a net increasers in highway fuel use-contrary to the stated goals of most accelerated scrappage programs. Although this result could be avoided by awarding only a fractional credit (that is, a credit equal to perhaps one-third of the fuel economy difference between the new and traded-in vehicles), the lower value of the credit to the automakers would then be unlikely to stimulate their participation in the program.

Past emissions testing programs have demonstrated wide variations in emissions performance among older vehicles of the same model type and vintage, probably because of different maintenance regimes as well as the random nature of failures of emission control systems. Policymakers concerned about obtaining a better cost/benefit ratio from a scrappage program might wish to examine options that tie participation in such a program to emissions performance. For example, scrappage bonuses might be offered only to vehicles that failed scheduled emissions tests in a State I/M program, or that were identified as high polluters by remote sensing. Although some vehicle owners might deliberately sabotage their vehicles to cause them to fail an emissions test, the effectiveness of a ''selective" program in the face of such tampering would be no worse than that obtained by a program offering scrappage bonuses to *all willing* participants, and most likely would be considerably better. If a vehicle retirement program can selectively retire vehicles with average emissions double the national average for their age group, program benefits would greatly exceed likely costs.

Another option for removing polluting vehicles from the fleet that policymakers might consider is to insist that vehicles failing State I/M emission tests be removed from service if they cannot be repaired. Currently, States specify a dollar value for repairs that, if exceeded, exempts vehicle owners from having to satisfy the emission standards. Although some States currently have very low repair cost limits, the Clean Air Act Amendments require a ***$450*** floor on cost limits for the most polluted areas, and this will likely move many of the worst polluting vehicles out of the fleet or force their repair and improved emissions performance. As noted above, more effective I/M programs will reduce the net emissions benefits of a vehicle retirement program by removing the highest emission (and highest net benefit) vehicles from the fleet.

Policymakers maybe reluctant to force retirement of all noncomplying vehicles because of the negative impact on lower income drivers, who are more likely to own an older vehicle in poor condition. A preferable alternative to an absolute pass/fail system may be a two-tier system—vehicles that are out of compliance but not drastically so would be subject to a dollar limit on repairs, while vehicles outside of this ''moderate failure" range would have to *at least* be brought within this range, or be retired. This would get the very worst vehicles off the road, yet affect fewer drivers.

Still another option would be to vary the size of the bonus (or the magnitude of the corporate incentive, e.g., emission credit) according to some measure of the potential emissions benefits. The measure could be based on previous emissions experience with different engine classes, data on average remaining lifetime and average emissions of different vintages, etc. The new Administration proposal seeks to tie the magnitude of emission credits rewarded by the program to the expected average emissions and remaining lifetimes for older cars, on a model year and region-speciftic basis.[14] Given an accurate basis for estimating emissions and lifetimes, this approach would yield an improvement in the cost-effectiveness of the program. However, there may be important concerns here about the availability of adequate data, especially about remaining lifetime. Certainly, the data collected by the Unocal experiment, which was limited in size and confined to Los Angeles, are only of limited use to evaluating a large national program.

PREDICTING THE IMPACTS OF AN EARLY RETIREMENT PROGRAM

Whatever its form, a large early retirement program for automobiles will affect the entire car market. Removing the oldest vehicles from the fleet should increase the demand for and price of the remaining vehicles, and should shift ownership and use patterns for these vehicles. To the extent that new car prices will appear more attractive relative to increased prices of late model used cars, sales of new

13 Compared to the value that would have occurred in the absence of a scrappage program.

14 Press briefing, op. cit., footnote 6. Also, William Schroeer, Office of Planning and Policy Evaluation personal communication Mar. 12, 1992.

cars should increase. There may be some net import of used vehicles into the area to supply replacement vehicles for some of the scrapped cars. Any attempt to quantify the costs and benefits of an early retirement program must somehow account for these market changes.

