Travel Behavior and Older Vehicles: Implications for Air Quality and Voluntary Accelerated Vehicle Retirement Programs

by

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Abstract

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Older vehicles contribute a significant and disproportionate share of the pollution in urban areas. Starting in 1990, several areas adopted voluntary accelerated vehicle retirement (VAVR) programs to address this problem and to respond to demands for flexible, market-based approaches to controlling air pollution. VAVR programs offer owners of older vehicles cash to scrap their vehicles. VAVR programs have been adopted throughout the U.S. and abroad, though not without controversy and uncertainty over the programs' benefits.

This research first examined the roles of older vehicles in U.S. households. Lower income households are more likely to own older vehicles and to rely upon them more for their daily transportation needs. While older vehicles are generally driven less than newer vehicles, they serve a wide range of roles within households. This makes estimating the emissions reduction benefits of VAVR programs more difficult.

This research then examined how household characteristics and behavior influence participation in VAVR programs and, therefore, the benefits from the programs. The assumptions used by regulators to estimate the air pollutant reductions

from VAVR programs are compared with data from VAVR programs in California. Changing the assumptions did significantly change the estimated benefits. However, in nearly all the scenarios examined, the programs still reduce emissions significantly, particularly of reactive organic gases.

Data from surveys of program participants show that the programs are diverting vehicles from the used vehicle market, which is not built into the current assumptions for estimating program benefits. The scrapped vehicles are generally in poorer condition, are worth less, and are driven less than other older vehicles. However, the criticism that most of the scrapped vehicles were headed to the junkyard anyway appears unfounded. Nearly all of the scrapped vehicles were replaced with another vehicle and nearly all of the replacement vehicles were newer than the scrapped vehicles.

Policymakers should consider ways to expand, improve, and/or supplement VAVR programs. First, adjustments to the methodology to calculate emissions reductions should be made to make the estimates more conservative. Second, policymakers should explore ways to change and supplement the programs to address key factors that reduce program effectiveness. Current programs are missing certain households that drive older vehicles a lot and have little impact on the vehicle replacement decision. Promising options include repair programs, targeting certain vehicles for participation in VAVR programs, and increasing the incentive for households that replace the vehicle with significantly cleaner alternatives.

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1 CHAPTER 1: BACKGROUND AND RESEARCH OVERVIEW

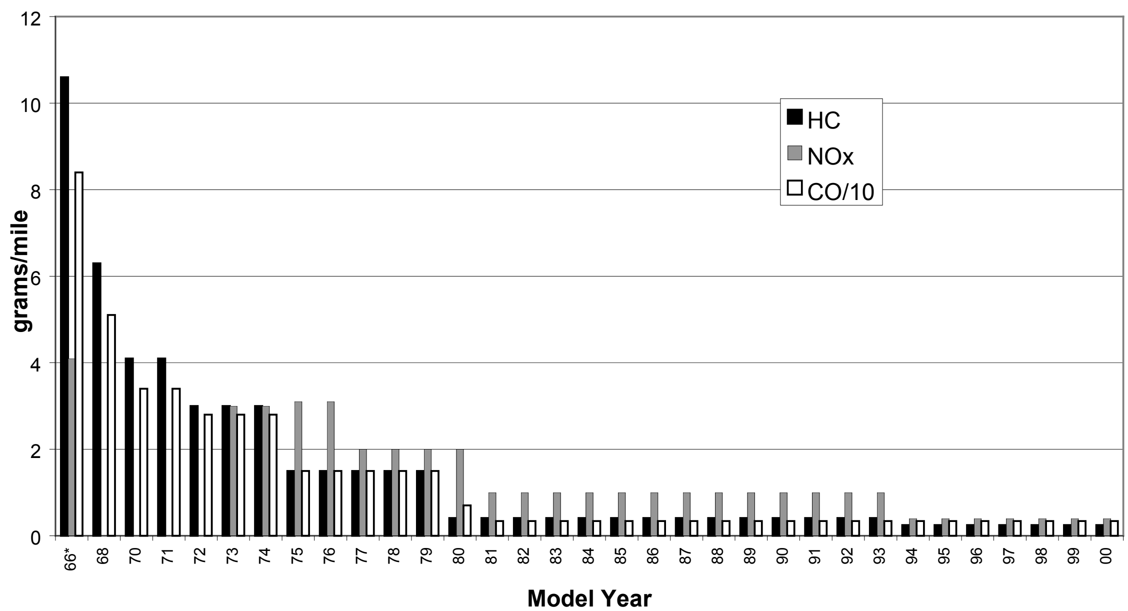
In the 1990s, older vehicles emerged as a serious air pollution problem, both in the U.S. and abroad. Older vehicles were shown to contribute a significant share of the pollution in urban areas, despite their relatively small numbers. At the same time, businesses and other entities were advocating a more flexible, market-based approach to controlling air pollution. These two factors led to the start of voluntary accelerated vehicle retirement (VAVR) programs. VAVR programs, also known as vehicle buy-back, vehicle scrappage, or "cash-for-clunkers," offer owners of older vehicles a monetary incentive to scrap their vehicles. Since 1990, VAVR programs have been adopted throughout the country, though not without controversy and uncertainty over the programs' benefits. This research examines how household characteristics and behavior influence participation in VAVR programs and, therefore, the air pollutant emission reduction benefits from the programs.

1.1 Background

1.1.1 Older Vehicles as an Air Quality Problem

Air pollutant emissions and vehicle age are tied together in two ways. First, starting in 1968, federal standards reduced air pollutant emissions from new automobiles (Figure 1). Newer vehicles include more and better pollution control devices, such as catalytic converters. Second, pollution control equipment deteriorates over time. For example, the model used by the U.S. Environmental Protection Agency (EPA) to quantify mobile source emissions (MOBILE) estimates that carbon monoxide (CO) emissions are ten times higher after four years or 50,000 miles than they are in new cars, volatile organic compounds (VOCs) are about four times higher, and nitrogen oxide (NO_x) emissions are about twice as high as when the car was new (National Cooperative Highway Research Program, 1997).

Figure 1: Federal Automobile Tailpipe Emission Standards

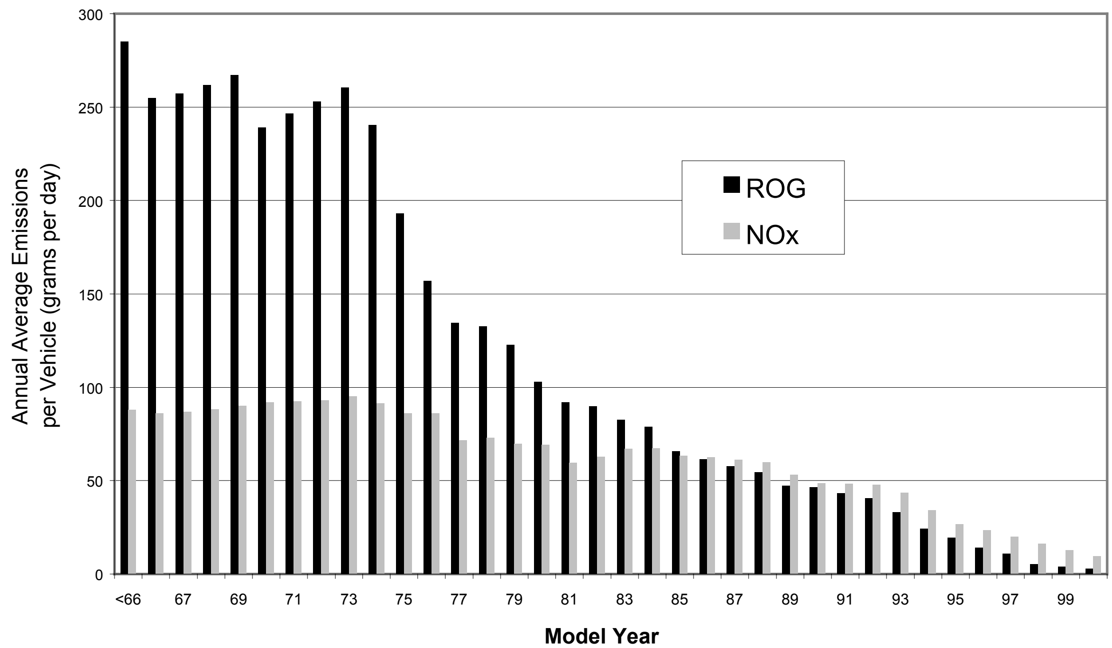


* 1966: pre-control

Source: (Davis, 2000)

The result is that older vehicles pollute a lot more, even though they are driven less. The average annual emissions per vehicle by model year in California for the year 2000 are shown in Figure 2. The increase in reactive organic gas (ROG) emissions with vehicle age is most significant. ROG contributes to the formation of ozone (aka smog).

Figure 2: Year 2000 Daily Emissions for California Light Duty Vehicles by Model Year



Source: Author's calculations from EMFAC2000

Because older vehicles' emissions are higher, they contribute disproportionately to overall emissions from motor vehicles. For example, in 1990 the EPA estimated that cars built before 1972 comprised about 3.4% of the total auto fleet and only 1.7% of the vehicle miles traveled (VMT), but produced 7.5% of the hydrocarbon[1] (HC), 7.6% of the CO, and 4.7% of the NO_x emissions of the fleet. The California Air Resources Board (CARB) estimated that pre-1972 cars were 4% of all California vehicles in 1990, yet produced 13% of the HC and 9% of the CO emissions (U.S. Congress, 1992). The South Coast Air Quality Management District (SCAQMD) estimated that pre-1982 vehicles accounted for 18% of the fleet in the region, but contributed as much as 60% of the VOCs, 54% of the NO_x, and 60% of the CO from vehicles (South Coast Air Quality

[1] Hydrocarbons (HC), volatile organic compounds (VOCs), and reactive organic gases (ROG) are all groups of chemical compounds containing carbon that contribute to the formation of ozone, also known as smog.

Management District, 1995). The difference between the EPA and CARB estimates reflects the fact that a higher portion of the vehicles in California are older and they are probably driven further. The SCAQMD estimate is so much higher because it includes an additional ten years of vehicles (model years 1972-1981), which are driven more than the pre-1972 vehicles.

Estimates for the San Francisco Bay Area are shown in Figure 3. These estimates were derived using the latest emissions factor model from CARB (EMFAC 2000) and the EMFAC default assumptions for vehicle population and travel. The estimates show that in 2000, pre-1986 light duty[2] vehicles (15-year-old and older vehicles) contributed about 12% of the VMT, but over half of the ROG emissions from light duty vehicles. Singer and Harley (2000) used a fuel-based approach relying upon remote sensor measurements to estimate mileage and emissions by model year in the South Coast Air Basin for the summer of 1997. This methodology also showed that older vehicles contribute disproportionately to mobile source emissions. They found that 15-year-old and older vehicles represented less than 10% of the travel, but over 35% of the VOC stabilized exhaust emissions from cars, light-duty trucks, and medium-duty trucks.[3]

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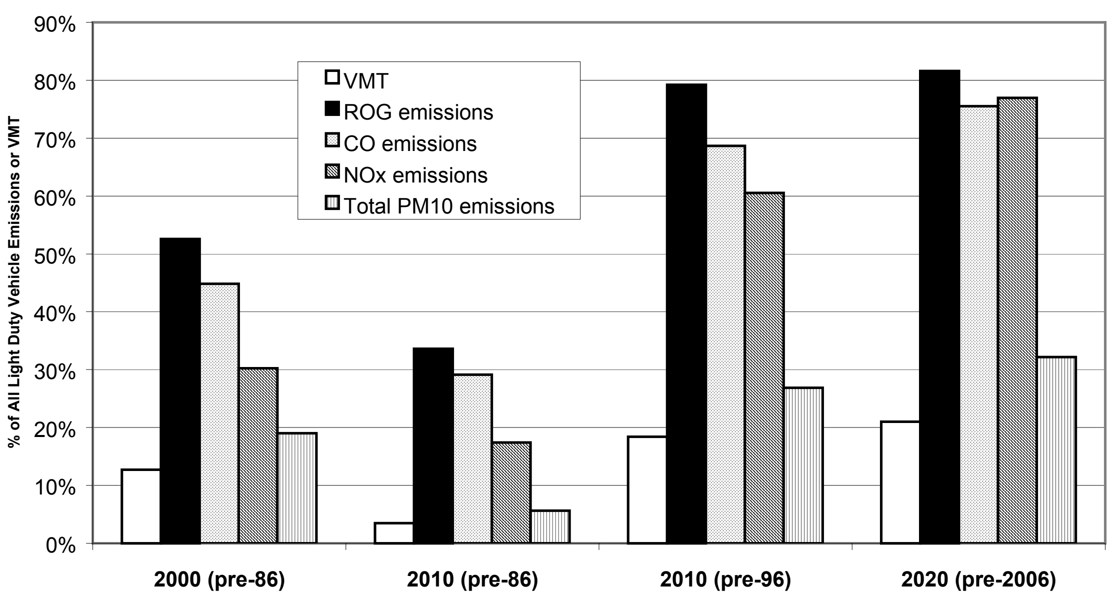
[2] Light-duty vehicles include automobiles, pickup trucks, vans, minivans, station wagons, and most sport utility vehicles.

[3] Note that the Singer and Harley figures represent stabilized exhaust emissions, while the estimates based upon EMFAC include evaporative and start emissions. Also, the Bay Area estimates do not include medium-duty trucks.

In the year 2010, Figure 3 shows that, for the Bay Area, the share of emissions from these pre-1986 vehicles (now 25 or more years old) declines, but is still over 30% of the ROG. Perhaps more importantly, the 15-year-old vehicles in 2010 (pre-1996) contribute nearly 80% of the ROG, while driving less than 20% of the miles. These estimates show that the problem of older vehicles will persist over the next twenty years, as newer vehicles continue to get cleaner due to more stringent controls. In addition, California recently amended its Smog Check requirement to exempt 1973 and older vehicles. After 2003 this will become a rolling 30-year exemption. The lack of a Smog Check requirement may act as an incentive to keep vehicles past this age, thus increasing the portion of older vehicles.

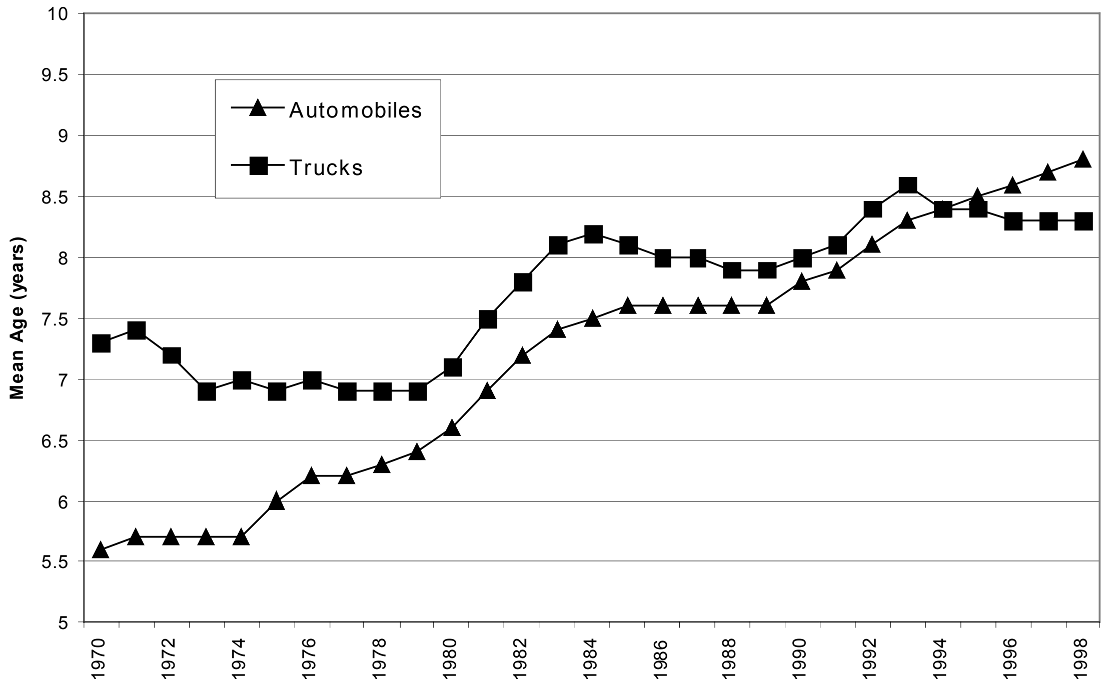
Figure 3: Share of Pollution from Older Light Duty Vehicles, San Francisco Bay Area



Because older vehicles pollute more and new vehicle standards are periodically strengthened, fleet turnover is important in reducing overall vehicle emissions. However, over the past 30 years, vehicle turnover has slowed as the personal vehicle fleet has aged.

In 1970 only 2.9% of the automobiles in operation were 15 years old or older and 8.8% were 10-14 years old. In 1998 those figures were 13.2% and 26.0%, respectively (Davis, 2000, Table 6.6). The average age of automobiles and trucks in the U.S. since 1970 is shown in Figure 4. Of note is the fact that the historical pattern of trucks being older than cars no longer holds true. The increased use of trucks and SUVs (which are classified as trucks) for personal use contributes to this new trend. Two factors are often believed to contribute to increased vehicle age: vehicles have become more durable and households are owning and keeping more vehicles, i.e. rather than trading in, selling or scrapping a vehicle before purchasing a new one, households simply increase their fleet (Pickrell, 1998). The latter reason is linked to rising household incomes. However, Hamilton and Macauley (1998) assert that the increase in car longevity over the past 25 years has little to do with increases in inherent durability. They argue that competition in the industry led to increased longevity by forcing a reduction in the price of auto maintenance and repair.

Figure 4: Mean Age of Automobiles and Trucks in the U.S., 1970-1998



Source: (Davis, 2000, Table 6.8)

1.1.2 A Brief History and Overview of VAVR Programs

In the early 1990s, the increasing age of the fleet and higher emissions from older vehicles attracted the attention of private industry, regulators, and elected officials faced with new mandates from the 1990 Clean Air Act Amendments. In 1990, the Unocal oil company launched the South Coast Recycled Auto Project (SCRAP) by offering residents of the Los Angeles region $700 for their pre-1971 cars. Nearly 8,400 cars were scrapped through this program (Unocal Corporation, no date). Unocal's objective was to demonstrate that scrapping older vehicles reduced emissions in a more cost-effective manner than stringent new standards on stationary sources of air pollution, including oil refineries.

The program attracted national attention to the problem of older vehicles and the potential use of "mobile source emission reduction credits" (MERCs) to comply with air quality regulations. A system for banking and trading emission credits generated by stationary sources of pollution, such as factories and refineries, was already in place in the South Coast Air Basin and many other regions. Credits are generated when emissions are reduced from one source below what is required under regulations. The credits can then be bought or traded to permit a new source of pollution in the basin or allow an existing source to delay compliance with a regulation. Often, the credits are discounted to help ensure a net decrease in emissions.

Since Unocal's initial SCRAP program, several companies and public agencies throughout the country have implemented similar programs. U.S. House and Senate Committees developed legislative proposals, as did the Bush (senior) administration and numerous state legislatures (Bearden, 1996; U.S. Congress, 1992). The U.S. Environmental Protection Agency (EPA) adopted guidance on implementing VAVR programs in 1993 (Environmental Protection Agency Office of Mobile Sources, 1993). In 1994, the California Air Resources Board adopted Measure M1 in the State Implementation Plan (SIP) which called for scrapping up to 75,000 older vehicles per year in the South Coast Air Basin between 1999 and 2010, though funding for the program has not been approved (Sierra Research, 2001). Vehicle scrappage programs were also adopted in about a dozen countries outside the U.S. (European Conference of Ministers of Transport, 1999). These programs are listed and described in Chapter 2 (Table 5).

The concept of a VAVR program is simple – get an older, polluting vehicle off the road earlier than would normally occur by offering a financial incentive. The air pollution benefits of a VAVR program stem from two basic assumptions: (1) without the retirement program, the vehicle would continue to be driven for some time period and (2) the replacement travel (including the mode and amount of travel) produces fewer emissions than the retired vehicle. In some cases vehicles are scrapped to generate emission credits. Some agencies use public funds to purchase vehicles without generating credits, thereby reducing the region's overall emissions. To help ensure that real pollution reductions occur, VAVR programs impose several conditions. For example, in most areas the vehicle must be in operating condition and be registered in the region for a certain length of time (to prevent the importation of old vehicles). The emissions benefits from the programs are assumed to be temporary – the difference between when the vehicle would have normally been scrapped and when the VAVR program scrapped it.

1.1.3 VAVR Opponents

The programs did not evolve without controversy, however. The most vocal and adamant opponents are car collectors. For example, one car enthusiast was quoted in a *New York Times* article about VAVR programs that "We're in danger of having two or three generations of our automotive heritage disappear" (Motavalli, 1994). Car collectors and hobbyists have joined automotive aftermarket groups, such as the Automotive Service Association (ASA) and the Specialty Equipment Market Association (SEMA) to lobby against VAVR programs. Because some VAVR programs prohibit the re-sale of the parts from the scrapped vehicles, these groups fear the programs will reduce the supply and raise the price of older car parts (California Air Resources Board, 1998). The organizations use a variety of arguments to support their position. The Arizona Automobile Hobbyist Council developed a list of ten arguments against VAVR programs that has been widely posted around the World Wide Web (Arizona Automobile Hobbyist

Council, 1999) and is representative of the arguments made by car collectors, hobbyists, and related business groups:

1. Scrappage laws (aka "clunker bills") and pollution taxes discriminate against a car simply based on its age. Maintenance is the key to a clean-burning car, not its age.
2. Those people who drive cars worth only $700 usually have no choice because of their economic status. Adding a pollution tax simply makes for a greater hardship.
3. Scrappage laws and pollution taxes tend to be promoted by - and/or funded by - the petroleum industry, which is looking for ways to delay expensive improvements to its own refineries.
4. The "cash for clunkers" programs are a farce because they suggest that oil companies are doing "good will" by cleaning up the air. They're not. (See #3)
5. Offering an individual $500-$700 for his older car is no guarantee that he will go out and buy a cleaner-burning car because A) He most likely doesn't have the extra money to pay for it and B) low interest loans, while a nice gesture, still require some income that the owner just doesn't have. A smarter solution? Pay them to bring their current car in line with emissions standards.
6. Scrappage laws are a possible solution when a stringent emissions plan is absent. Arizona taxpayers are absorbing the high cost of the I/M-240 and the Smog Dogs to catch polluters. If these programs are in force and working properly, why should we need a plan to take the high polluting cars off the road?
7. Scrappage laws hurt the used-car parts dealers and scrap yards who lose an opportunity to recycle automotive parts.
8. Scrappage laws make vast, unproven assumptions about the reduction in mobile pollutants. We have no data to show how much pollution a scrappage program could remove from the air.
9. Scrappage laws and pollution taxes often are implemented as a scapegoat to help focus attention away from tackling problems created by larger sources of pollution - commercial transport and industry - and from the need to make the large but necessary investment into mass transit.
10. Scrappage laws can significantly impact the survival of the automotive heritage of this country - and will accomplish little but hurt the working poor and give powerful industry an easy break from meeting their own responsibilities.

The environmental justice movement opposes the use of the emission reduction credits generated from the programs to offset emissions from stationary sources often located in poor and/or minority neighborhoods, thereby exposing residents to increased levels of pollution. In 1998, Communities for a Better Environment sued the SCAQMD, charging that their rule violated civil rights because it allowed industries to scrap cars instead of cleaning up pollution in Latino and African-American neighborhoods (Cone, 1998). To support their case, the organization used a deposition from a SCAQMD inspector that claimed that many of the scrapped vehicles were in such poor condition that they would not have been driven anyway.[4]

The opponents of VAVR programs have lobbied actively to stop program adoption in many states. In addition, some researchers have questioned the emissions benefits of the programs (Beaton et al., 1995; Hsu & Sperling, 1994). This opposition and doubt has slowed the adoption of VAVR programs in the U.S. For example, the Congestion Mitigation and Air Quality (CMAQ) program in the federal transportation funding program specifically prohibits the use of funds for VAVR programs, while allowing a broad range of other projects. Despite the opposition, several areas continue to operate programs and others are considering adopting new programs (discussed further in Chapter 2).

1.2 Research

1.2.1 Research Objectives and Framework

The opponents of VAVR programs, as well as researchers, raise a number of valid questions regarding the impacts of VAVR programs. The primary objective of VAVR programs is to reduce air pollutant emissions. In some cases, these reductions may be used by private industry to offset increases in emissions from other sources. In other cases, taxpayers fund the programs and the reductions are for the public good. In either case, the validity of the program hinges upon an accurate estimate of the emissions

[4] The status of this suit is unknown.

reduced. Moreover, for residents of regions relying on these programs to attain air quality standards, the quality of the air they breathe may depend, in part, upon the effectiveness of the programs.

The primary objective of this research is to increase knowledge regarding the emissions reductions from VAVR programs through a better understanding of household behavior. The effectiveness of a VAVR program in reducing air pollution hinges upon the answers to several questions, all of which relate to the household's decisions and actions (Hsu & Sperling, 1994):

- How much earlier was the vehicle retired?
- How would the vehicle be driven if not retired?
- What are the emissions levels of the retired vehicles?
- How was the VMT replaced?
- What is the VMT for the replacement vehicle, if there is one?
- What are the emissions of the replacement vehicle?

The overall hypothesis of this research is that the effectiveness of the programs depends largely upon which households decide to scrap vehicles. Household characteristics influence whether the household owns an older vehicle in the first place, how they use that vehicle, whether they decide to scrap it, how they would have used it if they had not scrapped it, and how they replace the transportation services provided by the vehicle. Figure 5 presents the analytical framework behind this approach, which is described below:

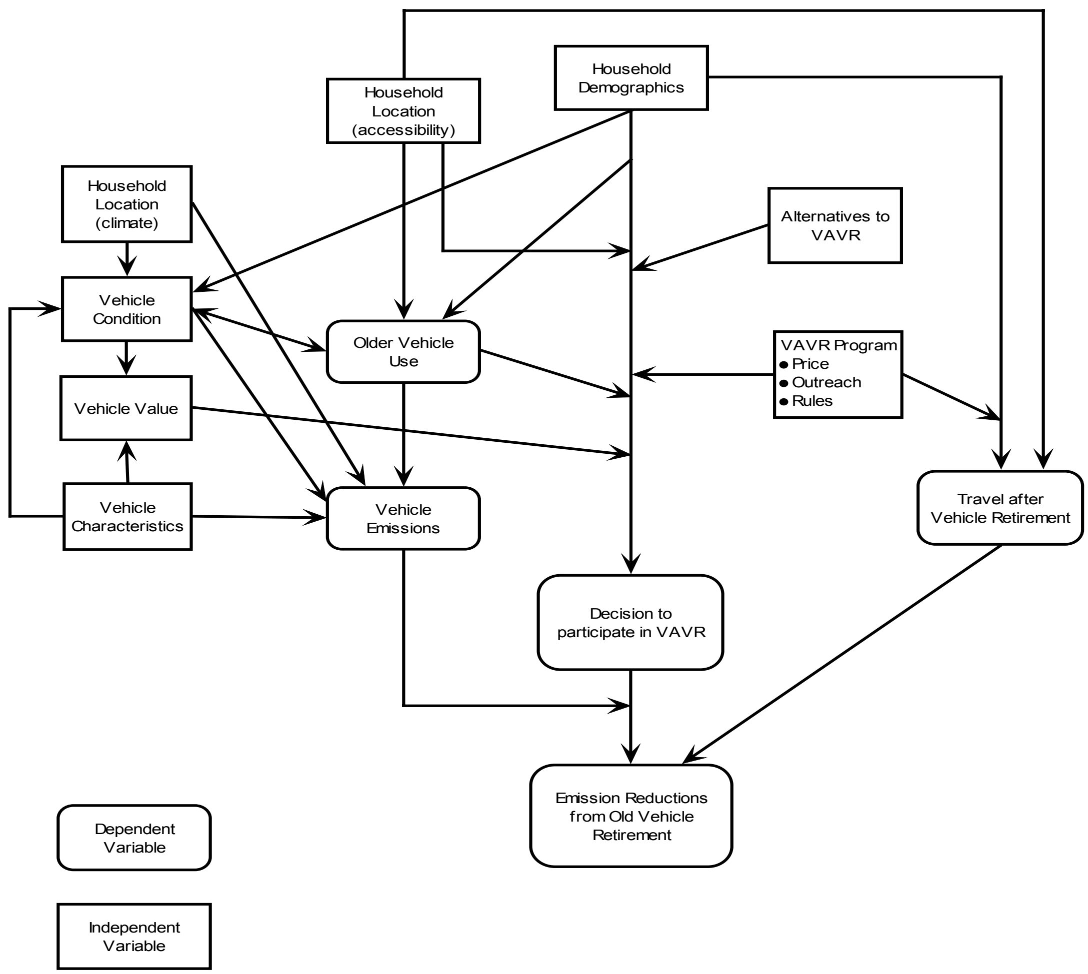
- Older vehicle ownership and use is largely determined by of two sets of household characteristics: demographics (including income, size, gender, ages, employment, and other variables) and location (e.g. land use and transit access).
- In addition, the condition and characteristics of the vehicle will impact its use. Vehicle condition is partially determined by household demographics (e.g. income impacts repair history) and location (e.g. climate impacts condition).

Some vehicle characteristics (e.g. size) are also largely determined by the preferences of the household when they acquired the vehicle.

- The use of the older vehicle, along with the vehicle characteristics and condition, determines the emissions produced by that vehicle.
- Household demographics influence the decision to participate in a VAVR program, with intervening variables including the program design, vehicle use, vehicle condition, and alternatives to VAVR. For example, the price offered for the vehicle, *along* with household income, will impact the decision. The availability of vehicle donation programs for a tax deduction, *along* with income, will impact the decision. Vehicle characteristics and condition will determine the vehicle's value, which also influences the decision.
- Household demographics and location, along with the VAVR program design (primarily the price offered) will help determine how the household replaces the travel provided by the scrapped vehicle ("replacement travel").
- The decision to participate in the VAVR program, coupled with the emissions from the old vehicle, and the replacement travel (and its associated emissions) determine the emissions reduction from early retirement of the vehicle.

This research will test the importance of these relationships, focusing on the household, in determining the benefits of VAVR programs. The results will be used to make policy recommendations.

Figure 5: Analytical Framework



1.2.2 Overview of Research Methodology

To examine the relationships outlined above, this research uses a number of disaggregate data sources, which are described in detail in Chapter 3. Existing travel and vehicle surveys are used to examine the ownership and use of all older vehicles. These data are then compared to data on VAVR participants. The detailed data on VAVR participants comes first from prior surveys of VAVR program participants in the San Francisco and Los Angeles regions.

Two additional surveys were undertaken to provide more detailed data for the San Francisco area. A “Participant Survey” surveyed households that had sold a vehicle to the Bay Area Air Quality Management District (BAAQMD) VAVR program. A “Non-Participant Survey” included Bay Area households who owned an older vehicle (pre-1982), but did not participate in the BAAQMD’s VAVR program. The primary purpose of this survey was to compare older vehicle owners that decide not to sell a vehicle to a VAVR program to VAVR participants. The new data were gathered for the San Francisco area for several reasons. First, the Bay Area's VAVR program is one of the largest and longest running in the nation. Second, data from the South Coast area, which has the largest VAVR program in the country, is available from an existing study. Finally, data collection in the Bay Area was logistically easier, and the staff at the BAAQMD was very supportive of this research.

In addition to the data analysis described above, I undertook an extensive literature and document review, supplemented by personal contacts, on VAVR programs in the U.S. and abroad. These findings are described in Chapter 2.

1.2.3 Outline of What Follows

Chapter 2 presents more extensive background information useful to understanding VAVR programs. There are two parts: (1) an overview and discussion of the existing research on VAVR programs; and (2) a description of VAVR programs in the U.S. and abroad. Chapter 3 describes in more detail the data sources mentioned briefly above. Chapter 4 presents a profile of older vehicle owners and drivers and how older vehicles are used in the United States. Chapter 5 evaluates the emissions impacts of VAVR programs. This includes an examination of who participates in VAVR programs compared to all older vehicle owners, the use of scrapped vehicles compared to all older vehicles, the relationship between household characteristics and scrapped vehicle replacement, and how all of these factors impact emissions reductions. These results are then used to examine several options to improve the effectiveness of VAVR programs. Chapter 6 concludes the research, highlighting the important findings and presenting policy and future research recommendations.

2 Chapter 2: Description of Existing Research and VAVR Programs

2.1 Existing Research

The existing research on VAVR programs falls into two broad categories. First, a number of studies use various economic theories to model the household decision to participate in a VAVR program and/or the overall market impacts of a VAVR program. Some of these studies from the economics literature evaluate the air pollutant emissions impacts as well, based upon economic models. Second, a number of studies evaluate the air pollutant emissions impacts of VAVR programs without employing economic models. These evolution studies are often based on pilot or on-going projects. The methodologies and major findings of both these types of research are discussed below. The discussion focuses on studies conducted by independent researchers, and not by program sponsors, though findings from those studies are included. None of the existing research looks in depth at the characteristics of older vehicle owners and VAVR participants and how they influence decisions and program effectiveness.

A large body of literature exists regarding vehicle ownership and use. This literature will be discussed in Chapter 4 to enlighten the discussion of the ownership and use of older vehicles. Literature regarding vehicle emissions is reviewed and used in Chapter 5.

2.1.1 Economics Literature

Manski and Goldin (1983) were among the earliest to model the scrappage decision, long before the air pollution effects of older vehicles were an issue. They developed a model for scrappage based upon the simple premise that a vehicle will be scrapped if the vehicle's scrap value exceeds its market value minus repair costs. Using two years of vehicle registration data from Israel, Manski and Goldin determined actual scrappage rates for each model year. The authors then developed a model of the probability of scrappage that depended upon the vehicle's technological attributes and the price of the vehicle. The automobile attributes in the model included age, engine size (which correlates with seating capacity and vehicle dimensions) and continent of origin. Vehicle prices were estimated from an Israeli publication similar to the U.S. Bluebook.

Maximum likelihood estimation was used to estimate parameters and the authors found that older vehicles tended to have higher probabilities of failure (scrappage), though there is some variation between years and the trend is not consistent. They also found that scrappage increased as vehicle size increased, that European cars failed more often than American or other vehicles, and that a vehicle's scrappage probability decreased as its price increased, all else equal. The authors concluded that the large increase in scrappage rates as vehicles aged was due "much more to the depreciation of prices as vehicles age than to increases in failure-proneness. This implies that policies which affect vehicle prices can have relatively large effects on the age distribution of the aggregate automobile fleet." If these findings held in the U.S., this would imply that programs to increase the cost of owning older vehicles could be effective at increasing their scrappage rate. In general, however, this model is limited by its data. This was not a disaggregate study. The analysis was conducted at the make and model-year level, rather than vehicle level, and, therefore, does not take into account the condition of the vehicle or miles driven.

Alberini, Harrington, and McConnell (1995) developed a theoretical model of the scrappage decision that included a VAVR program incentive. They first contended that economic theory dictates that vehicles in the worst condition will be recruited for scrappage programs first, leading to a "selection problem." To help deal with this problem, the researchers developed a theoretical model of a vehicle owner's car tenure and scrappage decision. They then used the model to forecast participation in a vehicle retirement program. Their research was based upon a survey of pre-1980 vehicle owners conducted in conjunction with a scrappage program in the state of Delaware. The data included actual or revealed behavior (whether or not the individual participated in the scrap program after being solicited) and stated preference data (response to a hypothetical offer based upon a bidding procedure).

The model was based upon the vehicle owner's utility maximization. The decision to scrap a vehicle depended upon the difference between the offer price and the owner's "reservation price" – the minimum he/she is willing to accept. Therefore, the determinants of a person's "willingness to accept" (WTA) determined the supply of vehicles for a retirement program offering a certain price for vehicles. If the scrap program offer exceeded the person's WTA, they would scrap the car. The probability that the person would accept the offer was described as follows:

$$\Pr(\text{offer is accepted} \mid x_i) = F(\log(\text{offer}); x_i, \theta)$$

where θ includes the slope coefficients β from: $\log WTA_i = x_i\beta + \varepsilon_i$

or a shape parameter (or both), depending upon the F distribution

Based upon survey data, the researchers developed a linear regression model for the WTA. The significant variables were: (1) how long the person thinks the vehicle would last (residual or remaining life); (2) blue book value of the car; (3) vehicle condition; and (4) anticipated expenses to keep the car running another year. As one would expect, the WTA was higher for vehicles with higher blue book values, in better condition, with longer expected remaining life, and with lower anticipated expenses. Variables that were not significant included the annual miles driven, the number of cars owned by the household, whether the car was used for commuting, household income, and whether the person had driven the car on a trip longer than 150 miles recently. In general, the WTA related more to characteristics of the vehicle than how it was used or household characteristics.

The authors then used the estimated WTA function and the model of owner behavior to predict participation rates in a scrappage program for various offer prices. Not surprisingly, they found that at low offer prices, the vehicles most likely to be scrapped were those in the poorest condition and with a short remaining life.

This model differs from Manski and Goldin's, which looked at a household's decision at given point in time. Alberini, et al examined the optimal timing for scrapping a vehicle and how that changed over time, particularly in response to an incentive offered at a certain point in time (such as through a scrappage program). In addition, Manski and Goldin only determined scrappage rates for entire vehicle classes. This model was based on more detailed data and could be used to predict the behavior of owners having given characteristics. The model could also be used to predict behavior in response to other changes, such as an increase in taxes or registration fees for older vehicles.

Alberini, Harrington, and McConnell (1996) build upon the authors' 1995 publication to estimate emissions reductions from a VAVR program. First they described the estimation of the WTA function. However, the estimation differed slightly from that in the 1995 article. The significant variables still included the blue book value of the vehicle, condition of the car, and anticipated future expenses. However, it included a new variable, the amount spent on the vehicle in the past year. In addition, rather than having the owner's expected residual life for the car as a variable in the WTA estimation, the authors used a model to estimate the residual life based upon the owner's WTA and vehicle characteristics. The model confirms expectations that vehicles attracted to scrappage programs were those with the shortest remaining life. The use of a model to predict remaining life is an advance over the common practice of assuming a 3-year remaining life. The authors were able to link the offer price ("bounty") with remaining life to show that the higher the offer, the longer the expected remaining life of the vehicles attracted to the program. This makes intuitive sense; as the offer price increases, higher quality vehicles will be sold.

To calculate emissions reductions, the authors used survey data from program participants to arrive at the annual VMT. The authors found that the scrapped vehicles were driven as many miles as the average vehicle in the old car fleet. Emission tests were performed on a sample of the vehicles scrapped in the Delaware program and the authors used these figures, rather than MOBILE estimates, to calculate reductions. They did compare the two and found that the scrapped vehicles emitted more hydrocarbons, but less carbon monoxide and nitrogen oxides than predicted by MOBILE (pre-1980 vehicles).

As for replacement vehicles, the authors used several scenarios: (1) VMT is replaced by new vehicles; (2) VMT is replaced by the vehicle reported to be purchased by the participant in the survey; and (3) replacement is provided by vehicles throughout the entire fleet in proportion to the existing age distribution of the fleet. In this analysis the first scenario resulted in the largest reductions, while the second resulted in the smallest reductions. The authors concluded that small scale targeted VAVR programs are a cost-effective way to reduce emissions, though the level of cost-effectiveness (dollars per ton of emissions reduced) depends upon the offer price. Higher offer prices reduced the cost-effectiveness (higher $/ton), though more vehicles were scrapped.

Hahn (1995) assessed the likely benefits and costs of a vehicle scrappage program. Rather than using a "full-blown model of the automobile market", Hahn used a simpler approach to estimate equilibrium prices in the new and used car markets. He first constructed a vehicle supply curve using fleet composition data and the value of each car. The costs of the VAVR program were measured in two ways: (1) the area under the supply curve up to the amount of the bounty offered by the program (does not include transfer payments); and (2) multiplying the bounty price by the number of vehicles.

Hahn then estimated the net emission reductions and cost-effectiveness. In doing so, Hahn used VMT data from the MOBILE model, which has an average annual VMT for each model year. In general, older cars are driven less and this is reflected in MOBILE's data. Though Alberini et al (1996) found no difference in annual VMT for the Delaware vehicles, the assumption that the scrapped vehicles are driven the same as the fleet average for that model year is questionable. Moreover, Deysher and Pickrell (1998) cast doubt on MOBILE's VMT numbers. Hahn adjusted the emissions benefits to account for vehicles that would have been scrapped anyway, using natural scrappage rates for each model year. The "natural" scrappage rate is the percent of vehicles that would be scrapped without a VAVR program incentive. Emissions factors were from California's EMFAC model. As with the mileage figures, these emissions may not reflect the emissions from scrapped vehicles, since scrapped vehicles might be in worse condition than the fleet as a whole. Alberini et al (1996) reported that the MOBILE model under predicted HC and over predicted CO and NO_x emissions for scrapped vehicles.

Key assumptions in the base case analysis included: (1) all scrapped vehicles were replaced by a "typical" vehicle in the fleet, calculated by a weighted average; (2) scrapped vehicles had a remaining lifespan of three years; and (3) the replacement vehicle was driven the same number of miles as the scrapped vehicle. Hahn also performed a sensitivity analysis using three replacement scenarios: (1) a typical 1983 model-year vehicle; (2) a new vehicle; and (3) a typical pre-1980 vehicle. The cost-effectiveness of the program improved in the second scenario and was negative for the last scenario (since the vehicles scrapped were also pre-1980). In addition, he conducted sensitivity analyses using 2- and 4-year remaining lifetimes. As expected, cost-effectiveness declined with the 2-year assumption and improved with the 4-year assumption. Like Alberini et al, Hahn concluded that it is possible to design a VAVR program to achieve cost-effective emission reductions. However, Hahn also questioned how a scrappage program will perform over time, speculating that cleaner cars and lower deterioration rates will reduce future cost-effectiveness.

Kavalec and Setiawan (1997) used a vehicle choice-demand-usage model for California (CALCARS) to estimate the costs and benefits of a large-scale scrap program. CALCARS was estimated using both stated and revealed preference data from a survey of 5,000 households. CALCARS was a nested, multinomial logit model that simulated the ownership, use, and transactions (replacement, addition, or disposal) of personal cars and trucks at the household level. It used 41 model years (1970-2010) and 14 class sizes. Each year each household decided whether or not to keep a vehicle based upon the utility associated with all possible choices. This depends upon vehicle and household characteristics, as well as the disutility (i.e. transaction costs) associated with replacing a vehicle. The model projected annual VMT based upon the vehicles owned and other factors. Table 1 lists the model variables.

Table 1: Kavalec and Setiawan (1997) Model Variables

Submodel	Household Characteristics	Vehicle Characteristics	Other
Vehicle Quantity (multinomial logit)	income # hhld members # employed members	the log-sum of all individual choices (the maximum expected utility)	Availability of transit in region
Vehicle Choice (multinomial logit)	income # of hhld members	age of vehicle size class (dummy) market value fuel operating cost per mile acceleration top speed	
Vehicle transactions/replacement (binomial logit)		estimated utility of currently held vehicle(s) the log-sum of all individual choices (the maximum expected utility)	
VMT (ordinary least squares)	Income # hhld members # employed members	size class (dummy) age fuel operating cost per mile other hhld vehicle characteristics	availability of transit in region

A major advantage of this model in the evaluation of VAVR programs is that it predicted how vehicles would be replaced and the level of VMT for the household after a vehicle was disposed of. Unlike the other models described above, this model explicitly allowed for the possibility that some users might not replace the VMT on a one-for-one basis (some may drive more, others less) and attempted to simulate the type of replacement vehicle. Kavalec and Setiawan used the model to simulate various VAVR program scenarios. They estimated that about 85% of the vehicles that were retired in each year of a program would be replaced. The replacement vehicles were on average newer, and, therefore, VMT per vehicle would rise, leading to an overall increase in VMT. Under a scenario where 10-year-old and older vehicles are scrapped, fuel use was projected to increase, as small, lower-value, compact cars are replaced with larger vehicles and light trucks. This was not projected to occur in a program targeting 20-year-old and older vehicles.

Kavalec and Setiawan also analyzed the welfare impacts of a VAVR program. Since the scrap offer price effectively sets a price floor for a particular category of vehicles, some prospective buyers pay a higher price or buy a less preferred option, leading to a welfare loss. The authors attempted to measure the loss by the change in consumer surplus between the base case and the case with the VAVR program. They converted the loss in ‘utils’ to a dollar amount using an estimate of the household’s marginal utility of income. They found that the average loss per household would be highest for the lowest income groups, though the effects would be relatively minor (e.g. about $2 annually per household). This assumed no price increase for non-targeted (by the VAVR program) used vehicles, i.e. vehicles from outside the region and existing inventories would meet the higher demand without an increase in prices. This assumption may not hold if the VAVR programs grow large enough to affect the market for used vehicles.

That issue – whether a large-scale VAVR program would impact the vehicle market – was a primary focus of a study by Rand (Dixon, 2001). This study looked at the implementation of California's SIP measure M1, which calls for scrapping 75,000 older vehicles per year in the South Coast Air Basin from 2001 to 2010. The authors modeled the impacts of such a large-scale program on the prices of vehicles and the potential for vehicles to enter the market from other regions. They predicted that the program could increase prices for used light duty vehicles by $22 to $271 in 2010, with the best point estimate being $66. They assumed that some vehicles will enter the market from other regions, partly due to this increase in value, and that the emissions benefits of the program are, therefore, reduced. Overall, however, the authors concluded "despite attenuation by vehicle migration into the South Coast – the planned VAVR program would result in substantial emissions benefits, albeit perhaps short of the SIP target of 25 tons per day in 2010" (Dixon, 2001, p. 74). Moreover, their estimated cost-effectiveness of the program compared favorably to other strategies to reduce vehicle emissions.

2.1.2 Evaluation Studies

One of the earliest independent evaluation studies was conducted by the U.S. Congress's Office of Technology Assessment (OTA) (U.S. Congress, 1992). A Congressional subcommittee requested the analysis, prompted, in part, by two Senate proposals to stimulate vehicle scrappage programs using a corporate average fuel economy (CAFE) incentive process and a Bush Administration plan to allow pollution credits for VAVR programs. The analysis concluded that "it is quite likely that a carefully designed early retirement program, targeted at areas that are out of compliance with air quality standards, can achieve environmental benefits at costs equal to or lower than those of other emissions-reduction options that are already in use or scheduled to be used" (U.S. Congress, 1992, p. 2). The OTA assumed that there would be no net change in total VMT, e.g. participants would replace the scrapped vehicle's VMT on a one-for-one basis. The study used three scenarios for replacement travel: (1) all VMT would be in new cars; (2) all VMT would be from the existing fleet, distributed across model years as currently distributed; and (3) half in new cars and half from the existing fleet. Assuming a $700 bounty for pre-1970 or pre-1975 vehicles, OTA estimated a cost/benefit ratio with respect to emissions reductions of 0.59 to 0.75, depending upon the replacement assumption. Costs outweighed benefits when the bounty was raised to $1,000 to attract pre-1980 vehicles and the third VMT replacement scenario was in place. However, the OTA did not model whether the $1,000 bounty was necessary to attract the newer model years, as the economic models discussed in Section 2.1.1 did. The study also examined other changes in assumptions and program design, including waiting until the Tier 1 new vehicle standards went into place, retiring only higher-than-average emitting vehicles, and assuming the cars would have lasted four, instead of three, years.

The goal of Deysher and Pickrell's research (1998) was to determine the maximum potential effectiveness of vehicle retirement programs. The authors started with the assumption that all light-duty vehicles more than 20 years old would be retired, representing an extreme approach intended to test the maximum potential in reducing ozone precursor emissions. The analysis was completed for 1995, 2000, and 2005. The old vehicles represented about 3.1% of the fleet in the test area, Eastern Massachusetts.

The analysis also assumed that “100 percent of the vehicle miles traveled (VMT) by the retired vehicles is replaced through more intensive usage of the remaining light-duty vehicle fleet, rather than by increased vehicle occupancy or increased use of other transportation modes.” Three scenarios were used to simulate how the VMT is distributed throughout the remaining fleet: (1) VMT was redistributed to the two newest model year vehicles; (2) VMT was redistributed in proportion to the fraction of VMT accounted for by vehicles from one to 20 years old; and (3) VMT was redistributed to the two oldest model years, i.e. those 19 and 20 years old. The first was a best case scenario, in that the two newest model years should be the cleanest, while the third scenario is the worst case.

The modeled retirement program would reduce fleet wide emissions of volatile organic compounds (VOCs) by a low of 0.1% and a high of 3.6%. Emission reductions were larger in 1995 than 2000 and 2005 because natural fleet turnover (that which occurs without a VAVR program) reduces fleet emissions. As expected, replacement scenario 1 (two newest model years) resulted in the largest emission reductions, followed by scenarios 2 and 3. The modeled program was far less cost-effective than those found in the other research because of the scale of the program. Purchase prices ranged from $750 to $1,500, which increase the cost of the program. In addition, since all older vehicles are scrapped, relatively clean vehicles are scrapped, thereby reducing the program’s effectiveness.

The three major explicit assumptions in this research – all vehicles over 20 years old are retired, 100% of the VMT is replaced, and how that VMT is redistributed – were key to the results. In addition, underlying the analysis was an assumption that the MOBILE emissions model accurately estimated the emissions of the scrapped vehicles.

In fact, the authors analyzed this assumption using emissions data from four VAVR programs and VMT data from four other sources. They showed that MOBILE probably underestimated emissions from older vehicles because of underestimating both VMT and emission factors. There are two issues here. First, the data upon which the MOBILE emissions model was based may not be accurate, thereby over- or under-estimating emissions on a fleet level for all older vehicles. Second, the actual emissions from scrapped vehicles may not be representative of the old vehicle fleet as a whole. In Deysher and Pickrell's analysis, since all old vehicles were retired, this was not an issue. However, in reality, only a portion of old vehicles will be retired through such programs. If the vehicles recruited for the programs are in worse condition than most vehicles of that model year, MOBILE may underestimate the emission *rates* for the retired vehicles, i.e. actual emissions from the vehicle may be higher than estimated and, therefore, benefits from scrappage may be larger. Using data from three VAVR programs, Deysher and Pickrell reported that MOBILE5a under predicted HC rates for scrapped vehicles, but over predicted NO_x rates. On the other hand, assumptions for VMT for such vehicles may underestimate use (vehicles in the worst shape may be driven less than the model year average). This factor may lead to overestimating the benefits of scrapping.

Hsu and Sperling (1994) examine the various uncertainties involved in estimating the air quality impacts of VAVR programs. The authors first look at the question of how much longer the vehicle would have been on the road if not for the retirement program. They question using fleet averages because of the large standard deviations. For example, the average remaining lifetime for a 15-year-old car was 4.41 years, with a standard deviation of 3.17 years. Moreover, they pointed out that the modest prices offered in

VAVR program ensure a biased sample, unlike fleet averages. Similarly, they questioned the use of fleet averages by model year for the assumption of how far the vehicle would be driven if not scrapped. With respect to the scrapped vehicle's emissions, they used Unocal's SCRAP data to show that scrapped vehicles were far dirtier than predicted by CARB's EMFAC model and that the standard deviations were quite large – further adding to the uncertainty. The authors also raised a number of questions regarding replacement transportation.

To demonstrate the overall uncertainty in evaluating VAVR programs, they performed a sensitivity analysis with a range of assumptions. The results showed a ten-fold difference between the most and least cost-effective program scenarios. Throughout the analysis, Hsu and Sperling pointed to the lack of understanding of the behavior of older vehicle owners – their decision to scrap their cars or not, their driving patterns, etc. "Research is very much needed to improve our understanding of the behavior and motivations of automobile owners that might be candidates for participation in such programs, and the kinds of automobiles that these persons will turn in" (Hsu & Sperling, 1994, p. 28).

2.1.3 Summary of Cost-Effectiveness Estimates

Regulatory agencies often assess different air pollution control strategies in terms of cost per ton of pollutant reduced. Table 2 includes such cost-effectiveness estimates from the studies described above, along with estimates from six program sponsors (Unocal, the states of Illinois and California, and air districts in the South Coast, Bay Area, and Santa Barbara). *These studies, however, are not directly comparable.* Each has different assumptions and methods of calculating costs and emissions reductions, not to mention different base years and sizes of programs (some of which are noted). The impacts of such differences in estimating cost-effectiveness of emission control strategies are discussed and evaluated by Wang (1997). Moreover, cost-effectiveness as it is usually measured is limited as an evaluation criterion. For example, costs usually only include the direct costs of implementing the regulation on the part of the agency and regulated industries. Larger societal costs or the direct and indirect monetary benefits of reducing pollution are not captured. Equity impacts – how the costs and benefits are distributed – are also not addressed. Therefore, while the data on the cost-effectiveness of VAVR programs are presented here, it is by no means the only or best criterion upon which to judge a VAVR program. It is, however, one of the most popular evaluation criterion currently used by regulatory agencies to evaluate measures for inclusion in air quality plans.

