched from road- building to improving public transportation.

## 4.5 Analysis and Discussion

All vehicles subject to I/M program are required to meet emissions cut points appropriate to their age. Failure rates in a typical I/M program are 5 to 15 percent so that approximately ten vehicles need to be tested to find one vehicle in need of repairs (Lawson et al. 1996). Emissions repairs differ in one important respect from ordinary maintenance and safety repairs in that vehicle owners receive no direct benefit from reduced emissions. Scholars argue that repair costs are heterogeneous, and expenditure bears little relationship to emission reductions.

Reducing aggregate mobile emissions has been the focus of many policy-makers and legislators. As a result of deterioration in air quality, amendments were passed to the original U.S. Federal Air Quality Act in the hope of achieving reduction of overall fleet emissions.

Recent studies point to the fact that emissions vary by both age and mileage of the vehicle. Scholars have demonstrated other systematic variations among similar-age vehicle and in-use emissions. Also, emissions appear to vary by manufacturer, including whether the vehicle is imported or domestic (Bishop et al. 1996 and Bin 2003). The heterogeneity among vehicle characteristics makes generalization more difficult.

Legislators also hoped that regulations would provide a self-policing device for vehicle owners to maintain their vehicles well, but numerous evidences have shown otherwise. Differences in maintenance probably account for the apparent correlation between vehicles' emissions and the owners' socioeconomic status,

even when correcting for vehicle age (Ando et al. 1999). Other ideas have emerged from recent in-use emissions studies suggesting that vehicles with transferred ownership have substantially higher emissions than vehicles still belonging to the original owner (Slott 1997).

Another variation among test results has also surfaced as a problem-variation in lane test emissions results. Vehicle emissions depend on a vehicle's speed, acceleration, load, and whether the vehicle is in a "cold start" mode. Inherent vehicle variability and variation in emissions results have implications for *how* emissions reductions are calculated. Emission improvements are determined by taking the difference in emissions between the vehicle's initial test results and its final results (NRC 2001). Because improvements are determined only by examining the emissions of failed vehicles, a bias is introduced. Another variation that is well documented is in the failed vehicles' repair costs and the variation in the repair effectiveness. I/M program regulators assumed that repair costs for tailpipe emissions would be about \$120 per repaired vehicle; studies have proved that is not the case (Lodder and Livo 1999).

There is strong evidence that suggest that high-emitting vehicles belong to low income owners. Program officials tried to make emissions testing and repairs more equitable by instituting waivers when repair costs exceed a certain amount of monies paid: such waivers can alleviate the harshness of repair costs. As was demonstrated, this aspect has led to ineffective repairs.

Most of the policies addressing the universal pursuit of marginally emitting vehicles have problems. Among them are the differences in vehicle emissions levels in relation to vehicle characteristics. It is the policy of pursuing the marginally emitting vehicles that makes the program cost ineffective and unfair. Marginally emitting vehicles usually have emissions just above the threshold of emissions standards for vehicle-year models. Marginal failure is probably due to the fact a vehicle is not maintained over its life or is caused by some initial breakdown in the emissions control systems. It could also be attributable to some engine wear and tear. According to the literature, to repair these vehicles could range from \$100 to \$250 depending on the defective component. Thus, the expected repair cost is below that where waivers can kick in. Based on personal interviews with auto mechanics, in Fort Collins, Colorado, it is well known in the business that consumers can pay the fix-it amount and to some extent mechanics guarantee passing the test retake. These actions are taken by motorists and mechanics to overcome the inequitable side of present I/M policy to pursue the marginally emitter vehicles.

To combat the above deficiencies, scholars have proposed a variety of solutions. Some are theoretical in nature, and others have practical applications. Some proposals require minor modifications to current I/M programs and others have the potential for public disapproval. The proposals suggested here are contrasted below in terms of efficiency and equity. These two are broad concepts; critical components of each are the following:

Efficiency criterion:

1. Effective at reducing excess vehicle emissions.
2. Produce emissions reduction at lowest cost when evaluated against alternative policies.
3. Produce net benefits to society.
4. Designed to be updated with changes in socioeconomic and environmental conditions and technological developments.

Equity criterion:

1. Polluter pays principle.
2. If it does not impose a burden on the non-polluter.
3. If it does not shift the harm from one group to another.
4. If it does not transfer the harm from the environment to the economy.
5. If it is sensitive to social equity.

The trade-off between efficiency and equity has been long discussed by economists and politicians alike; they are two competing goals that depend on society's objectives. The efficiency notion proclaims how society is using its resources and, equity defines the well-being of individuals. They are two competing requirements that influence the acceptability of any policy reform. One condition that must be met for individuals to accept a policy change is that his/her utility is not reduced (Mayers and Proost 2002). Another condition is how society values the burden of a policy (or policy change) on low-income groups (Stedman et al. 1998). Additionally, this study finds that there exists a trade-off among some

equity criteria. Consequently, this study leaves acceptability to be determined by societal values. In what follows, an analysis is made of each proposal given the efficiency and equity criteria as defined above. Table 4.2 displays summary evaluation of these proposals.

Table 4.2 Summary Evaluation of Various Proposals								
	Remote Sensing	Early Retirement*	Emissions Fees	Tighter Cut Points	Coase Approach			
Efficiency					Extended Warranty	Repair Subsidy	Centralized Liability	Mandatory Leasing
Effective at reducing excessive emissions	Yes if: Motorists comply to the Notice. If devised to address effective repair.	Yes	Yes	Yes for high opportunity cost motorists	Yes on the long run	Yes	Yes	Yes
Produce emissions reductions at lowest costs	15 cents per reading	\$6,000/ ton of HC reduction	\$3,000/ton of HC reduction \$10,000/ton of Nox reduction	\$920/ ton of HC reduction	No	Yes	No	No
Proposal impact	250,000 screened vehicles versus 19,000 vehicle under current lane testing	5 Million Meteoric Tons of reduced greenhouse emissions by 2005: 33% of HC reductions 42% of CO reductions	7 tons of HC and Nox reduction per year	43% of HC reductions 29% of CO reductions 39% of NOx reductions	N/A	N/A	N/A	N/A
Up-date given socio-economic	Yes	Yes	Yes	N/A	No	Yes	Yes	Yes
Up-date given technology level	Yes	Yes	Yes	N/A	No	Yes	Yes	Yes
<b>Equity**</b>								
Implement Polluter-pay-principle	Yes	Yes	Yes	Yes	No	No	No	No
Elevate burden on non-polluter	Yes	Yes	No	Yes	No	No	No	Yes
Eliminate the harm to another group	Yes	Yes	No	Yes	No	No	No	No
Lift the harm to the environment	Yes	No; with manufacturing new vehicles	Yes	No	No	Yes	Yes	Yes
Sensitive to social equity	No	No	Yes with a subsidy program	No	No	Yes	Yes	Yes

\* Comparative evaluation is found in table 4.2.1

**Table 4.2.1**  
**Comparing the Scrappage Program Estimated Costs and Emissions Reductions**

	HC reduction	CO reduction	Total cost
<b>Scrappage Program (Alberini et al. 1996)</b>			
Scrapping 1980 year model vehicles and older	33 percent	42 percent	\$2.2 Billion
Scrapping 1988 year model vehicles and older	44 percent	74 percent	\$17 Billion
<b>Alternative to Scrappage Program (Alberini et al. 1996)</b>			
Reformulated Gasoline			\$3,900 per ton
Natural Gas Vehicles			\$12,000 per ton of HC reduction
Methanol Vehicles			\$30,000 per ton

#### 4.5.1 Proposals to Combat High Administrative Costs

##### *Remote Sensing*

According to the literature, the fact that smaller numbers of vehicles generate a large fraction of mobile emissions indicates that it is cost ineffective and unfair policy to subject all vehicles to a periodic lane test. Scholars advocate that the high variability in vehicles' emissions and motorists' behavior suggest that lane emissions testing results are not dependable. Remote sensing technology has emerged to provide solutions to those problems. This technology can be updated to reflect different cut points for different program areas, taking into consideration factors such as latitude and air temperature. Given the flexibility of remote sensing, it can be updated to reflect changes in the environment.