In attempting to quantify the impact of an early retirement program on gasoline demand, vehicle emissions, new car sales, and other related factors, a precise calculation would seek to estimate the changes in driving patterns of the entire vehicle fleet. Unfortunately, the only existing example of a scrappage program, the Unocal program in California, was far too small to cause measurable changes in the overall car market, and data are insufficient to credibly evaluate the changes likely to occur from a large scrappage program.

For the purpose of roughly quantifying costs and benefits of a major scrappage program, we make the following critical assumptions:

a. There will be no change in total vehicle miles traveled (VMT) of the fleet; that is, we assume that car owners who sell their cars to a scrappage program will, *on average*, replace all of their miles as drivers of other vehicles.

   We recognize that it is unlikely that each owner will drive as many miles as he or she drove before. Some owners may reduce driving or cease driving altogether, shifting to transit or carpools—with a net decrease in total VMT. Other owners will shift their driving to newer, possibly more reliable, and probably more fuel efficient vehicles-and, in turn, will push other drivers into newer vehicles (by buying vehicles they otherwise would have owned)---with a likely net increase in total vehicle miles for these drivers. The overall effect is uncertain, but an assumption of NO CHANGE IN TOTAL VMT seems a reasonable starting point.

b. The VMT "lost' due to the scrappage of older vehicles will be regained in either one of three ways:
   1. All of the regained VMT will be obtained from new cars added to the fleet, with no change in the use of the remainder of the existing light-duty fleet.
   2. The regained VMT will be obtained from increased driving in the existing fleet, with this VMT distributed across the fleet in the same proportions as the total VMT *per model year* of the fleet is currently distributed. This method assigns only a small percentage of the total replacement VMT to new vehicles.[15]
   3. Half of the regained VMT will be obtained from new cars, and half distributed across the existing fleet as above.

Note that, in assumption b, we do not assume that the sellers of the old cars are the purchasers of the postulated additional new cars. It is more likely that many of these sellers will use their bonus to purchase a later model used car; some may simply stop driving, or may have been using the car for a ''spare' and will simply drive another family car a bit more. We assume, however, that the increased demand for later model used cars will reverberate upwards through the total market for both used and new cars and ultimately lead to some increased demand for new cars. In other words, the later model used car purchased by a participant in the scrappage program would have been bought and driven by some other individual had the program not existed. That individual must seek another car. If the program is large enough to create a squeeze on models of this vintage, many of this second group of individuals will be forced to purchase still newer cars, which will in turn force some of the would-be purchasers of those cars to look for still newer cars and eventually will force some would-be purchasers of virtually new used cars to decide instead to buy a new car.

In assumption b1, we assume that these new cars absorb most of the net demand for VMT lost by the early retirements; in assumption b2, we assume that these new cars absorb only a small part of the VMT, and that increased usage of later model used cars absorbs most of the mileage. However, even if assumption b2 more accurately reflects the ***initial*** *effect on new car sales of a scrappage program, the increased usage of the existing vehicles in the fleet may shorten the lifespan (in years) of these vehicles, creating additional demand for replacements-and additional sales of new cars-some years after the*

[15] This method is used in W.L. Schroeer, ''A Cost-Effective Accelerated Scrappage Program for Urban Automobiles, ' presented to the Transportation Research Board, Jan. 13, 1992.

Box A—Unocal's Vehicle Scrappage Program

Unocal's South Coast Recycled Auto Project (SCRAP[tm]) was designed to demonstrate that there are more efficient ways to solve urban air pollution problems than to clamp down on stationary sources in the absence of local authority to regulate mobile sources. In the South Coast Air Quality Management District, Unocal has selected an area that fails to meet Federal air standards for four of the six criteria pollutants-ozone, CO, fine particulate matter, and NO_x. In fact, the Los Angeles Basin in general has the worst air pollution problems in the United States. And in the basin, vehicles account for three-quarters of all emissions,[1] making them a tempting target for further control.