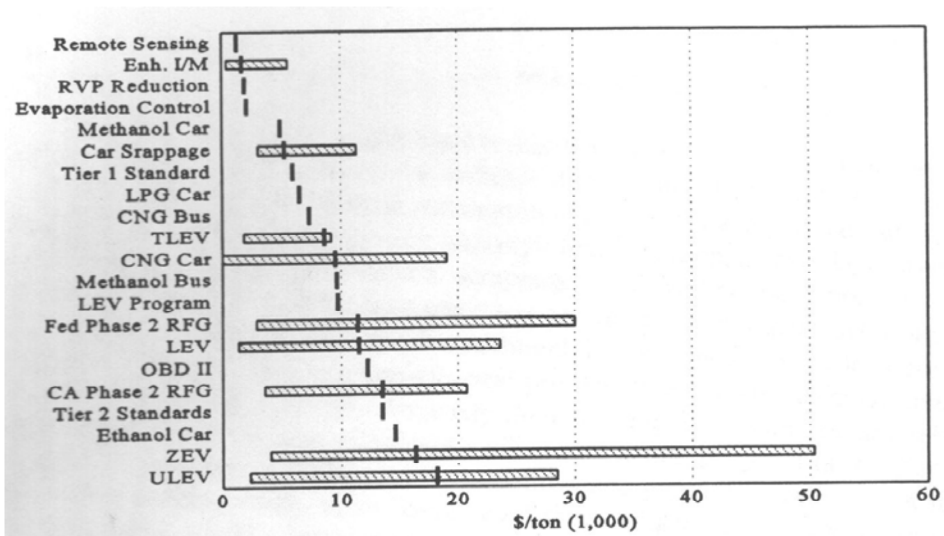
Table 2: Summary of Cost-Effectiveness Estimates

	$ per ton of VOC, ROG, or HC reduced		
	High	**Low**	**Most Likely**
Deysher & Pickrell (1998) All 20-yr-old vehicles	$80,000	$ 10,000	$ 20,000
Alberini, et al (1996) Non-targeted program	$10,500	$5,200	
Hahn (1995)*	$10,800	$5,000	
OTA (1992) 1 million vehicle program	$10,300	$2,000	
Hsu and Sperling (1994)	$16,200	$1,700	
Kavalec and Setiawan (1997)	$6,700 (ROG+NOx)	$3,400 (ROG+NOx)	
Rand Study (2001) 75,000 vehicles	$33,300 (ROG+NOx)	$3,700 (ROG+NOx)	
BAAQMD	$ 14,200		$6,300*
Illinois Pilot Project			$7,600*
Illinois projected program	$3,800	$2,900	
Santa Barbara			$5,000*
Unocal SCRAP II			$5,700*
SCAQMD 10,000 vehicles	$ 21,000	$5,800	
CARB 10,000 vehicles			$5,700

All figures rounded to nearest $100
*Program as implemented
Sources for studies not listed above: (California Air Resources Board, 1992; Illinois Environmental Protection Agency, 1993; Santa Barbara County Air Pollution Control District, 1997; South Coast Air Quality Management District, 1992; Steinberger, 2000; Unocal Corporation, 1994)

Though the numbers are not directly comparable, it is useful to see that most of the studies are within a reasonable range of each other, with most between $2,000 and $20,000 per ton. The highest estimate (Deysher and Pickrell) is for a program that would scrap all 20-year-old vehicles, which is an unlikely scenario. What is perhaps even more useful is to compare these estimates to other pollution control strategies. Wang performed such an analysis while standardizing the calculation methods from several studies. These results are shown in Figure 6. The median values are shown, along with the range of estimates. The figure shows that car scrappage programs are among the more cost-effective of the mobile source control measures included.

Figure 6: Range of Cost-Effectiveness for Mobile Source Measures from Wang (1997)



2.2 VAVR Programs in the U.S. and Abroad

2.2.1 Overview of Programs in North America

Table 3 is a list of 23 VAVR programs and regulations in the U.S. and Canada. VAVR programs in North America fall into two broad categories – programs that generate “mobile source emission reduction credits” (MERCs or MSERCs) and those that don’t. Companies can use MERCs to comply with other air pollution regulations. For example, a refinery might delay installation of costly control equipment by purchasing credits generated by scrapping old cars. The credits are worth a certain amount of pollution (e.g. pounds of reactive organic gases per day) and last for a designated time period, often three years. These types of programs would result in a net reduction in air pollution if credits are not used, if credits are purchased for the purpose of retiring them, or if the rules require a margin of error when purchasing or using credits.

Programs generating MERCs are usually authorized through rules adopted by a state or local air quality regulatory agency. These rules set forth guidelines on how the programs operate and how MERCs are calculated, sold, and traded. The purchase and scrappage of the vehicles is undertaken by private (or non-profit) enterprises that are certified by the oversight agency. Examples of such programs include the South Coast Air Quality Management District's Rule 1610 and statewide rules in Illinois, Louisiana, and California (California Air Resources Board, 1999; Illinois Pollution Control Board, 2000; South Coast Air Quality Management District, 2000a; State of Louisiana, 2001). However, the presence of a rule does not mean that vehicles are actually being scrapped. For example, no evidence of a program in Louisiana could be found. One of the first uses of MERCs from vehicle retirement was by employers purchasing credits in lieu of implementing mandatory employee trip reduction programs in both the South Coast and Bay Area regions. In fact, since 1998, all of the credits generated through SCAQMD's Rule 1610 have been used by employers to comply with a rule requiring them to reduce emissions from employee commutes (South Coast Air Quality Management District, 2001)

The second category of programs, those that do not generate MERCs, are sometimes short-term pilot projects to demonstrate the efficacy of a VAVR program or publicly-funded programs designed to reduce air pollutant emissions. Some pilot projects, such as Unocal's SCRAP I, are started by private companies to demonstrate VAVR program effectiveness compared to other regulations (Unocal Corporation, no date).

Others are publicly-funded, such as the California Air Resources Board Pilot Program, which was undertaken to collect data to help evaluate the effectiveness of VAVR programs (Sierra Research, 2001). Public-private partnerships are also common. For example, Unocal's SCRAP eventually attracted other public and private partners.

Longer-term programs in the United States are often publicly-funded and aim at reducing air pollutant emissions to help meet state or federal air quality standards. The programs may help meet emission reduction targets in a State Implementation Plan (SIP) prepared under the Federal Clean Air Act or state air quality planning requirements. One of the oldest and largest such programs is operated by the Bay Area Air Quality Management District (BAAQMD), covering the nine-county San Francisco Bay Area. This program is funded by an annual registration fee imposed on all registered vehicles in the region (Air Pollution Control Officer, 1998). The other programs in operation as of this writing are run by the Santa Barbara County Air Pollution Control District, the California Bureau of Automotive Repair, the State of Maine, and Vancouver, British Columbia. In addition, the South Coast Air Quality Management District's Rule 1610 is in active operation, with vehicles being purchased for MERCs.

In April 2000, the Texas Natural Resource Conservation Commission (TNRCC) adopted a rule that establishes a process for local agencies to adopt VAVR programs to generate emission reduction credits to use in meeting air quality attainment goals, not for MERCs (Texas Natural Resource Conservation Commission, 1999). After the TNRCC adopted a target of reducing mobile source emissions by 90%, the legislature expanded the agency's inspection and maintenance (I&M) program (Office of House Bill Analysis, 2001). The new I&M program includes an inspection fee, part of which will go towards low-income vehicle repair assistance, retrofit, and accelerated vehicle retirement programs (State of Texas, 2001). The new law takes effect September 2001 and directs the TNRCC to develop a process to allow the use of emissions reduction credits from the VAVR portion of the low-income program.

Table 3: VAVR Programs in the U.S. and Canada

Program	Dates	Amount of Incentive	Model Year Eligibility	Notes
Pilot or Short-term Programs				
Unocal South Coast Recycled Auto Project (SCRAP) (Los Angeles region)	I: 1990 II: 1993	$700	I: pre-1971 II: 1971-1979	
Illinois Environmental Protection Agency - Cash for Clunkers	1992	Varied by model year (MY): $647 (1968 MY) - $902 (1979 MY)	1968-1979	
U.S. Generating Company – Delaware Vehicle Retirement Program	1992-1993	$500	pre-1980 and vehicles that failed I&M	Project to offset tugboat emissions associated with new power plant
Total Clean Cars Program (Denver, CO)	1993-1994	$1,000	1981 and older high-emitting vehicles found through remote sensing, hotlines, and I&M	Privately funded. Included repair and retirement program
Crown Central Petroleum (Baltimore, Maryland)	1994	$700	1976 and older	
San Luis Obispo County Air Pollution Control District	1996	Unknown	1981 and older	
California Air Resources Board Pilot Program	1998 – 1999	$500	All MYs	

Program	Dates	Amount of Incentive	Model Year Eligibility	Notes
Calgary, Canada - Alberta Clean Air Strategic Alliance Vehicle Scrappage Pilot Project	2001-2002	Unknown	1980 and older	Program currently under development
Ontario, Canada – ProtectAir Vehicle Retirement and Recovery Program	1996 (Nov.-Dec.)	$400 (Canadian $)	1987 and older	Pilot project sponsored by Ontario Hydro to generate MERCs
Longer/Ongoing Programs that Do Not Generate MERCs				
Bay Area Air Quality Management District (San Francisco, CA region)	1996 – ongoing	$500	1981 and earlier	
San Diego County Air Pollution Control District (CA)	1994 – 2000	$600 (pre-1975 vehicles) $500 (1975-1981 vehicles)	1981 and earlier	
Santa Barbara County Air Pollution Control District (CA)				
Old Vehicle Cleanup Partnership	1993-1996	$500	1981 and older	
Old Car Buyback program	1999 - ongoing	$500	1984 and older	
San Joaquin Valley Unified Air Pollution Control District (CA) - through Project Clean Air and other contractors	1992 – 1999	$400 – 600	Varied	
California Bureau of Automotive Repair	1998 – ongoing	$1,000 (previously $450)	All MYs, must fail Smog Check	

Program	Dates	Amount of Incentive	Model Year Eligibility	Notes
State of Maine, Dept. of Environmental Protection High-Pollution Vehicle Retirement Pilot Program	Began November 1, 2000, expires 11/1/2003	Voucher for $1,000, $1,500 or $2,000, depending on size of vehicle scrapped	1987 and older	Voucher good for purchasing a 1996 or newer vehicle
State of Texas (H.B. 2134) - Low-income repair, retrofit and retirement program	Passed 2001	To be determined	To be determined	Tied to I&M program; MERCs allowed
Vancouver, British Columbia - Scrap-It	1996 – 1998 (pilot phase) 1998 - ongoing	$500 – 1,000 (Canadian $), depending on replacement	1987 and older	Public-private partnership
Regulations				
Texas Natural Resource Conservation Commission – 30 Texas Administrative Code Chapter 114	Adopted April 2000	Not applicable		Rule for SIP credit
California Air Resources Board – CA Code of Regulations, Title 13, Chapter 13, Article 1 sections 2600-2610	Adopted October 1999	Not applicable	Not specified	Rule for generating MERCs and SIP credit
South Coast Air Quality Management District (Los Angeles region) - Rule 1610	Adopted January 1993	Market rate, generally $500-600	1981 and older	Rule for generating MERCs

Program	Dates	Amount of Incentive	Model Year Eligibility	Notes
Illinois Pollution Control Board - Part 207 of Title 35, Subtitle B, Chapter I, Subchapter b	Adopted June 2000	Not applicable	No more than 25 years old	Rule for generating MERCs
State of Louisiana – Environmental Regulatory Code, Title 33, Part III, Chapter 6	Adopted August 1994	Not applicable	1981 and older LDVs	Rule for generating MERCS
Other				
Toronto, Ontario – Clean Car Heaven (Clean Air Foundation)	July 2000 – ongoing	None; entered in drawing for prizes, including a new Toyota Prius	All MYs	Public-private partnership; vehicle donation program. May be used for MERCs in future

Sources: (*Canadian Government Programs and Services Report,* 2001; Air Pollution Control Officer, 1998; Alberini, Edlestein, & McConnell, 1994; California Air Resources Board, 1999; Car Heaven, 2000; Department of Consumer Affairs, 2000; Illinois Environmental Protection Agency, 1993; Maine Department of Environmental Protection, 2000; Mullaney, 1994; Pilot Emission Reduction Trading Project, ; Project Clean Air, 2000; San Diego Air Pollution Control District, 2000a; San Luis Obispo Air Pollution Control District, 1996; San Luis Obispo Air Pollution Control District, 1997; Santa Barbara County Air Pollution Control District, 1997; Santa Barbara County Air Pollution Control District, 2000; Scrap-It Program, 2000; South Coast Air Quality Management District, 2000a; State of Illinois, 2000; State of Louisiana, 2001; State of Texas, 2001; Texas Natural Resource Conservation Commission, 1999; The Regional Air Quality Council & The Colorado Department of Public Health and Environment, 1994; Unocal Corporation, no date)

Several states have considered and rejected, or are still considering VAVR programs (Table 4). For example, in 1996 the State of Virginia passed a law authorizing the state's Department of Environmental Protection to start a VAVR program to generate MERCs. Private industry expressed little interest in starting such a program (Bearden, 1996). In 1997, the state's legislature repealed the provision after lobbying by the hobbyists and the automotive aftermarket industry (Coalition for Auto Repair Equality, 1997).

Table 4: VAVR Programs not Adopted

Location	Description
State of Arizona	Scrappage provision amended out of proposed legislation in 1996
State of Missouri	Legislative amendment to adopt program failed in 1998
State of New Jersey	Plan for a VAVR program submitted to Legislature in 1994, pursuant to State Law, and no further action taken
State of Vermont	Legislation (H 377) introduced in February 2001. Similar legislation failed to pass in 1999
State of Virginia	Repealed Virginia Motor Vehicle Scrappage Program in 1997

Sources: (Coalition for Auto Repair Equality, 1996; Coalition for Auto Repair Equality, 1997; Missouri State Senate, 1998; New Jersey Department of Environmental Protection and Energy, 1998; Representative David Zuckerman, 2001; Vermont State Legislature, 2000; Virginia General Assembly, 1996)

2.2.2 Overview of Programs Abroad

Beyond North America, VAVR programs are not used for MERCs. Most of the programs are publicly-funded (or public-private partnerships) and fall into two broad categories: cash-for-scrappage and cash-for-replacement (European Conference of Ministers of Transport, 1999). A cash-for-replacement program requires that the owner purchase a new vehicle. A cash-for-scrappage program provides the cash with no requirement for replacing the vehicle or options for replacement in addition to purchasing a new vehicle. (With the exception of the program in Maine, all of the programs in the

United States are cash-for-scrappage.) The programs outside North America are listed in Table 5.

Except in the Czech Republic and Glasgow, all of the programs were funded in full or part by the government. The Czech program was funded by the automaker and the Glasgow program was funded by the local bus company.[5] In some cases, such as Italy and Argentina, government subsidies were matched or supplemented by auto manufacturers or dealers. Most of the cash-for-replacement programs were administered through government tax breaks or price breaks with the dealer, rather than providing a check to participants, which is how the U.S. programs work. For example, the Greek program that targeted Athens offered at 40-60% reduction in the excise duty on new cars, conditional upon scrapping a ten-year or older vehicle (European Conference of Ministers of Transport, 1999).

[5] The bus company is private. However, I do now know how much of its funding may be from public sources, e.g. contracts for service.

Table 5: VAVR Programs Outside North America

Country	Dates	Type of Program
South America		
Argentina	May 1999 – Jan. 2000	Cash-for-replacement
Europe		
Denmark	1994 – June 1995	Cash-for-scrappage
Norway	1996	Cash-for-scrappage
Glasgow, Scotland	One day, June 1999	Cash-for-scrappage[a]
Hungary	September 1993 – ??	Cash-for-scrappage[b]
Czech Republic	1999	Cash-for-replacement
France (Prime a la casse)	February 1994 – June 1995	Cash-for-replacement
France (Prime qualite automobile)	Oct. 1995 – Sept. 1996	Cash-for-replacement
Greece	Jan. 1991 – March 1993	Cash-for-replacement
Ireland	June 1995 – Dec. 1997	Cash-for-replacement
Italy	Jan. 1997 – Jan. 1998	Cash-for-replacement
Italy	Feb. 1998 – Sept. 1998	Cash-for-replacement
Spain (Renove I and II, Plan prever)	April 1994 – ??	Cash-for-replacement

[a]Transit pass was the only option
[b]Replacement car or transit pass were the only options
Sources: (*The Herald,* 1999; Czech News Agency, 1999; European Conference of Ministers of Transport, 1999; South American Business Information, 1999)

With the possible exception of Argentina, all of the programs were adopted with the primary objective of accelerating the retirement of older vehicles and thereby reducing air pollution.[6] However, for several programs additional objectives were identified. For example, Italy, Ireland, and Argentina identified safety as a reason to get older vehicles off the road (Government of Ireland, 1996; Mitchener, 1997; South American Business Information, 1999).

[6] I have only found one source of information on the Argentina program, which does not identify air pollution as a program objective.

Stimulating automobile sales was often a goal in countries with significant domestic auto production (European Conference of Ministers of Transport, 1999). For example, Italy's program was introduced after four years of poor domestic sales. One analyst remarked that "It's going to be a major kick-start to the Italian market, which it now appears will lead the recovery in Europe this year" (Mitchener, 1997). The French program was also designed to help boost auto sales. The program was renewed in late 1995 in response to lagging domestic auto sales and when the French government was preparing to sell it's 51% stake in Renault (Wall Street Journal, 1995). When introduced in Ireland, the motor industry saw the scrappage incentives as a way to boost car sales, perhaps as much as ten percent (Brown, 1995). However, the Minister of Finance for Ireland denied that the scrappage program was extended for a year to benefit the automobile trade (Government of Ireland, 1996). Towards the end of the program, the Society of the Irish Motor Industry estimated that the program sustained 4,000 new jobs and added ,100 million in tax revenues. Sustaining automotive production appeared to be a major goal of the Argentina program, where the automotive industry estimated that 90% of the domestic production during the time of the program was directed at participants (South American Business Information, 1999).

In contrast, the carmakers in Britain proposed scrappage programs to boost sales and preserve jobs throughout the 1990s. The UK government rejected the idea because it conflicted with their efforts to discourage driving and encourage transit (Dunn, 1999). Only recently has the British government officially proposed a scrappage program to reduce air pollution, along with several retrofit proposals. The scrappage proposal includes transit incentives and would not be tied to the purchase of a new car

(Commission for Integrated Transport, 2000). A coalition of automobile associations and industry groups in Australia has also proposed a scrappage program, with stated objectives of improving safety, decreasing emissions and deterring vehicle theft (Australian Automobile Association, 1998).

2.2.3 Incentive Amounts

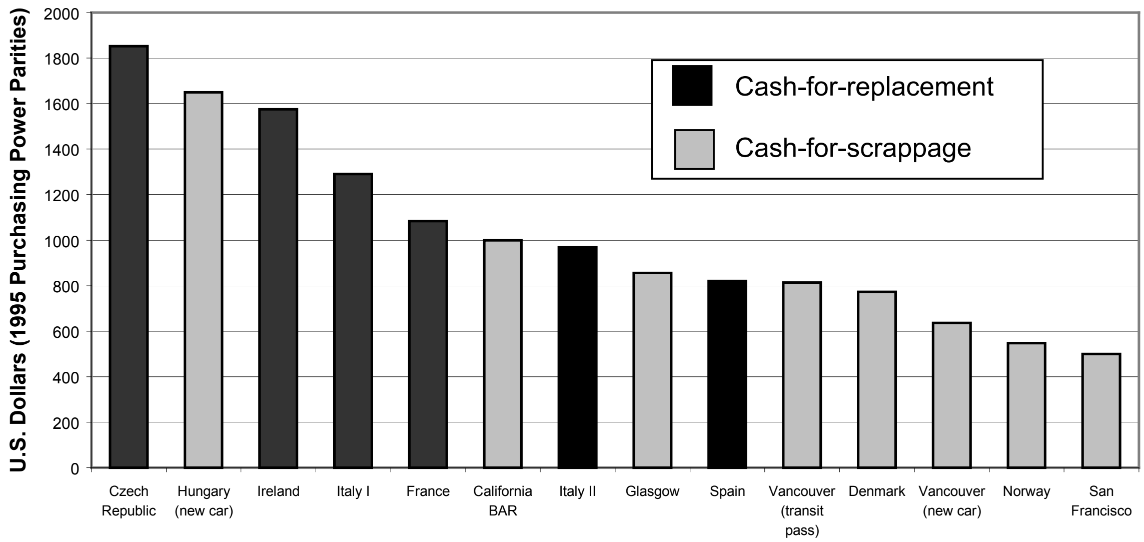
The amount of the incentive offered will help determine its attractiveness to vehicle owners. The lower the incentive, the less likely the cars sold to the program are scrapped earlier than normal. In addition, lower incentives will probably attract a higher percentage of older vehicles in poorer condition (Alberini et al., 1995). While vehicles in poorer condition may pollute more, they also may be driven less. The incentive will also impact the replacement transportation; a lower incentive is unlikely to help lower income households purchase a new vehicle. Because of these impacts, some researchers believe that higher incentives result in greater emission reductions (Alberini et al., 1996).

Incentives in the U.S. programs range from $400 to $2,000 (Table 3), with most programs around $500. Vancouver's Scrap-It program is unique, in that the incentive varies depending upon how the vehicle is replaced. The program offers $1000 (Canadian dollars) towards a new natural gas vehicle, $750 towards a new vehicle, $500 towards a 1988 or newer used vehicle, up to $500 towards a bicycle, $750 towards vanpooling, or a variety of transit passes (Scrap-it Program, 2001). No incentive is given for purchasing or driving a 1987 or older vehicle – the target years for the program. The Maine program is similar. It offers vouchers for $2,000 for a scrapping a pickup truck or SUV with an 8-cylinder engine, $1,500 for a pickup truck or SUV with a 6-cylinder engine, and $1,000 for any other 1987 or older vehicle. The vouchers can then be used to help purchase a 1996 or newer vehicle.

Figure 7 shows the amount of the incentive for several of the programs outside the U.S., converted to U.S. dollars using 1995 Purchasing Power Parities (OECD, 2000). The programs that don’t require a new car purchase are in gray. Two U.S. programs (San Francisco and California BAR) are included for comparison. With the exception of Hungary, the cash-for-scrappage programs generally offered lower incentives than the cash-for-replacement programs. Two factors may contribute to this: (1) Higher incentives are necessary to attract people to purchase new vehicles; and (2) Governments are more willing to offer higher incentives when auto sales are expected to increase, thereby increasing tax revenues from new car sales and possibly domestic auto production.

Another useful method of comparing the incentives is as a percent of the price of a new car. Limited data were available to make the comparison. The Hungary program incentive was about 2-6 percent of the cost of a new vehicle. The incentive offered during the first French program was about 5-6 percent of the average cost of a new car in that country (European Conference of Ministers of Transport, 1999)).

Figure 7: Amount of Incentives (International)



2.2.4 Vehicle Selection Criteria

Most North American programs limit eligible vehicles to certain model years, based upon when new vehicle standards went into effect (see Table 3). The model year requirements are imposed to help ensure that dirtier vehicles are scrapped, without having to test each vehicle's emissions. Three of the programs in California (BAAQMD, SCAQMD, and San Diego) accept 1981 and older vehicles. Santa Barbara accepts vehicles up to the 1984 model year. Vancouver's program sets 1987 as the cut-off, which is when Canadian new car standards changed significantly. In contrast, the European programs simply target vehicles of a certain age, usually 10 or more years old (European Conference of Ministers of Transport, 1999). These vehicles, therefore, tend to be newer than the vehicles targeted in the California programs. However, European emission standards have generally lagged behind the U.S. and California (Small & Kazimi, 1995)).

In order to claim credit for a VAVR program in a state implementation plan (SIP) in the U.S., the emissions reductions must be in "surplus" of what reductions would occur without the program. Therefore, California requires that the vehicles have passed all Smog Check requirements and not be operating with a repair cost waiver or economic hardship extension (California Air Resources Board, 1999). Presumably, vehicles failing a Smog Check would be repaired under Smog Check program requirements, for which emission reduction credits are already claimed in SIPs. One exception is for 1973 and older vehicles that are exempt from Smog Check requirements. Illinois' new regulations also require compliance with their inspection and maintenance (I&M) program. The California Bureau of Automotive Repair (BAR), however, operates a separate scrapping program targeting vehicles that fail their Smog Check. This program offers $1,000 for failing vehicles and was adopted to help improve the effectiveness of the State's Smog Check program (California Bureau of Automotive Repair, 1999). Vancouver, which is not subject to SIP accounting requirements like those in the U.S., only accepts vehicles that have failed an AirCare test (similar to Smog Check) at some point. Denver's pilot program also targeted high emitting vehicles. The new Texas low-income program will also target vehicles that fail an I&M inspection.

Offering a relatively easy way to sell older vehicles might attract sellers from nearby regions. Scrapping vehicles that would otherwise operate in other states or regions would not reduce emissions for the jurisdiction operating the program. Therefore, most programs establish ownership requirements to prevent the importation of vehicles. Both Texas and Illinois require that the vehicle be registered in the county or region claiming the emissions credit for at least 12 months prior to scrapping. Vancouver also has a 12-month requirement. California requires a 24-month registration period, with some exceptions. California's BAR program also limits participants to one vehicle per 12-month period.

A true "clunker" that is no longer drivable is unlikely to produce emissions in the future. VAVR programs only reduce emissions if the vehicles that are scrapped would have continued to operate. Therefore, all the U.S. programs have screening criteria to help ensure that the vehicles at least have the potential to continue to operate and pollute. All of the programs require that the vehicle be driven to the scrap yard under its own power. California's vehicle eligibility requirements are perhaps the most extensive and are shown in Table 6. Texas's new regulations include most, but not all, of the same operational requirements. Illinois requires an operability check that includes start-up, driving at least five feet forward and reverse, shut-off, and a visual inspection of fluid leakage or "any malfunction or other damage that would render the vehicle unsuitable for normal operation" (Illinois Pollution Control Board, 2000). CARB is considering simplifying their requirements, in part to make them consistent with the California Bureau of Automotive Repair's program (California Air Resources Board, 2001b). The Rand Study (Dixon, 2001) questioned the strict requirements, speculating that they prompt owners to spend money to repair their vehicles prior to scrapping – a pure economic waste.

Table 6: California's Requirements for Vehicle Eligibility (for emissions credits)

Ownership Requirements

- Currently registered and registered for 24 consecutive month within the air pollution district where vehicle is scrapped. Exceptions: (1) Two months of nonoperational status is acceptable at least three months prior to scrapping; (2) Registration lapses of 180 days if all fees and late penalties have been paid and vehicle is registered for at least 90 days before scrapping.
- If the owner has sold a vehicle to a VAVR operator within the previous 12 months, any subsequent vehicles sold to the same operator must have been registered continuously to that owner for 24 months.

Operational Requirements

- Vehicle must be driven to the purchase site under its own power.
- Vehicle can not be a high emitter or a gross polluter (as defined by the State).
- Vehicle can not be operating under a Smog Check repair cost waiver or economic hardship extension.
- If the vehicle is due for a Smog Check within the next 60 days, the vehicle must pass the inspection prior to scrapping.
- All doors must be present and the driver's side door must operate. An additional rear door must operate in a 4-door vehicle. "Operate" means that they can open and remain closed without ropes, wire, etc.
- The trunk lid must remain closed without ropes, wire, etc.
- The hood must open and remain closed with a functional latching mechanism.
- The dashboard must contain warning lights and gauges as originally supplied by the manufacturer, or equivalent aftermarket replacements.
- Windshield wipers must be present and operational.
- The windshield and rear window can not contain and holes or other defective condition that impairs the driver's vision, and it cannot be held in place by components not part of the original vehicle design.
- The driver's seat must be present and the back can not be reinforced or supported with add-on components, such as blocks.
- Interior pedals (for brake, clutch, accelerator) must be present.
- Vehicle must include bumpers, fenders, exhaust system, and side and quarter panels as originally supplied or equivalent aftermarket parts.
- The can not be any holes in the floorboard or holes penetrating through the body into the passenger compartment (except if originally designed by the manufacturer).
- Headlights, tail and brake lights must be present and operational. Burned out bulbs are okay.
- Driver's side and opposing side window must be present and not supported by add-on components. Other side windows or functional replacements must be present.
- No obvious indications that the vehicle is not operated on a routine basis for extended time periods.
- The vehicle must pass at least three of the following five tests: (1) Turn signals present and working (burned out bulbs okay if the light otherwise would work); (2) Driver's side window and opposing side passenger window must go up and down; (3) Rear-view mirror and left-hand side-view mirror must be present and work; (4) Interior door panels must be present and attached normally; and (5) No holes in the vehicle body exceeding two inches in length.
- The vehicle must pass at least four of the following five tests: (1) The engine must start using the keyed ignition system; (2) The vehicle must idle without using the accelerator for at least 10 seconds; (3) The transmission must shift into forward with the brake pedal applied and remain operating for 10 seconds without the accelerator (except manual transmissions); (4) The vehicle must be driven forward and reverse for a minimum of 25 feet under its own power; and (5) Under its own power, the vehicle must be driven forward at least 100 feet, starting a 0 mph, and then completely stop using the vehicle's brakes. The first 60 feet must be traveled in 5.5 or 8.5 seconds (depending upon weather, dry or wet, respectively). The vehicle also must turn around and return to the point of origin.
- Vehicles must be rejected if the engine shuts down after starting, if there are any "whining, grinding, clanking, squealing, or knocking noises, or noises from engine backfire," or if the brake pedal drops to the floor when the inspector tries to stop the vehicle.
- Failing vehicles can be re-tested after being fixed.

Source: (California Air Resources Board, 1999)

2.2.5 Scope of Programs

With the exception of the one-day Glasgow program, all of the European programs and the Argentinean program were much larger in scope than the California and Vancouver programs (Table 7).

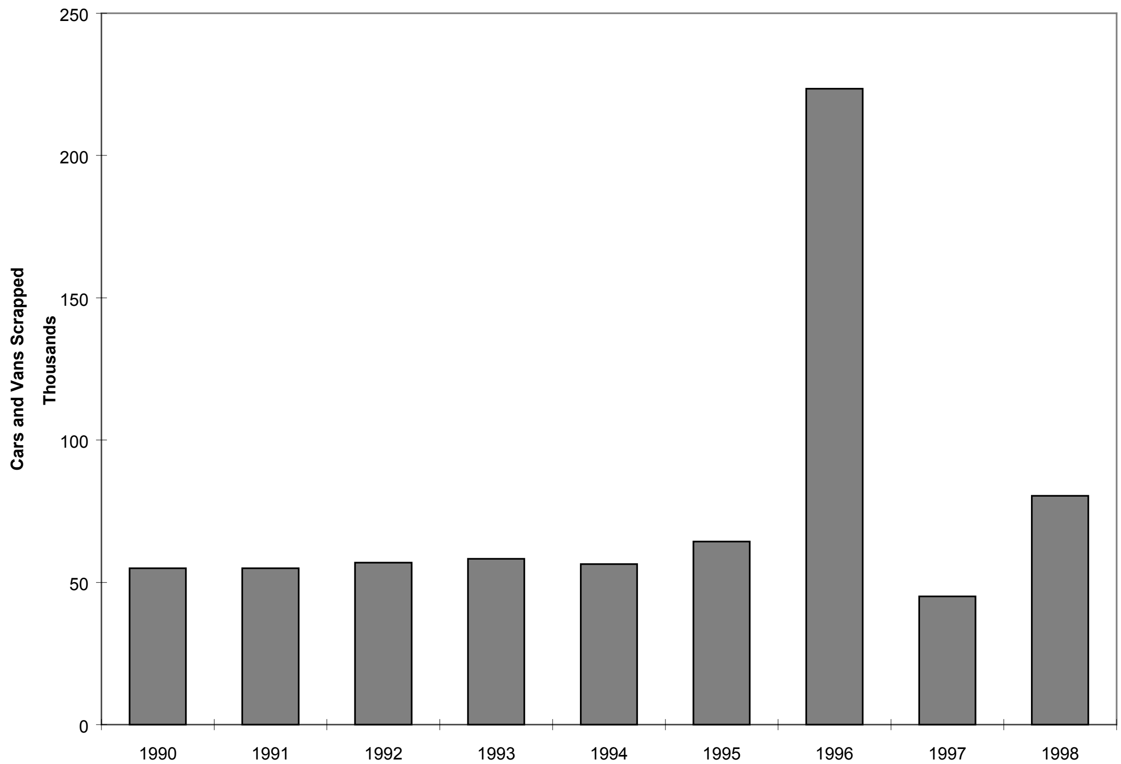
The impact on overall vehicle scrappage rates for some programs can be significant. Figure 8 shows the number of private vehicles scrapped in Norway from 1990 to 1998. The extra incentive for scrapping older vehicles was offered in 1996, when the rate of scrappage went up to 12.7% of all private cars. This is significantly higher than the rate the previous six years – 3.2-3.6%. The rate diminished the following year (2.4% in 1997), indicating that some people shifted their scrappage decision a year early. However, the dramatic increase in scrapping indicates that some vehicles were scrapped that may not have been scrapped in the near term otherwise. The program did not attract older or newer cars than in other years; the average age of the scrapped cars in 1996 (17.4 years) was the same as in 1995 and 1997 (Statistics Norway, 1999a). But the program did appear to have an impact on overall vehicle age. From 1995 to 1998 the average age of a car in Norway dropped from 10.4 years to 9.9 years (Statistics Norway, 1999b)).

Table 7: Number of Vehicles Scrapped

Country/Region	Approximate number of vehicles scrapped	% of fleet scrapped
South Coast Air Basin	1993 - June 2000: 27,255	~1%
San Francisco Bay Area	1996 – May 2001: 10,000	<1%
San Joaquin Valley	5,600 (1992-2000)	<1%
California Bureau of Automotive Repair	7,000 through February 2001	<1%
Vancouver	Pilot: ~900 On-going: ~500 per year	<1%
Denmark 1994 – June 1995	100,000 in first 6 months	Unknown
Norway 1996	Est. net 150,000	7%
France February 1994 – June 1995 and October 1995 – September 1996	1,560,000 Estimated net 700,000*	8% (max. in 1996)
Ireland June 1995 – December 1997	1995: 5,140 1996: 19,400 1997: 35,000	1995: 5% 1997: 3%
Italy January 1997 – January 1998	1,148,000	6.6%
Spain April 1994 to present	1994: 211,000 Estimated net 199,000 1995: 146,000 Estimated net 23,000	1994: 11.5% 1995: 7.4%
Argentina	103,532 in first four months	Unknown

* “Estimated net” is the estimated number of vehicles that were scrapped that would not have been scrapped without the incentive program. Only France and Spain provided such estimates.
Sources: (Air Pollution Control Officer, 1998; British Columbia Ministry of Environment, 1998; Commission for Integrated Transport, 2000; European Conference of Ministers of Transport, 1999; South American Business Information, 1999; South Coast Air Quality Management District, 2000b; Steinberger, 2001; Wilson-Combs & Davis, 2001).

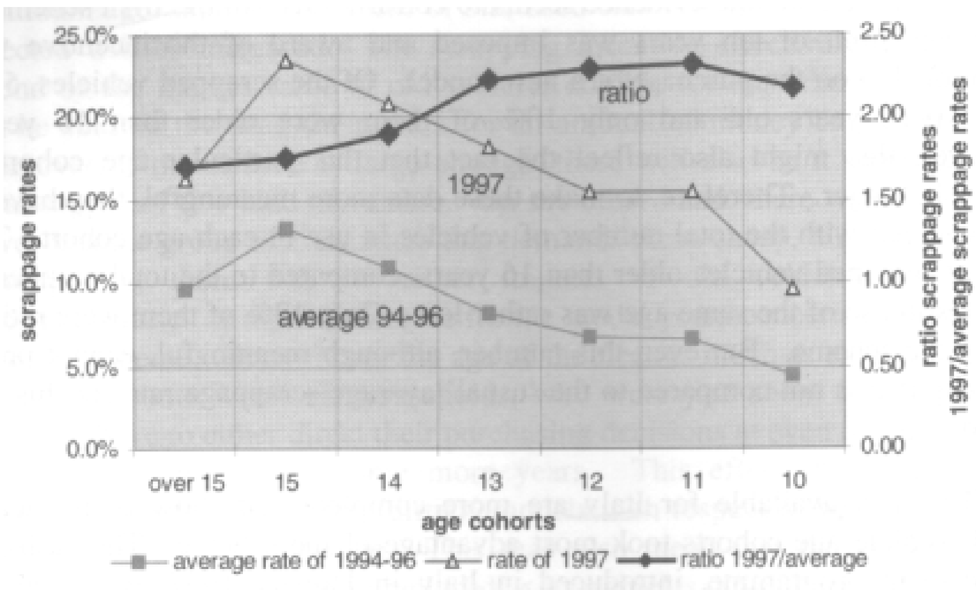
Figure 8: Vehicles Scrapped in Norway



Source: (Statistics Norway, 1999a)

The program in Italy was estimated to increase the overall scrappage rate from 3.7% to 6.6% (European Conference of Ministers of Transport, 1999). In contrast to Norway, the Italian program did appear to change scrappage rates for newer vehicles. Figure 9 shows the scrappage rate by age cohort. The scrappage rates for vehicles ages 10-13 years are generally lower than for vehicles 14-15 years old. However, the scrappage rate during the program (1997) for the 10-13 year old vehicles was about 2.3 times higher than the average for the four years before the program for that same cohort.

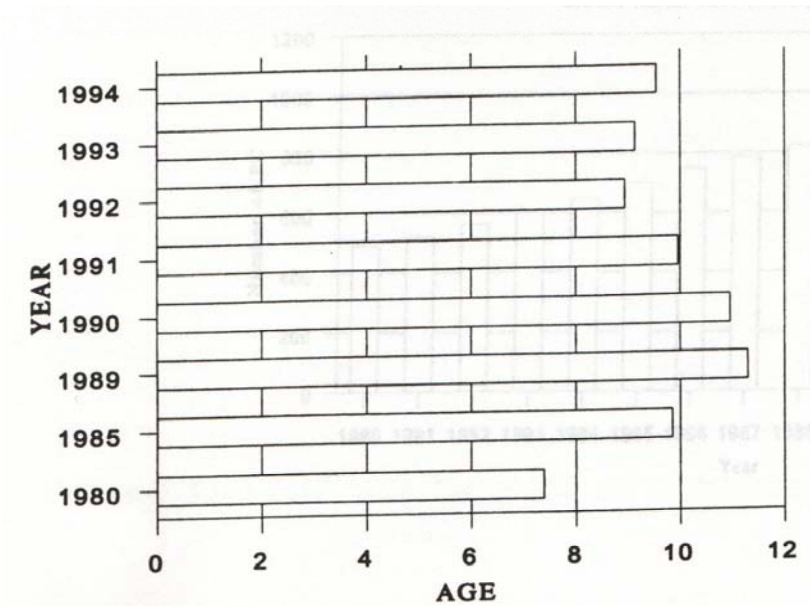
Figure 9: Comparison of Italian scrappage rates before and during the program



Source: (European Conference of Ministers of Transport, 1999)

The program in Greece, which targeted the Athens area, also had significant impacts on vehicle replacement rates and average vehicle age. From 1981 to 1994 the average replacement rate (the percentage of cars that are replaced each year in relation to the total car fleet) was about one percent. In 1991 and 1992, the years of the scrappage incentive program, the rate increased to about 7-8%. Prior to the program, Greece had one of the highest average fleet ages in Europe, over 11 years by the end of 1990. With the program, the average age in Athens reached a short-term low of about nine years in 1992 (Figure 10) (Baltas & Xepapadeas, 1999).

Figure 10: Average Vehicle Age in Athens, Greece

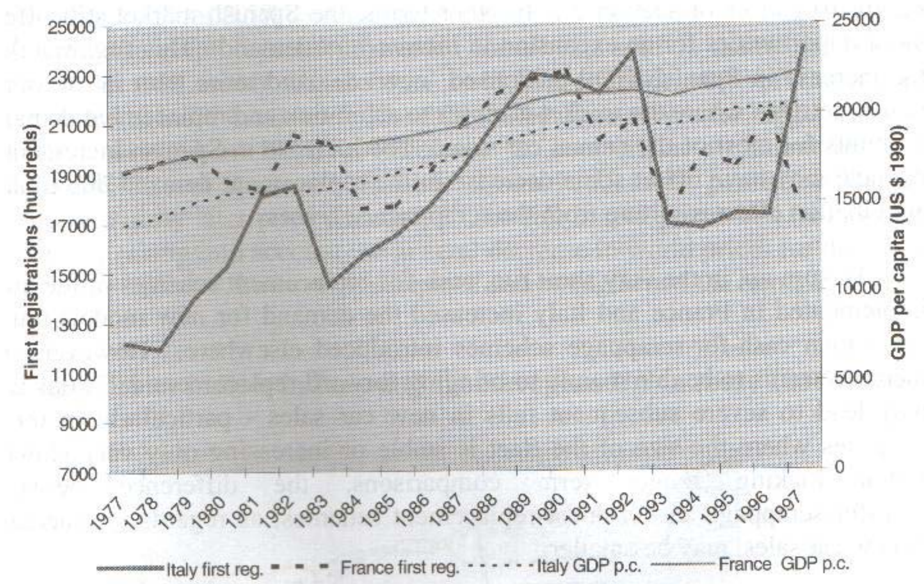


Source: (Baltas & Xepapadeas, 1999)

One of the common objectives of the cash-for-replacement programs is to boost new car sales. However, the programs are usually short-term and, therefore, may only shift sales forward, rather than increasing long-term demand. shows the "first registration" (registration of new vehicles) trends for vehicles in France and Italy, along with GDP per capita. Both countries experienced similar GDP per capita trends during the period from 1977 and 1997. First registrations were also similar up until 1994. In 1993 both countries saw a sharp drop in registrations due to recession. However, France offered a cash-for-replacement incentive from February 1994 to September 1996, during which time first registrations went up. Registrations went sharply down in 1997, after the incentive ended. Italy's first registrations remained flat from 1993 to 1996, but increased dramatically in 1997, when the cash-for-replacement incentive was offered (European Conference of Ministers of Transport, 1999). In 1998, Italian automobile production fell.

Forecasts for car registrations were 2.2 million for 1998 and 1.8 million for 1999, compared to 2.4 million in 1997 (World Reporter, 1998).

Figure 11: First Registration Trends in Italy and France



Source: (European Conference of Ministers of Transport, 1999)

3 CHAPTER 3: DATA SOURCES AND METHODOLOGY

3.1 Prior Data from Outside Sources

The data from outside sources used in this research fall into two main categories: (1) Travel or vehicle surveys that provide information about the ownership and use of older vehicles; and (2) VAVR survey data that provides information about people who sell vehicles to a VAVR program and those vehicles. The travel surveys only sample households. Therefore, the only commercial vehicles in those samples would be “company” cars kept at home and vehicles owned by a family business kept at home. The only public source of data for commercial vehicles is the Vehicle Inventory and Use Survey, which does not include passenger cars. There is no comprehensive source of information for passenger vehicles that would include commercial vehicles, such as rental cars and business-owned vehicles (Bureau of Transportation Statistics, 1998). The share of vehicles and travel for commercial versus private vehicles is discussed further in Section 4.2.2. A description of each prior data source, along with a discussion of issues involved with using the data for this research, follows below.

3.1.1 1995 Nationwide Personal Transportation Survey

3.1.1.1 Overview

The Nationwide Personal Transportation Survey (NPTS), sponsored by the U.S. Department of Transportation, was conducted in 1969, 1977, 1983, 1990, and 1995. Another survey is being undertaken in 2001, now renamed the National Household Travel Survey. The NPTS serves as “the nation’s inventory of daily personal travel. It is the only authoritative source of national data on daily trips” (Federal Highway

Administration, 1997, p. 1-2). The 1995 survey collected travel, vehicle, and household data from 42,033 civilian households throughout the country. The data includes weights to adjust for planned over-sampling in certain states and cities, sampling bias, and non-response. Though labeled “1995,” data were collected between May 1995 and June 1996. The 1995 NPTS included 75,217 vehicles, of which 7,772 were pre-1982.

The key data available from the NPTS used in this research includes:

- Vehicle make, model, and year
- Vehicle type
- Annual VMT for each vehicle by recall
- Annual VMT for each vehicle by odometer reading
- Number, length, time, and purpose of trips
- Number of persons in vehicle (household members and non-household members)
- Whether there is a main driver for the vehicle, and main driver characteristics (age, sex, education)
- Household income
- Household race
  (based upon the race of the “reference” person, usually the head of the household)
- Family lifecycle
- Age (person)
- Sex (person)
- Number of persons in household
- Number of vehicles in household
- Education level (person)
- Drivers license (person)
- Employment status (person)
- Seat belt use
- Attitudes about air pollution from vehicles
- Transit accessibility
- Land use characteristics

Some desirable information that is not included in the NPTS includes whether the vehicle is owned or leased by an employer, vehicle fuel efficiency, race of members of the household, detailed vehicle information (e.g. engine size, transmission, etc.), total mileage on the vehicle, and date of acquisition (only collected for vehicles obtained in the past 12 months).

3.1.1.2 Data Concerns

The NPTS is a telephone survey, which can result in sample bias. Households without telephones tend to have very low incomes and to be in rural areas. For example, while only five percent of all households do not have telephones, over 30 percent of the households receiving welfare reported not having continuous phone service (Murakami & Young, 1997). The under representation of lower income households without a phone should not be a problem in this research because these households are also less likely to own vehicles, even older vehicles. While rural households (which may be underrepresented because they are less likely to have phones) are more likely to have older vehicles (to be shown later), these areas are not the target of VAVR programs. Therefore, this under representation is not a concern. In addition, the NPTS data includes household weights to help correct for non-response and non-coverage (Federal Highway Administration, 1997).

The NPTS does not include people living in college dormitories, nursing homes, other medical institutions, prisons, and on military bases. The omission of nursing homes, medical institutions, and prisons is not a problem, considering the very low likelihood of these residents having older vehicles. While military personnel and college students do have older vehicles, their omission from the survey is probably not a significant problem for several reasons. First, these households are also more likely to move frequently, which may make their vehicles ineligible for VAVR programs. Programs usually require registration for 12-24 months within the program boundaries. Second, the survey does include college students and military personnel that live outside dormitories and bases, so that they are not excluded entirely. Third, these populations make up a small portion of the U.S. population and their behavior with respect to older vehicles is probably not so different from the sampled population that their omission would impact the findings.

During an initial telephone interview with the household, the NPTS collected information on each household vehicle. This included "licensed vehicles" owned or "available for regular use" by members of the household. In a final screening question, the survey asked whether these were "all the vehicles that were in working condition and available" to the household. Three potential problems arise with this data collection process. First, some households may not report vehicles that are unlicensed or for which registration has lapsed. While unregistered vehicles are generally ineligible for VAVR programs, they may be older vehicles that contribute to air quality problems and, therefore, an appropriate target for policy intervention. Without any information on the possible underreporting of these vehicles, it is impossible to gauge the impact of this omission. Second, some households may decide not to report collector cars and trucks that are owned strictly for hobby that are not driven – even though the survey wording does not make such a distinction. Third, vehicles that, at the time of the survey, were not operational may be screened out. The interviewer asked about vehicles that were "available for regular use." At the end of the vehicle portion of the telephone interview, the interviewer asked whether all of the vehicles that "were in working condition" were included. Some respondents may have decided not to list vehicles that were temporarily unavailable because they did not operate. The "working condition" wording at the end of the survey might have resulted in the omission of some vehicles. Again, it is impossible to gauge the extent of these two potential sources of underreporting. However, the contribution of emissions from collector vehicles that are only driven for events and parades and inoperable vehicles would be insignificant. Moreover, inoperable vehicles are ineligible for VAVR programs, and owners of collector vehicles are highly unlikely to participate. Therefore, these potential omissions are not a problem.

Third, the NPTS included leased or company-owned vehicles kept at the home. However, these vehicles are not distinguished in the NPTS data. If the vehicle is provided by an employer (i.e. not a family-owned business), the household is not in the position of making a decision to sell the vehicle to a VAVR program. In addition, the use of the vehicle is dictated, in part, by the employer. Ideally, these vehicles would be analyzed separately. The impact of including these vehicles in the analysis depends upon their share in the sample population. The Residential Transportation Energy Consumption Survey (RTECS, explained in more detail below) does collect information on whether a business owns the vehicle. In the RTECS weighted sample of vehicles, only 1.6% were owned by a business and only 0.6% of the pre-1982 vehicles were owned by a business. An unknown portion of these would be owned by the household businesses. Given the small portion of business vehicles, including them in the analysis should not be a problem.

The NPTS asked each household to estimate the number of miles each vehicle was driven in the previous 12 months. This “self-reported” annual mileage data exists for 88% of all the household vehicles and 86% of the pre-1982 vehicles. In addition, odometer readings were taken at the time of the initial interview. Follow-up readings were obtained on many vehicles and used to calculate annual mileage. Annual mileage estimates from odometer readings are available for 44% of all the vehicles and 30% of the pre-1982 vehicles. Both figures are capped at 115,000 miles, "considered to be a reasonable upper limit for the annual miles driven in a vehicle" (Federal Highway Administration, 1997, p. K-2.)

While possibilities for error are obvious in the self-reported data, the odometer readings are also subject to potential errors (Pickrell & Schimek, 1999). In addition to the potential for errors in reading and reporting the odometer figures, the NPTS used a complicated process to convert the odometer readings to annual mileage estimates. The time intervals for the readings ranged from less than 1½ months to over 18 months, though over 90% of the readings were between 1½ months and 10½ months. The mileage readings were adjusted for seasonality using a linear model (Federal Highway Administration, 1997). While they may seem more prone to error, the self-reported figures were obtained for such a large proportion of the vehicles that they are more likely to closely mirror all of the households and vehicles included in the NPTS. The odometer readings were not obtained evenly across the vehicle sample. Newer vehicles, automobiles (vs. trucks, SUVs, vans, etc.), and vehicles in households with fewer vehicles are over represented in the sample of odometer-based mileage estimates (Pickrell & Schimek, 1999).

For over 28,000 vehicles, the NPTS includes both self-reported and odometer-based annual mileage estimates. Comparing the two values, several patterns become apparent. Overall, the mean difference between the self-reported and the odometer-based estimates is 516 miles, i.e. on average, people estimated their annual mileage to be just over 500 miles higher than the odometer-based estimate. This does not seem like a significant difference. However, 41.0% of the households reported mileage over 2,000 miles higher than the odometer estimate and another 29.6% reported mileage over 2,000 miles less than the odometer estimate (Table 8). The differences between the two estimates is smaller for older vehicles. For 31.0% of the pre-1970 vehicles, the two estimates were within 500 miles or less (in either direction). This was true for 14.5% of the 1970-1981 vehicles and only 7.5% of the 1982 and newer vehicles.

Table 8: Self-reported annual mileage compared to odometer-based estimates

Self-reported annual mileage compared to odometer-based estimate	**Pre-1970**	**1970-81**	**1982+**	**All Model Years**
Under by >2,000 miles	14.1%	22.7%	30.4%	29.6%
Under by 1,001 – 2,000 miles	6.1	6.1	5.6	5.7
Under by 501 – 1,000 miles	3.9	3.1	3.3	3.3
Under/over by 500 miles or less	31.0	14.5	7.5	8.4
Over by 501 – 1,000 miles	7.0	6.6	3.8	4.1
Over by 1,001 – 2,000 miles	13.4	12.4	7.5	8.0
Over by >2,000 miles	24.6	34.7	41.8	41.0
	100.0	100.0	100.0	100.0
N	285	1,755	26,528	28,568

Source: 1995 NPTS weighted vehicle data

Some researchers strongly favor the use of odometer-based data over self-reporting (Lave, 1994). However, given the more limited sample of vehicles with odometer-based estimates (2,342, or 30% of the pre-1982 vehicles) and potential sources of error, both sets of estimates will be included in this research.