As was stated earlier this technology is cost effective in identifying high polluters, but there is doubt about motorists' response to the notice, and even more doubt concerning whether they will resolve their vehicles' emissions problems. The literature asserts that identifying non-compliant vehicles alone will not yield correction in the current I/M program. Assuming motorists conform with the notice, then the program will yield a cost-efficient outcome compared to present I/M testing. To that end, remote sensing has the potential to remove toxins from the air if effective repairs are addressed.

This proposal has a certain appeal to some researchers because it emphasizes a polluter-pay policy. It also does not impose burdens on non-polluters and does not shift the harm on to another group. With remote sensing technology, vehicles running clean will be congratulated immediately through billboard notification. This message signals that a driver's vehicle is in compliance with model year emission standards. This process saves motorists the time and cost of going through lane testing. This proposal could be very cost effective in achieving lower fleet aggregate emissions and yield net benefits to society, if devised to address effective emissions repair issues.

Remote sensing technology was invented with the sole purpose of identifying high polluting vehicles. This purpose indicates its inequitable nature. Researchers assert that the probability of low income individuals owning high polluting vehicles is high; therefore, remote sensing will target low income motorists. Thus, a program that uses remote sensing technology to identify high polluters will probably be insensitive to social equity. Also, motorist ingenuity in detecting locations of remote sensing will lead them to avoid these sites. Consequently, this program is not only unfair but also does not provide the results for which it was invented.

Most researchers agree that an I/M program based on remote sensing alone would not be effective in addressing mobile emissions reductions, but it would serve as a tool to identify vehicles that fail to meet emissions standards. Given that all vehicles in a program area are unlikely to be screened by remote testing, data gathered will probably not reflect accurate fleet emissions. It may indicate average

emissions, but this aspect will not deliver a clear representation of ambient air quality. Accordingly, this tool will not provide regulators with proper measurements with which to effectively address aggregate fleet emissions reductions.

Despite the enthusiasm of most researchers for this technology, studies have demonstrated its erroneousness in data collection. These studies point to those vehicles that were identified as high polluters, yet when tested in lane testing had passing results. Relying solely on remote sensing technology has a major drawback compared to current emissions testing. I/M programs, most likely, would be converted to automatic process, neglecting the human aspect of lane testing. If it is not accompanied with a repair subsidy program, then the program is deemed to be inefficient and inequitable as defined by this study's criteria. It will be inefficient because it will be inflexible in regard to the socioeconomic setting for a given program area and inequitable because low income motorists are going to be disproportionately harmed. If remote sensing technology is implemented as a complementary testing tool to a current I/M program, then these deficiencies would be eliminated. Another political issue might arise from the fact that remote sensing compromises the right of privacy by identifying travel patterns of individual vehicles.

### *Coase Approach*

According to some studies, the current I/M institutional arrangements have provided motorists with ample opportunities and incentives to avoid compliance. These studies also raise questions about the original justification of assigning liability to motorists. They provide evidence consistent with the possibility that the relatively poor emission performance of some vehicles is attributable to defective design and to non-durability of emissions control systems. These inadequacies in design originated with the manufacturer or perhaps poor maintenance by previous owners, or perhaps little service is done by present owners. These causes/effects pressed some researchers to explore other ways to change manufacturer and motorists' incentives alike. They claim that motorists' opportunities and incentives to avoid the system are largely attributed to the high transaction costs. These costs are associated with program enforcement and compliance. These researchers maintain that the existence of large transaction costs could have serious implications and that transaction costs determines the cost effectiveness of any program and undermine a program's perceived benefits. Thus, they assert that reduction in transaction costs will enhance programs' efficiency. Therefore, they explored other means of shifting the responsibility for maintaining vehicles and the burden of fixing them away from motorists.

Reduction in transaction costs can be implemented using one of four different approaches; extended warranty, repair subsidy, centralized repair liability, and mandatory leasing. All four approaches reduce the number of agents involved in

vehicle maintenance and emissions components repairs. As for reducing aggregate fleet emissions, all four approaches are predicted to achieve a certain enhancement of ambient air quality (Harrington and McConnell 1999b). Moreover, researchers assert that all four approaches are sensitive to social equity, more so than the current program's setup. There is no empirical evidence concerning any approach that can be used to evaluate net benefits to society. Therefore, inferences about their application serve as suitable alternatives.

For those motorists who periodically service their vehicles, all four approaches have no impact; if anything, they may attempt to reduce their out-of-pocket expenses toward considerable maintenance actions. This is explained in economic theory through the principal-agent problem. Also, with a system that helps motorists with the expenses of repairing emissions control systems, there will be a tendency to free-ride the system and misuse vehicles, thus increasing the predicted program's aggregate cost. As a result, these proposals disregard the polluter-pay-policy. In addition, in the presence of a program that provides for maintenance and emissions-related repairs there will be greater tendency for moral hazard problem to emerge. This will increase motorists' reluctance to implement any meaningful maintenance; thus increasing program's compliance costs. Principle-agent and moral hazard problems are related dilemmas, but one needs to emphasize that the first is related to pre-contractual agreement, while the latter is post-contractual agreement. For any of Coase approaches to have a successful implementation, regulators need to address these incentive issues. Specifically, in emphasizing on what emissions component parts are covered under the modified I/M lane testing.

Hence, consumers' tendencies to free ride the system are minimized, and reduce the moral hazard dilemma.

The *extended warranty* program applies *only* to newer vehicles and not the existing fleet. This program has a series of drawbacks. Motorists would probably be tempted to take advantage of the extended warranty program to sell and/or junk their vehicles for newer ones. This action has some implications, the first of which is increased demand for newer vehicles, which would probably increase new car prices causing the retention of older vehicles. Another presumption is that there would probably be decreased aggregate emissions levels in the short run. However, the environmental impact of manufacturing new ones would have a detrimental impact on the environment in the long run.<sup>87</sup> Manufacturing new vehicles involves steel processing, an action that generally creates environmental hazards.

Accordingly, this program, if devised, would shift the burden from individuals to the environment. Under this proposal, auto manufacturers would most likely experience increases in operating costs. History provides evidence that they would probably lobby for relief. The extended financial aid would come from federal tax revenues. Thus, this proposal, if implemented, would deprive other federally funded programs of financial support. Also, individuals who pay taxes and do not possess vehicles would subsidize the cost of fixing these high polluters. Therefore, this proposal would impose a burden on the non-polluter. This approach would be effective at reducing excessive emissions from new vehicles, but would fall short in addressing other program problems. Benefits of this approach would be realized at

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<sup>87</sup> It is reported by EPA (1996, pp 58) there is 88,930,556 pounds per year of toxic chemical released from vehicle manufacturing facilities and related sources.

some point in the future, but would not solve the existing dilemmas associated with finding and fixing marginal and high-polluting vehicles. This program does not have a social equity target. Low income motorists would not be able to purchase newer vehicles. To correct for this, the state could establish a subsidy program to help low income groups endure the cost of buying newer vehicles. This is similar to the mortgage arrangements for first-time home buyers.

The second approach, *subsidizing emissions repairs*, would generate substantial transaction cost reductions and probably create immediate and noticeable emissions reductions. Therefore, it would likely produce net benefits to society in terms of effectively reducing aggregate fleet emissions. It could also be designed to be updated given changing socioeconomic and environmental conditions. The emissions subsidy program would lessen the hardship on low income motorists; accordingly, it would be sensitive to those motorists. The obstacle, as indicated earlier, is funding for this program, which would require either instituting new taxes or raising old ones. Either action would probably lack public appeal. It would also doubtless shift some of the tax burden to those individuals who do not own vehicles, thus, inflicting harm on another group. Further, this approach would perhaps suffer from some form of collusion between drivers and mechanics in regard to the classification of emissions related repairs. If these actions became common practices, then the program would experience misallocation of resources and transfer the harm from the environment to the economy.

The third approach, establishing *centralized repair facilities*, has general public appeal. It would probably be effective at reducing aggregate fleet emissions but disregard the individual's responsibility for his/her vehicle. This approach would likely generate a more equitable outcome than current I/M programs. Low income motorists would mostly benefit from this program, achieving the goal of social equity. By doing so the program would shift the burden of fixing vehicles to another group, by financing a repair subsidy program through the use of federal tax revenue. This would inflict unnecessary costs on non-polluters. The biggest obstacle, though, is how to divide the responsibility of emissions repairs and, most importantly, who would take on this responsibility. The program could be set up on the basis of emissions reduction credits (allowances). This is similar to a program in place to address stationary polluting sources. Allowances could be distributed on either a grandfathering basis or by auction. But how would the fleet be partitioned, and how each motorist know his/her designated repair facility? It would probably be based on either residence or workplace; these details are not addressed. In sum, this approach would likely have to have a complex administration, which would require a large amount of funding. The goal of this proposal is lowering transaction costs; instead, there would be an increase in total costs of operations, defeating the purpose of this approach.

The fourth approach, *mandatory leasing*, would have serious political and public opposition. In this approach, each leasing firm would pay fees based on the sum of emissions through lessees depending on a vehicle's emissions. Motorists would have the option of choosing a leasing company over outright ownership. The

income tax system would need to be adjusted to favor leasing vehicles rather than owning them. The vehicle emissions control policy would be directed at the leasing firm, which presumably would hold leases on a large subfleet of vehicles. This approach, if implemented, would be efficient in terms of controlling policies in regard to fleets' emissions but it is ineffective given the high administrative costs. If policies were well designed to reflect marginal damage of subfleet excessive emissions, then this proposal would reduce environmental degradation in an efficient manner. It is equitable because the burden of repair costs are transferred to firms owning some permits that give them the right to pollute. It also does not impose a burden on the non-polluter. The detrimental impact of this approach would be on the privately owned emissions-related repair facilities that draw their income from emissions testing and repair. These shops would probably have to compete with repair shops affiliated with rental companies. The affiliated repair shops probably would experience economies of scales. The unaffiliated facilities would most likely shut down because of low demand or have to alter their business to handle other vehicle repairs. Consequently, the existence of state-independent emissions testing and repair facilities would likely be short lived. Also, quick-lube shops would be out of business. This program, if implemented, would shift the harm from the environment to another group.

All four approaches, if implemented, would decrease transactions costs by reducing the number of interacting agents involved in controlling mobile emissions. Except for extended warranties, these approaches would provide policy-makers with devices for controlling aggregate fleet emissions on the short run.

Each proposal has its own merits and drawbacks depending on the program's goals. If the goal is to address "motorists' avoidance incentives," then centralized repair liability and mandatory leasing approaches are more appealing. If the aim is reduction in monitoring costs, then the subsidized repair, centralized repair, and mandatory leasing approaches would be favored. And finally, if the purpose is to induce manufactures to produce durable vehicles, then extended warranties and mandatory leasing would be superior. All four approaches would probably eliminate the uncertainty of lemon used cars. Except for extended warranty proposal, all are sensitive to social equity, but would be likely to create other forms of dilemma-namely the principal-agent problem and free-riding the system.

### *Accelerated Vehicle Retirement*

This proposal features a policy that offers drivers a cash payment so that motorists would scrap their old vehicles. Vehicles must be driven to the junkyard for the owner to qualify for the payment. Since HC emissions from older vehicles can be many times greater than those from newer ones, researchers assert that this is a cost-effective policy for reducing HC emissions. The logic behind their recommendation is that catalytic converters lose their effectiveness between 50,000 and 100,000 miles. Also, older vehicles are prone to experience frequent breakdowns in fuel processing that result in high HC emissions. Furthermore, HC emissions regulations were considerably less stringent 15 years ago than they are currently. Consequently, this program, if implemented, enforces the polluter-pay-principle.

Scholars maintain that this policy is also effective in reducing greenhouse gas emissions because older cars, especially these manufactured before 1978, are not as fuel efficient as new ones are. According to some researchers' estimates, a greenhouse gas emissions reduction of 5 million metric tons can be achieved by 2005 as a consequence of this policy. But it is also argued that if a scrapped vehicle is a marginal rather than a high emitter, the expected emissions reduction represents a very modest improvement to air quality.<sup>88</sup>

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<sup>88</sup> Table 3.2.1 displays comparison of this proposal's costs and estimated emissions reductions to reformulated gasoline, natural gas vehicles, and methanol vehicles. Beyond this tabulation this study was not able to have a uniform benchmark unit to effectively compare costs and benefits.

Despite vehicle manufacturers' hesitation toward scrappage, they indicate their support. Their reluctance to take an active role in this technique points to their acknowledgement about making non-durable vehicles. Their agreement to participate in this program comes from the fact that they gain emissions credit by scrapping old high emitters that belong to their line of production.

This proposal, if implemented, needs to have well-tailored policy on the criteria for selection candidates for scrappage. According to the literature, there is good statistical information in regard to the average expected lifetime of vehicles of different vintages; nevertheless there is uncertainty about the remaining lifetimes of vehicles that have trouble passing lane testing.

For a scrappage policy to be efficient at reducing fleet emissions and produce a net benefit to society, all variables related to vehicles' conditions need to be recognized. If all relevant vehicles' attributes were quantified then this proposal would be cost-effective and produce net benefits to society. A scrappage program not only has the potential to reduce excessive emissions at the lowest cost, but it also has the ability and mechanisms to be updated given changes in environmental conditions. It also has the potential to be adapted to technological developments in the automobile industry. Additionally, scrappage-based I/M program elevate the burden of costs on non-polluters. Specific attention needs to address motorists' motivations in junking their vehicles in order to qualify for cash payments. A proper policy prescription to combat this is to grant motorists credits towards purchasing new or low emissions vehicles rather than lump-sum cash payments.

There are disagreements among researchers in regard to the linkage between vehicles' age, mileage, emissions levels, and motorist's behavior. Scholars maintain that there is no general rule that governs these variables; hence, generalizations will not serve the program's objectives. Yet studies have established strong link between older vehicles and low income motorists. Consequently, this proposal, if implemented without this consideration, would create disproportional harm to low income motorists. Some scholars are skeptical in regard to scrapped vehicles' replacement value; also, there are questions concerning alternative modes of transportation. Owners who scrapped their vehicles could possibly end up purchasing vehicles from the same class of older makes. If this were realized, then the program would be inefficient. Additionally, this proposal gives no incentives to reduce driving, nor does it motivate motorists to effectively repair their vehicles.

Another point under discussion is in regard to collectable vehicles, which certainly fall into the category of high emitters. Would policy-makers coerce motorist with collectable vehicles to scrap their vehicle? If so, what would be the replacement value for these vintages? If vehicles are scrapped and owners are compensated (favorably) in accordance with their vehicles' blue book value, would there be restrictions on the next vehicle purchased? If so, then the program would not preserve individual choice.

Old vehicle owners cannot afford new vehicles; would be there any subsidy program in place to help with the purchase of a newer vehicle? If not, then the program is deemed to be insensitive to social equity. Consequently, this program is seen as a regressive approach to controlling for mobile emissions.