3.1.2 1994 RTECS

The 1994 Residential Transportation Energy Consumption Survey (RTECS) was sponsored by the Department of Energy's Energy Information Administration to provide information about energy use by residential vehicles (Energy Information Administration, 1997). The 1994 RTECS is a sample of 3,020 households selected from the 7,000 households in the 1993 Residential Energy Consumption Survey. Data from Alaska and Hawaii are omitted from the public use data files to protect the identities of the respondents, bringing the sample down to 3,002. The data includes weights to represent the U.S. population. There are 5,961 vehicles in the data files, of which 970 are pre-1982.

The data collected regarding the vehicles and households is similar to the 1995 NPTS, with some exceptions. The RTECS includes information about the vehicle transmission type, number of cylinders, drive (front, rear, or 4-wheel), fuel system, type of fuel used, and fuel efficiency. As noted above, the RTECS also notes whether the vehicle is owned by a business. With respect to household information, the RTECS includes information on poverty status and whether the household uses food stamps or other public aid. The RTECS does not include the extensive land use information that the NPTS includes. The other major difference between the two surveys is that the RTECS only collects information about annual VMT through self-reporting and odometer readings, and not on trips.

Because of the smaller sample size and the lack of data on vehicle trips, this research will primarily use the 1995 NPTS. Data from the RTECS will be used if the NPTS does not have the desired information, as with the vehicles owned by businesses.

3.1.3 1997 VIUS

The Vehicle Inventory and Use Survey (VIUS), sponsored by the U.S. Census Bureau, collects data on the physical and operational characteristics of trucks. Prior to 1997, VIUS was TIUS, the Truck Inventory and Use Survey. “Trucks” are defined to include pickups, vans, minivans, panel trucks, light single-unit trucks, heavy single-unit trucks, and truck-tractors. The sample includes households and commercial enterprises, but not government vehicles. The VIUS is conducted every five years as part of the economic census. The most recently available sample included trucks licensed in the U.S. as of July 1, 1997 and asked about trucks disposed of since July 1, 1996. Survey forms were mailed to the registered owners of the vehicles. Approximately 84.5% of the forms were returned with data. There are 104,545 vehicles in the public data file, which includes weights to make the sample representative of the U.S. truck fleet (U.S. Census Bureau, 2000).

The 1997 VIUS includes extensive information about the physical characteristics of the vehicles, as well as information on how the vehicles were used and annual mileage. Annual mileage was estimated by the owners. The owners were also asked how many miles the vehicles had been driven since they were manufactured. The NPTS and RTECS do not include this information, which is would be useful in evaluating older vehicle and air quality problems. Missing data for the annual and lifetime mileage was replaced by predicted values. The NPTS does not impute missing data. The type of vehicle use was first characterized as business, personal, for-hire, daily rental, or mixed. Owners of trucks used for commercial purposes were asked to report the type of materials carried. Household demographic information was not collected. In addition, vehicle model years were not differentiated prior to 1988, which limits is usefulness for this research.

The 1997 VIUS included data for 47,275 pre-1988 vehicles and 77.2% of these were based at a residence or farm. Nearly 90% of the pre-1988 vehicles were pickup trucks, vans, sport utility vehicles, station wagons, or minivans and 71.0% were used primarily for personal transportation. Therefore, the VIUS data can be compared to the NPTS and used to examine non-personal use of older (pre-1988) vehicles.

3.1.4 1996 BATS

In 1996 the Metropolitan Transportation Commission (MTC) conducted a two-day time-use survey of 5,861 San Francisco Bay Area households (Metropolitan Transportation Commission, 1999). Named the 1996 Bay Area Travel Survey (BATS), the survey was prompted, in part, by efforts to pursue a congestion pricing project on the Bay Bridge. The survey collected, via telephone, household and vehicle information, as well as trip information for the two days. However, the data were not used by MTC for any official purposes and, therefore, were not cleaned or weighted to correct for response bias. MTC undertook another time-use survey in 2000, but those results are not yet available. The previous Bay Area travel survey was undertaken in 1990. The data tables were obtained for the 1996 BATS and some basic data cleaning was done. Given the uncertainty of these data, I used it only when other sources were inadequate.

3.1.5 CARB Pilot Program

In 1998, the California Air Resources Board (CARB) contracted with Sierra Research to implement a VAVR Pilot Program within the South Coast Air Basin (SCAB). The basin covers the greater Los Angeles region. The purpose of the Pilot Program was to assess the feasibility and impacts of a large-scale VAVR program proposed as Measure M1 in the State Implementation Plan for attaining the ozone standard in the basin (Sierra Research, 2001). Measure M1 aims to scrap 75,000 older vehicles per year in the SCAB. Under the Pilot Program, Sierra Research purchased and retired 1,001 vehicles for $500 each between November 1998 and November 1999.

Sellers completed a written survey prior to receiving payment for their vehicle ("yard survey"). Two to six months later, each seller was contacted via telephone for a follow-up survey, focusing on how they replaced the transportation provided by the retired vehicle. Sellers were offered five dollars to complete the follow-up survey. Both survey instruments are in the Appendix. There were 995 valid yard surveys and 729 valid follow-up surveys. In addition, 823 of the vehicles were tested for emissions.

Given the nearly 100% response to the yard survey, it surely represents the participants in this program. The follow-up survey, because it was conducted over the phone, may not include people with very busy schedules, though the surveyors made several attempts to contact each seller. Both surveys collected demographic information from the respondent. Comparing the data from the two surveys, there is no statistically significant difference in response in terms of sex, education, age, or race. There are some differences in terms of household size, employment, and income (Table 9). One-person households are slightly over represented in the follow-up survey and homemakers are underrepresented. The lowest income households (under $10,001) and those with incomes of $40,001 – 60,000 are also underrepresented. Some of these differences may be due to actual changes in the households between the two surveys. For example, people could have moved in or out of households or changed employment status. And, though the survey asked for 1998 income, people may respond with their current income, which can also change over time. The differences, while statistically significant, are not so large that the follow-up survey should not be considered reasonably representative of the participants.

Table 9: Comparison of Demographics for Pilot Program Yard and Follow-up Surveys

	Yard Survey	Follow-Up Survey	Difference Significant?*
Household Size			
One person	4.4%	5.9%	Yes
Two people	15.9%	14.8%	No
Three people	19.8%	18.2%	No
Four people	23.5%	25.1%	No
Five people	18.4%	19.1%	No
Six or more people	16.3%	16.9%	No
Employment			
Student	2.3%	1.5%	No
Homemaker	7.0%	4.8%	Yes
Retired	7.0%	6.9%	No
Unemployed	6.8%	8.2%	No
Employed part-time	8.5%	7.4%	No
Employed full-time	67.4%	70.2%	No
Income			
Less than $10,001	14.5%	11.9%	Yes
$10,001 – 20,000	37.2%	39.9%	No
$20,001 – 40,000	28.2%	28.4%	No
$40,001 – 60,000	12.8%	8.0%	Yes
$60,001 – 80,000	3.1%	3.8%	No
Over $80,000	2.1%	2.2%	No

Totals may not sum to 100% because of missing responses
* $\alpha = 0.10$

3.1.6 BAAQMD Yard Surveys

The BAAQMD asks its contractors to have each person selling a vehicle to the program to complete a one-page (two-sided) survey at the scrap yard. Between the start of the program in June 1996 and August 2000, the BAAQMD purchased and scrapped 8,028 vehicles. This research uses valid surveys from 7,493 of these purchases. Some people did not complete the survey at the scrap yard. In addition, 79 vehicles purchased from businesses and government agencies were omitted from this analysis. The survey data were entered by BAAQMD staff. I checked for errors by screening for invalid responses, e.g. a 66, when the valid responses were 1 – 6. However, data entry errors that resulted in valid responses are possible.

The survey asked the questions listed below. Most of the questions included a list of answers to choose from (see Appendix for a sample form).

- How did you hear about the program?
- How much do you think the car would sell for if you sold it through a newspaper ad?
- What is your reason for selling the car to us?
- How often was the car driven during the last 12 months?
- About how many miles was this car driven in the last 12 months?
- How many more years do you think this car would have lasted?
- If you did not sell your car through this program, what would you do with it?
- Number of cars owned by the household
- After selling this car, what will the primary driver of the car do for transportation?
- After selling this car, do you expect the total amount of driving by all members of your household to [stay about the same, increase, decrease]?
- Number of people in the household
- Employment status
- Household income last year
- Age
- Ethnic group

Given the very high response rate for this survey (over 90%), it should be considered representative of the population of BAAQMD VAVR participants. A small number of vehicles (less than one-percent) were sold by households selling more than one vehicle to the program. These households were asked to complete a survey each time they sold a vehicle. Because the survey data files are anonymous, these households could not be screened out and are double-counted when household data are generated. Given the small number, this should not be a problem. As with any survey, some respondents may not answer accurately or truthfully. Some respondents may be influenced by the context of the survey – administered while they are selling their vehicle for $500 to an air quality agency. The BAAQMD name and logo appears on the survey form. These issues will be addressed in the discussion of the data.

3.2 New Data – Methodology

Two additional surveys were undertaken to provide more detailed data for the San Francisco area. A "Participant Survey" surveyed households that had sold a vehicle to the BAAQMD VAVR program. This survey served as a follow-up to the original BAAQMD survey completed at the scrap yard. The primary purpose was to find out how the household replaced the travel provided by the retired vehicle. The "Non-Participant Survey" included Bay Area households that owned an older vehicle (pre-1982), but did not participate in the BAAQMD's VAVR program. The primary purpose of this survey was to compare older vehicle owners that decided not to sell vehicles to a VAVR program to VAVR participants. Both of these surveys are described in detail below.

3.2.1 Participant survey

3.2.1.1 Purpose

The Participant Survey aimed to fulfill three purposes. First, and most importantly, the Yard Survey included information on how the primary driver intended to replace the travel provided by the retired vehicle. However, what people intend to do may differ from what they actually do. Therefore, a primary purpose of the Participant Survey was to find out what sellers actually did to replace the transportation. Regarding replacement transportation, the survey first asked what the main driver of the retired vehicle was now doing most often for transportation. People who were now driving vehicles the households already had or who purchased or leased new or used vehicles were asked for the following information about those vehicles:

- Make, model, type, and model year
- When the household acquired the vehicle
- Purchase/lease price and where they acquired the vehicle (only for purchased/leased vehicles)
- Lifetime mileage
- Trip purposes for which the vehicle was used
- Frequency of use
- Current weekly mileage
- Change in mileage since vehicle retirement (only for vehicles already in the household)
- Whether the replacement vehicle is more or less reliable than the retired vehicle

- Whether the replacement vehicle gets better or worse gas mileage than the retired vehicle
- Whether the $500 impacted their vehicle choice (only for purchased/leased vehicles)
- How $1000 might impact their vehicle choice (only for purchased/leased vehicles)
- Importance of factors in choosing their replacement vehicle (only for purchased/leased vehicles)

Second, the Participant Survey intended to collect information about the scrapped vehicle that was not on the Yard Survey, but that would be useful in evaluating the use of older vehicles that are retired through VAVR programs. This information included:

- The year the household acquired the vehicle
- Trip purposes for which the vehicle was used
- Whether the household tried to sell the vehicle before retiring it
- Opinion of the vehicle, including whether it was "extra," needed repairs or cosmetic improvements, would pass Smog Check, polluted a lot, and was reliable and safe.
- Sex, age, ethnicity, employment, and education of main driver (rather than the person selling the vehicle, which was collected on the Yard Survey)
- The number of children, employed persons, retired persons, and people with driver's licenses in the household
- Basic information about other vehicles in the household

Third, the wording of some of the questions on the Yard Survey could be misinterpreted. For example, the survey asks for the "total number of cars owned by your household." If people responded literally, they would not include pickup trucks, vans, minivans, SUVs or any vehicle leased by the household. Therefore, the Participant Survey aimed to collect similar, but more accurate data, than the Yard Survey. Another example is how many miles the vehicle was driven. The Yard Survey asked how far it had been driven in the past 12 months. The Participant Survey asked how many miles per week the vehicle was driven during the three months prior to retiring it. The reasoning was that people may make a more accurate estimate for a shorter time frame.

3.2.1.2 Methodology

Because of budgetary limitations, the survey was conducted via the mail, rather than telephone. Response rates for a mail-out, mail-back survey are usually lower than for telephone surveys, and typically range from 20% to 50% (Richardson, Ampt, & Meyburg, 1995). Several things were done to help ensure a high response rate. Overall, the survey was designed and administered following the "total design method" created by Don A. Dillman as closely as possible (Dillman, 1978). Each envelope was stamped (not metered) and included the 8-page survey, a personalized cover letter on letterhead from the Institute of Transportation Studies at U.C. Berkeley (see Appendix), and a business-reply return envelope. The cover letter informed the person that all respondents would be entered into a random drawing for a $300, $150, or $50 gift certificate for Best Buy department stores. The survey form included an illustration on the front, to increase appeal, and room on the back for respondents to ask questions and provide comments about the survey and the VAVR program. Respondents were also invited to request a copy of the results of the survey.

The survey was mailed to all 2,018 households that sold a vehicle to the BAAQMD from March through August 2000. The BAAQMD provided the mailing list. The surveys were mailed in mid-November 2000. Each survey was numbered to keep track of responses. Reminder postcards were sent approximately one week after the initial survey. A second copy of the survey was sent to people who had not responded within three weeks.

3.2.1.3 Survey Response

The effort resulted in 1,273 valid responses, or 63% of the sample (Table 10). The high response rate can be attributed to two main factors: (1) the design and administration of the survey; and (2) the generally positive attitudes of the VAVR participants towards the program. On the Yard Survey, about 94% of the Participant Survey respondents stated that they had an "excellent" or "good" experience with the program.[7] Sending reminder postcards and second surveys increased the response rate from 36% to 63% of the number of surveys sent.

Table 10: Responses to Participant Survey

	Number	Percent
Surveys Sent	2,018	
Surveys Delivered*	1,915	95% of sent
Responded before postcard	728	57% of responses
Responded after postcard	355	28% of responses
Responded after 2nd mailing	190	15% of responses
Total Valid Responses	1,273	66% of delivered 63% of sent

*Surveys not returned by the U.S. Post Office were assumed to be delivered.

[7] Yard Survey responses were matched to Participant Survey responses via an anonymous numbering system.

Even with a high response rate, the survey may not be representative of the sample population. For example, the survey was only available in English, which may reduce the response from non-English speakers. The Yard Survey was also only in English, but it was much shorter and completing it was implied as mandatory. Table 11 shows the distribution of respondents by income for the Yard Surveys conducted between March and August 2000 (the sample population) and the Participant Survey. The lower income households ($30,000 and under) are underrepresented in the Participant Survey, while the highest income group (over $75,000) is over represented. This difference is significant and could impact the overall survey findings. Therefore, the analysis will consider this difference. In addition, a major part of this research will look at the responses by income. There are a large enough number of respondents from the two lowest income categories (over 300) that this analysis is still possible.

Table 11: Comparison of Income of BAAQMD Yard and Participant Survey Respondents

Income	March-August 2000 Yard Surveys	Participant Yard Surveys	
Under $15,000	**15.2%**	**10.1%**	115
$15,001 - $30,000	**21.0%**	**16.8%**	192
$30,001 – $45,000	18.2%	17.7%	202
$45,001 – $60,000	14.7%	16.9%	193
$60,001 - $75,000	12.5%	12.5%	143
Over $75,000	**18.3%**	**25.9%**	296
n	1,221		1,141

Boldface: Difference from March-August 2000 Yard Surveys is significant at $\alpha = 0.10$
Number of responses is less than total number of surveys due to non-response to this question

3.2.2 Non-participant survey

3.2.2.1 Purpose

One hypothesis is that households that own older vehicles and participate in a VAVR program differ in terms of socio-economic characteristics and vehicle use from those that own older vehicles and do not participate. Data on older vehicle owners who do not sell their vehicles to a VAVR program is needed to best test this hypothesis. This was gathered through the "Non-Participant Survey." The primary purpose of this survey, therefore, was to obtain information comparable to that gathered from the participants about their older vehicle use. The BAAQMD had obtained a mailing list of all older vehicle owners in the Bay Area. Prior to the registration deadline for each pre-1982 vehicle, the BAAQMD sent the household a letter encouraging them to participate in the VAVR program. This was the sampling frame for the Non-Participant Survey. Therefore, the survey respondents had been contacted about the VAVR program and, if they received and read the letter, knew of the program.

The survey was divided into four main parts (see Appendix). Part 1 asked for the following information for up to two 1985 or older vehicles:

- Make, model, type, and year
- The year the household acquired the vehicle
- Weekly, annual and lifetime mileage
- Frequency of use
- Trip purposes for which the vehicle was used
- Sex, age, ethnicity, employment, and education of main driver

- Opinion of the vehicle, including whether it was “extra,” needed repairs or cosmetic improvements, would pass Smog Check, polluted a lot, and was reliable and safe.
- How much longer the vehicle would be kept by the household and how long it would last
- Estimated vehicle value
- Potential replacement transportation if the vehicle was sold
- Necessary repairs
- Cost estimate to fix the vehicle and intentions to make repairs
- How the household would get rid of the vehicle

The second part focused on the VAVR program, covering the following items:

- Screening questions on whether the respondent remembered the letter and if they sold a vehicle to the program
- Why the respondent did not participate in the VAVR program
- Whether the respondent would participate if they were offered $800 or $1000 instead of the $500. Half of the surveys were for $800 and half for $1000.
- What changes to the program would probably entice them to the program
- Whether they would accept $500 to repair or upgrade their vehicle to run cleaner
- Whether they think the program should be continued

The third part gathered information on pre-1985 vehicles the household no longer owned – vehicles that were scrapped, sold, traded-in, donated, stolen, or otherwise disposed of during the previous 12 months. The intent was to find out if people who got rid of older vehicles by means other than the VAVR program differed from those using the VAVR program. This section gathered the same vehicle and driver information as the first section and in the Participant Survey, in addition to information about how the vehicle was replaced. The replacement transportation questions were the same as on the Participant Survey. The final part of the survey collected the same demographic information about the household as the Participant Survey: total number of people, number of people with driver's licenses, number of people, number of employed and retired people, and household income.

3.2.2.2 Methodology

The methodology for the Non-Participant Survey mirrored the Participant Survey, except for the sampling frame. The BAAQMD had obtained a mailing list of all older vehicle owners in the Bay Area. The agency screened out vehicles older than 1966, assuming these had a high probability of being collector vehicles. Approximately two months prior to the registration deadline for each 1966-1982 vehicle, the BAAQMD sent the households a letter encouraging them to participate in the VAVR program. The agency sent over 348,000 such letters between January and September of 2000. From this list, I selected a random sample of 3,000 households for the Non-Participant Survey. These names and addresses were checked against the VAVR participants and participants were removed and replaced. The Non-Participant surveys were sent in late November, 2-10 months after the vehicle registration was due. As with the Participant Survey, respondents were entered into a random drawing as an incentive to participate and were sent reminder postcards and second surveys.

3.2.2.3 Survey Response

The effort resulted in 679 valid responses, representing 23% of the 3,000 surveys mailed (Table 12). As with the Participant Survey, the follow-up postcard and second surveys increased response rate significantly, from 10% to 23%. The lower response rate (23% versus 63%) was expected for several reasons: (1) the mailing list was older and less accurate than the participant list; (2) the sample population had not invested any effort in the VAVR program as the participants had and, therefore, would not feel any obligation to respond; and (3) the survey form was longer (12 versus 8 pages), though few households would complete all four sections. In addition, the fact these households did not participate in the VAVR program may indicate a lower interest in contributing to public benefits, including this research.

Table 12: Responses to Non-Participant Survey

	Number	Percentages
Surveys Sent	3,000	
Surveys Delivered*	2,716	90% of sent
Responded before postcard	308	45% of responses
Responded after postcard	129	19% of responses
Responded after 2nd mailing	242	36% of responses
Total Valid Responses	679	25% of delivered 23% of sent

*Surveys not returned by the U.S. Post Office were assumed to be delivered.

Of the 679 valid surveys, 473 households had a pre-1982 vehicle at the time of the survey or had disposed of one in the past 12 months and had not participated in the BAAQMD VAVR program. This is the portion of the respondents that will be compared directly to the Participant Survey respondents. (The Non-Participant survey collected information about 1982-1985 vehicles as well, since these vehicles may be included in the BAAQMD program in the future.) There is no other source of information on the characteristics of the target population (pre-1982 vehicle owners that didn't participate in a VAVR program) that can be used to judge whether the respondents accurately reflect the population. The closest population for which there is data are that of households that own pre-1982 vehicles. An assumption that the Non-Participants should closely mirror all pre-1982 vehicle owners may be valid. While I hypothesize that participants are different from non-participants, the number of non-participants in the Bay Area so far outnumbers participants, that removing participants from the universe of pre-1982 vehicle owners should not have a noticeable impact on the income distribution of these households. Based on the original BAAQMD mailing list (pre-1966 vehicles included), there are about 595,000 pre-1982 vehicles in the Bay Area. As of the end of 2000, the BAAQMD had purchased just over 9,000 vehicles, or about 1.5% of the population.

Income data for Bay Area households with pre-1982 vehicles is available from the 1996 BATS and California data are available from the 1995 NPTS. These distributions, along with that of the Non-Participant Survey respondents, are shown in Table 13. Both the BATS and NPTS data are shown because of the potential weaknesses of the BATS data discussed previously. Unfortunately, the NPTS sample is not large enough to include only its Bay Area households. Comparing the respondents to the two populations, it appears that the highest income households are over represented in the Non-Respondent Survey. While the 1996 BATS may also over represent higher income households, the share of respondents reporting incomes over $75,000 is nearly double that of the 1996 BATS (41.1% versus 22.3%). Because of the preponderance of very high-income households, all of the other income categories are underrepresented. Aside from response bias, two additional factors may contribute to the skewed distribution. Some people may lie, choosing the highest income category on the form. Second, Bay Area incomes surely rose between 1995, 1996, and 1999 (respondents were asked for last year's income). However, neither of these explanations would account for more than a small portion of such a skewed distribution. The difference in income distribution could be a significant problem when using the survey data to test the hypotheses comparing participants and non-participants. One way to help correct the problem is to apply weights to the data.

Table 13: Income of Non-Participant Respondents Compared to Bay Area and California Households with pre-1982 Vehicles

	Non-Participant Respondents % (#)	1996 BATS Households with pre-1982 vehicles	1995 NPTS California Households with pre-1982 vehicles
$10,000 and under	2.0% (9)	3.6%	9.0%
$10,001 – 15,000	4.0% (18)	4.4%	8.3%
$15,001 – 20,000	3.4% (15)	4.6%	8.3%
$20,001 – 30,000	8.1% (36)	10.7%	14.9%
$30,001 – 45,000	11.9% (53)	24.0%	20.5%
$45,001 – 60,000	16.4% (73)	20.1%	17.7%
$60,001 – 75,000	13.0% (58)	10.3%	8.5%
Over $75,000	41.1% (183)	22.3%	12.7%
	445	700	490

Note that the income categories for the BATS and NPTS surveys are not defined exactly the same. Those surveys have intervals starting at 1,000 and ending at 999.

To explore the potential respondent bias further, the respondents were compared to the BATS and NPTS California households in terms of household size (total number of persons) and number of vehicles. The distribution by household size (Table 14) is not too far off from the BATS sample. Single-person households may be underrepresented. However, the distribution by number of household vehicles (Table 15) is skewed towards households with more vehicles. This, combined with the income distribution, indicates that people who collect vehicles as a hobby may have responded in large numbers. I would expect these households to have higher incomes and more vehicles. VAVR programs are a concern to car collectors, which may have prompted them to respond to the survey more than other households. The survey did ask whether the owner did not sell their pre-1982 vehicle to the BAAQMD program because they considered it a "classic" or "collector" vehicle. A large share (38.4%) responded positively to this question.

Table 14: Household Size of Non-Participant Respondents Compared to Bay Area and California Households with pre-1982 Vehicles

	Non-Participant Respondents	1996 BATS Households with pre-1982 vehicles	1995 NPTS California Households with pre-1982 vehicles
1	20.7%	27.8%	19.6%
2	39.7%	36.9%	32.4%
3	16.4%	14.4%	17.7%
4	15.4%	13.3%	17.9%
5 or more	7.9%	7.5%	12.4%
	469	796	574

Table 15: Number of vehicles of Non-Participant Respondents Compared to Bay Area and California Households with pre-1982 Vehicles

	Non-Participant Respondents	1996 BATS Households with pre-1982 vehicles	1995 NPTS California Households with pre-1982 vehicles
1	12.4%	17.7%	21.9%
2	29.8%	41.2%	38.4%
3	28.0%	27.1%	23.3%
4	17.9%	8.3%	11.8%
5 or more	11.9%	5.7%	4.6%
	403	796	574

To test whether a high response rate from car collectors may have caused the skewed income distribution, these households were removed from the sample and the income distribution recalculated, as shown in Table 16. The income distribution changed, but it is still skewed towards households with incomes over $75,000. A larger share of the non-classic vehicle households are middle-income households ($30,001 – 60,000) and slightly smaller share come from the lowest and highest income categories. While removing the classic vehicle households from the sample is not a solution to the income distribution problem, these households will be examined separately because they are a unique and important segment of the population.

Table 16: Income of Non-Participant Respondents with and without Classic Vehicle Households

	Non-Participant Respondents % (#)		1996 BATS Households with pre-1982 vehicles
	All	Non-Classic or Collector	
$10,000 and under	2.0%	1.5%	3.6%
$10,001 – 15,000	4.0%	3.3%	4.4%
$15,001 – 20,000	3.4%	4.1%	4.6%
$20,001 – 30,000	8.1%	7.4%	10.7%
$30,001 – 45,000	11.9%	15.1%	24.0%
$45,001 – 60,000	16.4%	17.3%	20.1%
$60,001 – 75,000	13.0%	13.7%	10.3%
Over $75,000	41.1%	37.6%	22.3%
	445	271	700

4 CHAPTER 4: OLDER VEHICLE OWNERSHIP AND USE

The major objective of this research is to understand how household characteristics and travel behavior impact the effectiveness of VAVR programs in reducing air pollutant emissions. An appropriate starting point is to understand which households own older vehicles and how they use them. Understanding why households own older vehicles and how they use them will help explain why they may or may not participate in a VAVR program. In addition, if certain types of households drive older vehicles further than other households, VAVR programs would be most effective if those households participated in the programs at high rates. This chapter focuses on the following questions:

- What households own older vehicles?
- Who drives older vehicles?
- How are older vehicles used?

Before answering those key questions, however, I will define "older vehicles." In addition, a profile of older vehicles is included to better understand what types of vehicles the analysis encompasses, including a discussion of larger vehicles (medium- and heavy-duty vehicles) and commercial and fleet vehicles.

4.1 Defining Older Vehicles

Before analyzing the use of older vehicles, "older" vehicles must be defined. Some analyses use ten or 15 years as a definition [see, for example Pisarski, 1996 #376]. This type of a definition may be particularly useful for comparing data over a long time period. Another definition could be based upon vehicle emissions standards. The U.S.

Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) periodically strengthen the emissions standards for new cars and trucks. Table 17 shows the standards through 1993. After the start of controls in 1966 and 1968, significant tightening of the standards occurred in model years 1970, 1972, 1975, 1980, and 1993 for HC, CO, and NO_x.

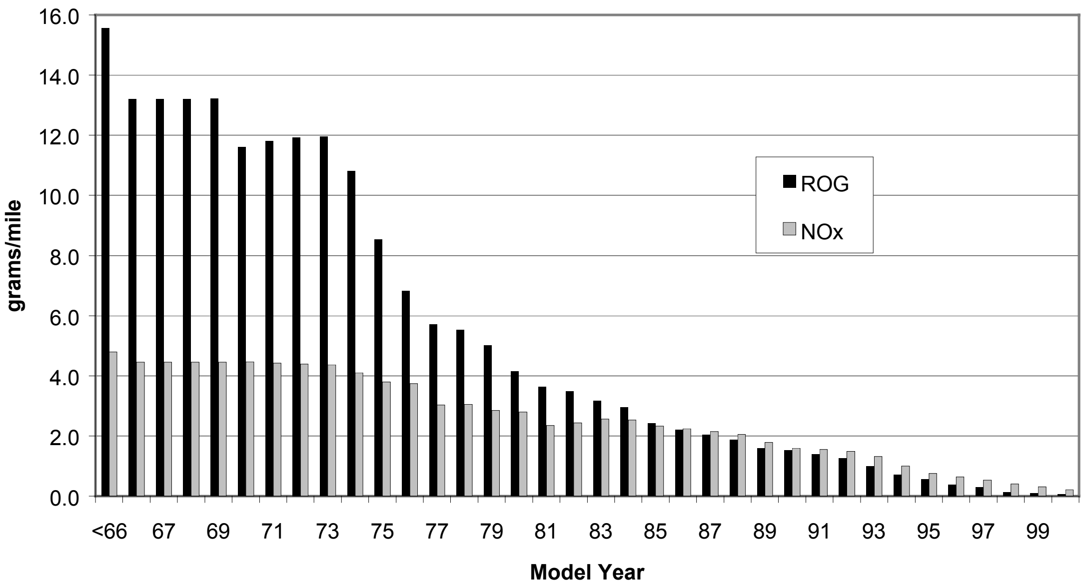
Table 17: Light-Duty Automobile Emissions Standards

Model Year	Federal			California			
	HC	CO	NOx	HC	CO	NOx	PM
Pre-control	10.60	84.0	4.1	10.60	84.0	4.1	
1966				6.30	51.0	(6.0)#	
1968	6.30	51.0	(6.0)#	6.30	51.0		
1970	4.10	34.0		4.10	34.0		
1971	4.10	34.0		4.10	34.0	4.0	
1972	3.00	28.0		2.90	34.0	3.0	
1973	3.00	28.0	3.0	2.90	34.0	3.0	
1974	3.00	28.0	3.0	2.90	34.0	2.0	
1975	1.50	15.0	3.1	0.90	9.0	2.0	
1977	1.50	15.0	2.0	0.41	9.0	1.5	
1978	1.50	15.0	2.0	0.41	9.0	1.5	
1980	0.41	7.0	2.0	0.39§	9.0	1.0	
1981	0.41	3.4	1.0	0.39*	7.0	0.7	
1983	0.41	3.4	1.0	0.39	7.0	0.4*	
1984	0.41	3.4	1.0	0.39	7.0	0.4	0.60
1985	0.41	3.4	1.0	0.39	7.0	0.4	0.40
1987	0.41	3.4	1.0	0.39	7.0	0.4	0.20
1989	0.41	3.4	1.0	0.39	7.0	0.4	0.20
1990	0.41	3.4	1.0	0.39	7.0	0.4	0.08
1991	0.41	3.4	1.0	0.39	7.0	0.4	0.08
1992	0.41	3.4	1.0	0.39	7.0	0.4	0.08
1993	0.41	3.4	1.0	0.25	3.4	0.4	0.08

Emissions of NOx (no standard) increased with control of HC and CO.
§ Nonmethane HC standard (of 0.41 g/mile for total HC)
* Options HC standard
Source: (Calvert, Heywood, Sawyer, & Seinfeld, 1993)

The results of these standards are evident in the emissions rates for vehicles in California. Figure 12 shows the average emissions (grams per mile) by model year for light duty passenger cars in California for the year 2000, based upon CARB's EMFAC2000 model. The model is based, in part, upon emissions data from a sample of vehicles. Through model year 1993, emission rates for ROG dropped at least 20% over the previous model year for model years 1975, 1977, 1980, 1985, and 1993. An older vehicle definition based upon significant differences in emissions rates could use any one of these years as a cut-off.

Figure 12: Average Emissions Rates for California Light Duty Cars and Trucks, 2000



Source: Author's calculations from EMFAC2000

A final source of a definition is the VAVR programs themselves. The Bay Area Air Quality Management District (BAAQMD) currently uses 1981 as the cut-off year for their VAVR program. The agency is considering changing this to 1985 (Garvey, 2000). CARB's analysis of the benefits of its VAVR regulations included vehicles through model year 1981 and 1985 (California Air Resources Board, 1998). The South Coast Air Quality Management District (SCAQMD) also uses 1981 as a cut-off year, but is considering expanding this to 1985 (South Coast Air Quality Management District, 2000b).

Because this research relies largely on data from the BAAQMD VAVR program and its participants, I will use 1981 as a cut-off year. However, because 1981 is not a model year for which a significant drop in emissions is evident, the 1985 cut-off (when emissions did drop over 20%) will also be used. This is consistent with the various agencies' analyses and future plans. Therefore, the 1981 ("pre-1982") definition will be used when making direct comparisons to data from VAVR participants. The 1985 ("pre-1986") definition is useful for looking ahead. The drawback to using a model year cutoff instead of a certain vehicle age (e.g. 15-year-old vehicles) is that a 1981 car in 2000 is older than a 1981 car in 1995. This may not be a major problem. In 1995 (the year of the NPTS), pre-1982 vehicles were 14 years old or older. In 2000, a 14-year-old vehicle is model year 1986 or older. Therefore, looking at pre-1986 vehicles, along with pre-1982 vehicles, helps account for differences in the dates the surveys were conducted.

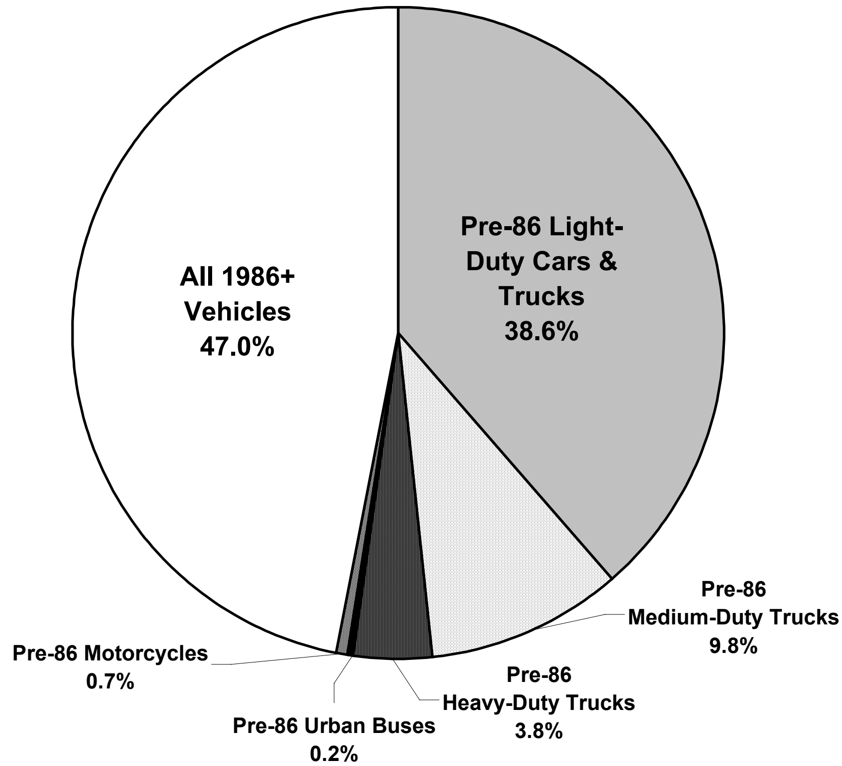
4.2 Profile of Older Vehicles

4.2.1 Light-Duty vs. Medium- and Heavy-Duty Vehicles

Regulatory agencies divide vehicles into various classes based upon body type and size. Light-duty automobiles include all sizes of automobiles and were targeted first for emissions standards. CARB's definition of light-duty trucks (LDTs) includes pickup trucks, vans, and sport utility vehicles (SUVs) weighing 5,750 pounds or less (California Air Resources Board, 2000). The other classes of vehicles include medium- and heavy-duty trucks, urban buses, and motorcycles. Current VAVR programs only accept light-duty cars and trucks. California recently began offering incentives to retrofit or replace heavy-duty diesel engines through the Carl Moyer program (California Air Resources Board, 2001a). Because the VAVR programs currently target light-duty vehicles, this research will also focus on those vehicles. However, it would be useful to understand the relative contribution of the other vehicle classes to the older vehicle emissions problem.

As with light-duty vehicles, older medium- and heavy-duty trucks contribute disproportionately to mobile source emissions. Moreover, a higher share of these vehicles are older, compared to light duty cars and trucks. According to CARB's EMFAC2000 model defaults for the year 2000 in California, 19.2% of all medium-duty trucks and 18.3% of all heavy-duty trucks are pre-1982, compared to 9.3% of the light-duty cars and 8.5% of the light-duty trucks. Figure 13 represents the total ROG emissions produced by on-road mobile sources for California in the year 2000. Just under half of the emissions (47.0%) come from 1986 or newer vehicles of all types, though these vehicles make up 80.1% of the fleet. Pre-1986 light-duty cars and trucks contribute to 38.6% of the emissions, while pre-1986 medium- and heavy-duty trucks comprise 13.6% of the total. These pre-1986 larger trucks represent only 3.1% of the total fleet, and the pre-1986 light-duty vehicles are 16.3% of the fleet. Overall, then, older vehicles represent about 53% of the on-road inventory, and the larger trucks are about one-quarter of that share.

Figure 13: California On-Road Mobile Source ROG Emissions by Vehicle Age and Type (2000)



Source: Author's calculations from EMFAC2000

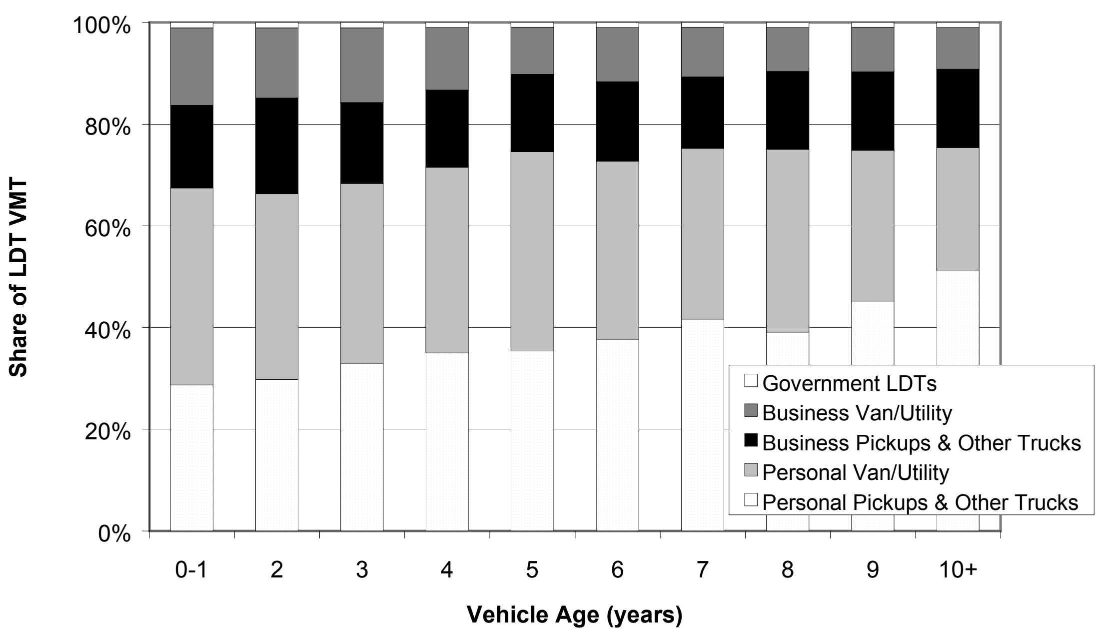
4.2.2 Household vs. Commercial/Fleet Vehicles

Unfortunately, there is no comprehensive source of travel or use data for all types of on-road motor vehicles (Bureau of Transportation Statistics, 1998). As discussed in Chapter 3, the NPTS collects data on all types of household vehicles and the VIUS collects data on all types of trucks (light-, medium- and heavy-duty) from both households and businesses. The RTECS also collects data only on household vehicles, but does distinguish between vehicles used for business and personal use. All of these sources include model year and annual VMT information, which is useful for this research. There is no similar, publicly-available source for all government or commercial automobiles, such as employer fleets and rental cars. While it will not be possible to examine the use of older vehicles by businesses and government agencies, it would be useful to know what share of the older vehicle fleet and travel these groups represent. If they represent a large share of the older vehicle travel, concentrating on personal vehicle use may be inappropriate.

One hypothesis is that older vehicles are less likely to be owned by businesses and government agencies because: (1) greater use of vehicles by these owners will speed up their turnover; (2) businesses and government agencies may have more resources to purchase newer vehicles, particularly for large fleets; and (3) rental car fleets will be much newer. In a 1991 study of fleets of 25 or more vehicles, the Oak Ridge National Laboratory (ORNL) found that businesses kept cars an average of 35 months (<3 years) and light trucks an average of 56 months (<5 years). Government agencies kept these vehicles an average of 81 and 82 months (<7 years), respectively (Davis, 2000). It is unknown what share of these vehicles are sold to individuals versus other businesses or government agencies. However, these data do indicate that business and government light-duty vehicles are less likely to be over 10 years old. Businesses drove cars nearly 30,000 miles per year on average and light trucks an average of 26,600 miles per year. Mileage for government cars and trucks was just under 14,000 miles per year.

Researchers at the ORNL also used a variety of data sources to try to estimate VMT trends for light duty cars and trucks (Hu, Davis, & Schmoyer, 1998). They estimated the differences in VMT for light-duty trucks (LDTs) used for personal, business, and government use, but not for automobiles. Their oldest age category was vehicles ten year or older. They estimate that 21.0% of all the light duty trucks 10-years-old or older are owned by businesses or government agencies, compared to 23.2% of all light duty trucks. Business and government LDTs made up 7.2% of the entire light-duty 10-year-old or older fleet (trucks and autos), but 10.5% of the new (0-1 years old) fleet. This supports the hypothesis that older vehicles are less likely to be government or business vehicles. In addition, the share of VMT from non-personal LDTs declines with vehicle age. Figure 14 shows the distribution of VMT from all LDTs in 1995 by type of use. The share of VMT for personal use LDTs (lowest two portions of the bars) grows as the vehicles age. Business and government LDTs (upper three portions of the bars) represent about one-fourth of the VMT from the oldest (10+ years) LDTs.

Figure 14: Share of Light-Duty Truck 1995 VMT – Government, Business and Personal Use



Source: Derived from data from (Hu et al., 1998)

However, LDTs are only a part of the story. Automobiles of all types of owners represented 67.8% of the VMT from the oldest (10+) light-duty vehicles and 64.6% of all the light-duty VMT in 1995 (Hu et al., 1998). One estimate for 1998 indicated that 7.6% of the automobiles were in fleets (government and business) of four or more vehicles

(Davis, 2000, Table 6.4). This estimate is consistent with an automotive fleet data source (Automotive Fleet, 2000). Unfortunately, there are no estimates of the number of automobiles owned by businesses or government agencies with less than four vehicles. Just over half (51.5%) of the vehicles in fleets of four or more were in fleets of 4-24 vehicles (Automotive Fleet, 2000). If there were an equal number of autos in "fleets" of 1-3, that would result in a total of 11.5% of the automobiles in non-personal use. An "educated guess" might be that 10-15% of the automobiles are for non-personal use. This is significantly less than the share of LDTs (23.2%, from above), but perhaps not unreasonable. Pickup trucks and vans have traditionally been associated more with commercial purposes, though that trend has changed in recent years. In 1991, almost half (46.6%) of the light duty vehicles in fleets of 25 or more were trucks and vans (Davis, 2000, Table 10.2). In contrast, 32.8% of the 1995 NPTS household vehicles were pickup trucks, SUVs, or vans.[8]

Table 18 presents an estimate of the share of older (10+ years old) vehicles that are for business and government versus personal use. The 10+-year-old definition is used because the starting point for the estimate is the ORNL study described above. The first two lines in the table (the share of business & government and personal LDTs) come from that study. The remaining automobiles are split between business & government and personal using the 10% (low) to 15% (high) estimate from above. The lower end may be more realistic, if we assume that older vehicles are less likely to be for non-personal use. The share of automobile VMT is apportioned by applying an additional multiplier representing the higher share of VMT from business & government (B&G) vehicles

[8] The fleet study did not differentiate SUVs from truck or vans.

(compared to their share of vehicles), as found among LDTs (7.9/7.2=1.10). This estimate indicates that at least 80% of the older light-duty vehicle travel is from personal vehicles. This number is likely to be higher for vehicles 15 or more years old, since the trend is for businesses and government agencies to own a smaller share of the vehicles as they age. While one-fifth of the older vehicle travel is a significant share, concentrating on personal vehicle use because of data limitations does not appear to diminish the importance of the findings.

Table 18: Estimated Share of Older (10+ years) Light-Duty Vehicles and VMT by Use

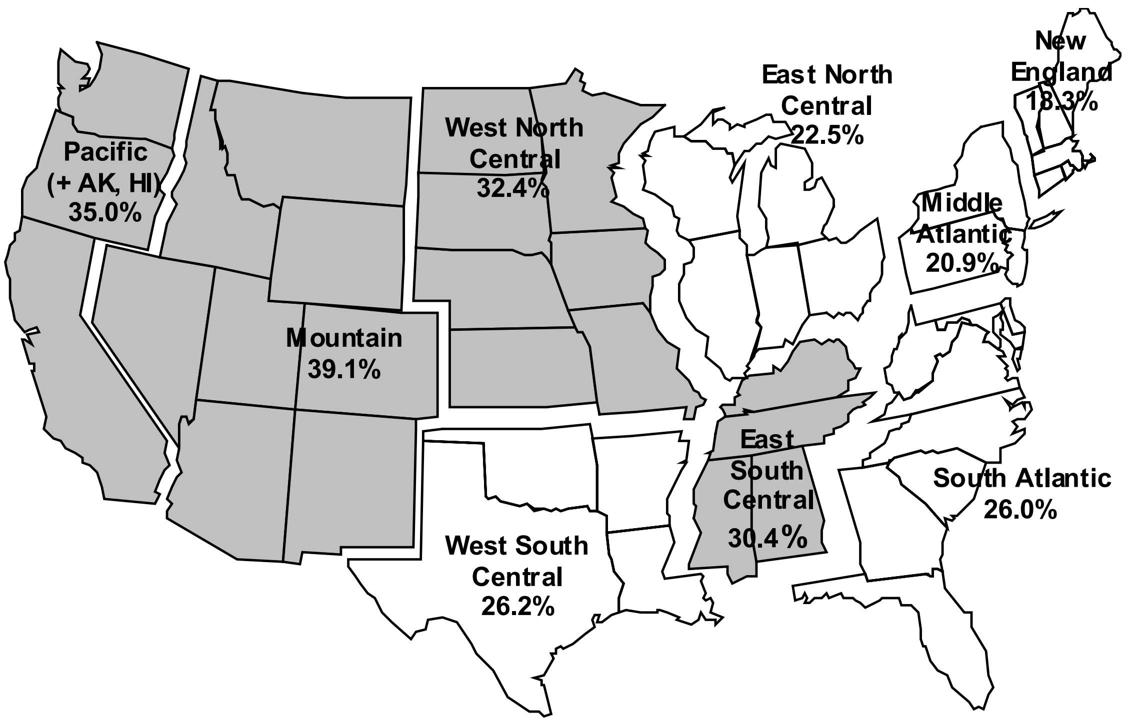
	% of Vehicles		% of VMT	
	Low	High	Low	High
Business & Govt LDTs	7.2%	7.2%	7.9%	7.9%
Personal LDTs	27.0%	27.0%	24.3%	24.3%
Business & Govt Autos	6.6%	9.9%	7.4%	11.2%
Personal Autos	59.2%	55.9%	60.4%	56.6%
	100.0%	100.0%	100.0%	100.0%
Total Share Personal	86.2%	82.9%	84.7%	80.9%

4.2.3 Geographic Distribution

Areas with high proportions of older vehicles should be most concerned with the air quality impacts from these vehicles. Nationwide, 13.1% of the household vehicles are pre-1982 and 27.5% are pre-1986 (Table 19). Older vehicles are a larger share of the household vehicle population in certain areas of the country (defined by the U.S. Census): Mountain (39.1% are pre-1986), Pacific (35.0%), West North Central (32.4%), and East South Central (30.4%) (Figure 15). New England has the smallest share of pre-1986 vehicles (18.3%). In California, 33.6% of the household vehicles are pre-1986, according to the NPTS sample. The data from the ‘96 BATS indicates that 31.1% of the

Bay Area household vehicles are pre-1986. These numbers would be slightly lower for the year 2000, given the rate of vehicle scrappage that occurs even without a VAVR program.

Figure 15: Share of Household Vehicles of Model Year 1985 or older, by Census Division



Source: 1995 NPTS weighted household data. Shaded regions are above the national share of 27.5%.

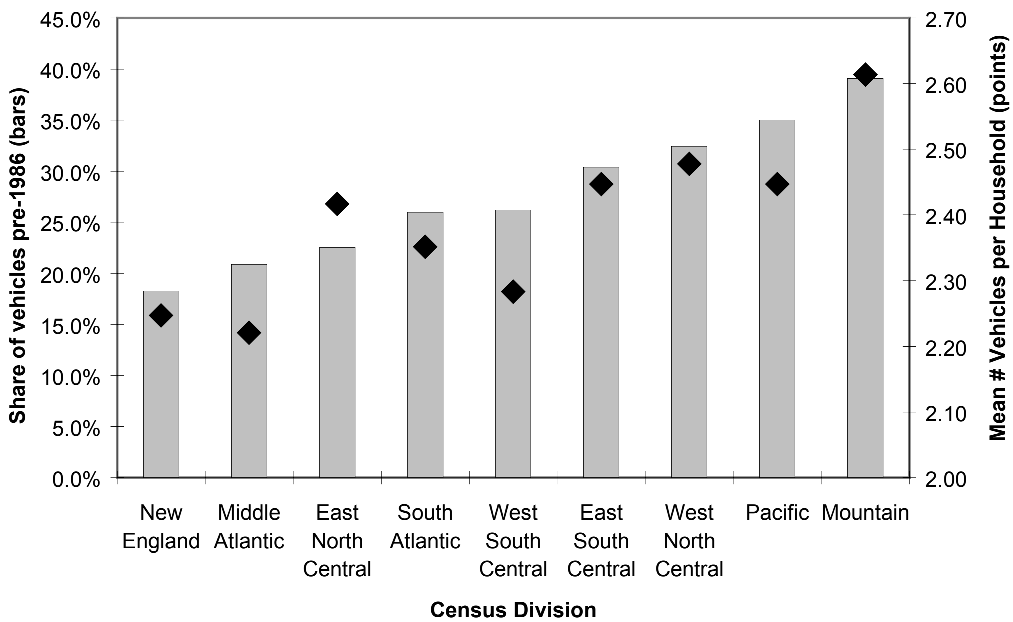
Table 19: Geographic Distribution of Household Vehicles by Age

	New England	Middle Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	U.S.
1969 & older	0.9%	0.7%	1.2%	**2.6%**	1.6%	1.7%	1.5%	**3.4%**	**4.2%**	2.0%
1970 - 1981	4.4%	7.2%	7.9%	**14.9%**	9.8%	**12.7%**	10.6%	**20.1%**	**15.4%**	11.1%
1982 - 1985	13.0%	13.0%	13.5%	**15.0%**	**14.6%**	**16.0%**	14.1%	**15.6%**	**15.4%**	14.4%
1986 – 1993	64.2%	60.9%	59.4%	54.4%	55.8%	55.7%	56.3%	49.1%	51.6%	56.3%
1994 & newer	17.5%	18.2%	18.1%	13.2%	18.2%	13.9%	17.5%	11.8%	13.4%	16.2%

Source: 1995 NPTS weighted household data. **Boldface** indicates higher than the U.S. share for older vehicles.

Weather likely contributes to some of the difference in distribution, with vehicles lasting longer in climates with less ice and snow. Another factor may be differences in the number of vehicles households keep. As will be discussed in Section 4.3.2.3, households with older vehicles tend to have more vehicles. Figure 16 shows the share of vehicles that are pre-1986 (bars), along with the mean number of vehicles per household (points), for each census division. With the exception of East North Central, the divisions with the highest number of vehicles per household also have the highest share of pre-1986 vehicles.

Figure 16: Share of Vehicles Pre-1986 and Number of Vehicles per Household, by Census Division



4.2.4 Vehicle Type

EPA and CARB regulations and emissions models divide vehicles into categories based upon size and type. Most household vehicles fall into the light duty automobile or light duty truck category. Most pickup trucks, vans, and sport utility vehicles (SUVs) are considered light duty trucks. There are differences in vehicle type between older and newer vehicles. In the U.S., older household vehicles are more likely to be pickup trucks compared to all household vehicles (Table 20). Household pickup trucks in the U.S. averaged 9.0 years old, compared to 7.6 years for automobiles. In contrast, vans and sport utility vehicles are a smaller share of the older vehicle population, reflecting their growing popularity in the 1990s. The differences in vehicle type between older and newer vehicles, however, is less pronounced in California, particularly for pre-1986 vehicles (Table 21).