Lastly, the environmental impact of scrapped vehicles could potentially transcend the environmental objectives of the program. This method transfers the harm from mobile emissions to stationary sources. Accordingly, implementing scrappage-based I/M program is analogous to shifting the damage from one media to another, if vehicles are improperly scrapped.<sup>89</sup>

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<sup>89</sup> Approximately 9 million cars (about 94 percent of all scrapped vehicles) are collected and recycled annually at one of the 12,000 scrappage/disassembly location in the U.S (EPA 1996, 89). At least 75 percent of the material collected from scrapped vehicles is recycled for raw material use, and 25 percent land filled. This comprises about 1.5 percent of total municipal landfill waste (EPA 1996, 89). When a vehicle is dismantled, fluids can be recovered, including oil, antifreeze, and refrigerant. Solid parts such as the radiator and catalytic converter are removed for recycling or reuse. The battery, fuel tank, and tires are also separated. The remaining vehicle is shredded (at one of the 200 shredding operations in North America) and sorted into ferrous, nonferrous (8.7 percent of the whole vehicle), and residual components. The residue contains plastics, glass, textiles, metal fines, and dirt, which are generally all landfilled (EPA 1996, pp 90). Disposal of used tires from motor vehicles, used parts and leaking fluids can pollute sewers, wastewater treatment plants, and groundwater supplies, as well as take up landfill capacity. The typical car battery weighs 30-36 pounds and contains 18-20 pounds of lead acid and electrolyte solution (EPA 1996, pp 91). Lead-acid batteries, primarily from automobiles, rank first, by a wide margin, of the products containing lead that enter the waste stream. The disposal (versus recycling) of such batteries means the introduction of lead, sulfuric acid, and polypropylene, all hazardous waste, into landfills or the environment (EPA 1996, pp 94.)

## 4.5.2 Proposals to Influence Motorist's Incentives

### *Emissions Fees*

Under this proposal, because of the subsidy program, vehicle owners are not subject to high repair costs; thus, emission repairs would be incorporated into the norms of owning vehicles. The negative aspect of this adoption is that motorists would have little incentive to maintain their vehicles well, knowing that if their vehicles failed it could be repaired at lower marginal costs. In terms of effectively lowering aggregate fleet emissions, this proposal provides simulated evidence of promising results. Whether actual reduction can be achieved depends on the concentration of effluents flowing from the polluting source.

Pollution fees has been theorized and assessed for water pollution and implemented by setting a tax per gallon of effluent. However, pollution fees to combat air pollution are somewhat different. In the meteorology literature, air pollution is recognized and simulated in four distinct phases: transport, dilution, depletion, and reaction (Stern 1976). The first three processes are governed by wind direction, speed, and latitude. According to Stern (1976), in the reaction phase, mobile emissions react differently in the presence of radiation from the sun and different atmospheric contents. He adds that the most distinct reactions combine HC and NO<sub>x</sub> to form smog. Moreover, the combination of moisture with sulfur oxide, form airborne sulfuric acid, which, among other things, tends to accelerate the deterioration of ancient monuments (Tietenberg 1974). The

implementation of this approach, imposing a baseline fee, would minimize the cost of reducing total emissions at the source but would fall short in minimizing the cost of reducing effluent concentrations (Tietenberg 1974). In addition, the marginal damage of pollutants among different regions is different depending on emissions inventories. Therefore, uniform baseline fees will not serve a program's efficiency.

The decision behind the initial I/M program vehicle's emissions standards, was an arbitrary decision and created uncertainty in regard to actual emissions reductions (NRC 2001). If these actions are replicated, then a new program would not reflect an optimal level of clean air. Although emissions standards manipulations leave uncertainty in emissions testing, they have an appealing aspect. Regulators in low ambient air quality areas can implement dynamic emissions fees adjustments to reflect the desired level of clean air. In areas (or seasons) where smog is a major environmental hazard, program officials are equipped with a mechanism with which to adjust/manipulate preferable cut points and flat-emissions fees. But this notion creates uncertainty in emissions standards among motorists and testing stations. Therefore, for this proposal to function favorably, regulators should set emissions fees based on historical levels of air quality and aggregate mobile emissions, and the updates, for emissions fees and standards, should not be frequent.

The authors provided evidence of a probable emissions reduction at a cost lower than command and control based programs. Contrasting the benefits of the HC reductions of this proposal with scrappage-based program, it seems that this proposal has the potential of achieving reductions at a lower cost. The scrappage

program's cost of HC reduction is \$6,000 per ton as opposed to the emission fees proposal of \$3,000 per ton of HC reduction.

According to their simulation, a flexible aspect of this proposal lies in instituting a repair ceiling; repair caps should equate fees collected. Under this proposal, repair ceilings and emissions fees could be easily manipulated to reflect the poverty line, thus achieving a subsidy level that is correlated with income levels in a given program area, state, or time frame. Such aspect makes this proposal sensitive to social equity. Moreover, the set-up choice of "paying high fees until the vehicle get fixed" and "fix it at subsidized payment" preserves individual choice. It also promotes a polluter-pay-policy.

Another point to bring up is, as with any subsidy program, whether such procedure can be devised that would work in the real world; that is, would it induce the right repairs to be made without excessive fraud or cumbersome bureaucracy? Fraud is a potential problem, for there is both the temptation and the opportunity for collusion between vehicle owners and mechanics to find ways to treat ordinary maintenance as environmental repairs and hence eligible for subsidy.

Similar to the initiation of many subsidy programs, there would be unsettling discomfort among some program officials and citizens. Their displeasure would arise on the basis of many arguments supporting the notions of wasting resources to support consumers' dependence on the system for relief, thus shifting the burden of fixing failed vehicles from one group to another. Nevertheless, given society's quest for cleaner air, measures such as subsidized repairs could achieve society's goal of a healthy environment in an equitable fashion.

### *Tighter Cut Points*

As was noted earlier, automakers adopted newer regulations by not only manufacturing vehicles that produce few in-use emissions, but also vehicles that require little maintenance compared to 1960 and 1970 vintages. The general trends in motorist's behavior are to use a vehicle for 100,000 to 150,000 miles and then sell it or junk it.<sup>90</sup> These actions have created a disposable car attitude. Researchers and mechanics have acknowledged that newer vehicles could last longer and cover more miles if maintenance were applied in accordance with manufacturers' suggested manuals.

According to interviews with auto-mechanics, new vehicles, if not well maintained, can suffer deteriorations in engine and emissions control equipments. The deterioration of emissions control equipment takes on accelerated rate as vehicles grow older, particularly if little service is applied. Evidence from various researches suggests that the probability of vehicles failing emissions tests tends to increase with age after controlling for vehicle characteristics. Accordingly, this proposal tries to motivate motorists to maintain their vehicles and purchase lasting repairs.

Tighter cut points mean vehicles will experience frequent test failures. The authors who have studied this matter suggest rational vehicle owners will make decisions based on their opportunity cost to maintain their vehicles in good condition. For individuals with high opportunity costs, the probable outcome is favorable to I/M regulators in terms of servicing their vehicles, achieving lower

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<sup>90</sup> According to auto mechanic interviews in Fort Collins, Colorado, 2003.

failure rates for moderately new vehicles. Also, under tighter cut point programs the proposal suggests, motorists with high opportunity costs would purchase proper repairs for their vehicles as well. Therefore, not only do tight cut points motivate consumers to maintain their vehicles, but also encourage motorists to fix their vehicles with proper repairs. Accordingly, this proposal has the potential to be effective in reducing excessive mobile emissions at lower costs. Compared to accelerated retirement program and emissions fees proposals, the estimated cost is \$920 per ton of emissions reductions, making this proposal the most cost-effective.

Conversely, studies demonstrate that older vehicles are likely to be owned by low income individuals and to have experienced multiple owners. These individuals not only have a low opportunity cost of time, but also cannot afford to maintain, let alone repair, their failed vehicles properly. It was substantiated that some failed vehicles do not show up for test retakes. Scholars explain that vehicles either went unregistered or were registered under false addresses in non-I/M program jurisdictions. Also, researchers verify that current I/M program administrators are experiencing difficulties in finding the high polluter vehicles.

As suggested by some authors, to motorists, present cut point programs inflect a burden of higher costs if they do not qualify for waivers. If this program were implanted, the burden on low income motorists would increase. Therefore, tighter cut point based program would be faulted for being insensitive to social equity.

The side effect of this proposal would likely be an increased skirting of the emissions testing program, thereby reducing the positive effects of emissions reduction. In decentralized programs, where testing and repairs can be carried out

by private firms, fraud action would probably increase as well. If fraud and evasive actions by motorist increased, then instituting tighter cut points would defeat the purpose of this proposal. Hence, few environmental benefits are attained.

Moreover, this policy, with its attempt to correct for motorist incentives, probably would shift the harm to low income motorists and to the environment. The total impact on air quality would depend on the vehicles in-compliance to non-compliance ratio. If the percentage of vehicles that are in compliance is lower than in non-compliance, then environmental degradation would result from this procedure.

A policy reform may change other factors not accounted for by legislators. A study by Kahn (1996) observed that between 1980 and 1990, the stock of passenger vehicles in the U.S. grew by 21 percent while the stock of trucks grew by 66 percent. He attributed this trend to the fact that trucks face less stringent fuel economy and emissions standards than do cars. The more stringent regulations on passenger vehicles pushed motorist to acquire vehicles that are less regulated. The lesson that one gets from this is that motorists will evade emissions regulations wherever possible. If tighter cut points proposal is implemented in such a way that they is easily evaded, consumers will likely be successful. The result being that net benefits to the environment and to society will not be realized.

This proposal has its own merits in regard to its attempt to encourage/entice vehicle owners with high emissions to take responsibility for their vehicle's emissions. This policy, if implemented, promotes equitable outcome for the non-polluter and enforces the polluter-pay-principle. Whether this proposal has public

appeal or not it depends on society's evaluation of the burden that low income motorists have to bear.

### *A Collection of Other Techniques*

These alternative policies promote reducing aggregate fleet emissions by increasing the variable cost of driving. Therefore, the objective of these policies is to reduce the dependence on personal vehicles for travel. In what follows, an evaluation is made of each alternative policy with three objectives in mind: cost effectiveness, equity, and public appeal, as discussed by different scholars. Cost effectiveness is investigated in terms of increasing the variable cost of owning vehicles and the potential to reduce mobile emissions. The equity criterion is based on the proposal's fairness in the absence of a new subsidy program. Public appeal refers to a general notion of acceptability. Table 4.3 displays the ranking of these techniques.

Table 4.3 Ranking of Complementary Tools*				
	Cost Effectiveness		Equitable in the Absence of instituting new subsidy Program	Public Appeal - Acceptability
	Increasing Variable Cost	Potential to Reduce Aggregate Mobile Emissions		
Gasoline Tax	2	3	3	2
Pay at the Pump 30-40 cents per gallon of Gasoline (Ayres 98)	1	3	2	1
Vehicle Mile Travel	1	2	2	2
New Vehicle Sale Tax and Annual Registration Fees Emissions Fee based Registration: .46 cents per gram of HC (Wells and Hensen 96) .45 cents per gram of HC and Nox (Small and Kazimi 95)	2	1	1	1

\* Ranking 1 through 3; 1 being the superior and 3 is an inferior option

### *Cost Effectiveness*

According to the literature, new vehicle sales tax and annual registration fees increase the variable cost of owning a vehicle. This is a cost effective technique because it give consumers an incentive to buy efficient vehicles, reduce travel, or retire old vehicles (Menz 2004).<sup>91</sup>

According to Ayres (1998) while a gasoline tax has the potential to increase the variable cost of driving (reduce driving in the short run), in the long run it leads to the purchase of more fuel-efficient vehicles and more driving – and thus more pollution (Ayres 1998). In addition, a gasoline tax does not distinguish between dirty and clean vehicles (Walls and Hanson 1996).

Scholars claim that the pay at the pump (PATP) policy is less cost effective than vehicle mile travel (VMT) and annual registration fees because it would internalize externality but would draw new drivers onto the road.

Ayres (1998) argues the VMT policy has the potential to be cost-effective; the fee would need to be weight by fuel economy and collected at least weekly, like a gasoline tax. The weekly collection, though, would increase the cost of implementation. Ayres advocates that the VMT fees are superior to gas taxes because of the wide differences in vehicles' fuel efficiency, but the potential problem is the discouragement of owning fuel efficient cars. Another potential problem that might arise is tampering with odometers (Wall and Hanson 1996).

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<sup>91</sup> Although an increase in new vehicles prices would lead motorists to retain their older vehicles longer, but given that they have to pay higher annual registration fees (which depends on their vehicles emissions) then Menz's presumption is that motorists would probably retire their polluting vehicles.

## *Equity*

Annual vehicle registration and emissions rate fees have the potential to deliver an equitable outcome because this proposal relies on vehicle characteristics.

According to the literature, an increase in gasoline prices would place particular burdens on low income motorists if a subsidy program is not in place. Ayres (1998) adheres to the fact that gas taxes could settle the equity issue by redesigning income and payroll tax cuts to benefit low income motorists by an amount proportional to their burden.

PATP and VMT policies do not directly penalize low income groups for their tendency to drive older, less fuel-efficient vehicles. However, these vehicles require more refueling; consequently, economic hardship will be felt among low income motorists. Accordingly, both require a subsidy program to insure social equity. Both policies enforce the polluter-pay-principle and do not exert a burden on non-polluters.

## *Public Appeal*

Ayres (1998) claims that, PATP auto insurance has a potential for public support because it promises to lower overall motorists' insurance costs. Instead of paying set premiums directly to an insurance agent for vehicle liability coverage, a motorist pays a surcharge per gallon of gasoline purchased. A driver would achieve lower insurance rates if he/she drove less or used a fuel-efficient vehicle.

The gasoline tax would be less popular since it might involve levying new taxes (Ayres 1998). Because the VMT fee is based on the number of miles a vehicle travels, it measure overall road use, and it probably would not have public appeal. This is based on the public's perception that this method would restrain their mobility (Menz 2002).

Vehicle sales tax and annual registration fee is a progressive approach because it is applicable to vehicle characteristics. This method, if used as a complementary tool to present lane testing accompanied with the current subsidy program, would most likely result in fair solutions. This method has the potential to be accepted by motorists who own fuel-efficient passenger vehicles. There would probably be objections from the public with "gas guzzler" vehicles. Probably this method, if implemented in conjunction with a media campaign educating citizens as to why they need to pay emissions fees, it would create awareness of the level of pollution their vehicles emit.

## 4.6 Conclusions and Recommendations

With the goal of achieving better air quality, there has been increase in coordination between the federal and states governments. The federal government establishes emissions standards through laws and the execution of these standards fall onto state agencies.

The initial intentions behind the Clean Air Act and its amendments were to serve as an extension of the 1960 Clean Air Act law. The goal of emissions laws, as set by legislators, is to contain the smog problem and reduce aggregate mobile emissions. Several studies mentioned above find the programs have had marginal success in controlling the mobile emissions problem. Accordingly, many scholars perceive that I/M programs are inefficient and inequitable.

The two significant factors that contribute to this belief are first, high administrative costs, and second, the apparent inability of program officials to correct for motorists' incentives. This section summarizes conclusions in this regard. It also makes recommendations to rectify I/M program deficiencies. This is followed by the author's recommendation for the possible creation of a technique to complement present lane testing in order to increase its effectiveness. Lastly, the author's final remarks on the study's recommendation are presented.

### *Assessment of the I/M program*

Based on the prevalent opinion of I/M effectiveness in controlling aggregate fleet emissions increases, this study finds that present policies have been effective. The combined effects of regulation and vehicle technology have contributed to a decrease in the rate of emissions increase. Also, scholars agree that there is an obvious decrease in emission patterns discharged from *new* vehicles. Although early regulations were overly ambitious and were arbitrarily instituted, they generated a momentum in the auto industry to combat mobile emissions. The development of “clean cars” is attributable to the surge in research and development in emission component control.

With regard to aggregate fleet emissions reductions in decentralized programs, the common conclusion in the literature is that it has not attained these goals when compared to centralized configurations. This could be a probable result of stringent emissions standards in centralized settings. Motorists’ inclination to implement effective repairs is higher in programs with tighter cut points than in programs with looser standards. These factors explain why centralized I/M programs are more effective in achieving emissions reduction goals. This conclusion is supported by hard evidence as presented in this study.