Table 20: Household Vehicle Type – U.S.

	pre-82	pre-86	All MYs	Mean Age (years)
Automobile	58.3%	63.4%	65.2%	7.6
Van	4.9%	5.0%	7.9%	6.0
Sport Utility Vehicle	4.1%	4.8%	7.0%	6.0
Pickup Truck	27.7%	22.9%	17.9%	9.0
Other truck	1.4%	0.9%	0.4%	14.4
RV	1.5%	1.1%	0.5%	12.6
Motorcycle	1.9%	1.8%	1.0%	10.4
Other private vehicle	0.2%	0.1%	0.1%	12.5
	100.0%	100.0%	100.0%	7.7

Source: 1995 NPTS weighted household data

Table 21: Household Vehicle Type - California

	pre-82	pre-86	All MYs	Mean Age (years)
Automobile	64.0%	69.6%	67.7%	8.9
Van	6.9%	6.2%	7.1%	8.0
Sport Utility Vehicle	3.3%	3.7%	7.2%	6.1
Pickup Truck	20.9%	16.2%	15.5%	10.3
Other truck	0.9%	0.6%	0.3%	15.7
RV	1.7%	1.7%	0.9%	11.6
Motorcycle	2.2%	1.8%	1.3%	10.3
Other private vehicle	0.2%	0.2%	0.1%	20.9
	100.0%	100.0%	100.0%	8.9

Source: 1995 NPTS weighted household data

4.2.5 Vehicle Makes

Ford is the most popular make of vehicle in households in the U.S. overall (Table 22). However, Chevrolets are the number one older vehicle, with Ford second. These two makes comprise nearly 50% of the pre-1982 vehicles and 42% of the pre-1986 vehicles. The growth in foreign automobile sales in the U.S. in the 1980s is reflected in the rise in the ranking of Toyotas: 8th in the pre-1982 vehicles, 5th in the pre-1986 vehicles, and 3rd overall. The distribution also reveals that certain makes may be kept in the fleet longer, such as Volkswagens, which makeup only 1.3% of all household vehicles, but 3.9% of the pre-1982 vehicles. This trend is also seen in California (Table 23), where Volkswagens and Mercedes Benzs show up in the top ten pre-1982 vehicles, while not ranking as highly overall.

Table 22: Makes of Older Household Vehicles in the U.S.

	Pre-1982		Pre-1986		All Household Vehicles	
Make	**Share**	**Rank**	**Share**	**Rank**	**Share**	**Rank**
Chevrolet	26.8%	1	22.9%	1	18.0%	2
Ford	22.7%	2	19.2%	2	19.4%	1
Dodge	5.8%	3	5.4%	6	6.5%	4
Buick	4.8%	4	5.9%	4	4.8%	6
Oldsmobile	4.7%	5	5.9%	3	4.7%	7
Volkswagen	3.9%	6	2.6%	12	1.3%	17
Pontiac	3.7%	7	3.7%	8	4.2%	9
Toyota	3.4%	8	5.4%	5	6.6%	3
GMC	2.8%	9	2.7%	11	2.4%	12
Cadillac	2.8%	10	2.8%	10	1.9%	15

Table 23: : Makes of Older Vehicles in California Households (from 1995 NPTS)

	Pre-1982		Pre-1986		All Household Vehicles	
Make	**Share**	**Rank**	**Share**	**Rank**	**Share**	**Rank**
Chevrolet	21.4%	1	16.5%	1	12.2%	3
Ford	18.7%	2	14.5%	2	16.3%	1
Volkswagen	8.4%	3	5.8%	5	3.0%	8
Datsun/Nissan	6.1%	4	7.8%	4	8.0%	4
Toyota	5.6%	5	10.2%	3	12.3%	2
Dodge	5.4%	6	4.2%	8	4.9%	6
Cadillac	4.5%	7	5.0%	7	3.0%	9
Honda	3.9%	8	5.6%	6	7.9%	5
Mercedes Benz	3.3%	9	3.0%	11	1.4%	19
GMC	3.0%	10	2.6%	12	2.0%	12

A difference in makes between older and newer vehicles is an air quality problem if certain makes pollute more than others. There is evidence of this trend. Using inspection and maintenance (I/M) data from California and Chicago, Kahn (1996) found significantly different emissions rates between General Motors, Ford, and Chrysler vehicles. He also found that for light trucks, compared to Fords, Dodges polluted more and GMCs and Chevrolets polluted less. Wenzel and Ross (Wenzel & Ross, 1997) found significantly different I/M failure rates for certain combinations of models and model years. Using data from California, Arizona, and Minnesota for MY87-89 and MY91-93, they found that a few models had failure rates several times higher than other cars. Those models were not identified, but the authors did state that most of the worst MY91-93 models were domestic. A similar analysis of data from Arizona, Colorado, and Wisconsin I/M programs also found that several models were consistently among the cleanest and dirtiest (Wenzel & Gumerman, 1999).

4.2.6 Collector or Classic Vehicles

Some older vehicles are considered "collector" or "classic" vehicles. The California Vehicle Code (CVC, Section 5051) defines a car collector as someone who has a collector vehicle "for his or her own use, in order to preserve, restore, and maintain such vehicle for hobby or historical purposes." Special license plates can be issued to collector vehicles defined under CVC Section 5004, which include vehicles with engines of 16 or more cylinders manufactured prior to 1965, vehicles made in 1922 or earlier, or vehicles made after 1922 that are at least 25 years old and "of historic interest." Vehicles are of "historic interest" if they are "collected, restored, maintained, and operated by a collector or hobbyist principally for purposes of exhibition and historic vehicle club activities" (CVC Section 5004(f)). In 2001, California State Senator Johannessen introduced Senate Bill 800 that, in part, would have exempted collector vehicles from Smog Check requirements. Under the proposed legislation, collector vehicles were to be 25 or more model-years old, not used as a primary source of transportation, and used primarily for display purposes at events such as shows and parades or to obtain repairs and maintenance. A second bill by the same author (SB 1811) added requirements that the vehicle not be used on a daily basis and operated less then 5,000 miles per year.

Owners of collector vehicles are highly unlikely to sell their collector vehicle to a VAVR program, and it would be useful to look at these vehicles separately. However, the NPTS does not ask whether the household considers each vehicle a collector or classic vehicle. Therefore, a definition was constructed:

(1) model year 1969 or older (so that vehicle was at least 25 years old in the 12 months preceding the survey); and

(2) the vehicle was driven 1,000 miles or less in the past 12 months. The annual mileage was based on both odometer readings and the self-reported information.

The 1,000-mile cut-off is somewhat arbitrary. The 5,000-mile proposal from SB 1811 seems too high. Three-quarters of the pre-1970 vehicles were driven 5,000 miles or less. The average annual mileage for pre-1970 vehicles was 2,561 miles. If a collector vehicle is driven only at parades, shows, etc. and to obtain repairs and maintenance, the 1,000-mile cutoff seems reasonable. Collectors going long distances for car events are likely to tow the vehicle to preserve its condition and avoid potential damage.

Overall, only 0.9% of all the vehicles (6.6% of the pre-1982 vehicles and 49.2% of the pre-1970 vehicles) qualified under this definition of collector vehicle. Just over 90% of the collector vehicles were not driven on the travel day surveyed, and the mean annual self-reported mileage was 392 miles. This indicates that the constructed definition did capture some of the intended vehicles. However, this definition undoubtedly captures some vehicles that are not considered a "collector" by their owners and misses others that are. Some vehicles were missing mileage information. In addition, some owners may consider their 1970 or newer vehicle a collector vehicle, even though at the time of the survey it might not meet a legal definition for special license plate purposes. Because these vehicles are a small portion of all the older vehicles and an accurate definition (one that is based upon the owners' concept of the vehicle's purpose) is impossible, collector vehicles are not excluded from all older vehicles for most of the analysis that follows. However, for the purposes of trying to understand these vehicles better, and how they differ from vehicles that would be attracted to VAVR programs, they are analyzed further in Sections 4.3.5, 4.4.3, and 4.5.4.

4.3 What Households Own Older Vehicles?

4.3.1 Literature Review

A large body of research exists regarding how many and what types of vehicles households own. However, none of the existing research I found focused on older vehicle ownership. Many of the studies on vehicle ownership did include vehicle age or vintage as a variable. Train (1986) reviewed the research up until about 1985 and found that higher income, lower ownership costs, decreased access to public transit, and more workers usually led to a household owning more vehicles. Models that explored what types of vehicles people purchased consistently found that price, operating cost, vehicle size, and age of the auto were significant variables. With respect to household characteristics, these models usually included income, number of people in the household, age of the household head or primary driver, and number of autos in the household as significant variables in the choice of vehicle type. Ewing et. al. (1998)

reviewed several studies up through 1996 and also consistently found that income, household size, and number of workers were positively related to the number of vehicles owned. Density was often linked with lower levels of vehicle ownership.

Train's review found that the models generally predicted that households prefer newer cars. Berkovec and Rust (1985) found this to be true for one-car households, though the model only looked at cars (not trucks, vans, or SUVs) 10 years old or newer. In particular, they found that higher income households placed a greater value on vehicle age (higher value for newer cars). Mannering and Winston (1985) also found that single-vehicle households were less likely to have an older vehicle (8 years or more) than two-vehicle households. With respect to vehicle purchase decisions, Berkovec (1985b) (1985a) found that one-car households had a much lower likelihood of purchasing an older vehicle (10 years old or older) than two- and three-car households. In a series of models of Dutch households, de Jong (1996) found that households with only one car were less likely to purchase a car five or more years old, compared to households with two or more cars.

Train (1986) pointed out a shortcoming of most of the studies conducted in the late 1970s and early 1980s – they did not consider how the household's choices interrelated, e.g. how the types of vehicles a household owns impacts the number they own. Another problem in modeling vehicle ownership is that of how to treat travel (Mannering & Train, 1985). How far a household drives will impact its vehicle choice decisions. What vehicle(s) it owns will impact how far it drives. For example, vehicles that cost more to drive (e.g. lower fuel efficiency) will be driven less. Households that drive a lot may purchase vehicles with lower operating costs, e.g. higher fuel efficiency.

Prompted by these shortcomings, Train developed a system of disaggregate models to forecast the number of vehicles owned and the number of miles driven by vehicle class and vintage (1986). The vehicle quantity sub model included the following significant variables (with direction of coefficient): household income (positive), number of workers (positive), transit access (negative), and a feedback variable representing vehicle class and vintage (positive). The class and vintage sub model included three significant vehicle age dummy variables: 1976-1978, 1972-1975, and 1976-1978 for household with income greater than $12,000. The model used data from 1978, so these variables measured relatively new vehicles and found that households with one or two vehicles preferred newer vehicles, particularly higher income households.

Another relevant area of research examines the scrappage decision (outside of VAVR programs) or how long households keep vehicles, also called the "holding duration." Some of the major relevant findings of this research are listed in Table 24. In a series of models developed to simulate the auto market, Berkovec (1985b) included a scrappage model relating the probability of a vehicle being scrapped to the vehicle's characteristics and price. He included a series of model year dummy variables, though none had significant t-statistics. He did find that pickup trucks, vans, and utility vehicles older than seven years were less likely to be scrapped (compared to newer vehicles of those types). As expected, the higher priced vehicles were less likely to be scrapped.

Yamamoto and Kitamura (2000) used a two-wave panel survey of California households to examine how long households actually keep vehicles, compared to how long they intend to keep them. Their data showed that vehicles were kept for a shorter length of time in the following cases: the vehicle was driven 15,000 miles per year or more; the vehicle was acquired used; the vehicle was leased; the higher the number of vehicles in the household; and annual household income $125,000 and over. The age of the primary driver had a positive relationship with holding duration. Vehicle age was not a significant variable in their models. When comparing actual with intended holding duration, they found that "households tend not to hold used vehicles as long as they intended, suggesting unexpected events such as breakdowns tend to shorten actual holding durations of used vehicles" (p. 348). In addition, the more vehicles in the household, the longer the household *intended* to keep a vehicle – but in reality they kept vehicles for shorter times than intended. Older individuals both intended and did keep vehicles longer. The authors hypothesized that younger drivers face more frequent life cycle and socioeconomic changes, which prompt them to replace vehicles more often.

Gilbert (1992) also looked at vehicle holding duration, but took the research further by considering whether the household replaced the vehicle with a new or used vehicle or didn't replace the vehicle at all. For example, higher household income was associated with shorter holding durations for vehicles that were replaced with new vehicles or not replaced. Higher education levels of the household heads led to keeping a vehicle for less time if a new vehicle was purchased, but more time if a used vehicle was purchased. Gilbert's findings also indicated that households that purchase new vehicles tend to replace them more frequently.

Table 24: Summary of Research on the Relationship between Household and Vehicle Characteristics and Vehicle Holding Duration

Variable	Source(s)
Increased holding duration linked to:	
↑ age of primary driver	(Yamamoto & Kitamura, 2000)
↑ education	(De Jong, 1996)*
↑ household size	(De Jong, 1996)*
Primary user is self-employed	(Yamamoto & Kitamura, 2000)
Households in Pacific, Mountain, West North Central, South Atlantic, and East South Central census divisions	(Gilbert, 1992)
"Honeymooner" households (under 35 years old, no children) (if vehicle replaced)	(Gilbert, 1992)
Decreased holding duration linked to:	
↑ income	(Yamamoto & Kitamura, 2000)
↑ age of driver	(De Jong, 1996)*
Female driver	(De Jong, 1996)*
Female head of household is employed	(Gilbert, 1992)
Driver is a worker	(De Jong, 1996)*
↑ # vehicles	(Yamamoto & Kitamura, 2000) (De Jong, 1996)* (Hensher, 1985)**
↑ VMT	(Yamamoto & Kitamura, 2000) (Gilbert, 1992) (De Jong, 1996)* (Hensher, 1985)**
↑ age of vehicle at purchase or purchased used	(Yamamoto & Kitamura, 2000) (De Jong, 1996)*
Primary user works in sales	(Yamamoto & Kitamura, 2000)
"New parent" households (all children under 6)	(Gilbert, 1992)
Young family households (if vehicle replaced)	(Gilbert, 1992)
New England households (if vehicle replaced)	(Gilbert, 1992)

*Dutch households
**Australian households

When a household purchases a vehicle it incurs transaction costs. These may include the cost of searching for a vehicle, transferring plates and registration, as well as psychological costs (Mannering & Train, 1985). Some researchers have tried to address the dynamics of household vehicle decisions by incorporating a transaction costs indicator variable in their models, (see, for example, Berkovec & Rust, 1985; Hocherman, Prashker, & Ben-Akiva, 1983). The concept of transaction costs could be equally applicable to the process of getting rid of a vehicle. Kavalec and Setiawan (1997) recognized this: "It is important to note that the bounty need not be higher than the market value of a targeted vehicle to induce scrappage, due to the reduction in transaction costs. Vehicle retirement will occur as long as the bounty plus the reduction in transaction costs is higher than the market value" (p. 99). Households have several options for getting rid of a vehicle – trade-in to a dealer, sell to a private, unknown party, sell or give to a friend or family member, donate to a charity, sell to a scrap yard or sell to a VAVR program. Each of these options involves different transaction costs. Some households view the transaction costs as higher than the cost of keeping the vehicle – insurance, storage, etc. – plus the utility they may gain from keeping an underused vehicle, e.g. having a spare vehicle for emergencies, or a truck for occasional hauling activities.

4.3.2 Description of Households with Older Vehicles

4.3.2.1 Income

Consistent with the literature, there is a relationship between income and vehicle age in the 1995 NPTS data. Older vehicles are disproportionately found in lower income households (Table 25). For example, 11.0% of all pre-1982 vehicles are in households with incomes less than $10,000, compared to 5.0% of all vehicles. Table 26 shows the proportion of U.S. households with and without pre-1982 vehicles by income. Nearly one-third of the households with incomes under $10,000 that have vehicles have at least one pre-1982 vehicle, compared to 19.6% of all U.S. households with vehicles.[9]

Table 25: Distribution of U.S. Household Vehicles by Income

	pre-1982 vehicles	pre-1986 vehicles	All Vehicles
Less than $10,000	11.0%	9.8%	5.0%
$10,000 - 14,999	8.7%	8.2%	5.1%
$15,000 - 19,999	9.3%	9.7%	7.2%
$20,000 - 29,999	19.6%	20.0%	17.1%
$30,000 - 44,999	21.5%	21.2%	21.6%
$45,000 - 59,999	16.1%	16.1%	19.3%
$60,000 - 74,999	6.2%	6.6%	9.1%
$75,000 and above	7.6%	8.5%	15.7%
	100.0%	100.0%	100.0%

Source: 1995 NPTS weighted household data

Table 26: U.S. Household Ownership of Older Vehicles, By Income

Household Income	One or more Pre-1982 vehicles	One or more Pre-1986 vehicles
Less than $10,000	32.3%	56.7%
$10,000 - 14,999	25.8%	47.6%
$15,000 - 19,999	20.9%	41.2%
$20,000 - 29,999	20.2%	40.0%
$30,000 - 44,999	19.2%	38.1%
$45,000 - 59,999	18.1%	35.2%
$60,000 - 74,999	15.9%	32.6%
$75,000 and above	12.2%	26.6%
All Households (with income reported)	19.6%	38.4%

Only households with vehicles included.
Source: 1995 NPTS weighted household data

[9] Note that only households with vehicles are included in this analysis.

4.3.2.2 Race and Ethnicity

White households with vehicles are the most likely to have a pre-1982 vehicle (Table 27). The difference between Hispanic and non-Hispanic households is very small. The differences in the distribution of older vehicles in households by race and Hispanic status (Table 28) is statistically significant, though the differences are very small.

Table 27: U.S. Household Ownership of Older Vehicles, By Race and Hispanic Status

Race/Ethnicity	One or more Pre-1982 vehicles	One or more Pre-1986 vehicles	n
White	20.1%	38.8%	33,831
African-American	16.3%	36.0%	2,152
Asian	11.4%	30.8%	613
Other	21.5%	43.0%	1,684
Total	19.6%	38.6%	38,280
Hispanic	20.2%	42.3%	1,390
Non-Hispanic	19.6%	38.2%	37,220
Total	19.6%	38.5%	38,610

Only households with vehicles included.
Source: 1995 NPTS weighted household data

Table 28: Distribution of U.S. Household Vehicles by Race and Hispanic Status

Race/Ethnicity	Share of pre-1982 vehicles	Share of pre-1986 vehicles	Share of all vehicles
White	85.8%	84.3%	84.7%
African-American	7.6%	8.5%	8.3%
Asian	0.9%	1.3%	1.9%
Other	5.6%	5.9%	5.2%
Total	100.0%	100.0%	100.0%
Hispanic	7.1%	7.9%	6.9%
Non-Hispanic	92.9%	92.1%	93.0%
Total	19.6%	19.6%	19.6%

Only households with vehicles included.
Source: 1995 NPTS weighted household data

4.3.2.3 Household Size, Structure, and Number of Vehicles

Households with more vehicles and more people are more likely to have an older vehicle (Table 29 and Table 30). For example, only 10.4% of the households with one vehicle have a pre-1982 vehicle, compared to over half of the households with four or more vehicles. Households with pre-1982 vehicles have an average of 1.3 vehicles per driver, compared to 1.0 vehicle per driver in households without pre-1982 vehicles. Overall, only 17% of the households with vehicles have more than one vehicle per driver. However, 42.3% of the households with pre-1982 vehicles and 31.4% of the households with pre-1986 vehicles have more than one vehicle per driver. This indicates that some older vehicles may be “extra” ones that are not used regularly or are collector vehicles used for pleasure and hobby.

These findings are consistent with the research that found that one-car households were less likely to purchase or have an older vehicle than two- or three-car households. Yamamoto and Kitamura (2000) found that holding duration for a vehicle decreased when household fleet size increased. However, this is not necessarily inconsistent with the NPTS data. Holding duration (how long a household keeps a vehicle) is not the same as vehicle age. A household can purchase a 1965 vehicle and keep it for a year. The NPTS does not have the acquisition year for each vehicle, so the holding duration for these vehicles can not be calculated. The closest indicator is whether he vehicle was new when acquired. Vehicles in NPTS households with three or more vehicles were more likely to have been purchased used than vehicles in households with one or two vehicles. Yamamoto and Kitamura found that used vehicles were kept for shorter periods. Therefore, the NPTS households with more vehicles may be purchasing older, used vehicles, but keeping them for shorter times.

Table 29: U.S. Household Ownership of Older Vehicles, By Number of Vehicles in Household

# of Vehicles	One or more pre-1982 vehicles	One or more pre-1986 vehicles
One	10.4%	24.8%
Two	16.4%	36.9%
Three	37.1%	61.2%
Four	50.8%	72.3%
Five or more	69.8%	87.7%
All Households with vehicles	19.7%	38.5%

Only households with vehicles included.
Source: 1995 NPTS weighted household data

Table 30: U.S. Household Ownership of Older Vehicles, By Number of People in Household

# of People	One or more pre-1982 vehicles	One or more pre-1986 vehicles
One	16.0%	31.5%
Two	19.2%	37.9%
Three	22.0%	41.8%
Four	20.2%	41.0%
Five	21.5%	43.1%
Six or more	28.7%	53.3%
All Households with vehicles	19.7%	38.5%

Only households with vehicles included.
Source: 1995 NPTS weighted household data

Families with two or more adults and the youngest child of driving age are the most likely to have a pre-1982 or pre-1986 vehicle (Table 31). This is consistent with the household size findings. In contrast, single, non-retired households without children are the least likely to have an older vehicle.

Table 31: U.S. Household Ownership of Older Vehicles, By Family Life Cycle

Family life cycle	One or more pre-1982 vehicles	One or more pre-1986 vehicles
2+ adults, youngest child age 16-21	27.2%	49.7%
2+ adults, retired, no children	21.6%	41.6%
One adult, retired, no children	21.0%	38.8%
2+ adults, youngest child age 0-15	20.3%	40.6%
2+ adults, no children	20.1%	39.0%
All Households	*19.7%*	*38.5%*
One adult, youngest child age 0-15	17.3%	35.9%
One adult, youngest child age 16-21	16.1%	36.9%
One adult, no children	14.1%	28.6%

Only households with vehicles included.
Source: 1995 NPTS weighted household data

4.3.2.4 Land Use Density

The 1995 NPTS included several land use density variables. One set of variables uses a urban/rural continuum developed by Claritas, Inc. based upon the density of the census tract or block group and the surrounding area (Federal Highway Administration, 1997). Households in rural census tracts were the most likely to have a pre-1982 vehicle (28.1%), compared to 19.6% of all households in census tracts that were categorized. Households in suburban tracts were the least likely to have pre-1982 vehicles (14.9%). Several other land use density variables also reveal that the lower the density the more likely a household is to have a pre-1982 vehicle. For example, 29.0% of households outside of MSAs and 21.3% of households in MSAs of fewer than 250,000 people have a pre-1982 vehicle, compared to 15.3% of households in MSAs with three million or more people. Households in census tracts with the lowest number of jobs per square mile were also the most likely to have a pre-1982 vehicle, with ownership rates decreasing as job density increased. This does not mean, however, that older vehicles are not an air quality problem in urban areas, as established in Chapter 1.

4.3.3 Logit Model

Table 32 displays the results of two binomial logit models describing the likelihood of a household having a pre-1982 vehicle. The difference between the two models is the inclusion of two extra variables in model 2 – whether the household is white/Caucasian and whether the household is outside an urbanized area. These variables are individually significant, but did not increase the explanatory power of the model, e.g. the pseudo-R^2 did not improve with their inclusion.

In both models, two geographic variables – whether the household is in the Northeast or West – are significant and have large, though opposite, impacts on the likelihood of having a pre-1982 vehicle. Two other significant variables with large absolute impacts are the number of vehicles in the household and whether there is more than one vehicle per driver ("extra vehicle" 1=yes, 0=no). Both variables add significantly to the model. For example, when the extra vehicle variable is excluded from model 1, the pseudo-R^2 falls to 0.165.

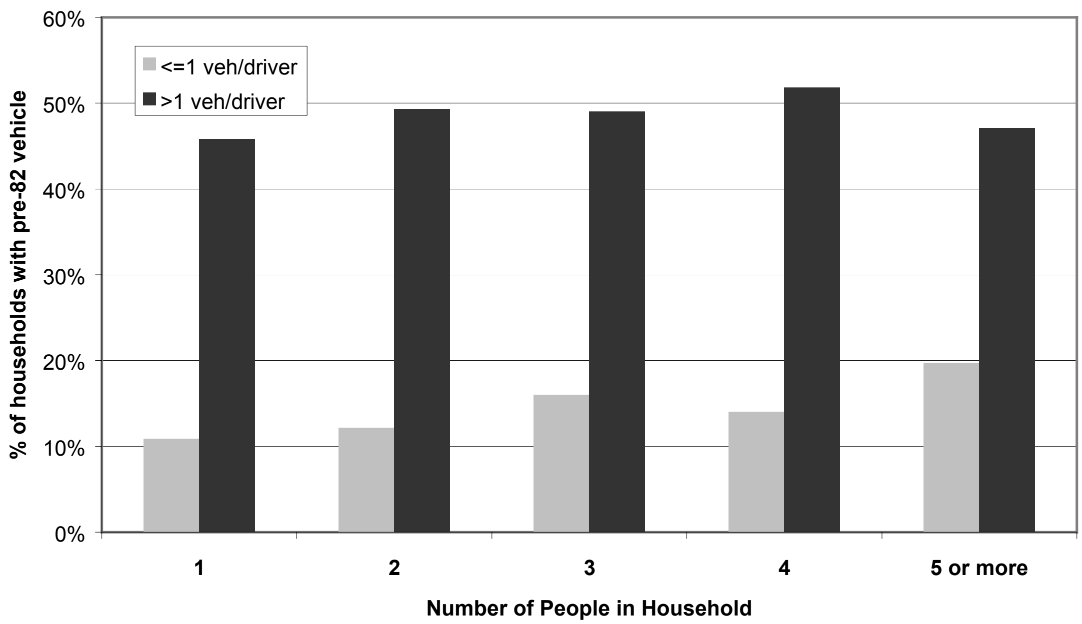
Table 32: Logit Model of Likelihood of Household having a pre-1982 Vehicle

	Model 1		Model 2	
	Coef.	**Sig.**	**Coef.**	**Sig.**
Intercept	-2.566	0.000	-2.675	0.000
Household in Northeast	-0.579	0.000	-0.589	0.000
Household in West	0.682	0.000	0.700	0.000
Household income ($1000)	-0.017	0.000	-0.017	0.000
# Workers in household	-0.179	0.000	-0.168	0.000
# People in household	0.063	0.000	0.060	0.000
# Vehicles in household	0.770	0.000	0.758	0.000
>1 vehicle per driver	1.063	0.000	1.058	0.000
White household			0.100	0.067
Nonurban household			0.085	0.016
Sample size	32,053		31,554	
-2 LL (int. only)	13,221		16,406	
-2 LL (full model)	8,017		11,296	
Chi-Square (sig)	5,206 (<0.000)		5,110 (<0.000)	
McFadden pseudo-R^2	0.182		0.182	

As expected, higher income decreases the likelihood of having a pre-1982 vehicle. The fact that the number of workers in the household is a significant variable, even when income is included in the model, may indicate that households with a higher demand for vehicles to commute are less likely to have older vehicles. When the number of workers was removed from model 1 the pseudo-R^2 went down slightly to 0.180. Two of the variables that were not significant and, therefore, not included in the model, were the number of people aged 16-21 years and the number of people over 65 years old.

Consistent with the descriptive data, larger household size increases the likelihood of having a pre-1982 vehicle. However, the household size variable (# people in household) becomes insignificant when the extra vehicle variable is dropped. Figure 17 helps explain this impact. For households with extra vehicles (more than one per driver), there is no strong relationship between the number of people in the household and the likelihood of having a pre-1982 vehicle. However, for households with one or fewer vehicles per driver, there is a clear increase in the share of households with pre-1982 vehicles as household size increases.

Figure 17: Household Size and Extra Vehicles



Another logit model was run with the same independent variables and the dependent variable of whether the household had a pre-1986 vehicle. The variables were all significant and of the same direction and magnitude as model 1, though the overall explanatory power of the model was less (pseudo-R^2 of 0.136). This is consistent with the descriptive tables in Section 4.3.1 where the relationships were less pronounced for households with pre-1986 vehicles compared to pre-1982 vehicles.

4.3.4 Cluster Analysis

While the data described above reveals some significant tendencies with respect to older vehicle ownership, they also indicate that the ownership of older vehicles is not homogeneous. There isn't one single type of household that owns older vehicles, while all others do not. Therefore, a cluster analysis should help sort out the different types of households that have older vehicles.

The cluster analysis of households with pre-1982 vehicles yielded five distinct clusters using the following variables: number of drivers in the household; number of vehicles in the household; number of workers in the household; whether the household includes one or more retired adults with no children (from the lifecycle variable); the number of children in the household; and the household income (converted to z-scores).[10] Table 33 shows the descriptive data defining the clusters. Most of the households fall into one of three clusters, with the largest being the "retired/single" cluster. The distribution of households by cluster was very similar for the California households in the NPTS sample, with less than a 1.0 percentage point difference in any one cluster.

Table 33: Clusters of Households with pre-1982 Vehicles

Cluster	Mean # drivers	Mean # vehicles	Mean # workers	Mean # children	% Retired	Mean Income	% in cluster
1. Retired/Single	1.42	1.70	0.52	0.13	46.4	$22,455	34.8%
2. 2 adults	2.08	2.70	1.74	0.29	10.0	$49,125	29.8%
3. Family with children	2.03	2.36	1.58	2.58	0.0	$38,585	20.9%
4. 3+ adults	3.46	3.67	3.13	0.86	3.9	$48,480	9.7%
5. Car Collectors	2.40	5.41	1.82	0.62	12.2	$79,105	4.8%

[10] These clustering variables were chosen because of the significant relationships between these household characteristics and vehicle ownership and use found in the literature and the NPTS data. Additional variables were tested, but did not result in significantly different clusters. The cluster analysis was performed using a k-means algorithm to iterate and classify and simple euclidean distances.

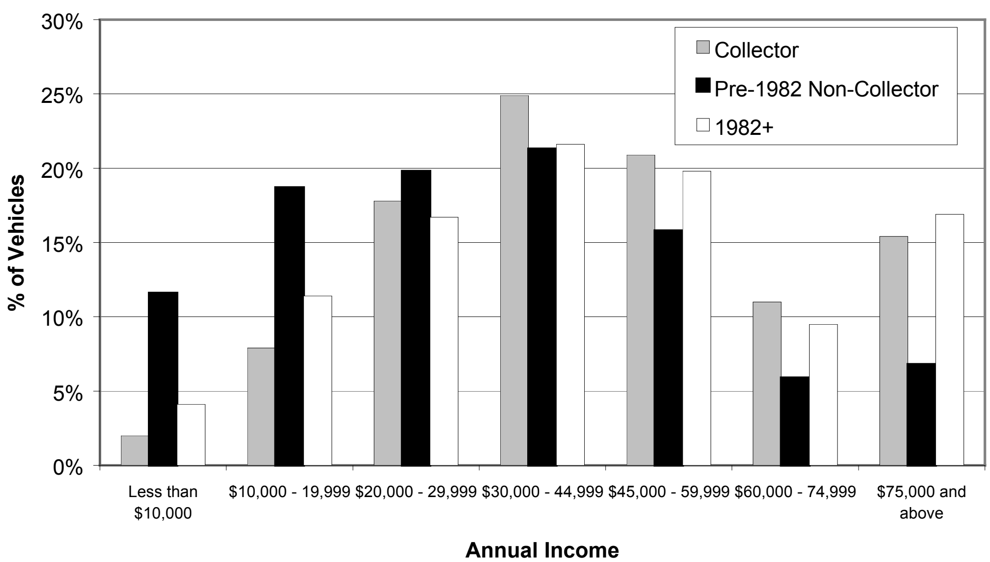
Table 34: Key Characteristics of the Clusters of pre-1982 Vehicle Households

Cluster Name	Key Characteristics
1. Retired/Single	• **Retired and/or single adults:** 46.4% include 1+ retired adults and no children and 25.5% include only one adult and no children • **No children:** 87.7% have no children • **Low incomes:** 76% have incomes under $30,000 • **Fewer workers:** 52.2% have no worker; 44.0% have only one worker • **Small households:** 86.4% have only one or two people • **More African-Americans:** 7.1%, compared to 5.4% overall • **Urban:** 60.4% live in urbanized areas, compared to 55.8% overall • **The older vehicle more likely to be the only vehicle:** 41.4% have only one vehicle, a pre-1982 vehicle
2. 2 adults	• **At least two adults:** 95.6% have two or more adults • **Small households:** 92.3% with 2 or 3 people • **Few with children:** 71.7% have no children and 28.1% have only one child • **Moderate-high incomes:** 48.1% have incomes of $30,000 – 59,999 and 22.1% have incomes $60,000+. • **Workers:** 70.6% have two workers and 25.4% have one worker • **Excess vehicles:** 52.7% have more vehicles than drivers, compared to 42.9% overall.
3. Family with children	• **"Traditional" families:** 93.8% have 2+ adults with the youngest child under age 16. • **Lots of children:** All have at least two children. • **1-2 workers:** 91.1% • **2 drivers:** 76.9% • **Large households:** 96.1% have 4+ people • **Moderate incomes:** 66.4% have incomes $20,000-59,999. • **Moderate # of vehicles:** 11.0% have only one vehicle and 82.7% have 2 or 3 vehicles. Only 36.7% have more vehicles than drivers.
4. 3+ adults	• **Large households:** All have at least three people. 68.9% have 4+ people. • **Several workers:** 59.5% have 3+ workers. Only 16.4% have 1-2 workers. • **More children:** 49.9% have 1-2 children. Only 44.6% have no children, compared to 58.4% overall. • **Moderate-high incomes:** 49.3% have incomes of $30,000 – 59,999 and 23.3% have incomes $60,000+. • **Lots of drivers:** 98.4% have 3+ drivers. • **More vehicles:** 79.1% have 3-4 vehicles and 14.5% have 5+ vehicles. But, only 35.8% have more vehicles than drivers.
5. Car Collectors	• **Lots of vehicles:** All have more vehicles than drivers. All have four or more vehicles. • **At least two adults:** 94.5% have two or more adults • **Few with children:** 61.0% have no children and 22.8% have only one child • **Larger households:** 67.7% have 2-3 people and 28.7% have 4+ people • **High incomes:** 37.0% have incomes $75,000+, 32.7% have incomes $45,000-74,999. • **Caucasian:** 92.5% are white, compared to 89.1% overall • **More rural:** 51.4% live outside an urbanized area, compared to 44.2% overall

4.3.5 Collector Vehicles

The collector vehicles (as defined in Section 4.2.6) are more likely to be found in middle- and higher-income households (Figure 18). Their ownership pattern is closer to that of the newer vehicles than other older vehicles. The collector vehicles are also more likely to be found in white households (92.5%), compared to all vehicles (84.7%). They are also more likely to be in households with a single adult (24.6% versus 16.2% of all vehicles). In terms of lifecycle categories, collector vehicles are found more often (than all vehicles) in households with one adult and no children, one adult and the youngest child age 16-21, 2 or more adults and the youngest child age 16-21, and one retired adult with no children.

Figure 18: Share of Collector Vehicles by Income



Over two-thirds (67.0%) of the collector vehicles are automobiles, compared to 57.6% of the non-collector pre-1982 vehicles. A smaller portion of the collector vehicles are pickup trucks (23.2%) compared to the other pre-1982 vehicles (28.1%), but more than the 1982+ vehicles (16.3%). A small portion (12.2%) of the collector vehicles were purchased new, compared to 18.2% of the other pre-1982 vehicles and 51.6% of the newer vehicles. As one might expect, Fords are the most popular collector vehicle (34.0% versus 21.8% of other pre-1982 vehicles). This is followed by Chevrolets, which make up 26.8% of the collector vehicles and 26.8% of the other pre-1982 vehicles. In other words, Chevrolets don't appear to be as collectible as Fords. A few other makes are found disproportionately among the collector vehicles, though each makes up less than five percent of the vehicles: American Motors, Jeep, Plymouth, Cadillac, Volkswagen, Mercedes Benz, and Porsche.

4.4 Who Drives Older Vehicles?

4.4.1 "Main" Drivers

The NPTS survey asked whether one household member "usually" drives each vehicle. Overall, 91.2% of the vehicles have a "main driver." The share of vehicles with main drivers does vary by model year. Only 85.9% of the pre-1982 vehicles, 87.9% of the pre-1986 vehicles, 92.4% of the 1986 and newer vehicles have main drivers. In other words, older vehicles are more likely to be shared by multiple drivers. There are two likely reasons for this: (1) some older vehicles are "extra" vehicles in the household, used when newer vehicles are unavailable (e.g. being fixed) or not well-suited for the task (e.g. older trucks used for hauling); and (2) older vehicles in lower income households may be used regularly by several drivers. The former explanation appears most prevalent. Of the pre-1982 vehicles without a main driver, 68.9% are in households with more vehicles than drivers, compared to 45.9% of the pre-1982 vehicles with main drivers. The pre-1982 vehicles without main drivers are also more likely to be in higher income households – 38.7% are in households with incomes of $45,000 or more, compared to 28.3% of the pre-1982 vehicles with main drivers.

The data that follows describe only the vehicles with main drivers and those main drivers.

4.4.2 Descriptive Data

Older vehicles are slightly more likely to be driven by people over 65 compared to all household vehicles (Table 35). The average age of a main driver of a pre-1982 vehicle is 47.6, compared to 44.4 for newer vehicles. Consistent with the age distribution, older vehicles are also more likely to be driven by retired persons (Table 36). However, the differences in the age distribution of main drivers is not consistent across all income groups. Table 37 shows that within the lowest and highest income categories, the vehicles are more likely to be driven by people over 65 years. However, the pattern does not hold or is very weak in the middle income categories. Since 14.4% of the main drivers over 65 years have household incomes under $10,000, compared to 4.9% of all the main drivers, the influence of income on older vehicle use contributes to the differences in age distribution.

Table 35: Distribution of U.S. Household Vehicles by Age of Main Driver

	pre-1982 vehicles	pre-1986 vehicles	All Vehicles
16 – 25 years	9.9%	11.0%	10.9%
26 – 45 years	40.1%	40.9%	45.4%
46 – 65 years	31.0%	30.8%	30.7%
66 – 75 years	12.1%	11.3%	9.2%
Over 75 years	6.9%	6.0%	3.8%
	100.0%	100.0%	100.0%
n	6,083	14,293	60,597

Source: 1995 NPTS weighted household data

Table 36: Distribution of U.S. Household Vehicles by Employment Status of Main Driver

	pre-1982 vehicles	pre-1986 vehicles	All Vehicles
Full-time	57.6%	56.9%	61.0%
Part-time	9.0%	11.0%	11.9%
Not at all	13.8%	14.2%	13.4%
Retired	19.6%	17.8%	13.7%
	100.0%	100.0%	100.0%
N	6,039	14,198	60,242

Source: 1995 NPTS weighted household data

Table 37: Share of Older Vehicles Driven by People over 65, by Income

	% of vehicles within income group driven by people over 65	
Household Income	**Pre-1982**	**All vehicles**
Less than $10,000	42.3%	35.2%
$10,000 - 14,999	29.9%	29.3%
$15,000 - 19,999	26.7%	27.0%
$20,000 - 29,999	15.1%	16.4%
$30,000 - 44,999	9.5%	8.6%
$45,000 - 59,999	5.1%	4.8%
$60,000 - 74,999	6.7%	4.2%
$75,000 and above	9.6%	4.8%
N	6,039	14,198

Source: 1995 NPTS weighted household data

Older vehicles are far more likely to be driven by men. While 51.7% of all vehicles with main drivers are driven by men, 72.7% of the pre-1982 and 65.3% of the pre-1986 vehicles are driven by men. The women driving older vehicles are more likely to be over 65 years of age. About 30% of the pre-1982 vehicles driven by women are driven by women over 65, compared to only 15% of the pre-1982 vehicles driven by men.

Older vehicles are also more likely to be driven by people with a high school diploma or less (Table 38). This is consistent with the income data presented above.

Table 38: Distribution of U.S. Household Vehicles by Education of Main Driver

	pre-1982 vehicles	pre-1986 vehicles	All Vehicles
Less than high school graduate	19.9%	17.5%	10.5%
High school graduate, including GED	37.5%	36.7%	32.7%
Some college, but no degree	20.0%	21.2%	22.1%
Associate degree	4.1%	4.7%	5.5%
Bachelor's degree	10.7%	11.5%	17.1%
Some graduate/ professional school	1.7%	1.7%	2.4%
Graduate/professional school degree	5.9%	6.7%	9.6%
	100.0%	100.0%	100.0%
n (unweighted)	6,032	14,197	60,251

Source: 1995 NPTS weighted household data

4.4.3 Collector Vehicles

Only 71.6% of the collector vehicles have a main driver. These main drivers are mainly men (87.8%) and most likely to be 46-75 years old. Over half (52.9%) are in this age range, compared to 42.3% of the pre-1982 vehicles that are not collector vehicles.

4.5 How are Older Vehicles Used?

4.5.1 Literature Review – Vehicle Travel

The negative relationship between vehicle age and annual mileage is well-documented (Kockelman & Zhao, 2000; Lave, 1996; Pickrell & Schimek, 1999; Pisarski, 1996). Pickrell and Schimek propose two explanations for this relationship and suggest that both models are at work. One assumes that people drive older vehicles less because the vehicles are older. The other explanation (actually put forth by Charles Lave, cited by Pickrell and Schimek) is that households that drive a lot purchase new vehicles frequently and "wear them out," while households with lower travel demands keep vehicles longer.

In other words, the household's demand for travel determines the age of their vehicles, rather than the other way around. While examining multiple-vehicle households in California, Golob et al (1996) concluded that vehicles would be driven less as they age if there were no vehicle transactions in the household.

The relationships between vehicle travel and various household and vehicle characteristics found in the research literature is summarized in Table 39. These findings are useful in selecting variables to examine with respect to older vehicle use. Researchers have also explored how vehicles are used in multiple-vehicle households. Some of this research was motivated by energy issues and explored whether vehicle efficiency and fuel price influenced vehicle use within a household (see, for example, Mannering, 1983). Within a multiple-vehicle household, each vehicle's use is impacted by the attributes and use of the other vehicles. Modeling this process is complicated in that there are several ways the decision can be made: (1) households match the vehicle attributes with the trip purpose or activity (e.g. vehicles with larger cargo capacity for major shopping trips); (2) members of the household bargain among themselves for access to certain vehicles; and (3) some household members may "own" or have priority for certain vehicles in the household (Mannering & Train, 1985).

Using data from California, Golob et al (1996) explored the use of two vehicles within a household, as a function of household, driver, and vehicle characteristics. With respect to vehicle age, they found that (1) the negative relationship between vehicle age and mileage was stronger for the older vehicle of the two vehicles modeled; (2) men were more likely to drive the older vehicle and (3) employed persons were more likely to drive the newer vehicle.[11] The first of these relationships is examined in the next section. The second was confirmed above. The data shown above also indicated that employed persons were *less* likely to drive older vehicles. However, this reflects the higher ownership of older vehicles among single-vehicle, retired households. The relationship between older vehicle use and commuting to work within different types of households, including those with multiple vehicles, is examined below.

Mannering (1983) developed a simultaneous equation model to model monthly VMT of each vehicle in a two-vehicle household. He did not include vehicle age as a dependent variable, but did include the probability of a vehicle being scrapped during the one-year time period as a variable. The variable was based on the theory that a vehicle will be scrapped if its market value drops below its scrappage value and was intended to account for expected vehicle downtime and reliability. Vehicles of lower value (in dollars), which would include most older vehicles, would have a higher scrappage probability. The variable did have a significant negative coefficient. As expected, he also found that the increased use of one vehicle decreased the use of the second vehicle.

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[11] "Older vehicle" here simply refers to the older of the two vehicles, and does not refer to absolute age or model year.

Table 39: Summary of Research on the Relationship between Household and Vehicle Characteristics and Vehicle Miles Traveled (VMT) per Vehicle

Relationship/Variables	Source(s)
Increased VMT (per vehicle) associated with:	
↑ Income	(Golob et al., 1996) (Mannering & Winston, 1985) (De Jong, 1996) (Pickrell & Schimek, 1999) (Train, 1986) (Kockelman & Zhao, 2000)
↑ # of workers in household or driver is worker	(Golob et al., 1996) (Mannering & Winston, 1985) (De Jong, 1996) (Train, 1986) (significant in one-vehicle households, not two-vehicle households)
↑ # people in household	(Train, 1986) (significant in one-vehicle households, not two-vehicle households)
↑ # people per vehicle in household	(Kockelman & Zhao, 2000)
↑ # of 16-20 year-olds in household	(Golob et al., 1996)
↑ # adults in household	(Pickrell & Schimek, 1999)
↑ # children in household	(Pickrell & Schimek, 1999)
↓ age of heads of household	(Golob et al., 1996) (Mannering & Winston, 1985)
Vans, pickups, SUVs, trucks	(Pickrell & Schimek, 1999) (Kockelman & Zhao, 2000)
↑ Education	(De Jong, 1996)*
Decreased VMT (per vehicle) associated with:	
Retired households	(Golob et al., 1996)
↑ driver age	(Mannering, 1983) (De Jong, 1996)*
Urban area/↑ density	(Mannering & Winston, 1985) (Mannering, 1983) (Pickrell & Schimek, 1999) (Kockelman & Zhao, 2000)
↑ transit use in area	(Train, 1986) (significant only for two-vehicle households)
Northeast U.S.	(Mannering & Winston, 1985) (Train, 1986)**
Female driver	(Mannering, 1983) (De Jong, 1996)*
↑ # vehicles in household	(Pickrell & Schimek, 1999)

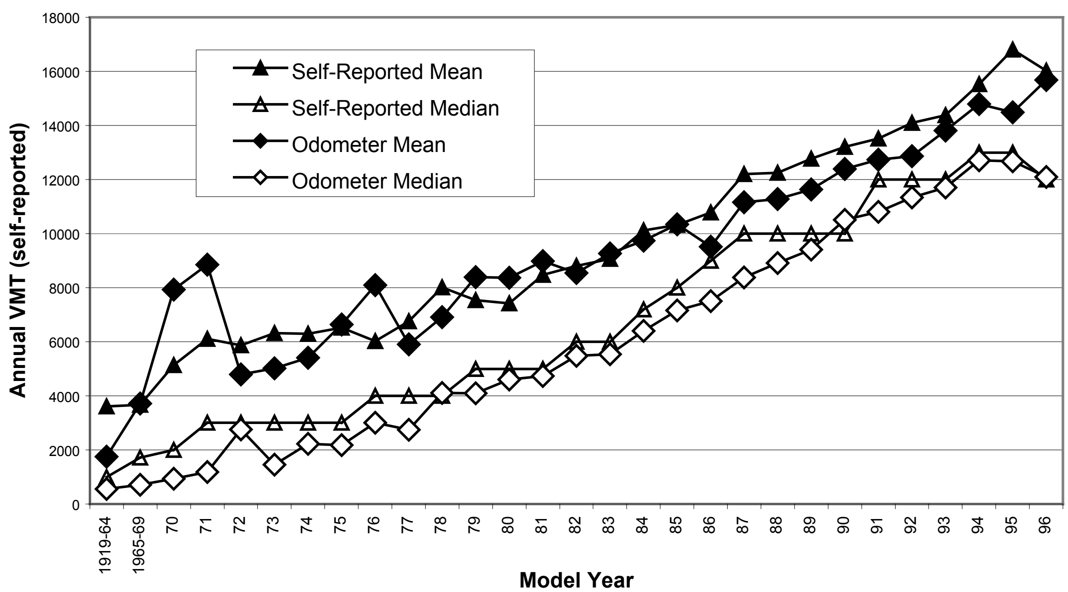
*Dutch households

** Variable included in model, but t-statistic was not significant

4.5.2 Annual mileage

As explained in Chapter 3, the 1995 NPTS collected estimates of annual vehicle miles traveled (VMT) for each vehicle from the household ("self-reported"), as well as odometer readings for a portion of the vehicles. These odometer readings were then used to estimate annual vehicle mileage. When possible, both measures are included here. Consistent with the literature, there is a negative relationship between vehicle age and annual mileage among the 1995 NPTS household vehicles (Figure 19).

Figure 19: Annual Mileage by Model Year



Also of note is the difference between the mean and median figures, indicating a positively skewed distribution and the presence of some high outliers in most model years. The difference between the mean and median decreases as vehicle age decreases. There are also larger relative standard deviations around the means for the older vehicles (Table 40). For 1986 and newer vehicles, the standard deviations are smaller than the means for both self-reported and odometer-based mileage estimates. For the older vehicles, the standard deviation can be up to twice the size of the mean. This indicates a far greater degree of variance in the use of older vehicles and confirms Hsu and Sperling's concern over the wide variance in older vehicle use when calculating emissions reductions. It also indicates that older vehicles may play a greater variety of roles in households, ranging from a collector car kept only for show, to a high-mileage vehicle driven to work, shop, etc. every day.

Table 40: Mean Annual Mileage by Vehicle Age

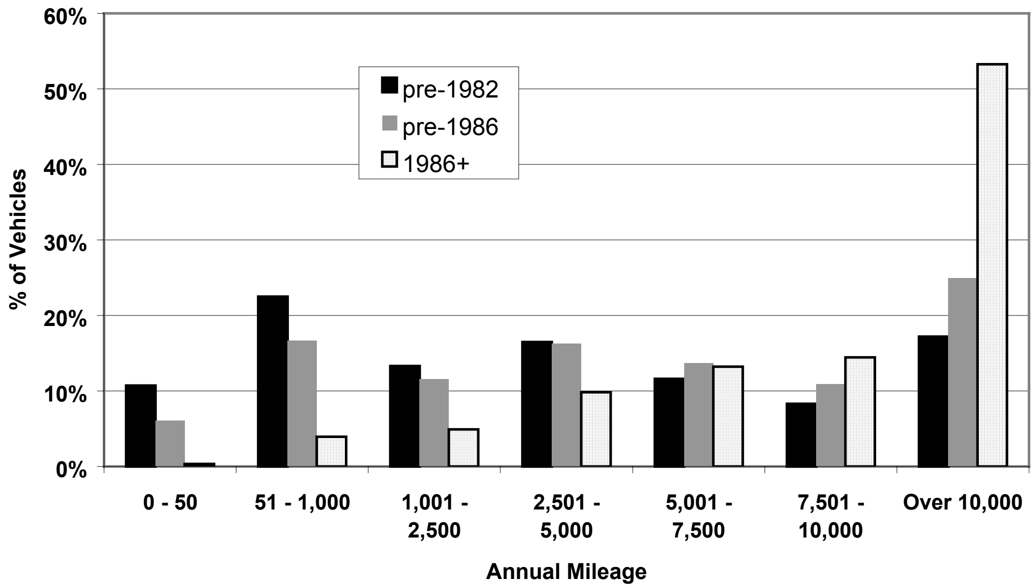
	Self-Reported		Odometer-based	
Model Years	**mean**	**std. dev.**	**mean**	**std. dev.**
1969 and older	3,708	7,586	3,181	9,411
1970-81	7,380	10,425	7,564	15,370
1982-85	10,010	10,854	9,794	14,062
1986-93	12,963	11,388	12,066	11,113
1994 & newer	16,085	14,417	15,712	10,942

Source: 1995 NPTS weighted household data.
Motorcycles, RVs, other trucks, and other vehicles excluded, about 2% of the vehicles.

The other point evident in Figure 19 is that the self-reported mileage is consistently higher than the odometer readings for MY86 and later, but there is no consistent pattern for older vehicles. One conclusion would be that the more people drive, the more they tend to overestimate their travel. There are also some very high odometer-based mileage estimates for the MY1970 and 1971 vehicles that pull the mean higher than most of the other 1970s model years.