The ongoing practice of subjecting all vehicles to testing is an inefficient policy. Researchers found that the distribution of mobile emissions is highly skewed, with a minority of vehicles producing the majority of fleet emissions. Policy-makers confirm that certain classes of vehicles are unlikely to be polluters and have a low

probability of failing lane testing. Attributes of new vehicles' technologies to control for emissions lead researcher to believe that newer vehicles are in fact clean cars. These vehicles have a smaller emissions fraction compared to older vehicles. Under current vehicle registration-based tests, I/M regulators take no account of the advancements in auto technology and its ability to reduce vehicles' in-use emissions. This blanket approach wastes program and motorists' resources, an aspect neglected by regulators. This policy contributes not only to reduced efficiency but also adds to the unfair practices of present I/M program.

Uniform vehicle year cut points guidelines imply that all similar-age vehicles are likely to have similar engine deterioration rates and similar emissions. In fact, researchers provide evidence that contradict the above assumption. The engine deterioration rate depends on different vehicle classes, driving patterns, and, most importantly, on maintenance. Moreover, the data verify that motorists are not alike in their driving patterns or their vehicle maintenance behavior.

Vehicle maintenance consists of routine check-up schedules recommended by automakers to counter the effects of deterioration rates from regular vehicle use. Regular maintenance requires motorists' time and money, but these added costs contribute to vehicles running clean. The general reluctance of motorists to perform regular maintenance is probably due to either lack of information or to time and monetary constraints. The probable results of poorly maintained vehicles include marginal failure of I/M lane testing. Thus, with regard to I/M effectiveness to tackle automobile maintenance, this study finds that regulations were poorly

designed. The miscalculation of motorists' incentive, toward maintenance contributes to underestimation of the I/M programs' emissions reductions.

Combined data on vehicle ownership and income levels suggest a strong link between the probabilities that low income motorists will own high emitters. The incentives for those motorists are weak when it comes to maintaining their vehicles. Also, those incentives become even weaker when it comes to repairing their failed vehicles effectively. This is supported by evidence that some of those vehicles that failed emission testing went unregistered to counter the effect of high repair costs. The economic harshness of effective repair adds to the perception of the present program as being inequitable.

Therefore, based on researchers' discussion, this study finds the I/M program has inefficient and unfair policies, the first concentrating efforts regarding marginal emitters and the second the lack of emphasis on gross polluters. It seems likely the shortsightedness in vehicle maintenance has helped perpetuate marginal emitters. Moreover, this study finds that high repair costs contribute to the existence of gross polluters and avoidance problems associated with those vehicles.

A more appropriate resource allocation would be to concentrate on a few gross emitters, finding and preferably subsidizing their repair expenses. There is a double payoff to this policy because it adds fairness to the program and eliminates a major source pollution problem.

A side effect of more stringent emissions reductions is the increase in the production cost of newer cars. This unintended outcome has generated two problems. The first is the retention of older vehicles and the second is inflicting

additional costs on motorists living in non-polluted areas. These side effects contribute to present program's inefficiency and unfair practices. Another equity issue surrounds additional costs of implementing more stringent emissions standards on testing and repair facilities. The added cost cannot be recovered by controlled fees for emissions testing.

This study finds that the problems associated with I/M program are not restricted to these mentioned above. With the exception of California, the program has been ineffective in instituting uniform emissions standards across geographical areas. Because the influence of emissions on ambient air quality depends on the number of vehicles, the composition of the fleet, driving patterns, meteorological conditions, and other factors, uniform standards are unlikely to be effective.

This study recommends that programs would be more effective if I/M standards were tailored to regional needs. Also, it recommends that I/M programs be administered in a centralized I/M lane testing programs. Because centralized programs have the potential to generate more effective emissions repairs, this would solve motorists' incentive issues.

### ***Alternative Policy Reform***

Proposals to solve the problems associated with I/M programs vary in their approach. Some advocate modifying the current command and control approach with a more incentive-compatible technique. Yet others prove, using hard data, that complementary measures will achieve improvement in air quality effectively. This study reviewed the literature on each approach and evaluated each proposal based

on efficiency and equity as defined earlier in this study. In this regard, it is the recommendation of this study that the new vehicle sales tax and annual registration fee proposal is superior to others, achieving the efficiency and equity objectives.

The new vehicles sales tax and annual registration fee proposal has the potential to solve current I/M programs' problems. It is equivalent to programs implemented in Germany and requires little modification to current lane testing. This proposal will not impose new regulations on automakers and testing facilities. Furthermore, unlike centralized repair facility and mandatory leasing proposals, this proposal does not require an additional administrative body.

As mentioned above, annual vehicle registration fees depend on fuel consumption patterns, and low-fuel efficient vehicles are taxed at higher rates. This is done by ranking vehicles from very fuel efficient to very inefficient, and, tax rates are set accordingly. This method has been proven that it entices motorists to acquire more fuel-efficient vehicles. Relying on statistics mentioned above, this would probably motivate motorists to voluntarily trade in their older high-emitting vehicles for more fuel-efficient ones. This action could achieve the objectives of the accelerated vehicle retirement and the PATP proposals. Also, it might prompt motorists to use alternative modes of transportation: namely, mass transit.

In general, there is a correlation between cylinder capacity and vehicle price when all else is equal. Consequently, when a vehicle's annual registration fee is assessed to reflect cylinder capacity, this implies that the bigger the engine capacity, the higher the annual registration fees. Hence, high-priced vehicles will have higher annual registration fees as opposed to lower-priced vehicles. The new

vehicle sales tax could create distortions, a characteristic that would contribute to a reduction in the program's efficiency.<sup>92</sup> This tax, though, has a progressive notion in its application. It also has the potential to address all equity criteria.

The current vehicle registration practice in the U.S. is based on the vehicle's class and year model only. If a new vehicles sales tax is assessed in accordance with the vehicle's environmental impact, this satisfies the environmental tenet of the polluter pay policy.

The annual registration fee proposal depends on emission rates. This aspect alone has the potential to solve the incentive issues mentioned above. It would likely encourage motorists to better maintain their vehicles and to purchase effective repairs, thus achieving the objectives of the remote sensing, emissions fees, tighter cut points, repair subsidy, centralized liability, and mandatory leasing proposals. This proposal relieves the burden on non-polluters, which is an obvious disadvantage in the extended warranty, repair subsidy, centralized liability, and emissions fees proposals. Also, it does not shift the harm from one group to another, which is a feature of all Coase approach and emissions fee proposals.

This proposal has the potential to reduce transaction costs, as opposed to redesigning the emissions liability system to a third party, as prescribed using the Coase approach. An additional advantage of this proposal over the Coase approach is that it has the potential to eliminate the free rider and principal-agent problems. Moreover, this proposal would probably be successful in addressing fraud and tampering plight, a likely problem in the VMT proposal. It would probably

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<sup>92</sup> This distortion could be seen either in demanding fewer new vehicles or allocating/shifting of motorist's budget for vehicle purchase.

overcome collusive action between motorists and service stations, a drawback in the emissions repair subsidy program. It does not compromise individual privacy rights as the remote sensing proposal does.

Furthermore, instead of instituting a subsidy program to correct the inequitable aspect of the emissions fees, tighter cut points, remote sensing, gasoline tax, PATP, and VMT proposals, this proposal would solve for this drawback. If devised properly, this proposal would meet the social equity goal as well, a goal not met by the remote sensing, extended warranty, early retirement, tighter cut points, PAPT, and VMT proposals.

This proposal has one further major advantage over all proposals; it has proved effective in actual implementation in Europe in achieving improvement in environmental quality. It seems to the author, that European societies view individuals and their actions as solutions to problematic environmental issues, especially when common destiny is stressed. A similar paradigm could be emphasized through education empowering citizens to take proper actions. This is very important for our society because the U.S. contributes approximately 25 percent of the world's carbon dioxide emissions.

### *Final Remarks*

Given the amount of funding needed to implement the Clean Air Act and its amendments, eliminating current I/M programs is not appealing to some policy-makers. Instead, this study has offered tools on ways to improve and correct the deficiencies of lane testing. This study has discussed the impact of a complementary technique to effectively control air quality; namely, a new vehicle sales tax and annual registration fee. This proposal could be introduced as a policy reform. This study also analyzed this complementary tool and found that it would probably enhance present I/M programs on two grounds - equity and efficiency.

A new vehicles sales tax and annual registration fees program would provide equitable solutions, but at a cost of reduced efficiency. The origin in efficiency reduction is increased taxes on newer vehicles. Although this tax is progressive, nevertheless it creates distortions. Given the negative externalities associated with normal vehicle use, government has a duty to intervene to reduce the side effect of normal use. Because auto use is a social activity, any policy or policy reform has to promote equitable solutions as well as efficiency. This may mean sacrificing some efficiency in order to obtain greater equity, an end result to society's quest for fair solutions.

For a successful policy reform, policy-makers also need to provide alternatives to citizens. A logical alternative to private vehicle transportation is a mass transit system. The revenue from a new vehicles sales tax could conceivably be funneled to the Department of Transportation to be used to construct reliable mass transit. This method can be thought of as weaning motorists away from their dependence

on private vehicles for transportation. From the recent experiment in Denver, Colorado, and St. Paul and Minneapolis, Minnesota, the introduction of light rail has gained politicians' attention for its popularity among those cities residents.<sup>93</sup>

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[http://rockymountainnews.com/drmn/business\\_columnists/article/0,1299,DRMN\\_82\\_3143390,00.html](http://rockymountainnews.com/drmn/business_columnists/article/0,1299,DRMN_82_3143390,00.html); <http://www.geocities.com/Yosemite/2288/mnlrt2002>

## Chapter 5

### Conclusions, Policy Recommendations, and Future Research

## 5. Conclusions, Policy Recommendations, and Future Research

The goal of any regulation is to solve existing problems. Regulations devise rules and guidelines to mitigate dilemmas facing our society. When smog became a problem in major metropolitan cities, legislation was enacted to reduce the pollution coming from vehicles. Legislation of this type can be seen in part in the Clean Air Act and its amendments and the establishment of the Environmental Protection Agency (EPA). This regulatory body in turn executed the Clean Air Act in two complementary forms. First, regulations were imposed on auto makers with regard to the types of technology they must use in auto production and emissions equipment. Because regulations on auto makers involved a smaller number of agents, there has been success in controlling mobile emissions emitted by new vehicles. The second form is the establishment of Inspection and Maintenance (I/M) programs. The aim of I/M programs is to ensure that vehicles operating in I/M regions have functioning emissions control equipment. This is accomplished in a periodic inspection test, which involves tailpipe emissions measurements and a visual check for missing, broken, or tampered-with emissions control equipment.

The inspection tests are implemented in either a centralized fashion, where the inspection test is administered by state agencies, or in a decentralized setting in which the inspection test is carried out by private firms. The implementation of either program depends on the level of the pollution in a geographic region. In regions classified as high non-attainment, inspection tests should be implemented in a centralized setting that involves higher emissions standards, and testing should be

carried out by state inspectors. In regions classified as moderate non-attainment for mobile emissions, inspections could be implemented in decentralized settings. In this case, inspection tests could be carried out by private testing stations, and the associated cut points would be looser than in the centralized setting. Hence, I/M programs are tailored in regions by state agencies, depending on non-attainment levels. However, despite best efforts, a number of researchers and regulators stress that I/M programs have not achieved the level of success once anticipated. This study addressed three related issues surrounding the way I/M programs impede attainment of emissions reduction goals.

With regard to the first component of this study, the data show that test administrators in the decentralized setting exercise discretion on how to implement the inspection test. Using Fort Collins, Colorado, inspection test results for 2000 and 2002 (Fort Collins is a location where inspection fees are regulated), this study found that discretion exists among firms with different organizational arrangements. This leads to situation in which vehicles that have malfunctioning emissions control equipment pass the inspection test without any meaningful repairs. A probable cause is the non-alignment of inspectors' incentives with those of the I/M officials. To solve for this, the policy recommendation is to educate inspectors about their vital role in the I/M program and how their actions undermine I/M program achievements. Since Hubbard (1995) established that discretion also exists in a price-competitive emissions testing market, it is interesting to determine the extent of discretion exercised in both types of markets. Examining the magnitude of

discretion in both markets and the impact on air quality will be the point of future research.

The second component examined in this study is motorists' incentives toward emissions-related repairs under the centralized and decentralized settings.

Repairing a failed vehicle is an important aspect of the effectiveness of I/M programs. Repairs are considered proper when failed vehicles' emissions are below emissions standards after repairs. If vehicle owners incur costs associated with emissions repairs and their vehicles continue to fail, then motorists can apply for a waiver if they provide evidence of repair attempts and their expenses.

Using emissions test results for Fort Collins, Colorado, and Kenosha, Wisconsin, to represent decentralized and centralized lane testing, respectively, the data show that motorists in decentralized programs are more likely to purchase quick fixes than lasting repairs for their failed vehicles. This might be due to the fact that vehicles that fail inspection under decentralized lane testing are subject to looser emissions standards and quick fixes can solve emissions problems more easily when compared to the centralized setting. To solve for this, a probable policy prescription would be to increase the waiver limits in decentralized I/M programs. Kukawka (1999) suggested that this approach would make the I/M program more successful in bringing a significant number of waived vehicles into compliance. Motorists usually decline effective repairs if they can satisfy waiver limits. Evaluating the increase in waiver limits and how that might entice motorists to acquire lasting repairs is an issue that is beyond the scope of this study and is deserving of future research.

The third component of this study evaluated I/M programs in terms of efficiency and equity. It is the finding of this study that the program has been effective in reducing emissions from new vehicles, but less effective in terms of reducing aggregate mobile emissions. This is partly because the program underestimated motorists' incentives regarding inspection tests and emissions-related repairs, and partly because of the divergence between the goals of I/M officials and those of emissions inspectors. Therefore, I/M programs are perceived as an inefficient mechanism for reducing mobile emissions. Actions taken by motorists and technicians to bend the system come to prevail over the high repair costs that are associated with vehicles failing the inspection tests. The cost of fixing failed vehicles is a particular burden on low income motorists since various studies have demonstrated that high polluting vehicles are more likely to be owned by destitute motorists. Consequently, forcing low income motorists to bring their vehicles into compliance with emissions standards adds to their burden. This aspect intensifies the inequitable nature of I/M programs.

This study explored other proposals to correct for the deficiencies of the I/M program, namely, the inefficient and inequitable side effects of lane testing. Among them are remote sensing, the Coase approach, the accelerated vehicle retirement program, emissions fees, tighter emissions standards, a gasoline tax, pay at the pump, vehicle miles traveled, and new vehicle sales tax and annual registration fee proposals.

This author concluded that a new vehicle sales tax and annual registration fee proposal would provide for efficient and equitable solutions, assuming that there would be a subsidy program for low income motorists. It is intended as a complementary tool to mitigate the I/M program's problems. This would increase motorists' fixed costs of acquiring vehicles, and increase their marginal cost of driving.

The new vehicle sales tax should be a function of the impact on the environment. Also, annual registration fees should reflect the amount of vehicles' emissions as documented during inspection tests. This policy would not likely be a popular policy reform given the increased cost of acquiring and driving vehicles. If this policy were to be enacted along with a media campaign educating motorists about the impact of their vehicles and their driving habits, it would more likely achieve some public acceptance. Another policy prescription would be to provide alternative modes of transportation, i.e., mass transit, providing alternatives to the private vehicle transportation mode. This research can be further advanced by assessing the new vehicle sales tax that would reflect impact on the environment.