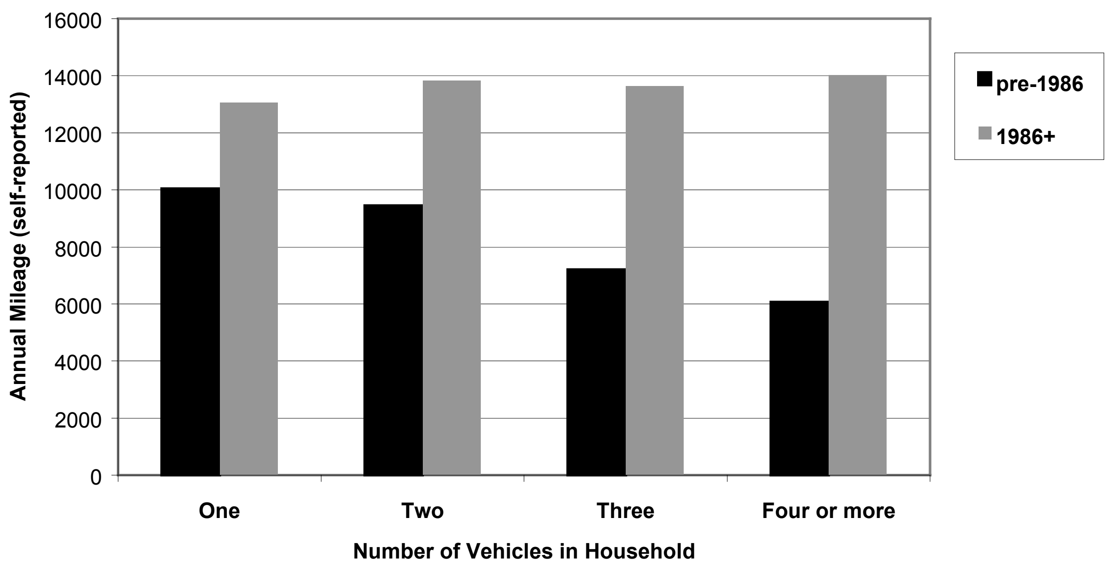
According to the odometer-based mileage estimates, over ten-percent of the pre-1982 vehicles are driven 50 or fewer miles per year (Figure 20). The self-reported mileage figures have 5.4% of the vehicles in this category (not shown in the figure). In contrast, less than one-percent of the newer vehicles travel so few miles (odometer-based). At the other end of the scale, half of the newer vehicles travel over 10,000 miles per year, compared to only 17.2% of the pre-1982 vehicles and 25.0% of the pre-1986 vehicles. The relatively even distribution of older vehicles among the mileage categories further supports the hypothesis that older vehicles are used for a greater variety of roles in households. Most newer vehicles are driven a lot; older vehicles vary much more.

Figure 20: Distribution of Older and Newer Vehicles by Mileage (odometer-based)



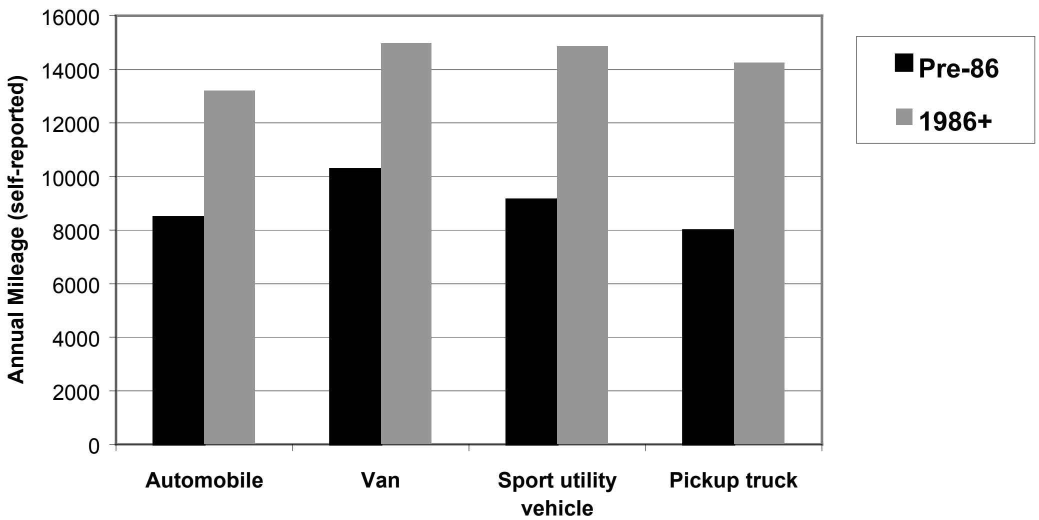
The literature indicated that vehicles in households with more vehicles were driven less. Vehicle age may be a factor here. We know that households with more vehicles are more likely to have older vehicles (Section 4.3.2.3). The negative relationship between annual mileage and vehicle age is strongest in households with three or more vehicles. The Pearson correlation coefficient between annual self-reported mileage and vehicle age is –0.28 for households with three or more vehicles, -0.20 for households with two vehicles, and –0.13 for one-vehicle households. In addition, older vehicles in households with more vehicles are driven less. The mean self-reported annual mileage for pre-1982 vehicles was 9,643 for one-vehicle households, 7,818 for two-vehicle households, 5,605 for three-vehicle households, and 4,669 for vehicles with four or more vehicles. This supports the hypothesis that older vehicles in households with lots of vehicles are more likely to be “extra” vehicles not used as the primary means of transportation in the household. Figure 21 further supports this hypothesis. The annual mileage for 1986 and newer vehicles actually increases slightly as the number of household vehicles increases, while the annual mileage for pre-1986 vehicles falls significantly when there are three or more vehicles in the household. Therefore, the negative relationship between annual vehicle mileage and number of household vehicles appears to be related to the presence of older vehicles.

Figure 21: Older Vehicles, Annual Mileage, and Number of Vehicles in Household



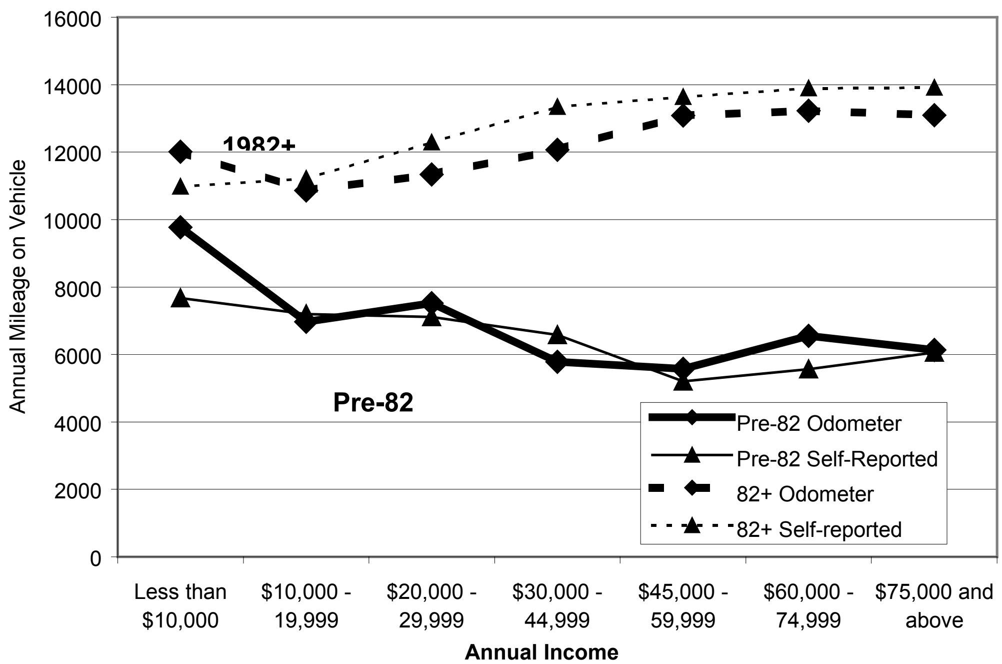
Using the 1995 NPTS data in a regression model, Pickrell and Schimek (1999) found that vans, SUVs, and pickups were driven more than automobiles. However, they did note that the declining use of pickups with increasing age was more pronounced than for automobiles. This is also seen in Figure 22. Pre-1986 pickup trucks are actually driven slightly less than pre-1986 automobiles, while the older vans and SUVs are driven more. Pickup trucks can uniquely serve certain types of trips—those requiring cargo space. Households may hold on to pickup trucks longer to serve these trips, while their other travel needs are served by newer vehicles.

Figure 22: Older Vehicles, Annual Mileage, and Vehicle Type



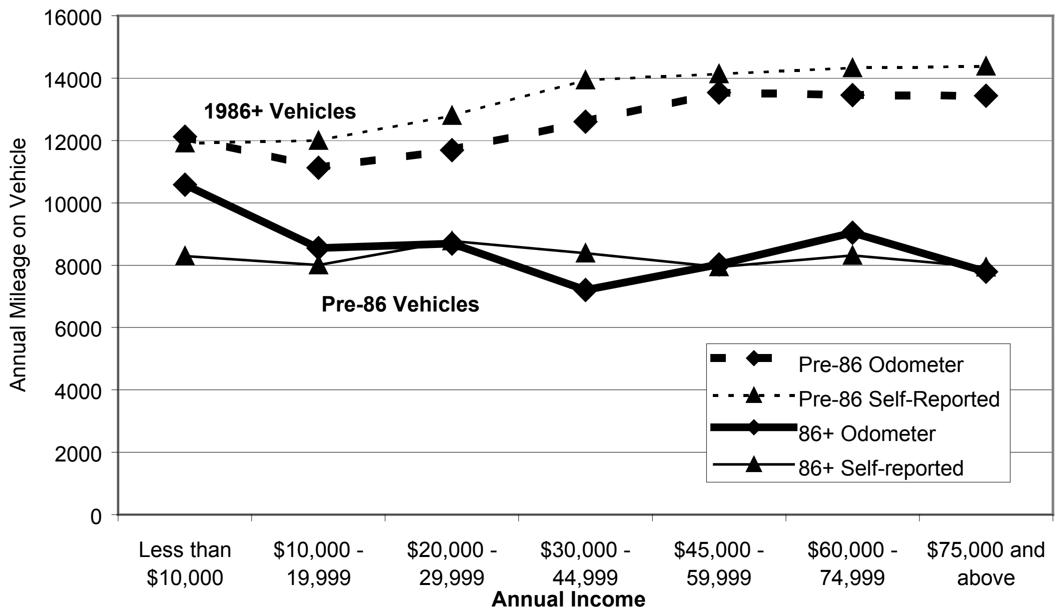
Income is another variable commonly associated with vehicle travel. Higher income households generally drive more than lower income households. Part of this is related to higher levels of employment and, therefore, more commute trips. However, there are differences depending upon vehicle age. Figure 23 shows that mileage in pre-1982 vehicles actually falls as income rises, while mileage in 1982 and newer vehicles increases. This indicates that the older vehicles in higher income households are more likely to be the "extra" vehicles. Lower income households are more likely to rely on their older vehicles for a larger share of their travel needs. The relationship between mileage and income for pre-1986 versus 1986+ vehicles is similar, but not as pronounced (Figure 24). Households with incomes under $10,000 have 9.4% of the pre-1982 vehicles, but drive 12.7% of the mileage driven in pre-1982 vehicles. At the upper end, households with incomes of $75,000 and above have 8.0% of the pre-1982 vehicles and drive only 6.7% of the pre-1982 vehicle mileage.

Figure 23: Annual Mileage of pre-1982 Household Vehicles by Income



Source: 1995 NPTS weighted household data

Figure 24: Annual Mileage of pre-1986 Household Vehicles by Income



Source: 1995 NPTS weighted household data

Table 41 presents the results from two sets of regression models, with annual mileage for a vehicle (either self-reported or odometer-based) as the dependent variable. Each model is predicting travel for a single vehicle, not total household travel. The models are similar to those developed by Pickrell and Schimek (1999) to explain vehicle usage. The dependent variables are in natural logarithmic form. The continuous explanatory variables (income and population density) are also in natural logarithmic form, so that their estimated coefficients represent the percentage change in annual VMT with a 1% change in the value of those variables. The coefficients for the categorical or "count" variables (e.g. number of vehicles) represent the percentage change in VMT associated with an increase of one in the value of that variable. Models 1a and 2a are for pre-1982 vehicles and models 1b and 2b are 1982 and newer vehicles. The models only include automobiles, pickup trucks, SUVs, and vans. Motorcycles, RVs, larger trucks, and other vehicle types are omitted. The adjusted R-squared for each model indicates that the variables only explain from six to 12 percent of the variation in the mileage data.

There are some notable similarities and differences between the models. In both pairs, the impact of vehicle age is similar – each one year increase in vehicle age leads to a five to seven percent decrease in annual mileage. In addition, the impact of the household having one or more retired adults with no children ("retired") is similar within the two pairs of models. In all of the models, a higher number of vehicles in the household is associated with lower usage of the particular vehicle. However, the impact is significantly more for the pre-1982 vehicles, where each additional vehicle in the household decreased annual use of a single pre-1982 vehicle by over 20%, compared to 7-10% for the newer vehicles. The number of children is associated with increased vehicle use, though the coefficients are about twice as large for the older vehicles. In addition, the relationship is more pronounced in the models using the odometer-based mileage estimates. A similar pattern exists for the number of adults variable – more adults is associated with more travel, particularly for older vehicles.

Table 41: Vehicle Usage Models – Regression Results

	Self-Reported Mileage (ln)				Odometer-based Mileage (ln)			
	Model 1a Pre-1982		Model 1b 1982+		Model 2a Pre-1982		Model 2b 1982+	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.
Constant	9.12	0.00	8.15	0.00	10.56	0.00	8.98	0.00
vehicle age	-0.055	0.00	-0.049	0.00	-0.066	0.00	-0.072	0.00
# vehicles in household	-0.21	0.00	-0.098	0.00	-0.27	0.00	-0.068	0.00
retired household	-0.44	0.00	-0.49	0.00	-0.58	0.00	-0.62	0.00
# of children	0.076	0.00	0.037	0.00	0.25	0.00	0.12	0.00
# adults	0.15	0.00	0.037	0.00	0.30	0.00	0.084	0.00
population density (ln)	0.006	0.60	-0.045	0.00	-0.025	0.27	-0.072	0.00
income (ln)	0.009	0.78	0.15	0.00	-0.079	0.20	0.088	0.00
white household	0.032	0.66	0.11	0.00	-0.65	0.00	-0.081	0.00
Pickup	0.13	0.01	-0.012	0.38	-0.056	0.55	-0.056	0.00
Van	0.30	0.00	0.057	0.00	-0.086	0.66	0.088	0.00
N	5,064		46,759		1,785		24,375	
Adj. R sq.	0.102		0.063		0.128		0.129	

Source: 1995 NPTS household data

The remaining five variables are not significant in all of the models. Increased population density at the block group level is associated with less mileage in newer vehicles, but the variable is not significant for older vehicles. Population density may also indicate the level of transit service, which tends to be higher in higher density neighborhoods. The fact that density, and perhaps transit availability, does not appear to affect older vehicle use may support the hypothesis that a portion of the older vehicles are "extra" vehicles and collector vehicles, not used for primary travel. Such vehicles would be driven less, but their mileage may not be associated with any of the variables in the model, except, perhaps, the number of vehicles in the household. Consistent with Figure 23, income has a significant positive impact on travel in newer vehicles. The income coefficients in the pre-1982 vehicle models are not significant. Again, this supports the notion that older vehicles are unlike newer vehicles and serve unique roles in the household – some may be collector vehicles, others are extras used for special purposes or emergencies, and others may be used for daily travel. Whereas, newer vehicles are more likely to be used for daily travel and the level of use is more directly influenced by factors such as income.

The variable representing white households is significant in three of the models, though the coefficients are inconsistent. White households are linked to more travel in newer vehicles when the vehicle mileage is reported by the household, but less travel when mileage was estimated using odometer readings. The coefficient for the model 2a (pre-1982, odometer-based mileage) is also negative and significant, but it is not significant for the self-reported mileage in older vehicles. The odometer-based models indicate that white households drive their older vehicles significantly less than households of other races. This may indicate that white households are more likely to have older collector or extra vehicles. One problem with this variable may be the lack of non-white households with odometer-based mileage estimates; there are only 192 pre-1982 vehicles in non-white households with odometer-based mileage estimates. In addition, there are large differences between the mean self-reported mileage and odometer-based mileage for non-white households, while white households are fairly close. Older vehicles in white households are driven an average of 6,203 miles (self-reported) and 6,538 miles (odometer-based) per year (Table 42). Older vehicles in non-white households are driven 13,160 and 8,581 miles per year, respectively. Though the huge difference in self-reported versus odometer-based mileage is problematic, both figures are significantly higher than for white households. The difference in annual mileage for newer vehicles is not nearly as large, though newer vehicles in non-white households are driven more according to both mileage estimates.

Table 42: Annual Mileage per Vehicle by Vehicle Age and Household Race

		Pre-1982 vehicles		1982+ vehicles	
		Self-Rptd	**Odometer**	**Self-Rptd**	**Odometer**
White	mean	6,538	6,203	13,054	12,102
	std. dev.	9,849	13,074	11,718	11,115
	n	5,523	2,071	50,864	26,818
Non-White	mean	8,581	13,160	13,325	13,818
	std. dev.	11,834	23,577	14,134	15,112
	n	580	192	5,164	2,113

Source: 1995 NPTS weighted household data, n is unweighted

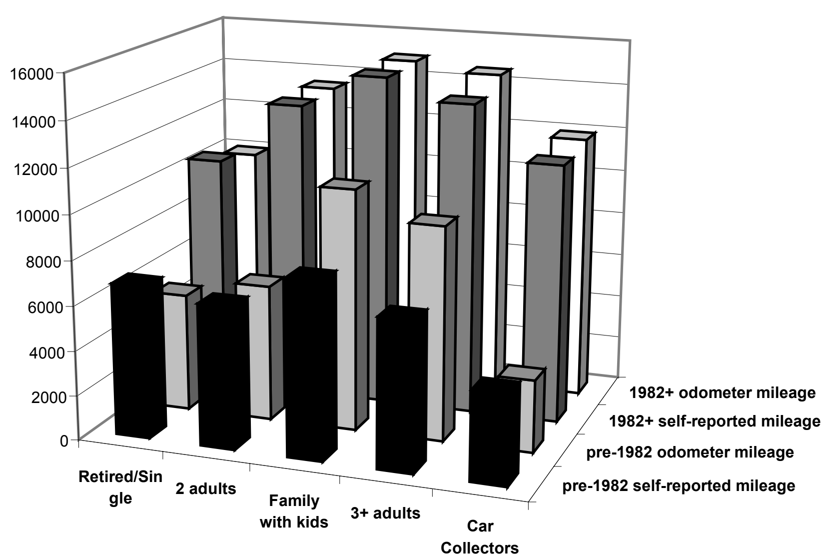
With respect to vehicle type, pickup trucks and vans are significant variables in some of the models (Table 41). An SUV variable was not significant in any of the models and was omitted. Older pickup trucks are driven more than other types of older vehicles in the self-reported mileage model, but the variable is not significant in the odometer-based mileage model. When the coefficient is significant, it indicates that vans (including mini-vans) are driven more than other vehicle types. This is particularly so for the older vans with self-reported mileage. The fact that the van coefficient is not significant for the odometer-based pre-1982 model may be due to the lack of data; there are only 104 pre-1982 vans with odometer-based mileage estimates, but 302 with self-reported mileage. It also may indicate that older van owners over-estimate their mileage.

There are significant differences in annual mileage between the different clusters of pre-1982 vehicle households (Table 43 and Figure 25). As one would expect, car collectors drive their older vehicles the least, about half as far as the other household drive their pre-1982 vehicles. These households also have the greatest discrepancy in vehicle mileage between the older and newer vehicles, indicating that the older vehicles in these households are extra or collector vehicles; they are not driven less just because these households drive less. The retired/single households have the smallest difference between vehicle mileage in older and newer vehicles, at least for the self-reported mileage. This makes sense, since half of these households only own pre-1982 vehicles and, therefore, can't make trade-offs between vehicles. The families with children drive both their older and newer vehicles the furthest. The standard deviations for these mean mileage figures still indicate greater variance for the older vehicles, even within the household groupings.

Table 43: Annual Mileage by pre-1982 Vehicle Household Clusters

		Pre-1982		1982+	
Cluster		**self-rptd**	**odometer**	**self-rptd**	**odometer**
1. Retired/Single	mean	6,805	5,289	10,530	9,982
	(std. dev.)	(11,949)	(10,992)	(9,264)	(11,741)
2. 2 adults		6,332	6,099	13,357	13,431
		(8,589)	(12,030)	(12,730)	(13,157)
3. Family with children		7,866	10,787	14,891	14,955
		(10,373)	(19,466)	(14,343)	(12,285)
4. 3+ adults		6,661	9,551	13,970	14,569
		(9,043)	(19,723)	(14,402)	(14,766)
5. Car Collectors		3,963	3,224	11,592	11,895
		(7,366)	(6,764)	(13,805)	(10,055)

Figure 25: Annual Mileage by Household Cluster



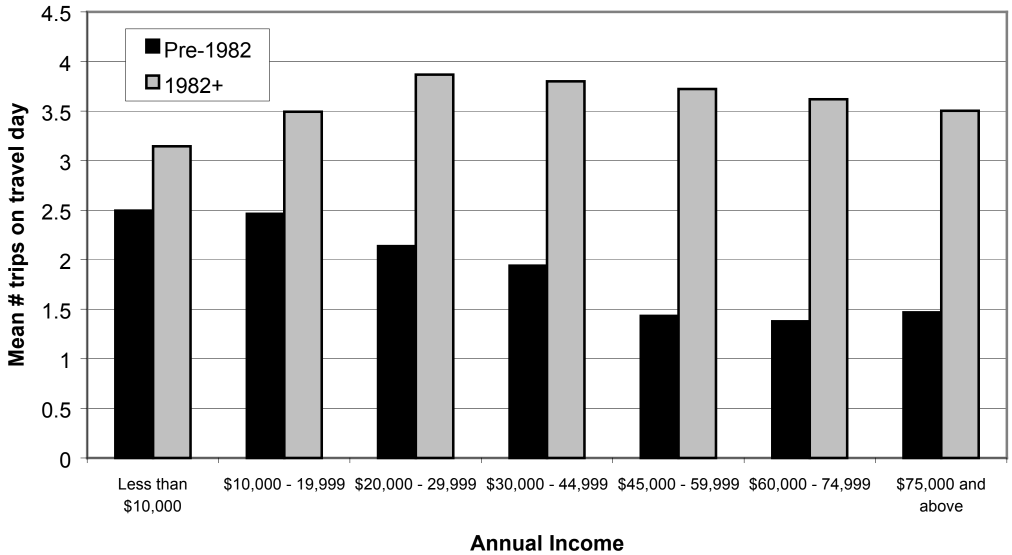
4.5.3 Trips

Pre-1982 vehicles made an average of 1.93 trips[12] (s.d. = 2.88) on the NPTS travel day, compared to 3.56 (s.d. = 3.42) trips for newer vehicles. Over half (55.4%) of the pre-1982 vehicles didn't make a trip on the travel day, while only 28.3% of the newer vehicles were inactive on the travel day. Pre-1982 vehicles made 7.4% and pre-1986 vehicles made 19.9% of all the vehicle trips made by household vehicles. These vehicles represent 13.1% and 27.5% of the household vehicle population, respectively. This confirms the hypothesis that older vehicles are more likely to be extra vehicles that are used less by households.

As with annual mileage, lower income households are more likely to rely on their older vehicles for daily trips (Figure 26). Pre-1982 vehicles in households with incomes under $10,000 made an average of 2.50 trips on the travel day, compared to 3.15 trips for newer vehicles. The difference in trip rates per day increases with income. As income rises, the number of trips made by older vehicles declines. The pre-1982 vehicles in households with incomes of $45,000 or more make only about 1.4 trips per day, while newer vehicles in these households make at least 3.5 trips per day. At least 64.0% of the pre-1982 vehicles in households with incomes of $45,000 or more did not make a trip on the travel day, compared to 45.0% of the older vehicles in the lowest income households.

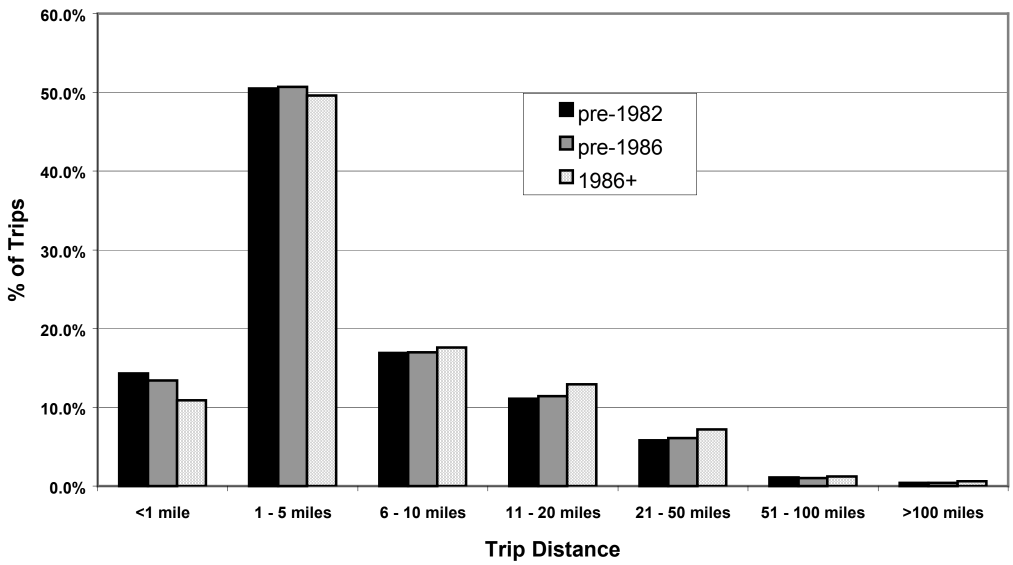
[12] The 1995 NPTS includes data on every person trip (regardless of mode) made by the household members. Only vehicle trips—trips made in privately operated vehicles—are considered here. Each link of a trip is a separate trip. A link begins or ends if the mode of travel changes or if the purpose changes. For example, if a person drives to work, but stops at the gym to exercise along the way, that would count as two trips. Therefore, most trips are "one-way." The only exception would be if the person left and returned to the same location without stopping or changing modes, e.g. taking a walk around the block.

Figure 26: Number of Trips per Day by Income and Model Year



Trips made in pre-1982 vehicles averaged 7.6 miles (median 4.0, s.d. 15.3). Trips in pre-1986 vehicles were 7.8 miles (median 4.0, s.d. 17.2), while trips in 1986 and newer vehicles were 9.0 miles (median 4.0, s.d. 21.4). These differences are not nearly as large as the difference in annual mileage. Trips in older vehicles are slightly more likely to be five mile or less (Figure 27). A few factors may contribute to this (not in order of significance). First, households may feel that the older vehicle is less reliable or comfortable and they choose to use a newer vehicle for longer trips, if available. Second, the households that use older vehicles more may make shorter trips. This could be a factor of the driver or household characteristics (e.g. more retired people, lower incomes). One explanation is probably not geography. Older vehicles are found more often outside urbanized areas and in less dense areas, where vehicle trip lengths are longer.

Figure 27: Distribution of Older and Newer Vehicle Trips by Distance



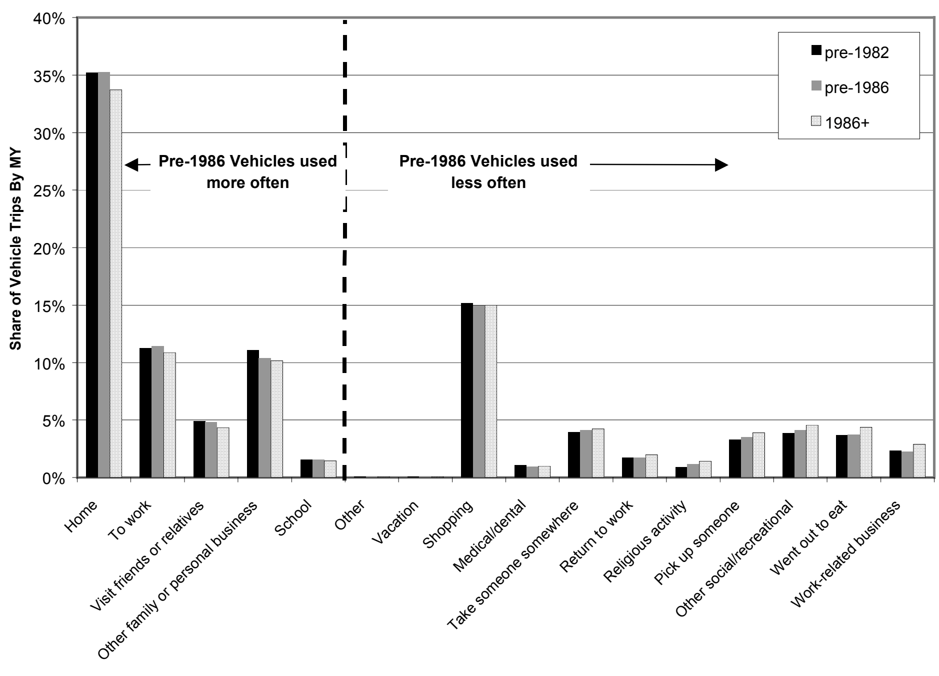
The significance of trip length for air quality is that per mile, the shorter trips can produce more pollution, because they are operating under cold (or hot) start conditions for a larger share of the trip mileage. However, the cold starts are not as significant of a problem for vehicles without catalytic converters, generally pre-1975. Older vehicle trips are also slower, which can increase emissions. The average speed[13] is 24.3 miles per hour (mph) for trips in pre-1982 vehicles, 25.0 mph for trips in pre-1986 vehicles, and 27.0 mph for trips in 1986+ vehicles. This is directly related to the differences in trip distance. Shorter trips are more likely to occur on neighborhood streets with slower speed limits and more intersections. These conditions can also increase emissions.

Older vehicles are generally used for the same types of trips as newer vehicles, with some slight differences. Figure 28 shows the distribution of household vehicle trips by model year among the trip purposes. Aside from returning home, shopping is the most popular trip purpose – 15.1% of the pre-1982, 14.9% of the pre-1986, and 15.0% of the

[13] Calculated by dividing the trip distance by time. 60 mph maximum applied.

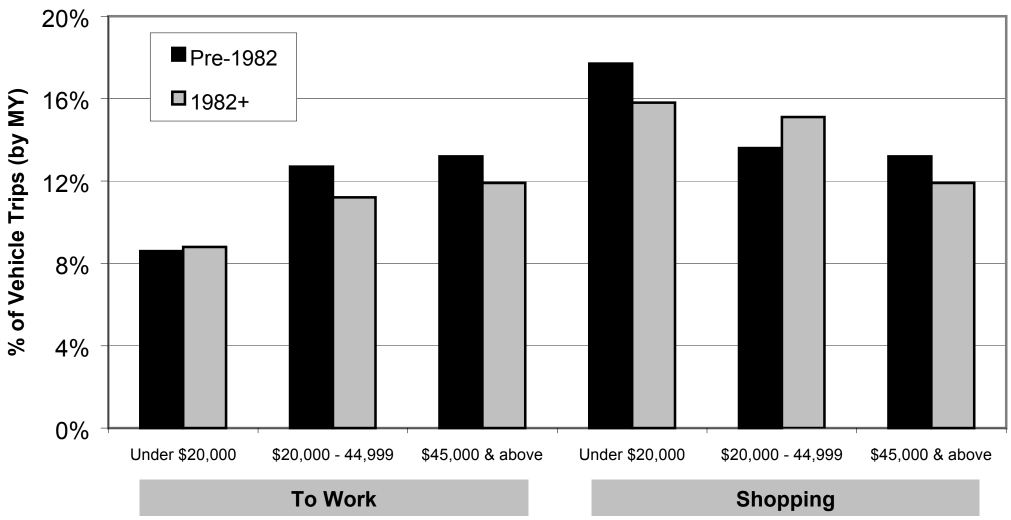
1986+ vehicle trips were for shopping. A slightly higher share of the older vehicle trips were to work—11.3% of the pre-1982, 11.4% of the pre-1986, and 10.9% of the 1986+ vehicle trips. While these differences are statistically significant, the absolute differences are not very large. Remember that over half of the pre-1982 vehicles were not driven at all on the travel day. Therefore, the older vehicle trips that were captured by the NPTS are more likely to be by the people who use the vehicles more frequently. These are probably the people who would use them like they would use a newer vehicle, rather than for specific, more limited purposes.

Figure 28: Trip Purpose by Vehicle Age



There are some differences in trip purposes by income. Figure 29 shows the share of older and newer vehicle trips that were to work or shopping by income category. For the lower income households, pre-1982 and newer vehicle trips are about equally likely to be trips to work. In contrast, in the higher income categories, the older vehicle trips are more likely to be for commuting to work. This may seem counterintuitive. However, remember that higher income households have more vehicles to choose from when making a trip. They may choose the older, lower-value vehicle for the predictable work trip, not worrying about leaving it all day on the street or parking lot (Pisarski, 1996). For shopping trips, a different pattern emerges. For trips made by the lowest and highest income households, a higher share of the pre-1982 vehicle trips are for shopping than the 1982-and-newer vehicle trips.

Figure 29: Work and Shopping Trips in Older Vehicles by Income



One hypothesis is that older vehicles play a variety of roles in households (including collector vehicle and extra vehicle), while newer vehicles are more all-purpose. This hypothesis has already been supported by the more even distribution of annual mileage among older vehicles. The overall distribution of trips by purpose did not shed much light on the roles older vehicles might play. However, it is more likely that the different roles the older vehicles play are related to the household characteristics. This theory was already supported by the differences in annual mileage for different numbers of household vehicles. The clusters of pre-1982 vehicle households may help support this hypothesis.

Figure 30 and 31 show the share of all trips made in pre-1982 vehicles (black bars) for each household cluster, along with the share of trips by trip purpose made by pre-1982 vehicles. The eight most frequent trip purposes are included. Two trip purposes were combined: take someone somewhere and pick up someone. The car collector cluster is not included because of the small number of trips made in pre-1982 vehicles for these households (327 total). The car collector households made the smallest share of their trips in pre-1982 vehicles (14.9%). This is consistent with the hypothesis that some of the their vehicles are collector cars and trucks that are driven infrequently.

The figures show that the 3+ adult households are using their pre-1982 vehicles at about the same rate for the eight trip purposes as for all trips. About one-quarter of all of their vehicle trips are made in pre-1982 vehicles. The share for the eight trip purposes included only ranges from 22.2% to 27.4%. One explanation for this pattern would be that vehicles in these households are "assigned" to or owned by particular individuals and are used by that person for all of their travel. This is more likely to happen among unrelated adults, in contrast to married couples. At least one of the vehicles in these households is older and is driven by one household member for most of his or her travel. This might be the young adult still living at home with his or her parents or a roommate in a house with several adults. This would also explain the lower overall share of trips made in the older vehicles. If there is only one older vehicle among the three or more adults and he or she makes most of their trips in it, that would be about one-quarter of the household trips. This notion is also supported by the fact that the vehicle trips made in pre-1982 vehicles by these households had an average of 1.18 household members in the vehicle (Table 44). This figure is lower than the 2-adult and retired/single households, even though these other households have fewer members.

Figure 30: Trips in pre-1982 Vehicles by Trip Purpose and Cluster

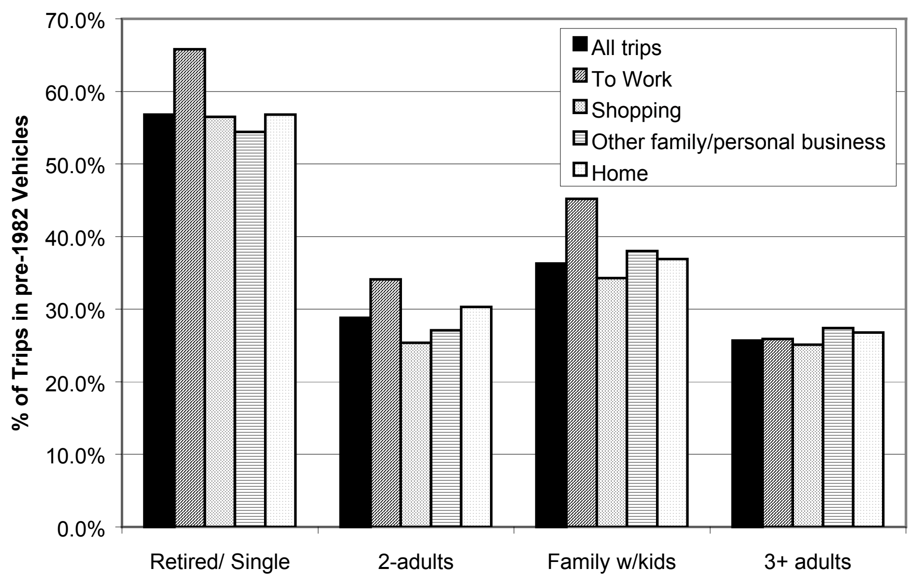


Figure 31: Trips in pre-1982 Vehicles by Trip Purpose and Cluster

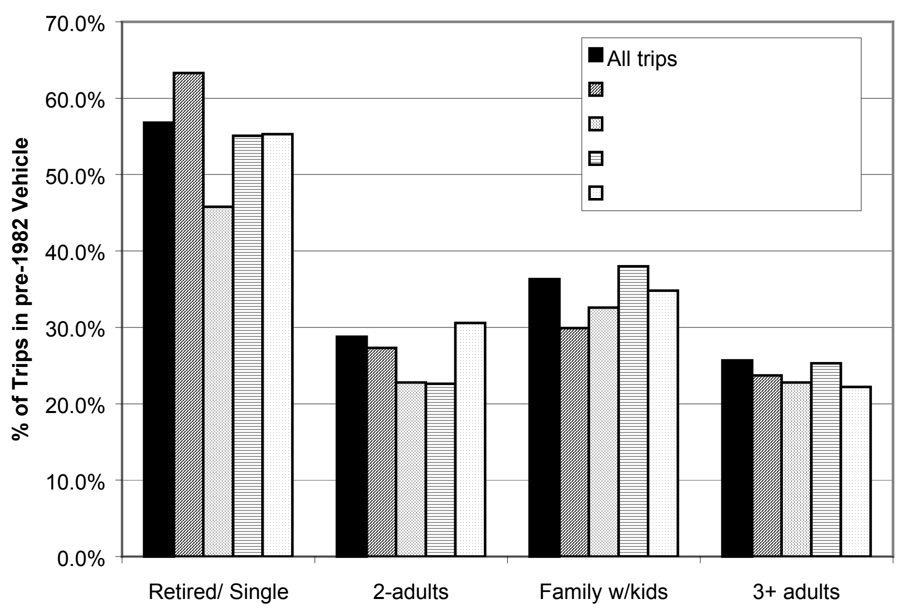


Table 44: Mean Number of Household Members on Trip by Cluster

	Pre-1982	1982+	Difference
Retired/Single	1.22	1.27	-4%
2-Adults	1.20	1.28	-6%
Family w/children	1.77	1.97	-10%
3+ Adults	1.18	1.32	-10%
Car Collector	1.09	1.33	-18%
All Households*	1.35	1.42	-5%

* Includes some households not assigned to a cluster due to lack of data.

The other clusters show a greater range in the share of trips made in the older vehicles, indicating that the older vehicles in these households play more specific roles. For example, in the family with children cluster, older vehicles make up a disproportionately larger share of the trips to work and a smaller share of the trips taking and picking up someone (probably children). One explanation would be that the primary worker in the household uses the pre-1982 vehicle to commute, while the person shuttling the children around uses the newer vehicle, more likely to be a minivan or SUV.

For the retired/single households the major differences in use are for work trips, take/pick up trips, and going out to eat. About half of these households only have pre-1982 vehicles. This half has no choice but to use the older vehicles for all trips. For those with a choice, they are choosing to use the newer vehicles to go out to eat and the older vehicles to commute (though they make far fewer commute trips). The 2-adult households are using their older vehicles to commute and for other social and recreational trips, but tend to prefer their newer vehicles for the other trip purposes. One explanation is that the trips out to eat and visiting people include both adults, in which case they choose the newer vehicle. The other social and recreational trips might be linked to the work trips, i.e. stopping at the gym on the way to or from work.

This examination has revealed some specific roles older vehicles play:

- Primary vehicles for retired and single households, usually with lower incomes;
- Primary vehicle for one adult in a household with three or more adults;
- Commuter vehicles for households with two-adults or families with children; and
- Low-use collector or extra vehicles among households with lots of vehicles.

4.5.4 Collector Vehicles

Because the collector vehicles are by definition driven infrequently, the NPTS data does not shed much light on how these vehicles are driven; the one-day travel diary will miss most of the trips made in these vehicles. Also, because the constructed definition of a collector vehicle limited annual mileage to 1,000 miles, the distribution of annual mileage will be different by definition. The collector vehicles are driven an average of 392 miles per year according to the household (self-reported). About one-quarter (25.5%) of the collector vehicles are driven 50 miles or less, compared to only 3.7% of the pre-1982 vehicles that were not defined as collector vehicles. Only a few (9.4%) of the vehicles made a trip on the NPTS travel day, compared to 47.5% of the non-collector pre-1982 vehicles.

4.6 Summary of Findings and Relevance to VAVR Programs

This chapter presented a detailed picture of older vehicle ownership and use in the U.S. The key findings are summarized here, highlighting their importance with respect to VAVR programs.

- Older light-duty cars and trucks represent a majority of the emissions from all types of older vehicles (including medium- and heavy-duty trucks, buses, and motorcycles). Therefore, the current focus of VAVR programs on cars and trucks is appropriate. However, older medium- and heavy-duty trucks also contribute disproportionately to emissions and represent over 10% of the on-road mobile source ROG emissions in California. With large sources of emissions reductions becoming scarcer in California, air quality agencies may want to examine the use of VAVR programs for these vehicle types. Several agencies have already taken the VAVR model in the other direction by implementing gasoline lawn mower buy-back programs.
- Air pollution from older vehicles is a larger problem in certain regions of the country, such as the Pacific Coast, where older vehicles represent a larger portion of the fleet. While VAVR programs may be equally effective on a per vehicle basis in any region, their potential impact in reducing total emissions will be less in regions where older vehicles are a smaller portion of the fleet.
- Classic or collector vehicles likely make up a very small proportion of the entire household vehicle fleet (less than one percent) and less than 10% of the pre-1982 vehicles. These vehicles probably represent an even smaller portion of the emissions from older vehicles because they are driven less. Because these vehicles are used differently than other older vehicles, and their owners are unlikely to sell them to a VAVR program, it is useful to analyze them separately. With respect to income, the ownership of collector vehicles closely

mirrors that of newer vehicles (higher income households own a higher share than lower income households), reflecting their higher value.

- Lower income households are more likely to own older vehicles and to rely upon them more for their daily transportation needs. Lower income households drive older vehicles further than higher income households. A VAVR program will be more effective if it attracts these vehicles from lower income households that are driven more. The higher concentration of older vehicles in lower income households confirms the need to maintain the voluntary nature of accelerated vehicle retirement programs. In addition, policy options such as higher taxes or registration fees on older vehicles would disproportionately impact lower income households.
- Older vehicles are not found disproportionately in non-white households. Race has not been a major issue with respect to VAVR programs (aside from the environmental justice issues surrounding the use of MERCs) and the data support this.
- A higher proportion of older (vs. newer) vehicles are "extra" vehicles in a household—they exist in households with more vehicles than drivers. They are not assigned to a particular driver and they are driven fewer miles than other older vehicles. "Extra" older vehicles are found more often in higher income households. Retiring these vehicles through a VAVR program would be less effective than, for example, retiring the higher-mileage vehicles found in lower-income households.

- Most of the older vehicles are found in three clusters of households: retired/single households, households with two adults (usually without children), and families with children (usually two or more). Families with children drive their older vehicles the most. Attracting these vehicles to a VAVR program may result in greater emissions reductions. Retired and single households with older vehicles are more likely to rely upon that older vehicle for most of their travel. Therefore, they may be less likely to participate in a VAVR program.
- Older drivers (over 65 years) and retired drivers are more likely to drive older vehicles, but they drive them fewer miles than younger, employed people. Therefore, scrapping vehicles driven by older people reduce program effectiveness. However, if these vehicles would have been sold to younger drivers, rather than being scrapped, this may not be an issue.
- Drivers with a high school diploma or less are more likely to drive older vehicles. This finding does not have an direct impact on emissions, because there is no significant relationship between education and VMT in older vehicles (after controlling for income and other variables), but should be considered in marketing VAVR programs.
- Older vehicles are driven less than newer vehicles. However, the distribution of vehicles into different mileage categories (e.g. 50 miles or less, 51-1,000 miles…Over 10,000 miles) is much more even than for newer vehicles. This indicates that older vehicles serve a greater range of roles within households, making their use more difficult to characterize. The wider variance also adds

more uncertainty in estimating emissions reductions from VAVR programs. A VAVR program will be more effective if it attracts the vehicles that are driven the most, but these represent a smaller proportion of older vehicles (compared to newer vehicles) and may be more difficult to target.

- Trips made in older vehicles are shorter in distance and slower in speed than trips in newer vehicles. This may mean that *per mile* older vehicles pollute even more than expected, because emissions are usually higher at slower speeds and after cold starts.
- Overall, older vehicles are generally used for the same trip purposes as newer vehicles. However, there are differences within the different types of households. Most households with multiple vehicles make trade-offs between their older and newer vehicles. For example, families with children use older vehicles more often for commuting and not for taking children places.

Older vehicles play a number of unique and varied roles in household travel. Therefore, broad characterizations of the vehicles that may be scrapped through a VAVR program based upon common stereotypes or perceptions (or misperceptions) of older vehicles are misleading. Understanding the different roles of older vehicles can help in efforts to improve the effectiveness of VAVR programs or design alternative programs.

5 Chapter 5: Evaluation of VAVR Programs

5.1 Literature Review: Emissions, Vehicle Characteristics, and Household Characteristics

Most research indicates that exhaust emissions per mile increase with increasing mileage (i.e. total mileage on the odometer) (Kahn, 1996; Wenzel & Ross, 1997. As noted in Section 4.2.5, certain makes and models also pollute more. Wenzel, Singer, and Slott (2000) summarize many of the factors that can influence vehicle emissions. For example, emissions are impacted by vehicle maintenance. Regular tune-ups and servicing can reduce the likelihood of emissions system failure or engine problems, thereby reducing emissions. Tampering with vehicle emissions systems will usually increase emissions. Certain driving patterns can also damage vehicles and increase emissions, such as prolonged high powered driving (e.g. towing a trailer uphill). In addition, Wenzel, Singer, and Slott highlight the high degree of variability in an individual vehicle's emissions.

There is little research relating emissions to household characteristics. Wenzel and Ross (1997) looked at inspection and maintenance (I/M) failure rates from Arizona. In addition to higher failure rates for older vehicles, they found higher failure rates at the station in the lowest income area and lower failure rates at the station in the highest income area. They suspected the difference was due to inadequate vehicle maintenance. Using I/M vehicle emissions data from California and county per-capita income data, Kahn concluded that, controlling for mileage, model year, and engine characteristics, cars registered in the richest counties polluted less than cars in the poorest and middle-income counties (1996). Singer and Harley (2000) compared mean vehicle emissions from remote sensor measurements to the median household income of the zip code where the vehicles were registered. They found that "CO and VOC emissions of vehicles registered in zip codes with the lowest median incomes were about twice those of vehicles registered in zip codes with the highest median incomes" (page 1791). Part of the difference was explained by the newer vehicles in higher income areas. However, vehicles of the same age also had higher emissions in the lower-income zip codes, particularly for model year 1991 and older vehicles.

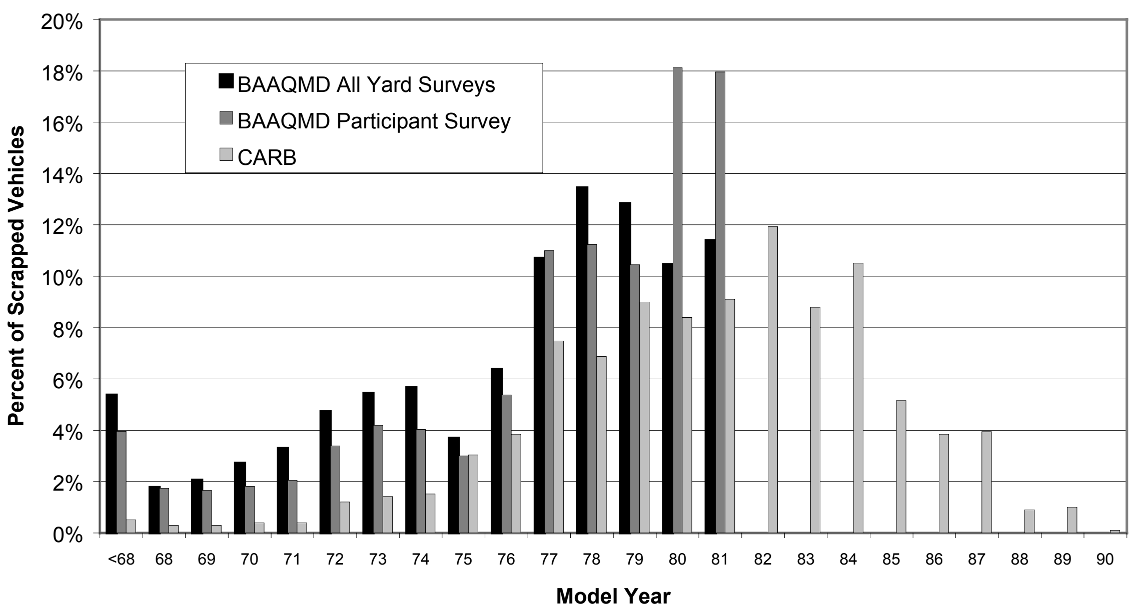
In 1993, the City of Los Angeles and Hughes Environmental Systems, Inc. implemented a remote sensing pilot program that collected socioeconomic information from households with high-emitting vehicles (Hughes Environmental Systems, 1995). One objective was to assess the impacts of mandating the repair of high emitting vehicles. The average annual income of drivers of higher emitting vehicles (HEVs) was about half that of drivers of lower emitting vehicles (LEVs). The average HEV was also significantly older, model year 1981 versus 1988. Income was a limiting factor for more HEV owners in maintaining their vehicle, and they spent an average of over $300 less per year on vehicle maintenance and repairs. Vehicle tampering (e.g. disconnected, modified, missing, or defective components) increased with vehicle age and as income decreased

5.2 VAVR Program Participation

5.2.1 What vehicles are scrapped through VAVR programs?

The eligibility requirements of a VAVR program impact the vehicles attracted to the program, including the model years accepted. Figure 32 shows the distribution of vehicles scrapped through the BAAQMD program and CARB's Pilot Program in the South Coast. The CARB Pilot Program accepted any model year, and the price was the same for all vehicles, $500. When the BAAQMD program started it accepted 1974 and earlier vehicles. This was expanded to 1979 and, now, 1981. The impact of this change is seen in the difference between “BAAQMD All Yard Surveys” and “BAAQMD Participant Survey.” The latter has a much higher share of vehicles from MYs 1980 and 1981 and a smaller share of the pre-1977 vehicles. The share of vehicles in the CARB program from MYs 1982-1984 indicates that these newer vehicles would be attracted to a VAVR program, even at an offer price of $500. Another thing to note from this distribution is the small share of vehicles in the potential collector category, pre-1970. Since the BAAQMD expanded eligibility to 1981 vehicles, less than seven percent of the scrapped vehicles are MY1969 or older. Only about one-percent of the CARB vehicles are from these model years.

Figure 32: Model Years of Vehicles Scrapped by BAAQMD and CARB



Nearly 80% of the BAAQMD scrapped vehicles are automobiles (Table 45). The program is not attracting SUVs and pickup trucks in proportion to their share of the fleet (represented by the California vehicles from the NPTS and the Non-Participant survey). Households may find that these vehicles serve unique purposes and are less willing to part with them, even if they are used infrequently. A small share (3.8%) of the Participant Survey respondents wrote in "hauling," "going to the dump," "towing," or a similar response as one of the uses of their scrapped vehicle. Of these, three-quarters were pickup trucks.

Table 45: Vehicle Types

	BAAQMD VAVR	CA pre-1982 Vehicles	Non-participants
Automobile	79.5%	67.3%	68.7%
Van	5.9%	7.2%	5.7%
Sport Utility Vehicle	0.5%	3.5%	3.9%
Pickup Truck	13.1%	22.0%	21.8%
	100.0%	100.0%	100.0%

Sources: 1995 NPTS weighted household data (RVs, other trucks, motorcycles, and other vehicles excluded); Participant and Non-participant Surveys

Table 46 shows the top 12 makes for the scrapped vehicles from the BAAQMD program. The share of these makes for the CARB Pilot Program participants are included, along with the California NPTS data for pre-1982 vehicles and the Non-Participant Survey vehicles. One clear pattern is the over-representation of Toyotas among the scrapped vehicles in both the Bay Area and CARB programs. In contrast, Chevrolets are underrepresented. In addition, the Bay Area participants are scrapping a higher than expected share of Volvos. One explanation for the difference in the distribution of makes is that most older Toyota and Datsun automobiles are probably not considered collector cars, like some older Fords (e.g. Mustangs) or Volkswagens (e.g. Beetles).

The value and condition of the vehicles is also likely a factor. All of the participants sold their vehicles for $500. Perhaps a higher share of the older Toyotas in the Bay Area are not worth much more than $500 compared to Chevrolets or other underrepresented makes. Chevrolets may remain in better condition for longer than Toyotas, either because they are inherently more durable, their owners maintain them better, and/or they are driven less. It may also be that Toyota owners are attracted to this type of program for getting rid of a vehicle more so than other vehicle make owners. However, greater concern for air pollution among Toyota owners is not the explanation; 39.9% of the Toyota owners said they scrapped their vehicle for air pollution reasons, compared to 38.7% of all the BAAQMD participants (Yard Surveys).

Table 46: Makes of Scrapped Vehicles

	Scrapped Vehicles			On-Road Vehicles	
Make	BAAQMD All Yard Surveys	BAAQMD Participant Survey	CARB Pilot Program	CA pre-1982 Vehicles	BA Non-participants
Ford	16.3%	14.8%	16.0%	18.7%	20.3%
Toyota	13.3	16.5	12.4	5.6	5.5
Chevrolet	10.8	9.7	13.4	21.4	18.4
Datsun/Nissan	7.3	8.4	11.1	6.1	2.9
Dodge	7.2	6.3	6.2	5.4	6.5
Volkswagen	5.4	5.5	1.0	8.4	8.9
Honda	5.2	6.2	3.8	3.9	1.9
Oldsmobile	5.1	4.4	7.3	2.7	2.6
Buick	4.5	4.2	4.4	2.6	1.9
Volvo	4.0	5.0	0.9	1.2	1.8
Plymouth	3.6	2.6	2.3	1.7	1.0
Cadillac	3.1	3.2	2.6	4.5	1.5
N	7,493	1,264	995	4,206	620

In the BAAQMD Yard Survey, respondents were asked to estimate how much their vehicle would have sold for if they tried to sell it through a newspaper ad. The

CARB Pilot Program survey asked how much they thought the vehicle was worth. In both cases, most sellers thought their vehicle was worth more than the $500 they sold it for (Table 47). The CARB program sellers thought their vehicles were worth more than the Bay Area sellers. This difference is probably due to two factors: (1) more newer model year vehicles, particularly post-1981; and (2) the wording of the question. About the same share (15%) of sellers in both programs thought their vehicles were worth or would sell for less than the $500 offered by the programs.

Table 47: Estimated Selling Price for Scrapped Vehicles

Estimated Selling Price	BAAQMD	CARB
Mean	$666	$857
Standard deviation	$521	$959
Median	$600	$750
$1 – 499	15.5%	15.1%
$500	30.2	11.7
$501 – 999	39.6	54.2
$1000 or more	14.8	19.0
N	5,929	990

Source: BAAQMD Yard Surveys, CARB Pilot Program yard surveys

5.2.2 Why do people sell vehicles to VAVR programs?

Both the Participant and Non-Participant Surveys asked a series of questions about the quality of the vehicle. The responses to these questions help explain why the participants scrapped their vehicles. The scrapped vehicles were far more likely than the non-participants' vehicles to need repairs to run well or need a paint job or other cosmetic improvements (Table 48). Despite the majority (59.5%) of the participants thinking that their scrapped vehicle needed repairs to run well, over three-quarters thought the vehicle was reliable and safe. Note that the question asked if the vehicle needed repairs "to run well" – not to run at all. The eligibility criteria are supposed to screen out the vehicles that don't run at all. About 30% of the participants thought that their vehicles might not pass its next Smog Check and a slightly lower share thought it polluted a lot. These shares are about three times that of the non-participants. The price of insurance does not seem to be a factor motivating many participants to scrap their vehicle. The low estimated values of the scrapped vehicles may indicate that insurance costs were also low. The differences between the participants' and non-participants' opinions of their vehicles indicates that the vehicles are probably in poorer condition than the average older vehicle, which is not surprising given the $500 offer price. The non-participants were also asked how much they thought their vehicle would sell for. The average estimated value of the non-classic vehicles was $3,879 (median = $2,000). The estimated values of the classic vehicles was more than twice that, $7,929 (median = $5,000).

Table 48: Owners' Opinions of their Scrapped Vehicles

% agreeing with the statement…	BAAQMD Scrapped Vehicles	Bay Area Non-Participants	Bay Area Non-Part. Non-Classic
The vehicle is an "extra" vehicle	51.1%	54.7%	50.3%
The vehicle needs repairs to run well	59.5	25.9	26.5
The vehicle needs a paint job or other cosmetic improvements	66.2	48.2	53.8
Insurance for the vehicle is too expensive	17.1	26.6	26.7
I don't think it will pass its next Smog Check	30.6	11.7	10.9
The vehicle pollutes a lot	28.7	8.1	7.6
The vehicle is reliable	75.7	87.8	88.2
The vehicle is safe	77.6	88.3	89.9

One hypothesis is that people sell their vehicles to a VAVR program because they are extra vehicles that are no longer driven much. The data indicate that just over half of the scrapped vehicles in the BAAQMD program were considered "extra." While this supports the hypothesis, the share is not significantly more than the share of non-classic vehicles among the non-participant households. Therefore, the "extra" older vehicles are not more likely to be scrapped.

The Non-Participant Survey asked the household if they remembered receiving the letter from the BAAQMD about the VAVR program and why they did not sell their pre-1982 vehicle to the program. The responses for the 463 households that remembered the letter are shown in Table 49. The primary reason is that the vehicle is worth more than $500, closely followed by "still drive the vehicle a lot." Over one-third of the vehicles are considered collector or classic vehicles, which is why they did not sell it to the VAVR program.

Table 49: Why Non-Participants did not Scrap their Pre-1982 Vehicle

Reason	**%**
It is worth more than $500	50.0
Still drive the vehicle a lot	43.8
It is a classic or collector vehicle	35.4
Intend to give it to a friend/family member	6.6
Would rather donate it to charity	5.2
No longer had the vehicle	3.8
Vehicle did not meet eligibility requirement	3.8
Process was too confusing	2.8
Locations were not convenient	2.1

A key question is why are most people selling their vehicle to a VAVR program for less than they think it's worth? First, the owners may be overestimating the value of their vehicles. Beyond this overestimation, the difference between the vehicle's estimated value and the $500 received could be interpreted as the value the seller placed on the VAVR program. The median value is $100 to $150 per vehicle. This value probably encompasses two things: (1) the ease of the transaction compared to selling the vehicle to a private party or getting rid of it another way; and (2) the value the person places on reducing air pollution. The first value represents the difference in transaction costs—the difference in time, effort, and/or risk involved in disposing of the vehicle another way is worth something to these sellers. This was recognized in the models developed by Kavalec and Setiawan (1997).

The relative contribution of these two factors is difficult to determine. In the BAAQMD Yard Surveys, respondents were asked their reasons for selling their car to the program. The responses are shown in Table 50 (multiple responses were allowed). Reducing air pollution and "easy way to sell car" were the top two reasons, followed closely by "do not use much." The air pollution motivation, however, should be discounted some due to the fact that the survey form has the BAAQMD logo on it and the money is coming from that agency, via the scrap yard. Some respondents were likely influenced by these circumstances and checked this answer. But, while the absolute share of people indicating air pollution as a motivation may be overstated, the relative share of sellers checking this answer among categories of sellers is worth examining, as seen below.

Table 50: Reasons for Selling Vehicles to the BAAQMD VAVR Program

Reason	%
Reduce air pollution	38.7
Easy way to sell car	36.3
Do not use much	36.0
Needs repairs	25.9
Need the money	16.6
Other	13.1
Failed Smog pre-test	1.9
N	7,493

Source: BAAQMD Yard Surveys

The sellers' motivations undoubtedly vary depending upon their perceived value of the vehicle and their other options. For example, the idea that the lower transaction costs of the VAVR program attracts sellers only really applies to vehicles that are worth more than $500. It is also more applicable to people already intended to get rid of the vehicle. People with vehicles worth less than $500 may be more motivated by the attractive price and the ability to skip the cost of repairs to make their vehicle saleable. Table 51 attempts to sort this out. The respondents who thought their vehicles were worth less or more than what they received are included. These two groups are further divided by how they answered the following question: "If you did not sell your car through this program, what would you do with it?" The responses are condensed to three options: sell it; keep it (includes keeping it as is or keeping it and fixing it up); and donate it to charity, junk it, or give it to a friend or family member.

The sellers with vehicles worth less than the $500 they received were more motivated by money, as indicated by their more frequent "need the money" responses. Donate/Junk/Give away was their most likely option, far more so than for the sellers with vehicles worth over $500. The $500 was particularly motivating to the low-value sellers that would have tried to sell the vehicle to someone else. People with vehicles worth less than $500 also appear more motivated by the potential to reduce air pollution, at least those that did not consider selling their vehicles as an option. For people with vehicles worth both over and under $500, "easy way to sell car" was their most frequently given reason. Therefore, the idea of people being attracted to the lower transaction costs of a VAVR program applies most to people intending to sell their vehicles. The low-value vehicle owners are attracted because they can get more money and avoid making repairs (a type of transaction cost). The high-value vehicle owners are motivated by the ease of the transaction. In addition, these people are more likely to not use the vehicle much.

Table 51: Reasons for Selling a Vehicle and Vehicle Value

			Reasons for Selling					
Value	**Option to VAVR**	**Share within Value**	**Reduce Air Poll'n**	**Easy Way to Sell Car**	**Need the Money**	**Needs Repairs**	**Do not use much**
< $500	Sell it	31.6%	35.5%	**45.9%**	24.7%	32.4%	31.2%
	Keep it	25.7	**45.6**	42.3	24.8	30.0	31.0
	Donate/Junk/Give away	41.3	**42.9**	37.1	17.6	37.7	30.6
>$500	Sell it	46.4%	38.4%	**45.0%**	15.6%	19.2%	37.3%
	Keep it	27.7	**39.9**	35.9	16.4	21.8	35.3
	Donate/Junk/Give away	24.8	36.4	39.3	13.4	27.1	**40.9**
All Respondents			38.7	36.3	16.6	25.9	36.0

Source: BAAQMD Yard Surveys. "Share within Value" does not total 100% because "Other" options were omitted from the table. Top reasons in **boldface**.

The idea that this is an easier transaction should be explained further, especially considering the new, tougher standards vehicles must meet to be accepted into a VAVR program in California. The VAVR process is not as easy as donating the car to a charity. The BAAQMD requires documentation, up-to-date registration, a valid Smog Check certificate, and proof of registration within the District over the past two years. In addition, the vehicle must pass the visual and operating tests described earlier. However, the seller knows that once he or she does this, they get a check for $500. There is no negotiation. The vehicle will be scrapped, so there is no risk of the buyer returning to complain. The Participant Survey included space for the respondent to describe in their own words how they used the scrapped vehicle and why they scrapped it. Most people (709 of the 1,264) wrote something, some in great detail. Selling the vehicle to the BAAQMD program "because it was easy" was a common response, along with the notion of not feeling comfortable selling the vehicle to someone because of mechanical or safety problems. A few examples are shown below. In some cases, the respondent has made an explicit calculation as to how much the ease of the transaction was worth.

> I sold it to the buy-back program because it was easy. Didn't want to sell by ads. No people came to my house.
>
> We sold it to the program because my wife feels uncomfortable running ads and having people come to our home in order to sell the vehicle. This program was an acceptable alternative to selling it.
>
> It was a spare car. I used it occasionally. I sold it to the program because it was easy. I feel that I could sell that car for more than $500 to a private party.
>
> …did not want to sell the car to someone who would have problems with it. Car had a bad paint and interior but ran well.
>
> It had over 160,000 miles and the engine was wearing out. I tried to donate it to charity but they would not take it--too old. I didn't want to sell it to an individual because of its condition.
>
> It was a lemon, for us, and broke down frequently. Would not like it on my conscience to sell it to anyone else.
>
> We were moving to Florida and I intended to sell the vehicle any way. I was offered $650 for it but decided the convenience of the program and need for repairs made the VBB attractive.
>
> My neighbor wanted to buy it and said he would work on it himself, but I would have had to smog it again to sell it to him, so I used the [VAVR program] instead. He offered $500 for it, but the smog check would have come out of his $500 and on the [VAVR program] I could keep the whole $500.

Another unique motivating factor for some people was the idea that no one else would drive their vehicle. This was revealed through the open-ended question and, while it doesn't represent a significant portion of the participants, it is interesting. Here are some examples:

… the main reason that I sold the car to VBB, was that I was told it would be smashed into a small cube, and I liked the idea that if I couldn't have the Bug, no one could.

The car was not used much in recent years because of a newer car purchased. I wanted to keep it for my son when he was old enough to drive it plus it was and is of great sentimental value to me since it was given by my mother who has died. I didn't want any one else to have it except of course my son but that would be in a few years.

The buy-back gave me the opportunity to get some cash for it. It was still reliable, but I was concerned that another owner might not know enough about its quirks to drive it safely and reliable. I did not want to sell it to another driver.

5.2.3 Who participates in VAVR programs?

Chapter 4 presented a comprehensive overview of who owns and drives older vehicles. One hypothesis is that the people who participate in VAVR programs differ from older vehicle owners in general. The characteristics of the household will influence whether they decide to scrap the vehicle. One such characteristic is the number of vehicles in the household. Households with older vehicles tend to have more vehicles. One hypothesis would be that households with extra vehicles would be more likely to participate in a VAVR program. In particular, households with only one vehicle would seem least likely to sell their vehicle to a VAVR program. These are more likely to be lower income households with fewer resources to replace the vehicle.

This hypothesis is supported by the data from the BAAQMD program and the CARB Pilot Program (Table 52). Including the vehicle they sold, the BAAQMD participants had an average of 2.91 vehicles, compared to 2.47 vehicles among the 1996 BATS households with pre-1982 vehicles. However, the Non-Participant Survey respondents have an average of 3.02 vehicles. This is a case where the skewed distribution (with respect to income) of the Non-Participant survey respondents impacts the interpretation of the results. Higher income households are more likely to have more vehicles. If the respondents are weighted to reflect the income distribution of pre-1982 vehicle households from the 1996 BATS results, the average is 2.77. Only 9.5% of the BAAQMD VAVR participants had one vehicle (the one they sold to the program). This is less than the share of BATS and Non-Participant households with only one vehicle (a pre-1982 vehicle). The Bay Area participants are more likely to have three or more vehicles.

Table 52: Number of Household Vehicles

# of Vehicles	BAAQMD All Yard Surveys	Non-Participant Survey HHs w/pre-82		'96 BATS HHs w/pre-82	CARB Pilot Program	NPTS LA CMSA HHs**
One	9.5%	12.4%	17.4%*	17.7%	24.5%	35.3%
Two	32.2	29.8	32.2	41.2	40.6	46.4
Three	33.1	28.0	26.6	27.1	20.2	13.0
Four	16.1	17.9	14.6	8.3	7.8	4.3
Five or more	9.2	11.9	9.1	5.7	6.9	1.1
Mean # vehicles	2.91	3.02	2.77	2.47	2.47	1.90
n	6,466	403	377	796	868	921

Sources: BAAQMD Yard Surveys, Non-Participant Survey, 1996 BATS, NPTS weighted sample
*weighted
**Households with vehicles only, weighted

The CARB program participants were far more likely to have only one vehicle (24.5%), the one they scrapped. The CARB program did not limit eligibility by model year and vehicles through MY1990 were actually purchased. The 1995 NPTS included over 900 households with vehicles in the Los Angeles region (the Consolidated Metropolitan Statistical Area). Of these, over one-third (35.5%) have only one vehicle. So, while the CARB program attracted significantly more one-vehicle households, they were still underrepresented compared to the region's households with vehicles. Prior to selling their vehicles, the CARB participants had an average of 2.47 vehicles, compared to 1.80 for the region's households. As in the Bay Area, a higher share of the participants had three or more vehicles.

Because a VAVR program offers an economic incentive, household income should influence participation in the program. Lower income households may be more motivated by the $500, because it represents a higher portion of their income. In addition, if the vehicle needs expensive repairs, lower income households are less able to make the repairs and may find the $500 particularly enticing. However, if the vehicle is worth more than $500 (and over half of the vehicles were, according to their owners), a lower income household may not find the convenience of the program worth the lost revenue. Higher income households have more older vehicles, particularly extra older vehicles. Critics of the programs speculate that it is an easy way for higher-income households to get rid of extra vehicles. This may be true. But the important question is whether the higher income households are attracted to the program at a disproportionate rate, i.e. at a higher rate than they own older vehicles. If higher income people are more motivated to reduce air pollution, this could happen.

The data from the BAAQMD program indicate that households with incomes of $30,000 or less are attracted disproportionately to the program (Table 53).[14] The same is true of participants in the CARB Pilot Program with incomes $20,000 and under (Table 54). For the BAAQMD participants, as income rose, the share of sellers stating that they sold their vehicle to the program to reduce air pollution also rose, supporting the

[14] The years of comparison are different. The Yard Surveys cover 1996-2000 and the 1996 BATS income would be from 1995. However, if incomes rose in the Bay Area after 1995, this would shift the distribution upwards slightly, not impacting the conclusion.

hypothesis that higher income people may be motivated more by environmental concerns. However, this was not enough of a motivation to attract disproportionate numbers of higher income households.

Table 53: Income of Bay Area VAVR Participants

	BAAQMD All Yard Surveys	Non-Participant Survey	1996 BATS Households with pre-1982 vehicles
$15,000 and under	15.4%	6.0%	8.0%
$15,001 – 30,000	24.4	11.5	15.3%
$30,001 – 45,000	19.6	11.9	24.0%
$45,001 – 60,000	15.7	16.4	20.1%
$60,001 – 75,000	11.5	13.0	10.3%
Over $75,000	13.4	41.1	22.3%
n	4,763	445	700

Table 54: Income of CARB Pilot Program VAVR Participants

	CARB Pilot Program	NPTS LA CMSA Households*
$10,000 and under	14.8%	6.0%
$10,001 – 20,000	38.0	14.0
$20,001 – 40,000	28.9	31.2
$40,001 – 60,000	13.0	21.8
$60,001 – 80,000	3.2	13.4
Over $80,000	2.2	13.6
n	974	773

*Households with vehicles only, weighted.
Note that the income categories for the CARB and NPTS surveys are not defined exactly the same. The NPTS intervals start at 1,000 and end at 999.

Whether people of different races or ethnicities may be attracted to VAVR programs more than others is perhaps influenced more by how the programs are marketed, rather than a characteristic of a particular race or ethnicity. There may be language barriers discouraging non-native English speakers from participating. But, if the program targets these populations, the outcome could be different. Table 55 shows the distribution of BAAQMD and CARB Pilot Program participants by race/ethnicity. Data from the 2000 Census is used for comparison.[15] The Bay Area program is attracting Caucasian households at a higher rate than the population, while the CARB Pilot Program attracted Hispanic households to a far greater degree than they are represented in the population.

These differences may be due to how the programs are advertised. The CARB Pilot Program advertised at the scrap yards, in weekly publications (the *PennySaver* and *Recycler*), two Spanish-language radio stations, and one general population station (Sierra Research, 2001). The BAAQMD outreach program originally relied on press releases, resulting in radio and newspaper stories, brochures at local Department of Motor Vehicles offices and scrap yards, public service announcements, a notice in utility bills, and limited print advertising. In 2000, they started a direct-mail program to older vehicle owners. The direct-mail campaign is the most extensive element of their advertising effort and is only in English. Therefore, most of the Bay Area outreach is in English, though the scrap yards, if telephoned, provide information in Spanish.

[15] The 2000 Census is probably a more accurate data source for race and ethnicity than the NPTS or BATS, though vehicle ownership information is not available yet. According to the NPTS, 94.3% of the households in California had a vehicle in 1995, so this is probably not a significant problem. The NPTS sample included very few Asian households, which is problematic for comparisons in California.

Table 55: Race/Ethnicity of VAVR Participants

	BAAQMD All Yard Surveys	Bay Area 2000 Census (all HHs)	CARB Pilot Program	SCAG 2000 Census (all HHs)
Caucasian	66.5%	50.0%	14.7%	38.9%
Asian	11.9	18.8	2.2	10.2
Hispanic	11.6	19.4	80.7	40.6
Black	4.8	7.3	1.5	7.3
Other	5.1	4.5	0.8	3.0
n	5,317	6,783,760	721	16,516,006

Sources for 2000 Census information: www.abag.ca.gov and www.scag.ca.gov

The survey forms used for the BAAQMD Yard Survey and the CARB Pilot Program did not include enough information on household structure (e.g., number of children, drivers, etc.) to make comparisons to the NPTS data presented in Chapter 4. Some of this information was collected in the Participant Survey. This comparison is shown in Table 56, along with data from the Non-Participant Survey. The life cycle categories are not identical, because of differences in the questionnaires, but they are close. The main difference is that the Participant Survey asked only about the number of people under 18, not 21.

The BAAQMD program is not attracting single-adult, non-retired households and single-adult households with children at the same rate that they own older vehicles in the Bay Area and the U.S. This is consistent with the data in Table 52 that showed that single vehicle households are less likely to participate. The households with only one adult who still works are more likely to have only one vehicle, which they use for commuting and other travel. The households with two adults and children are participating at a slightly lower rate than their share of the Non-Participant households and a much larger rate than their share nationwide. Some of these households may be holding on to the older vehicle for their children to use when they can drive (or they may be already).

The program is attracting households with no children and two adults, at least one of which is retired, at a disproportionate rate compared to both the U.S. and Non-Participant Survey. And, compared to the Non-Participant Survey, single-adult, retired households are also participating to a greater extent. The popularity of the program among retired households is not surprising. In the written comments, several respondents mentioned that the person who drove the vehicle the most was no longer driving due to health problems. The retired households also are likely to see their vehicle travel decline if one or more members recently retired and stopped commuting. In either case, the need for two or more vehicles may diminish. The larger retired households did answer “do not drive much” as a reason for selling their vehicles to the program at a higher rate than the rest of the respondents. In addition, the single-adult, retired households were far more likely to say that the driver was no longer driving, rather than driving a replacement vehicle after scrapping their older vehicle. Sadly, some households explained that the primary driver died.

Table 56: Life cycle of BAAQMD VAVR Participants

NPTS Family life cycle (U.S.)	% of pre-1982 vehicle HHs	BAAQMD Participant Survey life cycle	% of Participants	% of Non-Participants w/pre-82 vehicles unweighted	weighted*
One adult, no children	11.4%	One adult, no one under 18	9.6%	13.0%	16.3%
2+ adults, no children	25.1	2+ adults, no one under 18	30.7	28.9	21.3
One adult, retired, no children	6.8	One adult, retired, no one under 18	7.0	2.0	1.9
2+ adults, 1+ retired, no children	13.8	2+ adults, 1+ retired, no one under 18	24.2	21.3	20.3
One adult, youngest child age 0-21	4.0	One adult, 1+ person under 18	2.0	7.6	11.0
2+ adults, youngest child age 0-21	38.9	2+ adults, 1+ person under 18	26.6	27.4	29.1

*weighted to reflect 1996 BATS distribution

5.2.4 Who drove the scrapped vehicles?

The characteristics of the person who drove the scrapped vehicle the most may also impact the decision to sell it to a VAVR program. The BAAQMD Participant Survey asked specific questions about who drove the vehicle the most. The CARB Pilot Program survey collected similar information from the survey respondents, though they may not have been the vehicle's primary driver. There was a question on the survey asking whether the respondent or someone else in the family was the primary driver. The respondents who answered that they were the primary driver are included in the analysis below, which is 77.2% of the respondents. Therefore, these data may not be well representative of the scrapped vehicle drivers. Certain types of drivers, such as the elderly or non-English speakers, may have had another family member take the vehicle to the scrap yard.

Table 57 includes some of the driver characteristics for the scrapped vehicles in the BAAQMD and CARB programs, the BAAQMD Non-Participant Survey, and the NPTS nationwide data for older vehicles. As with older vehicles nationwide, most of the scrapped vehicles were driven by men. In the Bay Area, the average age of the drivers is slightly higher than nationwide, though the share of drivers over 65 is about the same. The CARB program did not attract older drivers. However, some of this difference may be due to missing information on about one-quarter of the vehicles where the respondent was not the main driver. A slightly higher share of the drivers of the BAAQMD scrapped vehicles are retired compared to the older vehicle drivers nationwide. However, the share of Non-Participant pre-1982 vehicle drivers over 65 is higher. The share of drivers that are employed full-time is about the same for all of the vehicles, except the CARB program, which seems to have attracted more employed and fewer retired drivers. Finally, the education levels of the Bay Area Participants are about he same as the Non-participants, which are higher than the CARB sellers and the nationwide distribution. As with the differences in participation based on race/ethnicity, the significant difference in education levels between the BAAQMD and CARB participants may be explained by the differences in program advertising.

Table 57: Main Driver Characteristics of Scrapped Vehicles

		BAAQMD Participant Survey	**BAAQMD Non-Part. Survey**	**CARB Pilot Program****	**NPTS pre-1982 Vehicles**	**NPTS pre-1986 Vehicles**
Sex	Male	65.1%	76.4%	69.3%	72.7%	65.3%
Age	Mean age	50.6	52.3	n.a.	47.6	46.7
	Over 65	19.2%	19.5%	6.3%	19.0%	17.3%
Employ-ment	Retired	22.8%	26.4%	6.9%	19.6%	17.8%
	Employed full-time	54.8%	56.1%	71.0%	57.6%	56.9%
Education*	Less than high school	7.6%	5.6%	42.5%	19.9%	17.5%
	Bachelor's degree or higher	41.6	40.2%	10.3%	18.3%	19.9%

*Bay Area and CARB data are based on highest level of education – 11 or less for less than high school and 16 or more for bachelor's degree.
** CARB Pilot Program data only from survey respondents that were main drivers.

5.2.5 How were the scrapped vehicles driven?

How much a household uses a vehicle likely impacts its decision to sell it to a VAVR program. However, the relationship may not be simple. Households may be more willing to part with vehicles that are rarely driven. On the other hand, a household that drives an older vehicle “into the ground” and needs to replace it may find a VAVR program an attractive alternative to selling it or trading it in. In addition, the eligibility requirements are designed to include only vehicles that can be driven. Therefore, vehicles that aren’t driven because they don’t run won’t be included in the programs, unless they are fixed.

Table 58 includes the annual mileage information for scrapped vehicles from the BAAQMD and CARB programs, along with estimates for vehicles on the road, based on the California vehicles from the NPTS and the Non-Participant Survey. The information from the CARB Pilot Program should be viewed cautiously. The BAAQMD Yard Survey asked how many miles the vehicle had been driven in the past 12 months. The CARB Pilot Program survey asked for the number of trips per week (weekday versus weekend) for each trip purpose and the distance of those trips (e.g. 3 shopping trips per week Monday-Friday of 5 miles per trip). This information was then used to calculate annual mileage. The annual mileage was capped at 115,000, which is what the NPTS did. It might be easy for someone to overestimate their travel using this methodology, if they rounded up consistently.

Participants in the BAAQMD program drove their vehicles an average of 5,817 miles during the 12 months before they were scrapped. This is higher than the average distance the non-participants drove their pre-1982 vehicles, even excluding the vehicles labeled by their owners as classics or collector vehicles. However, it is significantly lower than the distance the households from the California NPTS drove their older vehicles. In addition, the statewide average annual VMT for pre-1982 vehicles in CARB's EMFAC2000 model is 8,183 in the year 2000. This is within the range of the CA NPTS data, and significantly higher than the scrapped vehicles. On the other hand, the average annual mileage estimate for the CARB Pilot Program vehicles is over 9,700 miles, higher than the statewide numbers from the NPTS or EMFAC. But, the median, 4,680 miles, is within the range of the NPTS vehicles.

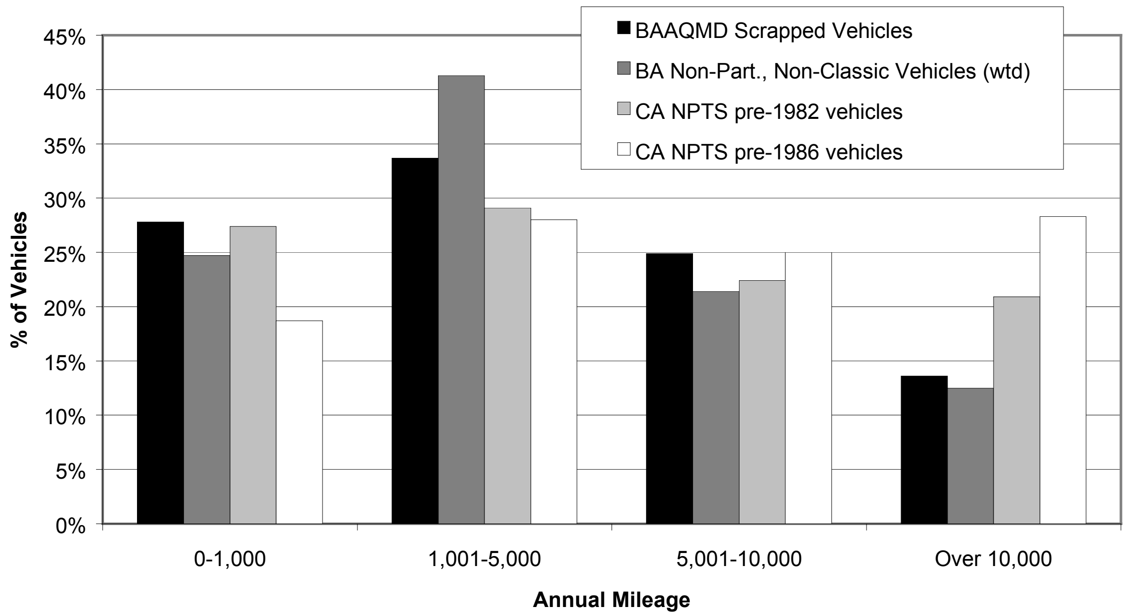
Table 58: Annual Mileage for Scrapped Vehicles

	Scrapped Vehicles		On-Road Vehicles			
	BAAQMD All Yard Surveys	CARB Pilot Program	California NPTS Vehicles*		Bay Area Non-Part. Vehicles**	
			Pre-82	Pre-86	All	Non-classic
Mean	5,817	9,732	7,108	8,839	4,824	5,072
Std. deviation	7,180	15,548	8,834	9,620	5,919	5,333
Median	4,000	4,680	4,200	6,000	3,000	3,960
25th percentile	1,000	1,911	1,000	2,000	1,000	1,100
75th percentile	8,000	10,400	10,000	12,000	7,000	7,500
n	6,520	802	611	1,080	503	306

* Self-reported annual miles, weighted. Only automobiles and light-duty trucks included.
** Weighted

Figure 33 shows the distribution of annual mileage for the BAAQMD scrapped vehicles and compared them to the California NPTS and Non-Participant data. Compared to the Non-Participant mileage figures, the scrapped vehicles are similar, except in the 1,001 – 5,000 mile category. Compared to the NPTS data, the BAAQMD program doesn't appear to be attracting the high mileage vehicles, those that are driven over 10,000 miles per year.

Figure 33: Distribution of Annual Mileage of Scrapped Vehicles



Does this mean that scrapped vehicles are driven more or less than all older vehicles? The data are unclear. The quality of the data must be considered. The Yard Survey and Participant Survey ask a similar question – how far the vehicle was driven in the past 12 months. The research discussed in Chapter 3 questions the accuracy of self-reported mileage estimates, finding that they are often too high compared to odometer readings. However, the NPTS data show that self-reported figures are closer to the odometer readings for older vehicles than newer vehicles. In the case of the scrapped vehicles, respondents completing the survey at the scrap yard may be inclined to think more of how they drove the vehicle over the course of their ownership, rather than more recently. Most participants know that the program intends to reduce air pollution. They may think that putting the higher or "more regular" amount of use, that mean they are helping reduce pollution more.

The Non-Participant Survey asked for both an estimate of mileage in the past 12 months and weekly mileage over the past three months. The figures in Table 58 are from the 12 month estimate, since the question is the same as for the Yard Surveys. However, a comparison to an annual mileage estimate based upon the weekly mileage tells a different story. The annual mileage estimate based upon a weekly mileage estimate are higher, and closer (or exceeding) the mileage estimates of the scrapped vehicles (Table 59). I asked for the weekly mileage, thinking that some people may be more accurate in making a short-term estimate. If people drive to work every day, they usually know that distance and could do a quick calculation in their head, adding other trips they make regularly. However, without odometer readings, it is impossible to know which figures are "right." In addition, if the VAVR participants were asked for weekly mileage, their estimates might be higher as well. One thing to note is the greater variation in the annual mileage estimates based upon the weekly mileage—the standard deviations are about twice the mean. However, the median figures are lower than the 12-month estimates, indicating more high-end estimates using the weekly mileage.

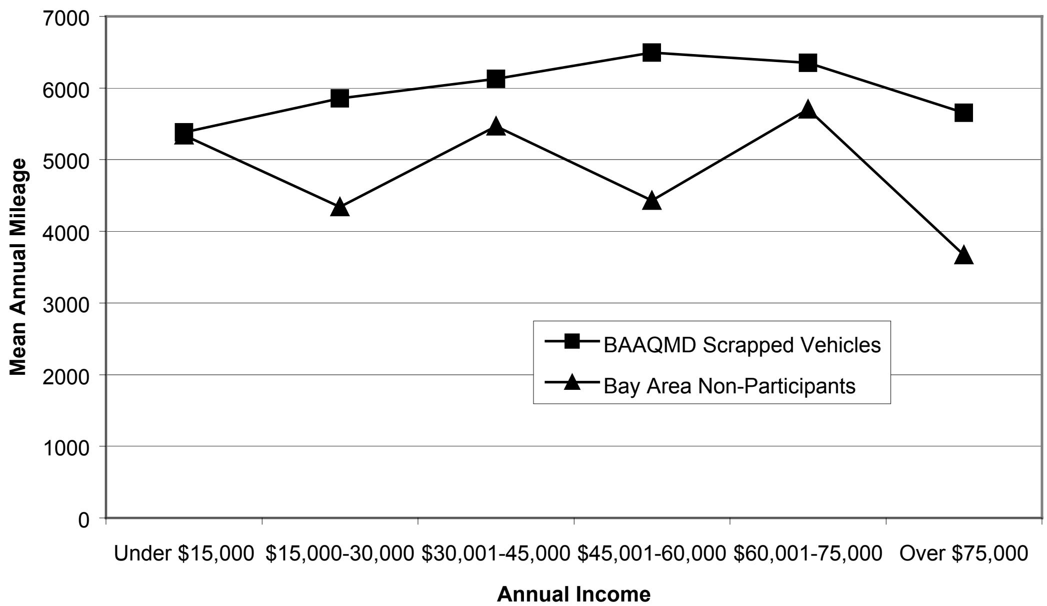
Table 59: BAAQMD Scrapped Vehicle Mileage based upon Different Estimates

	BAAQMD All Yard Surveys	Bay Area Non-Part. Vehicles**			
		12-month mileage		Annual Mileage based upon weekly estimate	
		All	Non-classic	All	Non-classic
Mean	5,817	4,824	5,072	5,769	6,353
Std. deviation	7,180	5,919	5,333	10,159	11,212
Median	4,000	3,000	3,960	2,600	3,120
25th percentile	1,000	1,000	1,100	624	1,040
75th percentile	8,000	7,000	7,500	6,565	7,800
N	6,520	503	306	490	297

Whether scrapped vehicles are driven more or less than the average for older vehicles is important when determining the air pollution benefits of the program. Though this discussion revealed that the answer is not clear, the issue will be examined further in Section 5.3.2.

Another aspect to this question of mileage involves which households are driving older vehicles more and whether they are participating in VAVR programs. Getting these higher mileage vehicles off the road may reduce air pollution more. In Chapter 4 we saw that lower income households drive their older vehicles further than higher income households. Does that relationship hold for scrapped vehicles? Figure 34 shows the annual mileage for the scrapped vehicles and the pre-1982 vehicles owned by the Non-Participant Survey respondents (including classic vehicles). Up through households with incomes of $60,000, average mileage in the scrapped vehicles increases with income. While mileage in the highest two income categories drops off, it is still higher than the mileage of households with incomes of $15,000 or lower. The difference between the means is statistically significant at the 0.10 level or better. This pattern is not consistent with the nationwide data for older vehicles. The Non-Participant Survey data are a little more difficult to interpret. Mileage for the households up to $75,000 hovers around 5,000 miles per year. The highest income households drive their pre-1982 vehicles less than 4,000 miles per year, on average. While this pattern is not as clear as that found in the NPTS data, it is not completely inconsistent – the lowest income households (up to $30,000) are driving their older vehicles more than the highest income households (over $75,000). However, the households in between are inconsistent.

Figure 34: Annual Mileage and Income – Scrapped versus Non-scrapped Vehicles



One interpretation of these data is that while the BAAQMD VAVR program is attracting lower-income households at a rate higher than they represent in the population, it is not attracting the lower-income households that drive their older vehicles like lower-income households do nationwide – more than higher-income households. Table 60 uses an annual mileage index to compare the mileage by income for the BAAQMD program participants, non-participants, and the NPTS households with pre-1982 vehicles. The CARB Pilot Program data are also included, though the income categories are different. The mean annual mileage figures are converted to an index, with the overall mean within the sample population equal to one. The index helps address differences in survey design and overall driving patterns between the Bay Area and the U.S.

Compared to the nationwide data, scrapped vehicles in the lowest income (under $15,000) households are driven 90% of the mean, while vehicles in the middle income categories are driven above average. A similar pattern appears in the CARB Pilot Project in the Los Angeles region. The difference between this pattern and the national pattern indicates that the lower income households that are participating in the Bay Area VAVR program are not typical – they are not the lower income households that drive their older vehicles a lot. A lower income household that uses an older vehicle a lot would seem less likely to sell it for $500. In addition, lower income households that drive vehicles more may include more undocumented immigrants or households with unregistered or uninsured vehicles, who may be less likely to participate in a government-sponsored VAVR program. Data to analyze this further, however, are not available.

Table 60: Annual Mileage Index

Income	BAAQMD Scrapped Vehicles	Bay Area Non-Participants	NPTS pre-1982 vehicles	Income	CARB Scrapped Vehicles
$15,000 and under	0.90	1.20	1.17	Less than $10,001	0.81
$15,001 – 30,000	0.98	0.97	1.08	$10,001 - 20,000	0.93
$30,001 – 45,000	1.02	1.22	1.01	$20,001 - 40,000	1.08
$45,001 – 60,000	1.09	0.99	0.80	$40,001 - 60,000	1.19
$60,001 – 75,000	1.06	1.28	0.85	$60,001 - 80,000	0.95
Over $75,000	0.95	0.82	0.93	More than $80,000	1.04
All Incomes	1.00	1.00	1.00	All Incomes	1.00

Chapter 4 presented a set of regression models relating annual mileage in older and newer vehicles to various household characteristics. A similar analysis of the scrapped vehicles appears in Table 61. The data for the BAAQMD scrapped vehicles comes from the Participant Survey. The independent variables are identical with two exceptions: (1) population density is not available for the Bay Area vehicles; and (2) the "white household" variable for the Bay Area vehicles is based upon the race of the vehicle's primary driver, not the household, as in the NPTS data. In addition, two models are presented for the Bay Area scrapped vehicle models. Model 2a uses the estimate of annual mileage given by the household in the Yard Survey. Model 2b uses an annual mileage estimate from the follow-up Participant Survey, based upon an estimate of weekly mileage in the three months before the vehicle was scrapped.

Some interesting differences emerge from this comparison. The relationships between vehicle age and whether the household is retired (with no children) in all four models are significant, of the same sign, and of similar magnitudes. Two variables that were significant in the nationwide models of older vehicles are not significant in the models of the scrapped vehicles: the number of vehicles and the number of children. The mileage for the scrapped vehicles does not decline significantly as the number of vehicles in the household rises. This may be due to the low participation among one-vehicle households, which would strengthen the relationship. The relationship between scrapped vehicle mileage and the number of adults is only significant in Model 2b using the second mileage estimate. The relationship is positive and consistent with the NPTS models, but much smaller in magnitude. The van and pickup truck variables are significant in Model 2a, but with opposite signs from the NPTS model 1a, where the variables are also significant. Scrapped vans and pickup trucks are driven less, while these types of older vehicles are driven more nationwide. This indicates that the vans and pickup trucks sold to the VAVR program are perhaps the extra vehicles people have kept around for special trips (e.g. hauling), but have finally decided that those trips are not worth more than $500.

Table 61: Vehicle Usage Models for Scrapped Vehicles – Regression Results

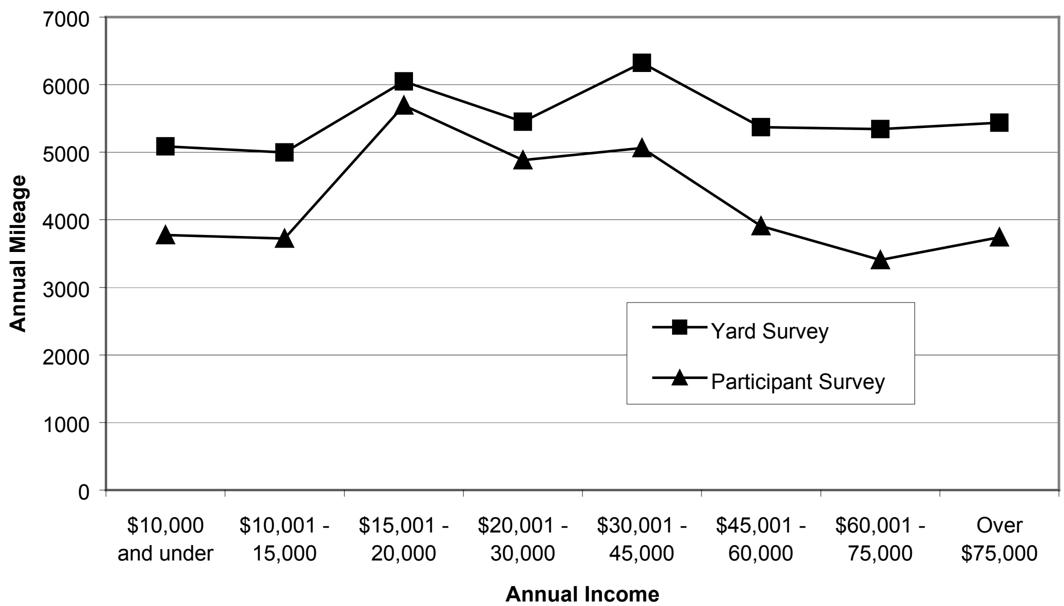
	NPTS pre-1982 Vehicles				BAAQMD Scrapped Vehicles			
	Model 1a Self-reptd		Model 1b Odometer		Model 2a Yard Survey est.		Model 2b Part. Survey est.	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.
Constant	9.12	0.00	10.56	0.00	10.50	0.00	12.55	0.00
vehicle age	-0.055	0.00	-0.066	0.00	-0.043	0.00	-0.058	0.00
# vehicles in household	-0.21	0.00	-0.27	0.00	-0.065	0.12	0.010	0.80
retired household	-0.44	0.00	-0.58	0.00	-0.72	0.00	-0.29	0.01
# of children	0.076	0.00	0.25	0.00	-0.024	0.67	-0.002	0.97
# adults	0.15	0.00	0.30	0.00	0.036	0.52	0.096	0.05
population density (ln)	0.006	0.60	-0.025	0.27				
income (ln)	0.009	0.78	-0.079	0.20	-0.12	0.13	-0.34	0.00
white household	0.032	0.66	-0.65	0.00	0.15	0.21	0.035	0.74
Pickup	0.13	0.01	-0.056	0.55	-0.34	0.02	-0.009	0.95
Van	0.30	0.00	-0.086	0.66	-0.47	0.04	-0.29	0.17
n	5,064		1,785		866		843	
Adj. R sq.	0.102		0.128		0.069		0.056	

Dependent variables are ln(annual mileage)

The income variable in the models is particularly interesting, in light of the discussion above. The income variable was not significant in the NPTS models, but is in the scrapped vehicle models. For the scrapped vehicles, as income rises, mileage falls. This is in contrast to the data in Figure 34, which was based on the Yard Surveys for scrapped vehicles over five years of the program. The Participant Survey included households that scrapped vehicles in 2000. Their mileage data by income is shown in Figure 35, which indicates that the middle-income households drove their scrapped vehicles the most. Model 2b has the more significant coefficient with respect to income. That data are the lower line in Figure 35, which has a much more pronounced downward slope for households with incomes over $15,000. An ANOVA test on the differences between the means shown in Figure 35 indicates that the means from the Participant Survey estimates are significantly different at the 0.05 level, but the means from the Yard

Survey estimates are not significantly different. The regression model may be capturing the strong negative relationship for the households with incomes over $15,000.

Figure 35: Annual Mileage and Income – BAAQMD Participant Survey



How often a household uses a vehicle may impact their decision to sell it to a VAVR program. As with mileage, there are two perhaps contradictory hypotheses: (1) households that don't use the vehicles much are more willing to sell them; and/or (2) households that wear their vehicles out with frequent use and are planning on getting rid of them may find the VAVR offer enticing. The Participant and Non-Participant Surveys collected information on the frequency of use and trip purposes for the scrapped and older vehicles. However, because these were not travel diary surveys, the data are not directly comparable to the NPTS data. One-third of the scrapped vehicles were driven 6-7 days per week and nearly 60% were driven at least three days per week. The scrapped vehicles were used more often than the pre-1982 vehicles from the non-participants. This is consistent with the lower annual mileage estimates from the Non-participant Survey.

Also note that 11.7% of the scrapped vehicles were used less than once a month or never. Unless these vehicles would have been transferred to people who would drive them, scrapping them did not reduce pollution significantly. That question will be examined further in Section 5.3.2. However, the notion that the scrapped vehicles were not being used before they were scrapped, as put forth by some program critics, is not the case for the majority of the vehicles. The data seems to support the hypothesis that people who use their vehicles frequently are being attracted to the program at a higher than expected rate, while those that use them infrequently are attracted at rates comparable to the population. However, as with the mileage information, the respondents may overestimate their frequency of use because: (1) they think about their use during the vehicle's lifetime with them or what was "regular," which may be different than the recent use pattern; and/or (2) they think that scrapping a higher-use vehicle is better for air quality.

Table 62: Frequency of Use of Scrapped Vehicles

	CARB Pilot Program Vehicles	BAAQMD Scrapped Vehicles	Bay Area Non-Participants	Bay Area Non-Part. Non-classic
6-7 days per week	56.3%	33.3%	22.5%	23.7%
3-5 days per week	21.1	25.7	24.4	28.2
1-2 days per week	10.2	16.2	18.9	19.9
1-3 days per month	4.7	13.0	17.4	15.2
Less than once a month	3.9	7.5	8.0	7.9
Not at all	3.3	4.2	8.8	5.1
Total	99.4*	100.0	100.0	100.0
N	982	1,250	512	316

Non-Participant data are weighted by income.
* 0.6% answered "don't know" which was not an option on the Bay Area surveys.

The survey respondents were also asked for what trip purposes they used their scrapped or older vehicles. One question allowed the respondent to check all the trip purposes and a second question asked for the most frequent trip purpose. These data are in Table 63 and Table 64, respectively. The scrapped vehicles were used more often for commuting, driving to and from a transit station, running errands/shopping/banking/dining (except as a primary trip purpose), taking children places, and for work or business. They are used less often for pleasure, vacation, or visiting friends and relatives. However, the fact that “Pleasure, vacation, visiting friends or relatives” was the primary purpose for 13.7% of the non-participants’ non-classic vehicles casts some doubt about the representativeness of the survey sample. Social/recreational and vacation trips made up less than five percent of the trips in older vehicles in the NPTS sample. The CARB Pilot Program also collected trip purpose information, but the survey form used different categories. Over three-quarters (77.2%) of those participants stated that the main use of the vehicle was for commuting to work or school.

Table 63: Trip Purposes for Scrapped Vehicles

	BAAQMD Scrapped Vehicles	Bay Area Non-Participants	Bay Area Non-Part. Non-classic
Commuting to work or school	51.2%	39.3%	41.7
Driving to/from transit station	7.1%	4.8	5.2
Running errands, shopping, banking, dining	65.2	53.2	57.8
Taking kids to school, events	12.9	8.8	9.1
Used for work/business	19.5	14.8	17.5
Pleasure, vacation, visiting friend or relatives	32.6	51.5	47.1
Other – Hauling, dump, towing	3.8	5.2	5.5
Other – Extra, backup vehicle	3.0	2.6	3.6
N	1,264	499	316

Non-Participant data are weighted by income.

Table 64: Most Frequent Trip Purpose for Scrapped Vehicles

	BAAQMD Scrapped Vehicles	Bay Area Non-Participants	Bay Area Non-Part. Non-classic
Commuting to work or school	44.3%	29.4%	31.3
Driving to/from transit station	2.8	1.2	1.3
Running errands, shopping, banking, dining	29.0	24.4	29.0
Taking kids to school, events	2.6	0.8	1.3
Used for work/business	11.1	5.3	6.0
Pleasure, vacation, visiting friend or relatives	4.4	20.3	13.7
Other – Hauling, dump, towing	2.3	5.1	5.7
Other – Extra, backup vehicle	1.2	2.7	3.7
Other – None	0.3	1.8	1.3
Other – Shows, races, restoration	0.0	4.1	2.0
Other	2.0	2.1	1.3
Don't know	0.0	2.7	3.3
Total	100.0	100.0	100.0
N	1,264	487	300

Non-Participant data are weighted by income.

5.3 Emissions Impacts

The effectiveness of a VAVR program in reducing air pollution hinges upon the answers to several questions, which relate to the household's decisions and actions (Hsu & Sperling, 1994):

- How much earlier was the vehicle retired?
- How would the vehicle be driven if not retired?
- What are the emissions levels of the retired vehicles?
- How was the VMT replaced?
- What is the VMT for the replacement vehicle, if there is one?
- What are the emissions of the replacement vehicle?

The answers to the questions above are used in the following equations[16] for calculating emission reduction credits (California Air Resources Board, 1999):

Exhaust Reduction = $[(ER_{retired} * VMT_{retired})-(ER_{replacement} * VMT_{replacement})] * LIFE_{retired}$

where:

Exhaust Reduction = total emission reduction for tailpipe emissions (grams/life)

$ER_{retired}$ = emission rate (grams/mile) of retired vehicle

$ER_{replacement}$ = emission rate (grams/mile) of replacement vehicle

$VMT_{retired}$ = vehicle miles traveled (miles/year) of retired vehicle

$VMT_{replacement}$ = vehicle miles traveled (miles/year) of replacement vehicle

$LIFE_{retired}$ = the retired vehicle remaining life

Evaporative Reduction =

$$\{[(ER_{runloss})_{retired} - (ER_{runloss})_{replacement}] * VMT_{retired}$$
$$+ [(ER_{hotsoak})_{retired} - (ER_{hotsoak})_{replacement}] * Trips_{retired}$$
$$+ [(ER_{diurnal})_{retired} - (ER_{diurnal})_{replacement}] * 365\ days/year$$
$$+ [(ER_{resting})_{retired} - (ER_{resting})_{replacement}] * 365\ days/year\}$$
$$* LIFE_{retired}$$

where:

[16] These equations are used to calculate ROG, NO_x, and CO emissions. If the calculations are used to generate MERCs or estimate emissions reductions for a SIP, the pollutants would be given equal weight. However, the MERCs might only be purchased for the purpose of reducing one of the pollutants, i.e. there may not be a market for CO MERCs. Also, if the objective of the SIP is to reduce ozone and, therefore, ROG and/or NO_x emissions , the CO reductions might be ignored. Some air quality analyses apply a weight, often 1/7, to CO emissions, partly because their absolute numbers are far greater than ROG and NO_x emissions and partly because CO is less of a focus in air quality planning in some regions. However, this would not be done when calculating MERCs or SIP credit.

Evaporative Reduction = total lifetime reduction of evaporative ROG emissions (grams/life)

$ER_{runloss}$ = running loss evaporative emission rate (grams/mile)

$ER_{hotsoak}$ = evaporative emission rate attributed to hot soak after shut down (grams/grip)

$ER_{diurnal}$ = emission rate for evaporative emissions occurring while vehicle is not operating and during periods of ambient temperature increase (grams/day)

$ER_{resting}$ = emission rate for evaporative emissions occurring while vehicle is not operating and during periods of constant or decreasing ambient temperature

$Trips_{retired}$ = number of trips per year expected from retired vehicle

Each of the questions is examined further below, with particular attention paid to the influence of household characteristics on the outcomes. The starting point for answering each question will be the current regulatory guidance. In other words, the hypotheses to be tested are the currently accepted methods.