The assessment of the marginal damage of vehicle ownership and use requires the skills of biologists, engineers, ecologists, and health practitioners, among others. However, one need not reinvent the wheel. Currently, some countries suffering from excessive mobile emissions have implemented new vehicle sales tax in the form of a "gas-guzzler tax," and vehicles' annual registration fees are assessed to reflect vehicles' emissions levels. An attempt to evaluate this scheme in the U.S. is beyond the scope of this research, but would be the focus of future endeavors.

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## Appendices

## Appendix A

**Station Name:** \_\_\_\_\_ **Address:** \_\_\_\_\_

1. **What do you consider your shop to be?**  
a) Tune-up    b) Independent garage    c) Service station    d) New car dealer
2. **How long have you been operating in the Fort Collins area?**  
a) 0-15 years    b) Over 15 years
3. **Has there been a change in ownership over the past 15 years?**  
a) Yes    b) No
4. **Do you consider your shop to be a full service station or just an emission- testing station?**  
a) Full    B) Only emissions
5. **Are you franchised?**  
a) Yes    b) No
- 6) **Mode of Ownership**  
a) Individual    b) Other
7. **If a vehicle fails emissions testing, do you offer free reinspection?**  
a) Yes    b) No
8. **Do you have the facilities and labor to complete repairs on the spot?**  
a) Yes    b) No
9. **Can consumers leave their vehicles to be repaired?**  
a) Yes    b) No
10. **Do customers need an appointment?**  
a) Yes    b) No
11. **Does the shop have a policy "pass or don't pay"?**  
a) Yes    b) No
12. **Are mechanics paid as a function of work completed?**  
a) Yes    b) No
13. **What is the average repair cost if a vehicle fails emissions testing?**

# Appendix B

Appendix B Summary of Survey Responses given by each firm											
Station Number	Type of Testing Station	How Long	Change in Ownership	Full Service Station	Franchised	Mode of Ownership	Mechanics Pay Rate function of work completed	Facility to Complete the Repair	Can consumers leave Vehicles	Do consumers need appointment	
	1)Tune up 2)Independent Garage 3)Service Station 4)New Car dealer 5)Old Car dealer	Number of year till 2002	D= 0 no D= 1 yes	D= 1 full D= 0 otherwise	D= 1 yes D= 0 no	D=1 individual D=0 otherwise	D= 1 yes D= 0 no	D= 1 yes D= 0 no	D= 1 yes D= 0 no	D= 1 yes D= 0 no	
SN	TOTS	Y/B	S/O	FSS	FRAN	MOF	MPR	FTCR	CCLV	DCNA	
1	3636	7	0	1	0	1	1	1	1	0	
2	1014	30	0	1	0	1	1	1	1	0	
3	1460	30	0	1	0	1	1	1	1	0	
4	3901	26	0	1	0	1	0	1	1	0	
5	1087	35	0	1	0	1	1	1	1	1	
6	3697	9	0	1	0	0	1	1	1	0	
7	3111	45	0	1	0	1	1	1	1	0	
8	3662	6	0	0	0	1	0	0	0	0	
9	3461	10	0	1	1	1	0	0	1	0	
10	2042	19	0	1	0	0	0	1	1	0	
11	3296	50	0	1	0	0	1	1	1	0	
12	3988	17	1	1	0	0	1	1	1	1	
13	3965	22	0	1	0	0	1	1	1	0	
14	3430	20	0	1	1	1	0	0	0	0	
15	3145	14	0	1	1	1	0	0	0	0	
16	1415	6	0	1	0	0	0	1	1	0	
17	1446	19	1	1	1	0	1	1	1	0	
18	1447	4	1	1	1	0	1	1	1	0	
19	1093	66	0	1	0	0	0	1	1	0	
20	3924	20	1	0	0	1	0	0	0	0	
21	3637	29	0	1	0	0	1	1	1	1	
22	3477	18	0	1	1	1	1	1	1	0	
23	3687	55	1	1	1	1	0	1	1	1	
24	1451	24	0	1	0	1	1	1	1	1	
25	3761	21	0	1	0	1	0	0	0	0	
26	3237	24	1	1	0	0	0	1	1	0	
27	2213	15	0	1	0	1	1	1	1	0	
28	1284	19	0	1	1	0	1	1	1	0	
29	1432	14	1	1	1	0	1	1	1	0	
30	2515	14	1	1	1	0	0	1	1	0	
31	1096	17	0	1	0	1	1	1	1	1	

## Appendix C

### Colorado's Vehicle Test Records (VTR) Data Definitions

FIELD NAME	DESCRIPTION
DATE_TIME	DATE/TIME OF INSPECTION
STATION	INSPECTION STATION
LANE	INSPECTION LANE/TAS ID
PROGRAM	PROGRAM TYPE
STATION_IDN	STATION INDICATOR
VIN	VIN NUMBER
PLATE	STATE VIN (REGISTRATION)
ST_VEH_YEAR	STATE VEHICLE YEAR (AS REGISTERED)
MAKE	VEHICLE MAKE
MODEL	VEHICLE MODEL
TYPE	VEHICLE TYPE
VEH_TYPE	CAR OR TRUCK
CYLINDERS	NUMBER OF CYLINDERS
GVW	VEHICLE GVW
NVW	VEHICLE NVM
DISP	ENGINE DISPLACEMENT
ODOMETER	ODOMETER READING
TEST	TEST NUMBER
EM_SECCH	EMISSIONS SECOND CHANGE TEST
OBD_REQ	OBD TEST REQUIRED
EM_PU_REQ	EMISSION AND PURGE TEST REQUIRED
OPAC_REQ	OPACITY TEST REQUIRED
INERT_WGT	INERTIA WEIGHT
HP	HORSE POWER
DEFAULT	WEIGH /HORSE POWER DEFAULT VALUES
HC_STD	HC STANDARD
CO_STD	CO STANDARD
NOX_STD	NOX STANDARD
HC	HC GRAMS PER MILE
CO	CO GRAMS PER MILE
CO2	CO2 GRAMS PER MILE
NOX	NOX GRAMS PER MILE
CO_IND	CO INDICATOR
HC_RES	HC RESULT
CO_RES	CO RESULT
NOX_RES	NOX RESULT
EM_RES	OVERALL EMISSIONS RESULT

OPAC_RES	OPACITY RESULT
HC_TSTD	HC IDLE STANDARD
CO_TSTD	CO IDLE STANDARD
PR_RES	PRESSURE RESULT
FFR_RES	FUEL FILLER RESTRICTOR RESULT
CAP_RES	GAS GAP RESULT
O2_RES	OXYGEN SENSOR RESULT
AIS_RES	AIR SYSTEM RESULT
ENG_RES	CHECK ENGINE LIGHT RESULT (VISUAL)
ONBOARD	OBD INTERROGATED
OBD_RES	OBD RESULT
RESULT	OVERALL RESULT
ABORT1	ABORT CODE 1
PPROGRAM	PREVIOUS PROGRAM
INC_2500	INITIAL HC 2500 RPM READINGS
ICO_2500	INITIAL CO 2500 RPM READINGS
IHC_IDLE	INITIAL HC IDLE READINGS
ICO	INITIAL CO IDLE READINGS
IHC	INITIAL HC 240 READINGS
ICO2	INITIAL CO 240 READINGS
INOX	INITIAL NOX 240 READINGS
REP_AEM	REPAIR ACCUMULATIVE OVERALL REPAIR COSTS
REP_ATAMP	REPAIR ACCUMULATIVE TAMPERED OVERALL REPAIR COSTS
REP_AWARR	REPAIR ACCUMULATIVE WARRANTY OVERALL REPAIR COSTS
REP_AMISC	REPAIR ACCUMULATIVE MISC OVERALL REPAIR COSTS
REP_ADIAG	REPAIR ACCUMULATIVE DIAGNOSTIC OVERALL REPAIR COSTS