5.3.1 How much earlier is the vehicle retired?

The California Air Resources Board (CARB) assumes that vehicles scrapped through VAVR programs are retired three years earlier than normal. This is based upon a fleet wide scrappage rate and an assumption that vehicles scrapped through VAVR would be in worse condition than the fleet average. Vehicle registration data showed that the half-life of older vehicles is six years. CARB then halved that estimate to account for the poorer quality of vehicles (California Air Resources Board, 1998). The assumption that the scrapped vehicles would be of poorer quality is confirmed by the data presented in Table 48.

Both the BAAQMD Yard Survey and the CARB Pilot Program Yard Survey asked the seller how much longer they thought the vehicle would have lasted. A higher share of the Bay Area vehicles were expected to last one year or less (23.4% versus 9.9% for the CARB vehicles), though a higher share were also expected to last more than five years. In both cases, the median value is 3.00 years, supporting the hypothesis and current practice (Table 65). However, people may overestimate how long their cars will last. In a pilot vehicle scrapping project in Illinois, vehicles were inspected by mechanics that gave professional opinions on the remaining life of each vehicle. The average mechanics' estimate was about five months shorter than the vehicle owner indicated on a survey (20.0 versus 25.2 months) (Illinois Environmental Protection Agency, 1993). However, these vehicles did not have to pass the strict eligibility requirements now applicable in California. This difference helps explain the shorter life expectancy for the Illinois vehicles. If the CARB and Bay Area respondents over-estimated their vehicles' life expectancies by the same 20%, the means would be 2.79 and 2.56 years, respectively, and the medians would be 2.40 years.

Table 65: Estimated Life Expectancy of Scrapped Vehicles

	CARB Pilot Program Vehicles	BAAQMD Scrapped Vehicles
Less than one year	n.a.	11.4%
1 year	9.9%	12.0
2 years	23.0	22.3
3 years	25.1	13.5
4 years	12.5	7.0
5 years	17.8	13.8
More than 5 years	11.8	20.0
Total	100.0	100.0
N	861	7,308
Mean	3.49	3.20
Std. deviation	1.70	1.95
Median	3.00	3.00

Means and medians calculated by assuming 6 years for "more than five years" in the BAAQMD survey and 7 years for "more than 6 years" in the CARB survey.

Data from the Bay Area participants (both the Yard Survey and Participant Survey) indicate that the vehicle life expectancy is negatively correlated with model year and how far the vehicle was driven in the past 12 months. There is a positive correlation with the estimated value of the vehicle and household income. The only statistically significant correlation among the same variables in the CARB data is model year. The Bay Area data confirms what is expected – higher value and newer vehicles and vehicles that are driven less are expected to last longer. In addition, the correlation with income is consistent with other research indicating that lower income households do not maintain vehicles as well as higher income households, which may be impacting their life expectancies.

The other part of the life expectancy equation involves what the household would do with the vehicle if they do not sell it to a VAVR program. Some critics argue that these are vehicles that were headed to the scrap yard anyway. To the extent that is the case, scrapping vehicles through a VAVR program is not reducing emissions. Both the CARB and BAAQMD Yard Surveys asked what the person would have done had they not sold the vehicle to the program. These results are shown in Table 66. In both cases, only a small share of the sellers said they would have junked their vehicles – 5.0% for the BAAQMD program and 1.4% for the CARB program. In the case of the Bay Area participants, nearly 20% would have donated the vehicles to charity. This was not an option on the CARB survey form, which is unfortunate, given the high response this answer received in the Bay Area. Some of the vehicles donated to charities are scrapped for parts to raise money. Therefore, perhaps between five and 25 percent of the scrapped vehicles might have been scrapped without the BAAQMD incentive program. On the other hand, about 40% of the sellers in both programs said that they would have sold the vehicle. Some portion of these owners might not have succeeded. They might then scrap the car or continue to own it, but not drive it much. On the other hand, nearly half (48.9%) of the CARB participants and 27.6% of the BAAQMD participants would have kept the vehicle, as is or fixed up. Vehicles that are fixed might emit fewer pollutants, but whether the person would have followed through in fixing the vehicle is unknown. The Participant Survey asked the respondents how much they estimated they would have to spend on the vehicles if they would have kept and fixed them up. The median amount was $750 and the mean was $974. These numbers cast some doubt on whether the repairs would have occurred.

Based on these survey responses, most of the vehicles would have continued in use without the VAVR programs. These are also the vehicles that were expected to last the longest—over three years, on average. Moreover, many of the vehicles would have had new owners, which could have increased their rate of use.

Table 66: VAVR Participants' Most Likely Option to Scrapping

	CARB Pilot Program Vehicles		BAAQMD Scrapped Vehicles	
Option to Scrapping	**%**	**Mean life expectancy**	**%**	**Mean life expectancy**
Would probably continue on the road:				
Sell it	42.9%	3.46	40.0%	3.24
Keep it as is	17.3	3.99	13.6	3.71
Keep it and fix it up	31.6	3.40	14.0	3.72
Give it to a family member or friend	n.a.	n.a.	6.5	3.41
Subtotal	91.8		74.1	
May not continue on the road:				
Junk it	1.4	1.67	5.0	1.73
Donate it to charity	n.a.	n.a.	19.6	2.65
Other/Don't know	6.7	3.20	1.3	3.35
N	860	3.49	7,239	3.19

One interesting question these data help answer is whether the VAVR programs are significantly changing people's behavior, i.e. getting them to get rid of a vehicle they would have kept, or simply providing another option for getting rid of a vehicle. In the Bay Area, about one-quarter of the households were enticed to get rid of a vehicle they would have kept. In the CARB program this figure is closer to 50%. In both cases, the programs diverted about 40% of the vehicles from being sold to another party. This relates back to the discussion of transaction costs in Section 5.2.2; people find this an attractive alternative to trying to sell a vehicle to a private party and some are willing to accept a lower price for this option.

If people are overestimating their vehicle's life expectancy, the three year assumption for life expectancy is too long. In addition, an assessment of life expectancy should consider the household's alternatives to the VAVR program. A high and low estimate of life expectancy for the scrapped vehicles from the BAAQMD program is made with the assumptions described in Table 69. The low estimate would reduce the effectiveness of the VAVR program the most. The impacts of these assumptions appears in Table 68. The high estimate results in a total number of remaining years that is slightly higher than the CARB default. The low estimate is about 64% of the CARB default.

Table 67: Assumptions for Estimates of Vehicle Life Expectancy

Alternative to scrapping	High		Low	
	Assumption	Reasoning	Assumption	Reasoning
Sell it Give it to a friend or family member Keep it as is Keep it and fix it up	Seller's estimate	Seller's estimate is accurate	75% of seller's estimate	Seller over estimated the vehicle's condition. Also, some vehicles won't be sold and will be scrapped or donated instead.
Junk it	Zero years	Vehicle would be junked	Zero years	Vehicle would be junked
Donate it to charity	Seller's estimate	All donated vehicles are sold to new owners.	Zero years	Donated vehicles would be junked
Other	Missing data		Missing data	

Table 68: Comparison of Estimates of Life Expectancy

	CARB Default	High Estimate	Low Estimate
Mean	3.00	3.10	1.93
Median	3.00	3.00	1.50
% lasting 0 years	n.a.	5.2%	25.0%
Total years remaining	21,450	22,141	13,789
% of EMFAC estimate		103%	64%

N=7,150

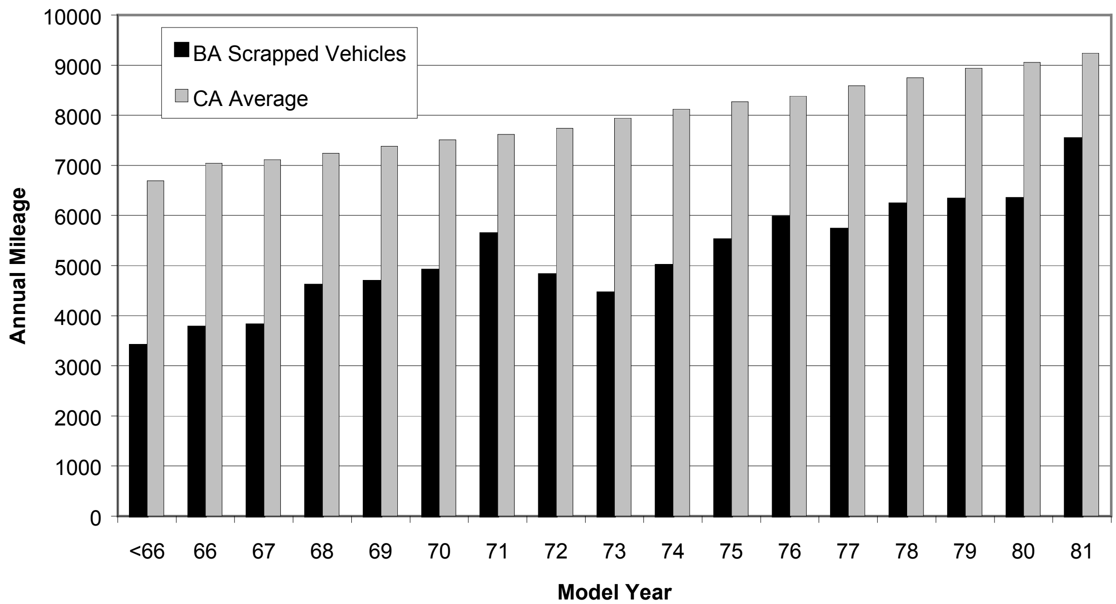
5.3.2 How would the vehicle be driven if not retired?

The next question is how far the vehicle would have been driven if it wasn't retired. CARB's current regulations recommend using the VMT averages from the emissions inventory model (EMFAC), which is based upon Smog Check odometer readings (California Air Resources Board, 1998). However, the agency does suggest that odometer readings may be appropriate. The discussion in Section 5.2.5 indicated that the scrapped vehicles in the Bay Area were driven less than the statewide average from the EMFAC model. This is shown in Figure 36 by model year. The difference is consistent across most model years. The analysis from above also suggests that this difference could be due to a number of factors, including those listed below.

- The scrapped vehicles are in poorer condition and less reliable than older vehicles in general.
- Certain types of high-use older vehicle owners, such as low-income households and households with only one vehicle, are not participating at a rate comparable to their rate of older vehicle ownership.

- Some households that tend to use their older vehicles less than the average, such as retired households and households with multiple vehicles, are attracted to VAVR programs at higher than expected rates.

Figure 36: Annual Mileage of Scrapped Vehicles from the Bay Area by Model Year



What is the impact of this probable overestimation of vehicle use? As with the life expectancy, such an analysis must take into account what the owner would have done with the vehicle had it not been retired. A high and low estimate of future annual mileage for the scrapped vehicles from the BAAQMD program is made with the assumptions described in Table 69. All else being equal, the low estimate would reduce the effectiveness of the VAVR program the most, because it assumes that the vehicles would have been driven the least amount in the future. The results of these assumptions, along with an estimate of total mileage using the EMFAC averages appears in Table 70. The actual future mileage in the vehicles, had they not been scrapped, may be as little as half and as high as 86% of what the EMFAC averages predict.

Table 69: Assumptions for Estimates of Future (Avoided) Mileage

Alternative to scrapping	High		Low	
	Assumption	**Reasoning**	**Assumption**	**Reasoning**
Sell it Give it to a friend or family member	EMFAC average for model year	New owner would drive like the average	Seller's estimated mileage	The vehicle's lower quality or other attributes will continue to keep its mileage low, even with a new owner
Keep it as is Keep it and fix it up	Seller's estimated mileage	Seller will continue to drive it the same amount in the near future	Seller's estimated mileage	Seller will continue to drive it the same amount in the near future
Junk it	Zero miles	Vehicle would be junked	Zero miles	Vehicle would be junked
Donate it to charity	EMFAC average for model year	All donated vehicles are sold to new owners, who drive them like the average	Zero miles	Donated vehicles would be junked
Other	Missing data		Missing data	

Table 70: Comparison of Estimates of Future (Avoided) Mileage

	EMFAC Averages	High Estimate	Low Estimate
Mean Mileage per vehicle	8,458	7,255	4,224
Total Annual Mileage	55,748,601	47,818,436	27,838,940
% of EMFAC estimate		86%	50%

N=6,591

5.3.3 What are the emissions from the retired vehicles?

CARB allows three methods for estimating the emissions from the scrapped vehicles: (1) direct testing of every vehicle; (2) sampling a statistically significant portion of the vehicles for testing; and (3) using emissions rates from the CARB inventory model (EMFAC) (California Air Resources Board, 1998). The first two options are usually cost-prohibitive for an ongoing VAVR program. The vehicles scrapped through the CARB Pilot Program were put through a variety of emissions tests, including the IM240 test used by some I/M programs. The results of these tests are used in the discussion below. The Participant and Non-Participant survey data indicates that the scrapped vehicles are of lower value and more likely to be in need of repairs than older vehicles that are not scrapped. They are also more likely to be owned by lower-income households. Based upon the literature, these three factors would indicate that the emissions from the scrapped vehicles may be higher than the older vehicle fleet as a whole.

The average exhaust emissions rates (grams/mile) for the CARB Pilot Program vehicles by model year are shown in Figure 37 (hydrocarbons), Figure 38 (nitrogen oxides), and Figure 39 (carbon monoxide). For HC and NO_x, emissions are significantly higher for the older vehicles (based upon ANOVA F-tests). There is no statistically significant difference between the means for CO emissions. The range of emissions (indicated by 95% confidence intervals) is important to note. Using data from the Unocal SCRAP and Illinois projects showing very wide ranges of emissions from scrapped vehicles, Hsu and Sperling (1994) questioned whether accurate estimates of emissions benefits were possible. This is a valid concern, yet a difficult one to address and one that is applicable to all ages of vehicles. One approach is to try to determine the cause of the variance in the data. This research has focused on the relationship between household characteristics and VAVR programs. Therefore, one question is whether and how the characteristics of a household explain the emissions from the vehicles.

Figure 37: Mean HC Emissions from Scrapped Vehicles

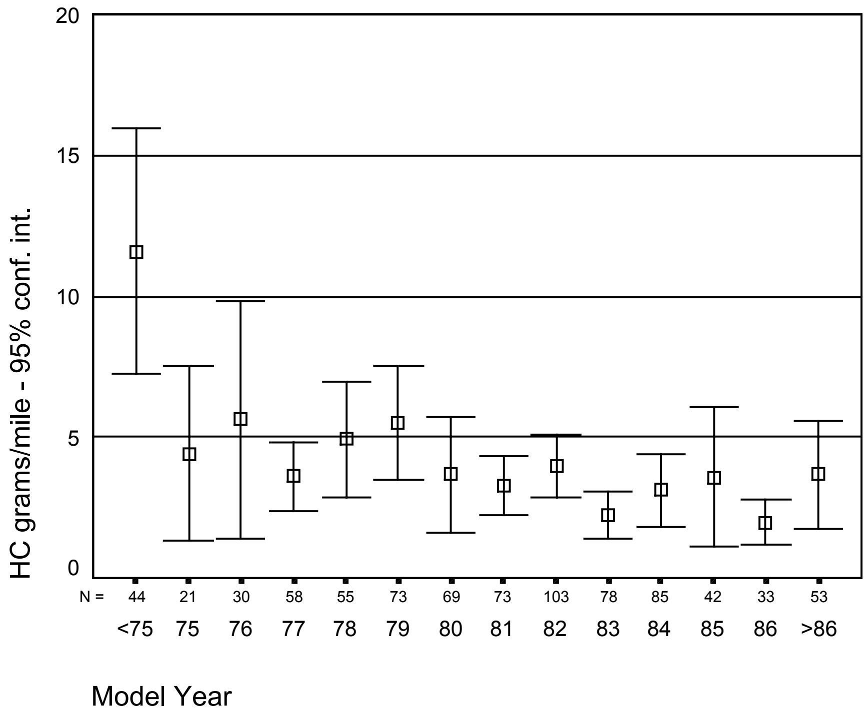


Figure 38: Mean NO_x Emissions from Scrapped Vehicles

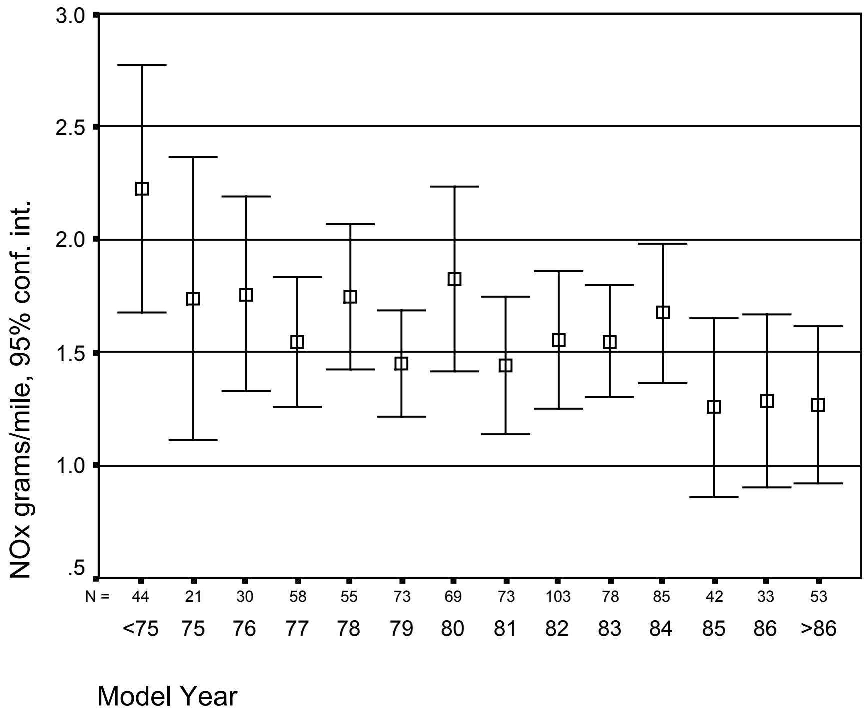
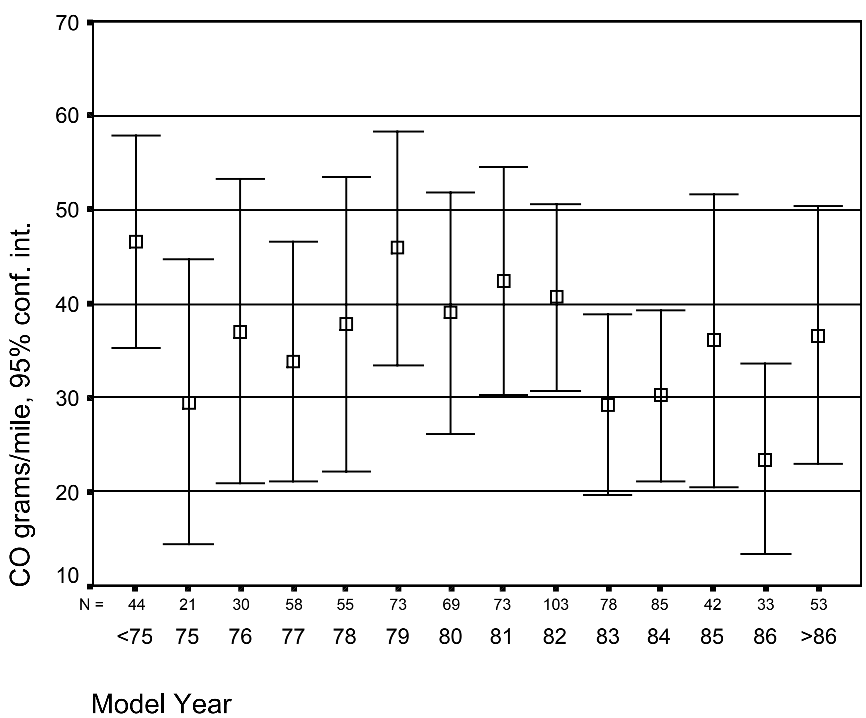


Figure 39: Mean CO Emissions from Scrapped Vehicles



The results of regression models exploring whether various household and vehicle characteristics help explain a scrapped vehicle's emissions appear in Table 71. In no model do the variables explain more than ten percent of the variation in the emissions data, though all four models are statistically significant. The variables do the poorest job predicting NO_x emissions. Income and the age of the seller have significant negative effects on emissions of HC and CO. Household size has a positive impact on emissions, as does the vehicle weight and total mileage. Vehicle model year is the only significant variable in the model predicting NO_x emissions. Several variables were tested in the models and found not to be significant, including the seller's estimates of how much longer the vehicle would last and the vehicle's value, owner's education levels, annual mileage, and whether the seller is Hispanic. It appears that the seller's opinion of their scrapped vehicle, as reflected in their estimate of its value and life expectancy, is not a good indicator of actual emissions as measured by the IM240 procedure.

Table 71: Regression Models – Vehicle Emissions[17]

Variable	IM240 Emissions (grams/mile)							
	$(CO/7)+HC+NO_x$		HC		CO		NO_x	
	β	**Sig.**	**β**	**Sig.**	**β**	**Sig.**	**β**	**Sig.**
Constant	29.78	0.006	19.29	0.005	31.98	0.47	5.92	0.00
Household Characteristics								
Income ($1,000)	-0.079	0.000	-0.034	0.01	-0.31	0.00	-0.0011	0.65
Age of seller	-0.11	0.002	-0.042	0.05	-0.41	0.004	-0.0061	0.13
Household size	0.80	0.001	0.50	0.001	1.91	0.06	0.027	0.35
Vehicle Characteristics								
Vehicle model year	-0.33	0.004	-0.26	0.00	-0.17	0.72	-0.050	0.00
Gross Vehicle Weight (000)	2.77	0.000	1.49	0.00	9.53	0.00	-0.082	0.26
Mileage (odometer, 000)	0.019	0.063	0.011	0.085	0.050	0.24	0.00096	0.43
Adjusted R^2	0.092		0.077		0.047		0.016	
F (sig)	14.41 (0.000)		12.00 (0.000)		7.52 (0.000)		3.17 (0.004)	

Variables that were not significant: Annual mileage (calculated), Hispanic seller, Highest education level, Vehicle value, How much longer the vehicle would have lasted, number of cylinders, automatic transmission

One hypothesis is that emissions from the scrapped vehicles will be higher than the on-road average, because the vehicles are in poorer condition than the vehicles from non-participant households. Figure 40 shows the emissions of reactive organic gases (ROG)[18] from the CARB Pilot Program scrapped vehicles and the statewide average in 2000 from the EMFAC 2000 model. Only exhaust emissions are included, not diurnal, hot soak, or evaporative emissions. For most model years, emissions from the scrapped vehicles are significantly higher, particularly for the 1974 and older vehicles. Through model year 1981, ROG emissions are 13-99% higher than the EMFAC statewide average. However, this is not the case for NO_x and CO emissions. NO_x emissions are 35-68% lower than the EMFAC average up to model year 1981; CO emissions range from 28% higher to 58% lower through model year 1981.

[17] This analysis was performed by the author. It also appears in (Sierra Research, 2001).

[18] HC emissions converted to ROG using CARB conversion factors.

The lower NO_x emissions is consistent with the data from the Delaware program (Alberini et al., 1996) and with data from the Unocal SCRAP II project, which found emissions from scrapped vehicles to be 13-32% lower than the EMFAC model predictions at the time (Unocal Corporation, 1994). Carbon monoxide emissions from the scrapped vehicles in SCRAP II were higher than the EMFAC prediction. One possible reason for the CARB scrapped vehicles being relatively cleaner (for CO) than the SCRAP II vehicles is that the eligibility requirements were stricter. Under SCRAP II the vehicle had to be driven to the purchase site under its own power and be complete with bumpers, fenders, doors, windshield, etc. Soon after the project, the SCAQMD started to require a functional inspection of the vehicle, including turning the engine off and re-starting it and driving it in forward and reverse (Unocal Corporation, 1994). Vehicles in the CARB Pilot Program had to pass a visual and operational inspection under the newer SCAQMD rules and had to have passed a Smog Check inspection (Sierra Research, 2001). Therefore, the vehicles in the CARB program, and most likely those in the BAAQMD program, are probably of higher quality than in the SCRAP program. The question remains, however, why the CARB Pilot Program scrapped vehicles emit more ROG, but less NO_x and CO, than EMFAC averages. The survey data indicate that scrapped vehicles are in poorer condition than the non-participants' vehicles, according to their owners. One potential explanation is that the screening criteria somehow results in vehicles that are in better condition (compared to the fleet) with respect to components that impact CO and NO emissions, but not ROG emissions. Further analysis of this theory, however, is beyond the scope of this research.

Figure 40: ROG Emissions from Scrapped Vehicles versus EMFAC average

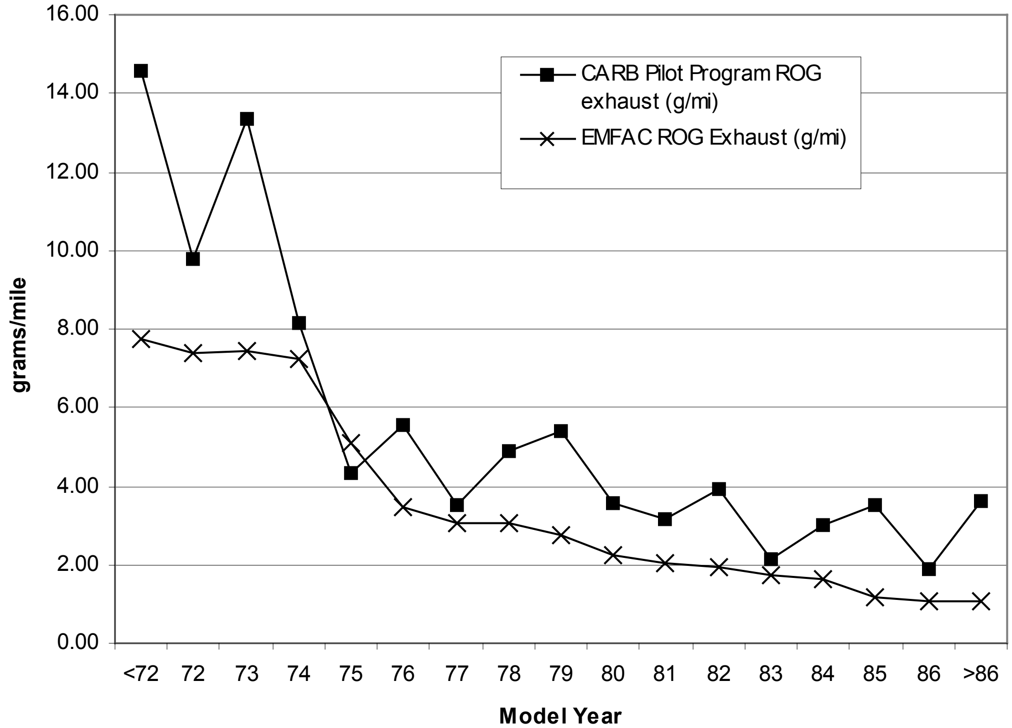


Figure 41: NO_x Emissions from Scrapped Vehicles versus EMFAC average

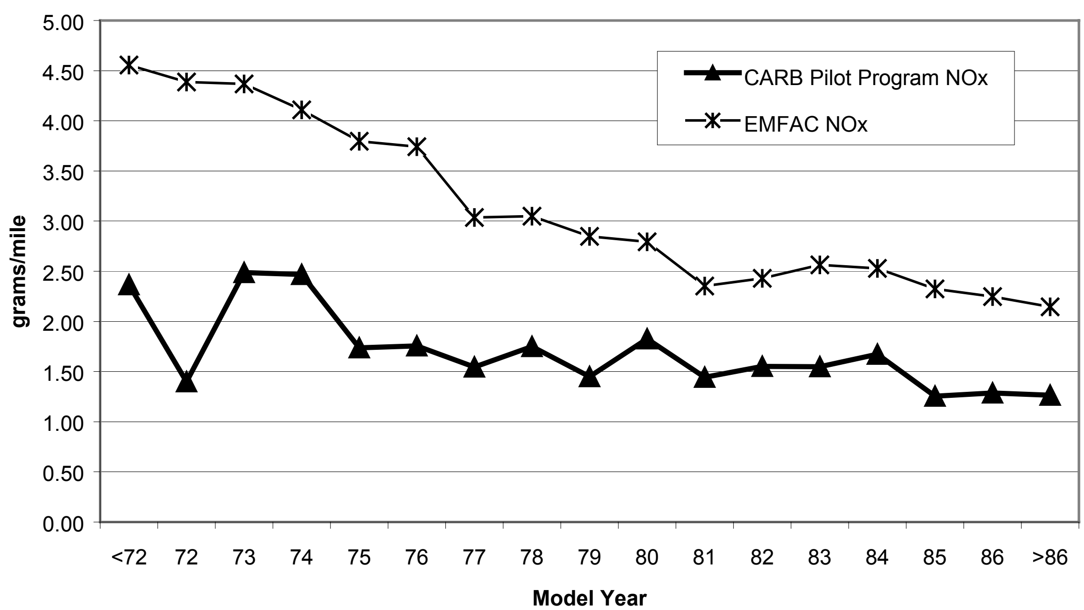
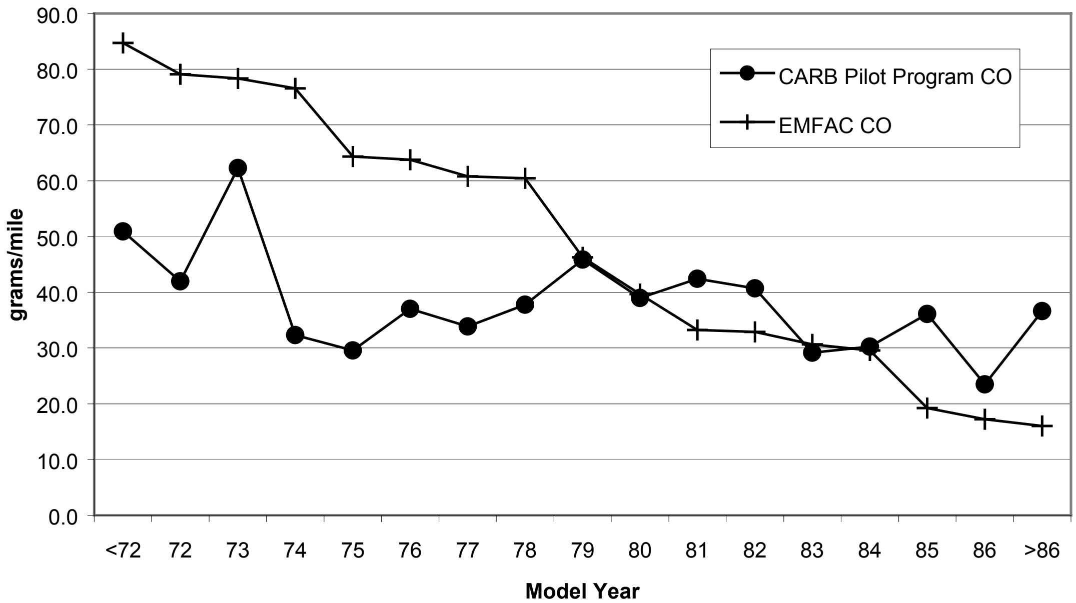


Figure 42: NO_x Emissions from Scrapped Vehicles versus EMFAC average



Overall, then, it appears that the ROG exhaust emissions from pre-1981 scrapped vehicles are higher than predicted with the EMFAC model, but NO_x and CO emissions are about the same or lower. In addition, the stricter eligibility requirements seem to have improved the quality of the vehicles accepted to VAVR programs and, therefore, reduced their emissions. While the overall emissions benefits of a VAVR program will be higher the more polluting the scrapped vehicles are, the lower quality vehicles likely had a shorter life expectancy, thus reducing program effectiveness.

5.3.4 How was the VMT replaced?

The final part of the assessment of the emission reduction from VAVR programs is how the travel provided by the retired vehicle is replaced. The BAAQMD Participant Survey and the CARB Pilot Program Follow-Up Survey included several questions regarding the replacement transportation. The surveys conducted at the scrap yard in both programs also asked about replacement transportation. However, the information from the follow-up surveys should be more accurate in terms of what the person actually did, and they will be used for this analysis. About half (47.7%) of the Bay Area participants are driving another vehicle they already had in the household and 43.4% are driving a new or used vehicle they purchased, leased, or were given recently. In both programs, a small share (6.8% in Bay Area, 6.0% in CARB program) of the drivers are no longer driving a vehicle for their primary transportation.

Table 72: Replacement Transportation

	BAAQMD Participant Survey	CARB Follow-Up Survey
Driving another vehicle already in the household	47.7%	37.4%
Bought, leased, or was given a new vehicle	15.0	56.1*
Bought, leased, or was given a used vehicle	28.4	
Getting ride with friends, family, or neighbors	2.0	
Using public transportation	2.3	
Riding bicycle or walking	1.5	
Multiple answers – all not driving	1.0	6.0
Other	2.2	0.4
N	1,240	729

*The CARB survey did not distinguish between new and used vehicles.

There is a relationship between income and the type of replacement transportation. Lower income households in the Bay Area are more likely to purchase, lease, or be given a replacement vehicle, rather than use a vehicle already in the household (Table 73). The lower-income households have fewer vehicles, so if they sell one to a VAVR program, they are more likely to need to replace it with a new or used one. A higher share of the higher-income households identified the scrapped vehicle as an "extra" vehicle in their household. Finally, a significant share (25.4%) of the lowest income households did not replace the vehicle with another vehicle.

Table 73: Replacement Transportation by Income, Bay Area Participant Survey

	Driving Vehicle already in hhld.	Purchase/ Lease New or Used Vehicle	Not driving	n
$15,000 and under	25.4%	49.1%	25.4%	114
$15,001 – 30,000	40.6	55.1	4.3	187
$30,001 – 45,000	44.8	49.3	6.0	201
$45,001 – 60,000	53.4	39.3	7.3	191
$60,001 – 75,000	57.7	34.5	7.7	142
Over $75,000	53.1	39.0	7.9	292
All Incomes	47.4	44.0	8.6	1,127

How much the seller drove their scrapped vehicle seems to have an impact on their replacement choice. In both the CARB and BAAQMD programs, mean annual mileage on the scrapped vehicles is highest for households that purchased a replacement vehicle. The differences, however, are not statistically significant in the CARB data.

Table 74: Mean Annual Mileage on Scrapped Vehicle by Replacement Transportation

	BAAQMD Participant Survey	CARB Follow-Up Survey
Driving another vehicle already in the household	4,766	8,848
Purchased/Leased another vehicle	6,864	10,109
Not driving	3,579	8,164
Level of sig. (F-test)	0.00	0.55
n	1,101	589

The CARB regulations assume that all vehicles are replaced and that the replacement vehicle will be the fleet average. The assumption that all the vehicles are replaced with another vehicle is not entirely true given these data, though over 90% of the vehicles are replaced. Kavalec and Setiawan (1997) estimated that 85% of the vehicles were replaced.

A key question is what types and ages of vehicles are being used as replacements? Critics often contend that with $500 the seller will simply go out and buy another "clunker." Both surveys collected model year information on the replacement vehicles. The fear that sellers are purchasing other old vehicles appears unfounded. Only about ten percent of the replacement vehicles are model year 1981 or older (Table 75). This is comparable to the share of vehicles throughout California that are 1981 or older (based upon the fleet distribution in EMFAC). About three-quarters of the replacement vehicles are model year 1986 or newer. Over one-third of the Bay Area replacement vehicles are from 1994 or newer, when new vehicle standards went into effect. About one-quarter of the CARB replacement vehicles are model year 1994 or newer. These vehicles have the least total mileage on them, averaging less than 40,000 miles. In contrast, the pre-1994 vehicles average over 100,000 miles. The Bay Area replacement vehicles are an average of 13.2 years newer and the CARB replacement vehicles are 8.1 years newer than the scrapped vehicles.

Table 75: Model Years of Replacement Vehicles

	BAAQMD Participant Survey		CARB Follow-Up Survey		EMFAC CA (2000)
	%	Mean mileage	%	Mean mileage	%
1969 & older	1.4%	148,700	0.7%	121,000	2.3%
1970 – 1981	8.9	138,700	8.8	105,600	7.7%
1982 – 1985	12.2	126,800	16.1	102,100	9.5%
1986 – 1993	41.4	115,500	50.1	100,400	38.7%
1994 & newer	36.1	31,900	24.3	37,200	41.8%
N	1,109	1,031	671	525	
Difference in vehicle age (scrap – replacement, years)					
Mean	-13.2		-8.1		
Median	-13.0		-8.0		
Std. deviation	7.7		6.5		

Most of the households are spending far more than the $500 on their purchased replacement vehicles. The average purchase price of replacement vehicles in the Bay Area Participant Survey is $8,267 (std. dev. = $8,708) and the median is $4,500. The average purchase price for the CARB program participants is $6,074 (std. dev. = $7,459) and the median is $2,800.

In the Bay Area and the CARB program, the model year of the replacement vehicle is positively correlated with income, i.e. replacement vehicles in higher income households are newer. In the Bay Area, the replacement vehicle model year is also negatively correlated with the number of vehicles per driver. This indicates that households with more vehicles per driver, and, therefore, a higher chance of having extra vehicles, replace the scrapped vehicles with older vehicles. This is because these households are more likely to use a vehicle already in the household, rather than go out an get another vehicle, and vehicles already in the household tend to be older. In neither program was the model year of the replacement vehicle correlated with the annual mileage on the scrapped vehicles. In other words, people who drove their scrapped vehicles more were not more likely to replace them with newer vehicles.

Another concern raised about VAVR programs is that, if the replacement vehicles are newer, they are more likely to be light duty trucks (LDTs), including SUVs and minivans, which are a larger portion of the newer vehicles. Emission standards for LDTs are currently not as strict those as for automobiles. A higher portion of the replacement vehicles in the Bay Area are SUVs or vans, compared to the scrapped vehicles. Vehicle type data were not collected in the CARB program. The results of this difference may be one reason a share of the households stated that their replacement vehicle gets worse gas mileage than the scrapped vehicle (Table 77). However, over half of the replacement vehicles get better gas mileage.

Table 76: Replacement Vehicle Types, Bay Area

		Replacement Vehicles	
	Scrapped Vehicles	**Already in Hhld.**	**Purchased/ Leased**
Car or station wagon	80.2	69.1%	67.3%
Pickup truck	13.3	14.4	18.8
Sport utility vehicle (SUV)	0.5	6.6	6.4
Van or minivan	6.0	9.3	7.3
Motorcycle/Other	0.0	0.7	0.2
N	1,253	592	532

Results are from Participant Survey, so they may differ from the Yard Survey vehicle types.

Table 77: Comparisons of Scrapped and Replacement Vehicles, Bay Area

Replacement vehicle …	Replacement Vehicles Already in Hhld.	Replacement Vehicles Purchased/ Leased
Is more reliable	74.8%	79.0%
Gets worse gas mileage	17.5%	14.0%
Gets better gas mileage	58.1%	66.3%

The CARB regulations also assume that people replace the mileage of the scrapped vehicle on a one-for-one basis, i.e. they drive it the same distance. The econometric models examining VAVR programs sometimes adjust mileage based upon the replacement vehicle model year; if people replace the vehicles with newer vehicles, they may drive more (Kavalec & Setiawan, 1997). The Participant Survey asked how frequently and how many miles per week the replacement vehicle is driven. These results are in Table 78 and Table 79. The replacement vehicles are driven significantly more frequently and further than the scrapped vehicles. However, this does not necessarily mean that overall household travel is increasing. In the case of the replacement vehicles already in the household, they are being used more intensively than before – the travel previously split between two vehicles is now provided by one vehicle. In the case of purchased or leased vehicles, mileage on other vehicles in the household may be reduced, as the household shifts to the newer vehicle. The data in Section 4.5.3 demonstrated that many households with multiple vehicles choose newer vehicles for certain types of trips and older vehicles for other trips. Vehicle use within a household is a dynamic process that will change when the mix of vehicles changes.

Table 78: Frequency of Use of Replacement Vehicles, Bay Area

	Scrapped Vehicles	Replacement Vehicles Already in Hhld.	Purchased/ Leased
6-7 days per week	33.3%	66.3%	67.2
3-5 days per week	25.7	27.1	26.8
1-2 days per week	16.2	5.8	4.2
1-3 days per month	13.0	0.5	1.1
Less than once a month	11.7	0.3	0.6
n	1,250	590	522

Table 79: Weekly Mileage in Replacement Vehicles, Bay Area

	Scrapped Vehicles	Replacement Vehicles Already in Hhld.	Purchased/ Leased
0 miles	9.2%	0.0%	0.6%
1 – 9 miles	9.4	1.2	0.6
10 – 19 miles	9.6	1.2	2.1
20 – 49 miles	20.2	13.7	13.6
50 – 99 miles	19.9	19.0	24.5
100 – 149 miles	13.1	21.1	20.0
150 or more miles	18.7	43.8	38.5
Mean	79.6	156.1	142.5
N	1,224	569	514

Short of gathering odometer readings over two or more years for all vehicles in the household, it is impossible to accurately assess overall household travel after vehicle retirement. However, the Participant Survey attempted to assess this question by asking the household, "Overall, do you feel that the people in your household all together are driving more, less, or about the same number of miles per week (combined) than they did before you sold your vehicle to the Vehicle Buy Back program?" Nearly three-quarters (73.6%) thought they were driving about the same. The remainder were evenly split between driving more and less (13.2% each). The household was also asked why their driving changed. The answers to this open-ended question were coded. About half of the people driving more and less are doing so because of changes in their household, such as a change in work location or the number of people in the household. Over one-quarter (27.8%) of the households who are driving more are doing so because of the qualities of their replacement vehicles, including being newer or more reliable. This represents 3.7% of all of the households from the Participant Survey. On the other hand, 12.7% of the households that thought they were driving less are doing so because they now have fewer vehicles. If people's perceptions of their travel are relatively accurate, the overall amount of travel probably did not change significantly *because* the household retired a vehicle through the VAVR program.

5.3.5 Overall Emissions Reductions

Sections 5.3.1 and 5.3.2 presented some high and low estimates using sets of assumptions that differ from the current CARB methodology. Those assumptions are carried through to calculate emissions reductions for the vehicles from the BAAQMD Participant Survey. The assumptions for this analysis are summarized in Table 80. Two assumptions are made regarding the emissions for the scrapped vehicles: (1) the EMFAC factors by model year; and (2) the average for that model year from the CARB Pilot Program vehicles. Some additional assumptions are made regarding replacement transportation. Unlike the CARB methodology, these assumptions are tied to the actual replacement vehicle and its model year. For the replacement VMT, the high assumption uses the default values from EMFAC by model year. The low assumption uses the seller's estimate of how far they drove the scrapped vehicle. If the seller did not replace the vehicle with another vehicle (e.g. they are using transit, etc.) the VMT is zero. The emissions of the replacement vehicle are the EMFAC emissions factors by model year (not an overall average).

Table 80: Assumptions for Emissions Reduction Estimates

Scenario	VMT of scrapped vehicle	VMT of replacement vehicle	Exhaust Emissions of Scrapped Vehicle	Exhaust Emissions of Replacement Vehicle	Life Expectancy
Default	EMFAC average for model year	Same as scrapped vehicle	EMFAC average by model year	EMFAC average for all model years	3.0 years
Low 1	Low (described in Table 69)	Seller's estimate of current mileage	EMFAC average by model year	EMFAC average by model year	Low (described in Table 67)
Low 2	Low (described in Table 69)	Seller's estimate of current mileage	CARB Pilot Program average by model year	EMFAC average by model year	Low (described in Table 67)
High 1	High (described in Table 69)	EMFAC average by model year	EMFAC average by model year	EMFAC average by model year	High (described in Table 67)
High 2	High (described in Table 69)	EMFAC average by model year	CARB Pilot Program average by model year	EMFAC average by model year	High (described in Table 67)

Additional Assumptions
High and Low Scenarios: No (zero) emissions reductions from scrapping vehicles that would have been junked if not sold to the program.
Low Scenarios: No (zero) emissions reductions from scrapping vehicles that would have been donated to charity if not sold to the program.
All Scenarios: ROG evaporative emission and trip rates from EMFAC.

The results of these calculations are shown in Table 81. Only vehicles for which complete information on all of the assumptions was available are included. For ROG emissions, three of the four scenarios result in smaller emissions reductions, ranging from 18 to 71 percent lower than the Default scenario, representing the current methodology. All of the scenarios predict smaller NO_x and CO emissions reductions. In two scenarios (Low 2 and High 2), NO_x emissions actually increase.

Table 81: Mean Total Emissions Reduction per Vehicle Retired (kilograms)

Scenario	ROG exhaust		ROG evaporative		ROG Total	
Default	71.87		52.25		124.12	
Low 1	15.59	-78%	20.66	-60%	36.24	-71%
Low 2	35.91	-50%	20.66	-60%	56.56	-54%
High 1	57.82	-20%	39.76	-24%	97.58	-21%
High 2	111.16	+55%	39.76	-24%	150.92	+22%
Scenario	**NOx**		**CO**			
Default	48.42		1056.17			
Low 1	1.35	-97%	202.62	-81%		
Low 2	-11.62	-124%	82.14	-92%		
High 1	28.91	-40%	802.75	-24%		
High 2	-4.85	-110%	471.98	-55%		

N=979

The sources for these differences are shown in Table 82. The VMT estimates for the scrapped vehicles in all scenarios are lower than the Default scenario. This reduces the estimated exhaust and running loss emissions from the scrapped vehicles for all three pollutants. The larger difference in the VMT for the Low scenarios (compared to the High scenarios) stems from the assumption that vehicles that would have been junked or donated to charity would have been driven zero miles in the future, e.g. they would have been scrapped with or without the VAVR program. Therefore, there is no benefit to scrapping these vehicles through a VAVR program. The Low 2 and High 2 scenarios use the CARB Pilot Program emissions data for the scrapped vehicles. For ROG, this results in higher emissions from the scrapped vehicles than the Default, Low 1, and High 1 scenarios, which use the EMFAC emissions factors. However, for NO_x and CO, the emissions from the CARB Pilot Program vehicles were 45% and 26% *lower*, respectively, than the EMFAC estimates by model year. This explains the increase in NO_x emissions for the Low 2 and High 2 scenarios. However, if the scrapped vehicles are actually cleaner than the EMFAC model predicts (for NO_x and CO), one might want to assume that the replacement vehicles would be cleaner as well. There is, however, no theoretical basis for such an assumption. In fact, a body of research literature questions whether the mobile source models significantly *under predict* real-life emissions (National Cooperative Highway Research Program, 1997; Singer & Harley, 1996). The question that still remains is why the tested emissions from the scrapped vehicles in the CARB program were cleaner than EMFAC would predict for NO_x and CO.

The final major difference with respect to the scrapped vehicles is the assumption for life expectancy. Both Low scenarios assume the vehicles would last, on average, 40% fewer years, while the mean life expectancy in the High scenarios is seven percent longer.

The other half of the equation involves the assumptions regarding the replacement vehicle. The Default scenario assumes that the vehicle is replaced by the average of the entire fleet. The other scenarios use the model year of the actual replacement vehicle, if there is one. This key difference in the assumptions results in higher emissions rates for the replacement vehicles. This is because the replacement vehicles are, on average, older than the fleet as a whole. The average model year for the actual replacement vehicles is 1989. The average model year for all light duty vehicles in the EMFAC model is 1991. Higher emissions from the scrapped vehicles under the four scenarios (compared to the Default) reduces the estimated emissions reductions from the program.

Table 82: Sources for Differences in Estimates of Emissions Reduction

	Mean per vehicle (% difference from Default)				
	Default	Low 1	Low 2	High 1	High 2
Scrapped Vehicle					
VMT	8,587	3,748 (-56%)	3,748 (-56%)	7,070 (-18%)	7,070 (-18%)
ROG exhaust (g/mi)	3.81	3.81 (same)	6.06 (+59%)	3.81 (same)	6.06 (+59%)
ROG evaporative	Same for all scenarios				
NO_x emissions (g/mi)	3.24	3.24 (same)	1.78 (-45%)	3.24 (same)	1.78 (-45%)
CO emissions (g/mi)	55.61	55.61 (same)	41.33 (-26%)	55.61 (same)	41.33 (-26%)
Life expectancy (years)	3.0	1.8 (-40%)	1.8 (-40%)	3.2 (+7%)	3.2 (+7%)
Replacement Vehicle					
VMT	8,587	3,472 (-60%)	3,472 (-60%)	9,643 (+12%)	9,643 (+12%)
ROG exhaust (g/mi)	0.87	1.04 (+20%)	1.04 (+20%)	1.04 (+20%)	1.04 (+20%)
ROG diurnal (g/day)	3.43	3.63 (+6%)	3.63 (+6%)	3.63 (+6%)	3.63 (+6%)
ROG hot soak (g/trip)	0.41	0.46 (+12%)	0.46 (+12%)	0.46 (+12%)	0.46 (+12%)
ROG running loss (g/mi)	0.41	0.52 (+27%)	0.52 (+27%)	0.52 (+27%)	0.52 (+27%)
ROG resting loss (g/day)	0.78	0.82 (+5%)	0.82 (+5%)	0.82 (+5%)	0.82 (+5%)
Trips per day	6.25	5.57 (-11%)	5.57 (-11%)	5.57 (-11%)	5.57 (-11%)
NO_x emissions (g/mi)	1.31	1.45 (+11%)	1.45 (+11%)	1.45 (+11%)	1.45 (+11%)
CO emissions (g/mi)	13.39	15.75 (+18%)	15.75 (+18%)	15.75 (+18%)	15.75 (+18%)

The two Low scenarios assume much lower VMT for the replacement vehicles, based on the owner's lower estimates of how far they drove the scrapped vehicle. The mean VMT for the Low scenarios is slightly lower than the VMT for the scrapped vehicles in the same scenarios because some of the vehicles were not replaced with another vehicle. In these cases, the VMT for the replacement vehicle is zero. In the Low scenarios, the difference in VMT between the scrapped and replacement vehicles increases the overall emissions reductions. On the other hand, the assumption in the High scenarios is that the replacement vehicles are driven the fleet average for their model year according to the EMFAC model. Because the replacement vehicles are generally newer than the scrapped vehicles, the average VMT for the replacement vehicles in the High scenarios is higher than the Default scenario and higher than the scrapped vehicles in the High scenarios. This is consistent with the theory that people will drive newer vehicles further. However, the Participant Survey did not support this theory. Moreover, if households are driving the replacement vehicle further, they are likely driving other household vehicles less. The Default methodology assumes that the VMT is replaced on a one-for-one basis, i.e. the replacement vehicle is driven the same distance as the scrapped vehicle. This is similar to the assumption in the Low scenarios, except that in the Low scenario vehicles that are not replaced are set to zero miles for the replacement vehicle. A second set of High scenarios was run using the VMT assumption from the Low scenarios. These are labeled High 1a and High 2a and the results are shown in Table 83. The change in the replacement VMT assumption makes a significant positive difference in the overall emission reductions, i.e. greater reductions occur compared to the High 1 and High 2 scenarios.

Table 83: Mean Total Emissions Reduction per Vehicle Retired (kilograms) with New High Scenarios

Scenario	ROG Total		NOx		CO	
Default	124.12		48.42		1056.17	
Low 1	36.24	-71%	1.35	-97%	202.62	-81%
Low 2	56.56	-54%	-11.62	-124%	82.14	-92%
High 1	97.58	-21%	28.91	-40%	802.75	-24%
High 2	150.92	+22%	-4.85	-110%	471.98	-55%
High 1a	125.99	+2%	57.51	+19%	1096.28	+4%
High 2a	179.33	+44%	23.75	-51%	765.51	-28%

This exercise shows that changing the assumptions used to calculate the emissions reductions from a VAVR program results in a very large range of benefits. In all but two scenarios, the VAVR program does reduce emissions of all three pollutants. In the High 1a scenario, the emission reductions of all three pollutants are actually greater than the Default scenario, and in the High 2 and High 2a scenarios the ROG reductions are greater. Using the CARB Pilot Program emissions data for the scrapped vehicles results in overall NO_x increases in the Low 2 and High 2 scenarios and a negligible CO reduction in the Low 2 scenario. This implies that VAVR programs may be most effective in reducing ROG emissions. This finding, however, may not be too detrimental to VAVR programs, since ROG reductions are often their primary objective.

The exercise is not directly applicable to the development of a new methodology to predict reductions for a MERC program or SIP measure. This is because many of the assumptions used in the six new scenarios could not be carried out without detailed survey data. The data used from the Yard and Participant Surveys that may not be available to air quality regulators includes the model year of the replacement vehicle, the most likely alternative to scrapping the vehicle, and the scrapped vehicles' VMT. However, air quality regulators could apply some assumptions that try to replicate what actually occurs. For example, instead of assuming that the replacement vehicles are the fleet average, one could assume that they are two years older than the fleet average. Instead of assuming that all of the vehicles would have continued to operate, one could assume that a certain percentage would have been scrapped without the VAVR program. Similarly, the annual VMT could be adjusted downward. Employing these adjustments would make the estimates more conservative, which may more accurately reflect reality.

5.4 *Summary of Findings*

Several key findings emerge from the data above.

- Expanding model year eligibility from 1981 to 1985 will likely attract more vehicles, even at the $500 price, and reduce emissions.
- VAVR programs are not be attracting older pickup trucks and SUVs at the same level they represent in the fleet, probably because these vehicles are used for specific purposes, e.g. towing or hauling. However, a higher proportion of the replacement vehicles are trucks and SUVs, compared to the scrapped vehicles. This reflects the trend of light-duty trucks (LDTs) replacing automobiles for household travel. The shift in vehicle type would only noticeably impact the emissions reductions from VAVR programs (as they were calculated here) if the proportion of LDTs as replacement vehicles is significantly higher than the proportion of LDTs by model year in the fleet as a whole.
- A majority of VAVR participants believe their vehicle is worth more than the $500 they received for it. The difference reflects, in part, the reduced transaction costs offered by a VAVR program. Any estimate of the potential number of vehicles attracted to a VAVR program must take this into account. The benefit of the difference in transaction costs (between a VAVR program and other methods of disposing of an older vehicle) means that a VAVR program diverts vehicles that would have been sold to other parties and continued on the road.
- About 40% or more of the vehicles would have been sold to other parties if they had not been scrapped. The diversion of vehicles from the used vehicle

market is an important aspect of the VAVR programs that previous research and the current methodology does not explicitly consider when evaluating emissions reductions. The current practice and most research assumes that the vehicles would have been driven by the same household about the same mileage as before. However, if the vehicles were sold to another household, driving patterns would likely change. This is particularly true for the “extra” vehicles that are not driven much. The new owner is likely to drive it further.

- About half of the vehicles scrapped in the San Francisco program were “extra” vehicles, about the same as those of non-participants. This indicates that extra vehicles are not disproportionately scrapped. However, the scrapped vehicles are generally in poorer condition, are worth less, and are driven less than other older vehicles.
- The VAVR programs are not attracting single, non-retired households where the older vehicle is the only vehicle and, therefore, it is driven a lot. In addition, lower income households that drive older vehicles further than other households do not appear to participate in VAVR programs at the same rate they represent in the population. This reduces the effectiveness of VAVR programs. Another category of high-mileage households that does not participate at the expected rate is families with children.
- Retired households are participating at rates higher than they represent in the population. Retired households drive older vehicles less than average, which lessens the emissions reductions from scrapping these vehicles. However, if these vehicles had been sold to other parties, rather than scrapped, the impact

on emissions reductions may not be significant. If retired households are disposing of vehicles because their driving patterns change (due to retirement, poorer health, etc.), this is likely the case.

- Most of the vehicles that are scrapped would have continued on the road in the near term, either with their current owner or another household. The criticism that most of the scrapped vehicles were headed to the junk yard anyway appears unfounded. The eligibility standards appear to be screening out most of these vehicles. The assumption that the vehicles would have continued on the road for three years may be high, but not unreasonably high.
- The average ROG emissions of scrapped vehicles are higher than the fleet average and increase with vehicle age. However, NO_x and CO emissions from the scrapped vehicles may be lower than predicted in the EMFAC model. In addition, there is a high degree of variance in emissions, meaning that some relatively clean vehicles are scrapped, along with some very dirty vehicles. Household characteristics, such as income, are related to vehicle emissions levels, though they explain only a small share of the variation in the data.
- Nearly all of the scrapped vehicles are replaced with another vehicle, one the household already had or one that is purchased or leased. Nearly all of the replacement vehicles are newer than the scrapped vehicles, though they are older than the fleet average.
- Changing the assumptions used to estimate emissions reductions from a VAVR program can significantly change the results. However, in nearly all the scenarios examined here, the programs are reducing emissions

significantly, particularly of ROG. Therefore, I conclude that the current programs are reducing emissions, though perhaps not as much as currently assumed. Regulators could make some adjustments to the methodology to make the estimates more conservative. This would be warranted particularly for programs that generate MERCs.

5.5 Potential Policy Responses

In light of the finding that VAVR programs do reduce emissions, but perhaps not as much as previously assumed, a useful question to ask is how the programs could be changed to increase effectiveness. This research found several factors that decrease the effectiveness of VAVR programs:

- Scrapped vehicles are driven less than average for their model years;
- A certain share of the scrapped vehicles would have been retired with or without the VAVR program incentive;
- Replacement vehicles are not as new as expected; and
- Replacement vehicles are more likely to be light duty trucks.

In addition, the scrapped vehicles are probably in poorer condition than other vehicles of the same vintages. The impact of this factor on program effectiveness is unclear. The vehicles may pollute more, making accelerated retirement a good thing. The CARB Pilot Program data did indicate that the vehicles emit more ROG exhaust than expected. On the other hand, vehicles in poorer condition will not last as long, reducing the life expectancy variable in the emissions reduction calculation.

The factors listed above that reduce program effectiveness are caused, in part, by which households decide to participate in the programs. For example, lower income households that drive their older vehicles a lot are not participating at levels equal to their ownership of older vehicles. Lower income households are also less likely to replace the vehicle with the least polluting, newest vehicles. Given these findings, five options for improving program effectiveness are described and discussed below: (1) Changing vehicle eligibility standards; (2) Offering repairs or retrofits as an option to scrapping; (3) Changing the incentive amounts; (4) Tying incentives to the vehicle replacement choice; and (5) Targeting vehicles.

5.5.1 Changing Vehicle Eligibility Standards

In 2000, CARB adopted detailed regulations for vehicle eligibility that generally tightened the standards previously used by air districts. These were discussed in Chapter 2. These requirements were intended to ensure that the vehicles sold to VAVR programs have a high probability of continuing on the road, if they were not scrapped. This directly impacts the life expectancy variable in the emissions reduction calculation. However, as suggested in the discussion of scrapped vehicle emissions in Section 5.3.3, stricter standards may also result in cleaner vehicles, thus reducing the emissions rates for the scrapped vehicles.

The BAAQMD implemented the new standards in July 2000. The Participant Survey included 308 households with vehicles that were subject to the new standards and 956 that sold vehicles to the program before July 2000. This allows for before and after comparisons of the households' perceptions of their vehicles, which may indicate whether the intent of the regulations was realized. The Participant Survey asked a series of questions regarding the scrapped vehicle, with responses of "strongly disagree",

“disagree”, “agree”, and “strongly agree” coded one through four, respectively. The mean scores for these questions are shown in Table 84.

For the most part, the results do not support the hypothesis that the stricter standards led to higher quality vehicles being retired. Most importantly, there is no significant difference between the vehicles on whether their owner thought they needed repairs to run well, polluted a lot, were reliable, or were safe. There is also no significant difference in the owners’ estimates of the vehicles’ worth (potential selling price) or life expectancy. The average age of the vehicles scrapped under the stricter standards was actually almost a year older than the other vehicles. However, the owners of vehicles scrapped under the stricter standards were less likely to think they would fail the next required Smog Check. The vehicles sold to the program under the stricter standards were more likely to be considered “extra” vehicles and need a paint job or other cosmetic improvements. In addition, they were driven fewer miles per week, which is consistent with the higher share of “extra” vehicles. Only 10.5% of the vehicles scrapped under the old standards were driven less than once a month, compared to 15.8% of the vehicles scrapped under the new standards.

Table 84: Differences Between Vehicles Before/After Stricter Eligibility Standards

	Vehicles scrapped before stricter standards	**Vehicles scrapped after stricter standards**	**Sig.**
	Mean score (1=strongly disagree, 4=strongly agree)		
Vehicle was an "extra" car/truck	**2.44**	**2.57**	**0.08**
Vehicle needed repairs to run well	2.70	2.63	0.27
Vehicle needed paint job or other cosmetic improvements	**2.76**	**2.89**	**0.05**
I did not think the vehicle would pass its next Smog Check	**2.15**	**1.93**	**0.001**
The vehicle polluted a lot	2.09	2.13	0.43
The vehicle was reliable	2.89	2.93	0.40
The vehicle was safe	2.94	2.90	0.37
	Mean		
Weekly mileage during 3 months before scrapping (Participant Survey)	**82.5**	**70.7**	**0.09**
Mileage in 12 months before scrapping (Yard Survey)	5,733	5,014	0.13
How many more years the vehicle would have lasted	3.25	3.38	0.32
How much do you think the car would sell for if you sold it through a newspaper ad?	$684	$682	0.94
Vehicle age (years)	**22.8**	**23.6**	**0.01**

The data indicate that the vehicles scrapped after the new standards went into effect were older, driven less, more likely to be "extra," and more likely to pass Smog Check, but were similar in terms of the need for repairs to run well, estimated value, and life expectancy. The reason for these differences is unclear. Given the higher share of "extra" vehicles that were not driven often, one hypothesis would be that higher income households were participating at higher rates after the new standards went into effect. However, there were significantly more households with incomes of $20,000 *or less* that sold vehicles to the program after the new standards went into effect. A higher share of the households (43.4% post-new standards versus 35.1% pre-new standards) would have sold the vehicle instead of scrapping it. Fewer of the vehicles scrapped under the new standards would have been donated to charity. This is probably related more to the higher proportion of lower income households participating, rather than a difference in the quality of the vehicles. There was a slightly higher share of retired households participating after the new standards went into effect, though the difference is not statistically significant.

If the owners' perceptions of their vehicles are accurate, it appears that the new standards did not directly impact the quality or condition of the vehicles sold to the program, except for a higher probability of passing Smog Check. The differences between the vehicles and households before and after the new standards went into effect may be related to other factors, such as the time of year (summer versus winter and spring) or types of advertising used to attract participants. For example, a smaller share of the participants under the new standards heard about the program through the newspaper and a higher share heard about it through a friend. About the same proportions heard about it from the direct mail letter sent from the BAAQMD. While the new standards may not have resulted in significantly better vehicles than those scrapped under the most recent previous standards, strict standards are necessary to ensure that scrapped vehicles would have continued on the road and to ensure public confidence in the programs.

Other options exist for changing eligibility standards. Vehicles could be tested for emissions and only accepted if the exceed a certain standard. However, this could encourage tampering and would increase program costs significantly. In addition, the literature indicates that a single emissions test, particularly the lower-cost tests that would be used in this case, may not represent real world emissions (Wenzel, 2001). The California Air Resources Board (CARB) recently considered using Smog Check odometer readings to screen out vehicles that have not been driven much. However, CARB staff found that the data are "not reliable enough to determine the total miles a specific vehicle traveled in a given period" due to errors in data entry by Smog Check technicians (California Air Resources Board, 2001b, p. 4). Moreover, a vehicle's past mileage does not always accurately represent future mileage. Vehicles that would have been sold to another household instead of scrapped might have been driven further in the future than in the immediate past.

5.5.2 Repair/retrofit

Some opponents of VAVR programs suggest that older vehicles be repaired or retrofitted, rather than retired. There is limited experience with such programs. The 1993 City of Los Angeles/Hughes remote sensing pilot project (described in Section 5.1) offered drivers of higher emitting vehicles a voucher for a free diagnostic/repair estimate, yet only five percent took advantage of the incentive. While nearly all participants (98%) said they would repair their vehicles if they were found to be high emitting, this number dropped to 75% after the vehicles failed an emissions test. Of those, only about one-third agreed to a follow-up contact, during which 56% claimed to have repaired the vehicle. This represented 8% of the vehicles that needed repairs. The average cost of the repairs undertaken was $146, and the most common repair was a tune-up, followed by a carburetor adjustment or replacement. The average repair estimate for the drivers using the free estimate vouchers was $197, ranging from $10 to $809 (Hughes Environmental Systems, 1995).

The Los Angeles pilot project concluded that a voluntary "Fix-It Request" program was unrealistic and ineffective. However, this program offered no financial incentive beyond the free estimate to repair the vehicles. Given the lower incomes of higher emitting vehicle drivers (the average income was $18,365), the lack of follow through in vehicle repair is not surprising. Over one-quarter of all the drivers (26.6%) stated that a cash rebate would increase their motivation to keep their vehicles in good running condition. For 76% of the higher emitting vehicle drivers lack of money was a major reason for not tuning up their vehicles, compared to 50% of the lower emitting vehicle drivers.

In the CARB Pilot Program, over 40 vehicles that were sold to the VAVR program were taken for further testing and were repaired until they passed various emissions tests. In almost all cases, exhaust emissions were significantly lower after repair. The difference in average emissions using Acceleration Simulation Mode (ASM) testing ranged from 59% to 85% lower, depending upon the pollutant and type of measurement. The difference in average emissions under the Federal Test Procedure (FTP) was 41% lower for NO_x, 68% lower for CO, and 72% lower for HC. The average repair cost (parts and labor) was $318. Five vehicles were taken for repairs aimed at reducing hot soak and diurnal evaporative emissions. The results were not as successful, with emissions increasing for two of the vehicles and decreasing or remaining about the same for the other three (Sierra Research, 2001). The Pilot Program did demonstrate that some vehicles that are sold to a VAVR program could be repaired at a cost comparable to the $500 VAVR incentive, resulting in significantly lower emissions. However, it is unknown how long the repairs will last and, therefore, how long the emissions reductions would be maintained.

Two California air districts have implemented repair or retrofit programs. Through its Old Vehicle Cleanup Partnership, the Santa Barbara County Air Pollution Control District offered to pay up to $450 toward the repair of a 1975 or newer vehicle that failed a Smog Check, if the cost of estimated repairs exceeded the state limits for required repairs. The program also offered $500 to scrap pre-1982 vehicles. Between April 1993 and February 1994, the program scrapped 216 vehicles and repaired ten vehicles (Santa Barbara County Air Pollution Control District, 1994). The District ended the repair element of the program in December 1994 due to low participation (43 vehicles), which was attributed to a complex procedure and lack of advertising (Santa Barbara County Air Pollution Control District, 1997).

The San Diego County Air Pollution Control District offered to retrofit 1,250 model year 1975-1980 vehicles with a kit consisting of an exhaust manifold feedback computer and a three-way catalytic converter. The kit costs approximately $500 (paid by the District), is approved by CARB, and is warrantied for two years (San Diego Air Pollution Control District, 2000b). Vehicle owners must ensure that their vehicle is in good running condition, spending up to $150 for a tune-up and minor repairs. The program is run through the kit manufacturer, Neutronics Enterprises. The District expected the device to reduce HC and NO_x emissions by 50% over 30,000 miles (Sommerville, 1996). However, the District recently revealed that, compared to VAVR, the retrofit program is at least four times more expensive per ton of pollutant reduced (California Air Resources Board, 2001b).

The experience from these programs indicates that a repair or retrofit program might reduce exhaust emissions from an older vehicle by about half, and perhaps more, for a comparable price per vehicle. The difference in average annual emissions between the scrapped and replacement vehicles calculated in Section 5.3.5 ranges from 57% to 76% lower for exhaust ROG, 19% to 59% lower for NO_x, and 43% to 75% lower for CO, depending upon the scenario. Whether a repair or retrofit program would be effective at reducing evaporative ROG emissions, which are a significant share of a vehicle's total ROG emissions, is unclear.

Some words of caution regarding repair and retrofit programs are warranted. Evidence from repair programs conducted to evaluate I/M programs indicates that repairing vehicles with marginally high emissions leads to few emissions benefits and in some cases can increase emissions (California Inspection and Maintenance Review Committee, 2000). Therefore, to be most effective, a repair program should employ a screening system, perhaps using remote sensing, to target higher emitting vehicles. However, if these vehicles exceed I/M standards, an effective I/M program should lead to the vehicles being fixed. In fact, the CARB Pilot Program only repaired vehicles that failed an I/M test procedure. Comparable emission reductions may not be possible for vehicles meeting I/M standards. In addition, the program employed sophisticated testing and mechanics experienced in and focused on reducing emissions. A repair or retrofit program would need to employ an oversight process to ensure similar effectiveness.

Finally, there is the question of how long the repairs would effectively reduce emissions or how long before something else fails on the vehicle and emissions increase again. Assuming that the emissions reductions would last the three years assumed as the effectiveness for retiring a vehicle is questionable. California's Smog Check program requires inspections every two years. The state assumes that this level of frequency is necessary to ensure continued clean operation of vehicles.

The question of how a repair and retrofit program would work with an existing I/M program to maximize effectiveness and eliminate double counting of benefits is an important one. Several studies have questioned the effectiveness of I/M programs (Glazer, Klein, & Lave, 1995). One criticism of such programs is that some owners anticipate the inspection and tamper with their vehicles before and after the test. These vehicles may pass the test on the required day, but they pollute at higher levels the remainder of the two years before the next inspection. A repair or retrofit program would not attract vehicle owners who tamper with their vehicle to improve performance knowing that emissions will increase. A repair program could, however, capture vehicles that are not maintained between the biennial inspections due to income constraints. A repair program might also capture vehicles that, due to the high variability of vehicle emissions, pass the I/M test, but pollute higher at other times, through no intervention of the owner. In addition, vehicles no longer subject to I/M (currently pre-1974 vehicles in California) could be targeted.

Given the limitations of a repair or retrofit program in a region with an effective I/M program and the questionable longevity of emissions reductions, such a program probably best serves to complement, and not replace, a VAVR program. A repair and retrofit program could be an option to households that will not or can not sell their older vehicle for the price offered – in particular, lower income households that drive their older vehicles a lot and are less able to afford regular maintenance or costly repairs. An important question to answer is whether these households would participate in such a program, in light of the low overall participation in the Santa Barbara program.

The Non-Participant Survey asked households if they would accept $500 to repair or upgrade their pre-1982 vehicle to make it run cleaner. Overall, 29.7% said “definitely yes” and 40.4% said “maybe yes.” About one-quarter (23.4%) answered “definitely no.” There was no significant difference in response by income level – households with incomes of $30,000 and under were just as likely to definitely accept the offer as households over $75,000. Respondents that would accept the offer are more likely to be employed full-time and less likely to be retired. Consequently, the vehicles of these owners are more likely to be used for commuting to work or school. The vehicles are also driven more frequently – 46.4% are driven three or more days per week, compared to 35.2% of the vehicles of respondents that would not accept the offer. The vehicles of the respondents that would definitely or maybe accept the offer were driven an average of 4,754 miles in the previous 12 months, compared to 3,987 miles for the vehicles driven by households that would not accept the offer. This difference is not significant at the 0.10 level. However, there is a significant difference in annual mileage when examined by income level. Households with incomes of $30,000 or less that would accept the repair incentive drove their vehicles an average of 5,511 miles the previous 12 months, compared to 3,548 miles for those that would not accept the offer. When classic vehicles are eliminated from the sample, the average mileage was 5,390 and 4,696, respectively. Overall, 71.0% of the lower-income households with vehicles driven 5,000 or more miles would definitely or maybe accept the offer. This is not significantly more than for lower-income households with vehicles driven less than 5,000 miles in the previous 12 months.

While the higher-mileage, lower-income households may not accept the repair incentive at a significantly higher rate than other households, their level of acceptance is high enough to believe that a significant portion of these households would participate in a repair program. Interestingly, the middle-income households ($30,001-75,000) that drove their older vehicle 5,000 or more miles were significantly more likely to accept the offer than those driving under 5,000 miles (72.4% versus 61.4%, respectively). Therefore, these households may also be appropriate targets for a repair program. Using public funds to repair vehicles of higher income households may not be politically popular, though this has not been a major issue for VAVR programs. California's Bureau of Automotive Repair currently operates a repair assistance program for lower-income households with vehicles that fail Smog Check.

Households that felt their vehicle needed repairs to run well were more likely to accept the $500 offer than those not needing repairs. However, about two-thirds of those who did *not* think their vehicle needed repairs still would accept the offer. This confirms the need to screen vehicles before offering to subsidize repairs and establish an oversight process to ensure emission reductions occur. However, the process must not be so cumbersome as to discourage participation. For example, in order to attract lower income households, the program should pay for repairs directly, rather than reimbursing vehicle owners for repairs.

5.5.3 Changing Incentive Amounts

The economic research on VAVR programs indicated that raising the offer price would attract more vehicles and vehicles in better condition that would have lasted longer had they not been scrapped. Alberini, Harrington, and McConnell (1996) concluded that higher offer prices reduced cost-effectiveness. However, higher prices would be necessary to attract significantly higher numbers of vehicles, as the supply of households willing to sell vehicles for $500 shrinks (Dixon, 2001). In the CARB Pilot Program, contractor Sierra Research estimated that in order to achieve the SIP M1 measure objective of retiring 75,000 vehicles annually, a program offering $500 would need to attract half of the used car market at this price level or lower. Current programs are only attracting a fraction of that share of the used vehicle market.

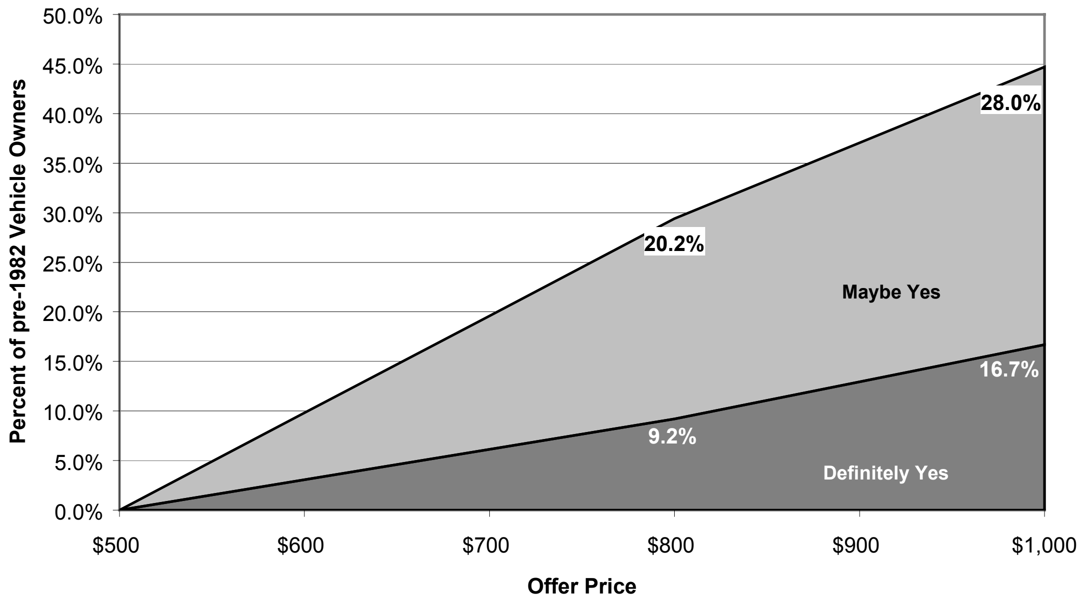
The Non-Participant Survey asked households if they would definitely or maybe sell their vehicle to the BAAQMD program if they were offered $800 or $1,000, instead of $500. Half of the surveys had the $800 price and half had the $1,000 price. The results from this question are shown in Table 85 for all pre-1982 vehicles and the non-classic pre-1982 vehicles. The non-classic vehicle information is shown graphically in Figure 43. The respondents definitely or maybe willing to sell their vehicle at the higher price ($800 or $1,000) estimated the potential selling price of their non-classic vehicle at an average of $2,018. This large discrepancy – larger than the difference between the participants' average estimated selling price for the scrapped vehicles and $500 – casts some doubt as to whether these households would follow through if actually offered the higher price.

Table 85: Willingness to Sell Vehicle to VAVR Program at a Higher Price

	All Vehicles		Non-Classic Vehicles	
	$800	**$1,000**	**$800**	**$1,000**
Definitely yes	7.2%	12.7%	9.2%	16.7%
Maybe yes	14.5	20.7	20.2	28.0
Maybe no	5.9	5.9	8.6	10.1
Definitely no	72.4	60.8	62.0	45.2
	100.0	100.0	100.0	100.0

All Vehicles: n=458, Chi-Square significant at 0.05 or better
Non-Classic Vehicles: n=331, Chi-Square significant at 0.05 or better.

Figure 43: Response to Higher Price Offer – Non-Classic pre-1982 Vehicle Owners



The data does support the finding that lower quality vehicles are attracted to VAVR programs. The average estimated price for the non-classic vehicles that would not be sold at the higher price is over $5,000. A higher portion of those potentially willing to sell their pre-1982 vehicle at the higher price stated that the vehicles needed repairs to run well or a paint job or other cosmetic improvements. A higher portion also feared that their vehicles would not pass their next Smog Check. The data also support the theory that the higher price will attract vehicles of higher quality than the vehicles scrapped for $500. In response to the statement “the vehicle needs repairs to run well” (1=strongly disagree, 4=strongly agree), the mean score for the vehicles that might be sold at the higher price was 2.18, compared to 2.68 for scrapped vehicles in the Participant Survey. A higher share of the Non-Participants that might sell the vehicle at the higher price also thought their vehicle would pass it next Smog Check, compared to the participants.

There are some significant differences between the vehicles whose owners might sell them at the higher price and those that would not be sold. The vehicles that might be sold at the higher price were driven an average of 140 miles per week during the three months preceding the survey, compared to 99 miles for the vehicles that would not be sold (difference significant at 0.10 level or better). Both of these figures are significantly higher than the average weekly mileage driven in the scrapped vehicles from the Participant Survey (79 miles). This implies that a higher price may attract a higher proportion of vehicles that are driven further. However, of the vehicles that might be sold at the higher price, only 22.0% are driven 6-7 days per week, compared to 33.3% of the scrapped vehicles from the Participant Survey. This indicates that the large difference in weekly mileage may be misleading. Still, among the Non-Participant Survey respondents, higher-mileage vehicles are more likely to be sold to a VAVR program at a higher price.

Contrary to what might be expected, lower-income households are not more likely to accept the higher price. However, this is consistent with the Alberini et. al. (1995) findings that the level of the willingness to accept amount was related more to vehicle than household characteristics. Of the non-participant households with incomes of $30,000 or less, 30.0% would definitely or maybe accept the higher price, compared to 42.5% of the households with incomes of $30,001-75,000, and 32.7% of the households with incomes over $75,000 (non-classic, pre-1982 vehicles only). The $800 or $1,000 still might not be enough for a lower income household to replace an older vehicle with a reasonable substitute. Moreover, the data indicate that the higher price would not attract the higher-mileage, lower-income households that the current program seems to be missing. The mean weekly mileage for the lower-income households that might accept the higher price was 65 miles, compared to 98 miles for those that would probably not accept the higher price. In contrast, the middle- and higher-income households that might accept the higher price drove their vehicles more than those that would not accept the higher offer. These differences are significant at the 0.10 level or better. However, the average mileage in the older vehicles for the lower-income households in the Non-Participant Survey is lower than the middle- and upper-income households, which is contrary to the NPTS data discussed in Chapter 4. This indicates that the responses to the Non-Participant Survey may not accurately reflect the population as a whole, missing some of the higher-mileage, lower-income households that this research attempts to analyze.

Another potential reason to increase the offer price is to allow households to purchase better replacement vehicles. The Participant Survey asked households that purchased or leased a replacement vehicle (rather than using a vehicle already in the household), whether the $500 affected the choice of replacement vehicle. Only about one-quarter (24.4%) said they purchased a "better" vehicle with the $500. Respondents were asked to describe how the vehicle was better. The most frequent response (27.8%) was that the vehicle performed better or was of higher quality. This may or may not relate to lower emissions. One-fifth (20.0%) said the vehicle was newer or had fewer miles and 18.3% said it had better gas mileage. Respondents were then asked if they had been given $1,000 instead of $500, if that would affect their replacement vehicle decision. Over half (55.7%) said that it would not – they would have purchased the same vehicle – and 29.9% said they would have purchased a different vehicle. The remainder were not sure.

When asked how the vehicle would have been different, 44.3% said they would have purchased a newer vehicle or a vehicle with fewer miles.

The overall response to these two questions indicates that the majority of participants are not dependent upon the VAVR incentive to replace the scrapped vehicle. The results, however, vary by income. The offer of $1,000 would have impacted the replacement vehicle decision for over 35% of the households with incomes of $30,000 or less, compared to 25% or fewer of the higher-income households. The replacement vehicles in the lower income households are generally older than in the higher income households. Therefore, one policy response would be to tie the incentive amount to household income. This would place additional administrative burden on the program contractors and perhaps raise questions of privacy. In response, participants not willing to provide income verification could be offered the minimum price. Households below a certain income, such as those that qualify for “lifeline” utility rates, that offer documentation of such, would receive a higher price for their vehicle. A certain share of these households, however, would spend the extra money on something besides the replacement vehicle, resulting in no net increase in emissions reductions. A response to this problem is discussed in the next policy option.

5.5.4 Tying Incentives to Replacement Decisions

Many of the VAVR programs in Europe are cash-for-replacement programs, which ensure that the scrapped vehicle is replaced by a newer (usually new) vehicle. The Vancouver, British Columbia program offers higher incentive amounts for cleaner replacement options and no incentive for replacing the vehicle with an older, used vehicle. The new program in Maine offers vouchers for purchasing new vehicles. These programs take the uncertainty out of the replacement vehicle portion of the emissions reduction calculation. The chance of the replacement vehicles polluting more than or about the same as the scrapped vehicles is very small. If the program only offers incentives for purchasing new vehicles, the emissions reductions per vehicle scrapped will increase significantly. This was demonstrated in several of the analyses reported in Sections 2.1.1 and 2.1.2.

There are, however, two questions regarding a cash-for-replacement program: (1) the administrative burden placed on the program and participants; and (2) requiring the purchase of a new vehicle may discourage participation from lower-income households, who drive older vehicles the most. Related to the second issue is a political concern that the program would be subsidizing higher-income households to purchase new vehicles. The first question will not be addressed here. Administrative problems could be minimized with a well-designed program and some time, effort, and planning on the part of the agency in charge. If the benefits, in terms of emissions reductions, are significant enough, the agency is more likely to make the program work smoothly.

The second question is worth further analysis. The requirement to purchase a new or newer vehicle has a direct impact on the replacement vehicle portion of the emissions reduction calculation and an indirect impact on the scrapped vehicle portion. The same group of households will not participate in this type of a program. The data from the Participant Survey provides some evidence as to who might not participate in a cash-for-replacement program – the households with lower-mileage, "extra" vehicles. Vehicles that were replaced with purchased vehicles, rather than with vehicles that the household already owned, were less likely to be the "extra" vehicles that are not driven much by the household (Table 86). Vehicles that were replaced with new (not used) vehicles were driven an average of over 7,000 miles the year before scrapping, compared to under 5,000 miles for vehicles that were replaced with a vehicle that was already in the household.

Table 86: Replacement Transportation, "Extra" Vehicles, and Annual Mileage

Replacement Transportation	% that agree that the scrapped vehicle was "extra"	Mean mileage in 12 months before scrapping
Driving another vehicle already in the household	73.8%	4,771
Purchased/leased new vehicle	35.6	7,063
Purchased/leased used vehicle	24.1	6,711
Other, not driving	41.9	3,579
Total	24.6	5,571
n	1,201	1,104

Only 13.2% of the households with incomes of $30,000 or less purchased new replacement vehicles, compared to 15.8% of the households of incomes $30,001-60,000, and 14.9% of the households with incomes over $60,000. These differences are not as large as one might expect, for reasons already discussed (Section 5.3.4). The lower-income households were more likely to purchase used vehicles. The average price of the vehicles purchased by the lower-income households was also significantly lower -- $4,337 for households with incomes of $15,000 or lower and $6,894 for incomes of $15,001-30,000, compared to $8,796 for all households. These differences are significant at the 0.001 level or better.

The data indicate that only offering incentives for purchasing new vehicles could significantly discourage participation from all income levels, slightly more from lower-income households. Allowing the purchase of used vehicles would not disproportionately impact lower-income households. However, to ensure greater emissions reductions than the current program, such a program would need to limit the purchase of used vehicles to newer model years, 1990 or newer, for example. The Vancouver program offers the lowest incentive amount for 1988 or newer used vehicles and nothing for older used vehicles. The major difference in replacement transportation between the lower and higher income households is that lower income households were far more likely to be using public transportation or other non-driving alternatives and less likely to be driving a vehicle already in the household. For these households, a transit pass incentive of equal value, like that offered in Vancouver, may be as attractive as the $500 cash.

The data discussed in Section 5.5.3 indicate that an incentive amount up to $1,000 may not significantly influence the type of vehicle purchased by a household. However, a program that only offers vouchers to help purchase new vehicles or newer used vehicles and transit passes, rather than cash, would discourage participation by households that use the program to dispose of extra, under-used vehicles. Emissions reductions per vehicle would likely increase. However, if the households using the VAVR program to dispose of extra, under-used vehicles and not replacing them with purchased vehicles, would have sold their vehicles to other parties, discouraging their participation may not be that beneficial. About one-third (32.6%) of the households that were driving a vehicle they already had in the household to replace the scrapped vehicle stated that they would have sold the vehicle if they had not scrapped it. This is significantly lower than the households that purchased new vehicles (46.2% would have sold it) or purchased used vehicles (40.6% would have sold it). Two program options might be employed to capture some of these extra vehicles that would be sold on the used car market: (1) offering a lower cash amount for vehicles that are not replaced with new vehicles, newer used vehicle, or transit; and (2) purchasing vehicles that are advertised for sale by owners (discussed in the following section). With the first option, the program would offer higher incentives to households whose replacement decisions will result in greater emissions reductions. In an example of such a program, the household would choose between the following options:

- $400 cash;
- $1,200 voucher towards the purchase of a new vehicle;
- $800 voucher towards the purchase of a 1990 or newer used vehicle; or
- $1,000 worth of transit pass vouchers.

This is very similar to the Vancouver program. The Vancouver program also offers an incentive specifically for bicycle purchase. A separate category for this may not be necessary; those wanting to purchase a bicycle could take the $400 cash. The cost of this type of a program might be offset by public-private partnerships. For example, transit agencies might provide the vouchers at a reduced price. Car dealers may also to cooperate and offer incentives. The Ford Motor Company has already done so in the Los Angeles region. A system to help prevent the re-sale of the incentives should be considered. If the vouchers are issued in the name of the owner of the scrapped vehicle and are not transferable, this should not be a serious problem, except perhaps for the transit pass vouchers. Transit passes purchased with the vouchers could be sold or given to other parties. However, the number of participants taking the transit vouchers is likely to be low and the harm of the passes being used by other individuals may not be worth the effort necessary to prevent transfers.

5.5.5 Targeting Vehicles

The final policy option discussed here is to target certain vehicles for purchase by a VAVR program. To increase emissions reductions, the vehicles that would be targeted include vehicles with higher exhaust and/or evaporative emissions, vehicles that are driven more, and vehicles that are most likely to continue to be driven. Such vehicles would be recruited for a VAVR program. This policy option does not involve changing the eligibility standards.

Remote sensing equipment could be used to identify higher-emitting vehicles. This equipment "reads" the exhaust from a vehicle driven on a roadway. When combined with license plate information, vehicle owners of high-emitting vehicles detected by remote sensing could be contacted and offered an incentive to scrap their vehicle. This would be similar to the BAAQMD's current smoking vehicle program where citizens can report smoking vehicles that they see being driven on the road. Using the license plate information reported, the District gets the vehicle owner's address from the DMV and sends them a letter suggesting that they have a mechanic check the vehicle. The letter also includes information on the VAVR program.

Older vehicles that are currently driven more than the average might be identified using the biennial Smog Check database, which records odometer information. CARB staff had rejected using these data to screen vehicles for eligibility because of inaccuracies. However, using the data to solicit participation, rather than as a screening criterion for participation, does not require absolute accuracy.

Finally, vehicles that have a high probability of remaining on the road might be identified via advertisements for used vehicles. This option was suggested by economist Severin Borenstein, who theorizes that the vehicles found through want ads "are cars that people actually think can survive a test drive" (Matzek, 2000, p. 30). Whether vehicles put up for sale by their owners are in better condition or would have a longer life expectancy than the vehicles currently being scrapped is difficult to determine without data representing all used vehicles for sale. The Participant Survey did ask whether the owner tried to sell the vehicle before scrapping it and 13.9% indicated that they had done so. The differences between these vehicles and the other scrapped vehicles are shown in Table 87. The vehicles that were offered for sale were expected to last slightly longer, but were about a year older. Moreover, the owners of the vehicles offered for sale were more likely to think they needed repairs to run well or a paint job or other cosmetic improvements. The difference is not very significant with respect to needing repairs to run well, but is for the paint job/cosmetic improvements. This may be a result of the eligibility requirements that focus on vehicle performance. The scrapped vehicles that were offered for sale, however, are not necessarily representative of all older vehicles offered for sale. These owners were not able to sell the vehicle for more than the $500 offered by the BAAQMD, or they changed their mind for another reason. Therefore, it may be reasonable to assume that other vehicles for sale might be in better condition. However, if the price offered is still $500, the VAVR program might not attract the better quality used vehicles. In addition, there is the trade-off mentioned already between vehicles that pollute more and those in better condition. The vehicles in the best condition that will last the longest are probably polluting less per mile.

Table 87: Vehicles that were Offered for Sale before Scrapping

	Owner tried to sell vehicle before scrapping	Owned did not try to sell vehicle before scrapping	Sig.
How much longer the vehicle would last (owner's estimate, years)	3.54	3.24	0.07
Model year	1976	1977	0.02
Mileage in previous 12 months	4,780	5,681	0.11
Opinions regarding vehicle (1=strongly disagree, 4=strongly agree)			
Vehicle was "extra"	2.67	2.44	0.02
Vehicle needed repairs to run well	2.78	2.66	0.14
Vehicle needed paint job or other cosmetic improvements	2.95	2.77	0.02
Insurance for the vehicle was too expensive	1.94	1.84	0.11

6 CHAPTER 6: SUMMARY AND CONCLUSIONS

6.1 Summary

This research attempted to increase knowledge regarding the emissions impacts of VAVR programs through a better understanding of household behavior. To provide context for the analysis, a history and overview of VAVR programs in the U.S. and abroad was presented. Unocal launched the first major pilot program in Los Angeles in 1990, focusing attention on the use of market incentives to reduce air pollution in contrast to less-flexible regulations. Since then, over twenty programs, including short-term pilot projects, have been implemented in the U.S. and Canada. Nearly all of these programs offer people cash for their older vehicles, often model year 1981 or older. These vehicles are then scrapped, presumably earlier than they would have been without the incentive. The programs have eligibility requirements to help ensure that the vehicles could continue to be driven and are not imported from outside the area of interest. Eleven additional countries have implemented programs at one time or another. Unlike most of the U.S. programs, many of those in Europe require that participants purchase new replacement vehicles. Some of these programs were implemented, in part, to stimulate vehicle manufacturing within those countries. These programs have also been much larger than U.S. programs, with some resulting in the retirement of five percent of the fleet or more.

Despite opposition from car collector and hobbyist groups in the U.S., interest in VAVR programs will likely continue. To facilitate implementation, the states of California, Texas, and Illinois have detailed, statewide regulations governing VAVR programs, and the U.S. Environmental Protection Agency issued a guidance document.

Moreover, the significant contribution older vehicles make to the mobile source emissions inventory will likely persist for at least 20 years in U.S. urban areas. Over 90% of the participants in the BAAQMD program and the CARB Pilot Program responded positively about the program, and two-thirds of the non-participants in the Bay Area thought the program should be continued as is or with changes. Increased funding from the BAAQMD indicates political support as well. The programs offer a simple, easily understood answer to air pollution problems that the general public can understand and support. They are voluntary, require little behavioral change, and focus on sources of pollution that usually belong to someone else. In contrast, many transportation control measures target all drivers in hope of getting them to drive less or use other modes of transportation. And, in contrast to congestion or parking pricing, people are paid to participate.

A major objective of this research was to examine how household characteristics and travel patterns impact older vehicle use and participation in VAVR programs and, consequently, the emissions reductions from such programs. The analysis of data from travel surveys in Chapter 4 and VAVR programs in Chapter 5 establish that such relationships do exist. Older vehicles are more likely to be "extra" vehicles – vehicles in households having more vehicles than drivers – and they are driven less than newer vehicles, on average. However, ownership and use vary with income. Lower income households are more likely to have older vehicles and drive them further than higher income households with older vehicles. Older vehicles found in higher income households are more likely to be extra vehicles or classic-type vehicles. Older (over 65) and retired drivers are also more likely to drive older vehicles, though not as many miles per year as younger, working drivers.

To be most effective, a VAVR program would want to attract the vehicles that are currently driven the most, in anticipation that those vehicles would continue to be driven more than other older vehicles. However, the data from the BAAQMD program show that, while lower income households do participate in VAVR programs, lower income households that drive their older vehicles the most are not participating at the same rate they are found in the population. The program is also not attracting many single-vehicle households, in which the older vehicles supply all of the households' transportation. In contrast, retired households are participating at higher rates than they represent in the population – probably because these households' transportation needs diminish more than others and they can or need to dispose of a vehicle. While these households drive older vehicles less, these are also vehicles that might have been sold to other parties who would drive them more.

Certain types of households and vehicles are attracted to VAVR programs, which may be decreasing their overall effectiveness in reducing emissions. However, the programs are reducing emissions, and many of the broad characterizations of the programs set forth by critics are unfounded. Most of the vehicles would not have been scrapped at the same time if it were not for the VAVR program. The programs appear to divert a share of vehicles from the used vehicle market. About 40% or more would have been sold to another household, which might have driven them further than their current owners. The strict eligibility standards appear to be screening out vehicles that were headed to the junkyard anyway. However, the vehicles are generally in poorer condition than other older vehicles on the road. As a result, the ROG emissions from scrapped vehicles are generally higher than predicted by the emissions model. Nearly all of the vehicles were replaced by other vehicles and nearly all of those were newer than the scrapped vehicles. Most households are either driving vehicles that they already owned or purchased other vehicles for significantly more than the $500 they received from the VAVR program. In fact, the $500 appears to have little impact on their vehicle replacement decision.

Finally, using the BAAQMD survey data, I calculated the emissions reductions from scrapping those vehicles using a variety of assumptions that differ from the current methodology. Using these alternative assumptions that are intended to more accurately reflect real behavior usually reduced the effectiveness of the program. However, in nearly all of the scenarios examined, emissions, particularly of ROG were still reduced significantly.

In addition to answering the research question regarding the effectiveness of VAVR programs, this analysis serves to highlight the importance of the regulator's or planner's assumptions when designing policies and programs. The lack of comprehensive and accurate data on all possible issues forces planners to make some assumptions when implementing and assessing new programs. Planners must do the best they can with the data they have. Now that VAVR programs have operated for a few years, it is timely to evaluate those assumptions. The methodology for estimating the benefits of VAVR programs assumes that in the absence of the program, the vehicles would continue to be owned by the same household. The underlying assumption is that the VAVR program is prompting household decisions to sell vehicles. However, the survey data indicate that many of the households would have sold their vehicles to other households or disposed of them in another way. The VAVR program gave them another, usually simpler, option. In terms of reducing emissions, diverting vehicles from the used vehicle market is more beneficial than diverting them from donation programs (where they might be scrapped anyway) and the traditional junkyard. This is because many of the latter vehicles would have been taken off the road even without the VAVR program. In addition, the current process assumes that scrapped vehicles are in poorer condition than other older vehicles, hence the use of a three-year life expectancy. However, the methodology assumes that the vehicle would be driven the same distance and emit the same amount of pollution per mile as the fleet average for that model year. This conflicts with the assumption of poorer quality vehicles, which one might expect to be driven less and pollute more. The data presented here indicate that the scrapped vehicles were driven less and emit more ROG than average. Overall, the findings support the need to reevaluate assumptions after program implementation.

6.2 Data Issues

This research relied on several data sources, primarily travel surveys and surveys of VAVR programs participants and non-participants. Some of the limitations of this survey data were discussed in Chapter 3. Survey sampling and response rates are important and help determine whether the survey accurately reflects the population in question. As discussed in Chapter 3, the limitations of the NPTS sampling were likely not sufficiently significant to impact this research, particularly for the nationwide analysis and when combined with the weighting methodology. In addition, the surveys of VAVR participants from the Bay Area and CARB Pilot Program had very high response rates and likely represent the population relatively well. However, the lower response rate in the Non-Participant Survey, particularly from lower- and middle-income households, made for more cautious conclusions drawn from that source. For example, the small number of lower-income households may not have represented the population well in terms of older vehicle travel.

In addition, all surveys rely upon the honesty and accuracy of the respondents, another potential source of error in any analysis. For example, respondents may over- or under-estimate how far they drive. The odometer readings employed by the NPTS helped address this source of error for the nationwide data, but the sample of odometer readings was limited in number and subject to other sources of error. VAVR program participants may overestimate the value of their vehicles or inaccurately predict what they would have done without the VAVR program.

While surveys may be the only sources for certain types of data (e.g. household opinions), other sources might help address some of the data limitations. For example, more accurate data on the value, quality, and potential lifespan of the scrapped vehicles could be provided by professional mechanics. However, it would still be worthwhile gathering this information from the households, because their perceptions impact their decisions. To collect accurate travel information, researchers have installed tracking devices on vehicles that record trips, mileage, location, and driving patterns (speed, acceleration, deceleration, idle, etc.). Combined with survey data about households, this type of research could provide an accurate picture of older vehicle travel. However, the higher cost of this type of research and the limited number of older vehicles in the fleet present sampling limitations. Odometer readings recorded by the Smog Check program are another source of data for annual (or biannual) mileage of older vehicles. However, this source is also subject to errors (e.g. poor data entry) and it does not provide data on the number of trips or trip purposes. While the Smog Check does not collect household information, these data could be collected separately and linked via vehicle identification numbers.

These two sources (vehicle instrumentation and odometer readings) could address the question of older vehicle mileage, but not questions regarding other household behavior related to VAVR programs. In particular, questions remain regarding travel after a household scraps a vehicle and what might have happened if the household did not scrap the vehicle. A multi-year panel survey of households that do and do not participate in a VAVR program could help answer these questions, particularly if it also employed odometer readings or vehicle instrumentation. The research conducted here did not indicate that the benefits of the programs are so questionable as to warrant the expense of such a research design. However, a panel survey conducted for other purposes (e.g. regional transportation modeling) could include questions and collect data to address VAVR research questions with little additional expense.

6.3 Policy Recommendations

Given the conclusion that VAVR programs reduce emissions significantly, though not as much as expected, and that air pollution from older vehicles will continue to be a problem, policymakers should consider ways to expand, improve, and/or supplement the programs. Such changes fall into two categories. First, the methodology to calculate emissions reductions should be adjusted to make the estimates more conservative. This could include simple adjustment factors based upon the data presented here or other data already collected, or adjustments based upon survey or emissions data collected from program being evaluated. For example, the calculations should take into account what would have happened to the vehicle had it not been scrapped, e.g. junked, donated to charity, kept, or sold to another household. Mileage assumptions might be adjusted downward from state averages, in the way CARB did for the life expectancy assumption.

Second, policymakers should explore ways to change and supplement the programs to address key factors that reduce program effectiveness: the households and vehicles that do not participate at high rates and the replacement vehicle decision. Current programs are missing certain high mileage households and have little impact on the vehicle replacement decision. A carefully designed repair program may help reduce emissions from older vehicles that are driven a lot. While such a program may not be as cost-effective as a VAVR program, it should attract households that will not participate in a VAVR program, thereby reducing emissions from a source currently not tapped. A repair program would also attract political support from some of the VAVR programs most vocal critics.

Targeting certain vehicles for participation in VAVR programs, by using odometer readings or remote sensing, could be an effective method of increasing emissions reductions. Changing eligibility standards may not be feasible or effective in attracting higher use vehicles, though changing the model years covered to at least 1985 is recommended. In addition, this research indicated that older medium- and heavy-duty vehicles also contribute disproportionately to mobile source emissions. Programs targeting these vehicles may also be warranted.

Increasing the cash incentive amount would attract more and better vehicles, though the overall impact on emissions reductions per vehicle scrapped is unclear. A more promising option is to increase the incentive for households to replace vehicles with significantly cleaner alternatives, such as new vehicles, newer used vehicles, and transit. A tiered incentive structure may discourage participation from households wishing to dispose of extra, under-utilized vehicles, and offer lower income households a better chance at purchasing a newer, cleaner vehicle.

These policy options may not be necessary for existing programs that are attracting enough vehicles, but should be considered when designing new programs or if an existing program becomes less effective. Since older vehicles are likely to be a problem for at least 20 more years, program changes are likely to be necessary to adjust to changes in household behavior and the vehicle market. In addition, the findings support the need for all programs to focus marketing efforts. For example, the Spanish-language marketing in the CARB Pilot Program effectively attracted Hispanic households. Marketing could also target lower-income households or households that plan to sell their vehicles.

6.4 Future Research

An appropriate next step is to further evaluate the impacts of these policy options. This could be done using two categories of approaches: (1) using existing data and new data collected from existing programs and populations; or (2) implementing and evaluating new pilot programs. The first category may require the use of stated preference survey techniques. For example, lower-income households could be asked how they would respond to different incentives for vehicle repairs or a scrappage incentive tied to vehicle replacement. The Non-Participant Survey asked one question about a repair incentive. However, a larger sample and more detailed questions would be needed to conduct a more thorough evaluation of such a program. Data collected from roadside surveys and emissions testing conducted to evaluate inspection and maintenance programs and from remote sensing studies may also be useful in evaluating the potential of a repair program. These data may indicate the type and extent of vehicle maintenance problems, which would be used to help evaluate the cost and potential benefit of repairs.

All three major policy options – a repair program, targeting vehicles for scrappage, and tying incentives to the replacement decision – could be evaluated using small-scale pilot programs. A program targeting vehicles using remote sensing or Smog Check odometer readings could be implemented in conjunction with an existing VAVR program. A pilot research program could also offer different levels of incentives or different incentives tied to various replacement options to different households to test which household respond to which incentives.

Finally, a few other potential areas of new or expanded research may be worth pursuing. This research relied primarily on data from the San Francisco Bay Area and CARB Pilot Program operated in the Los Angeles area. How those programs are operated and the households that live in those regions, therefore, impact the results. Data from another region or program may result in different findings. It would be useful to compare the data from this research to other regions.

Charity vehicle donation programs are another area of potential research. I found no existing research in this area. The only discussion of the programs I found in the popular press involved questions of propriety and whether the charities actually received money from the programs. A large share of the Bay Area participants said that they would have donated their vehicle to charity had they not scrapped it through the VAVR program. Therefore, what happens to the vehicles after they are donated is an important question that, if answered, could help in the evaluation of VAVR programs. Personal communications with BAAQMD staff suggest that many of the older vehicles are not accepted to these programs and, if they are, they are scrapped. Because the programs are likely to attract higher income households who can use the tax incentives, these may be vehicles that are driven less. It would be useful to compare the types of vehicles and households attracted to donation programs versus the VAVR program in a region.

As mentioned previously, California recently changed the Smog Check requirement to exempt 1973 and older vehicles. After 2003 this will become a rolling 30-year exemption. The lack of a Smog Check requirement may act as an incentive to keep a vehicle past this age, thus increasing the portion of older vehicles. Households may also be less willing to sell the vehicle to a VAVR program, since it will be easier and less expensive to keep the vehicle without the biennial inspection requirement. About 10% of the participants in the CARB Pilot Program indicated that they sold their vehicles to the program because they thought the vehicles would not pass Smog Check. This indicates that the inspection program encourages participation in a VAVR program. A recent evaluation of the program suggested eliminating the rolling exemption (California Inspection and Maintenance Review Committee, 2000). The impact of the exemption on the holding period of older vehicles and participation in VAVR programs could be studied further.

Finally, medium- and heavy-duty trucks are potential targets for VAVR programs. However, most of these vehicles are owned by businesses and used for far different purposes than the vehicles examined here. Therefore, research evaluating a potential VAVR program for these trucks would need to rely on different data sources. In addition, different policy approaches may be more appropriate, including retrofit programs.

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8 APPENDIX – SURVEY INSTRUMENTS

8.1 Participant Survey and Cover Letter

8.2 Non-Participant Survey and Cover Letter

8.3 BAAQMD Yard Survey

8.4 CARB Pilot Program Surveys