After extensive public opinion surveying, Unocal began the SCRAP program on June 1,1990 with a goal of scrapping 7,000 pre-1971 automobiles. Unocal offered owners of pre-1971 cars $700 each to relinquish their vehicles if the cars could be driven to the facility and if they had been registered during the previous year. Unocal also limited participation in the program to one car per owner and required participants to show they had owned the car for at least 6 months. These conditions sought to avoid paying to scrap vehicles that were already essentially retired, and to avoid providing profits to middlemen. The number of vehicles actually scrapped eventually grew to 8,376 with monetary contributions from Ford Motors, the South Coast Air Quality Management District, and others.

SCRAP was more successful in eliminating air pollution than Unocal had expected. Unocal estimates an annual reduction in emissions of 12.8 million pounds based on average driving of 5,500 miles per year (determined by surveying the owners of vehicles participating in the program), 53 percent more per car than expected. Based on a test sample of 74 vehicles subjected to the Federal Test Procedure, tailpipe HC emissions averaged 16.3 grams/mile versus 8.3 grams/mile projected and .25 grams/mile for new 1990 cars. CO emissions averaged 84 grams/mile versus an expected 50 grams/mile and 1.8 grams/mile for 1990 cars, Only NO_x emissions, at 3.0 grams/mile, were less than expected (4.4 grams/mile), though they were still much higher than the .27 grams/mile level of 1990 cars.

SCRAP cars generally were relatively inefficient—12.1 miles per gallon (mpg) on the Federal Test Procedure test for city cycle driving, versus about 23.4 mpg on the same cycle for 1990 cars.

A critical factor affecting net emissions and other benefits is the manner in which SCRAP vehicles were replaced. In a postprogram survey, 46 percent of those surveyed had bought a replacement vehicle, 6 percent intended to buy a replacement vehicle, and 36 percent were driving another vehicle they owned, The remainder were using transit, carpooling, or not driving. Most of the replacement vehicles, either pre-owned or newly purchased, were much newer than the pre-1971 vehicles sold to SCRAP: the pre-owned replacements had a median model year of 1981, and the purchased replacements had a median model year of 1983-84,

[1] South Coast Air Quality Management District, Southern California Association of Governments, 1991 *Air Quality Management Plan, South Coast Air Basin*, Draft Final, May 1991, table 3-1. Vehicles emit 50 percent of reactive organic gases, 70 percent of NO=, and 98 percent of CO.

SOURCE: M. Tatsutani, University of California at Berkeley, *Unocal Corporation's SCRAP: An Experiment in Corporate Environmental Initiative,* June 19, 1991; and Unocal brochure, "SCRAP: A Clean-Air Initiative From Unocal.''

scrappage program ceases. Assumption b3 represents a midway point between the two extremes.

Even with these simplifying assumptions, there is a paucity of data applicable to complete this type of analysis, and the estimates will have to rely on a variety of ''educated guesses. ' Further, only data from actual retirement programs will shed light on the nonrandom process by which vehicle owners choose to participate or avoid an early retirement program (see box A on results of the Unocal program). What is definite is that the vehicles entering the program will not be "average." Common sense would dictate that vehicles entering the program would tend to be more in need of expensive repairs, be in worse physical condition, be driven less, and be closer to retirement than the "average" vehicle of that age, because all of these factors would seem to encourage the owners to take a bounty and give up the vehicles for scrapping. Predicting the magnitude of these ''excursions from the average, ' and estimating their impact on emissions and fuel use, will be an uncertain exercise.

It is important to remember that the environmental and energy benefits of a limited program to remove older vehicles from the fleet will die out over time, as the vehicles would eventually have been retired even if the program never existed. In other words, an early retirement program will simply speed up the inevitable turnover of the fleet. However, if the benefits outweigh the costs—and our computations suggest that they will under some circumstances-such programs can bring positive short-term environmental relief to urban residents and give time for other pollution remedies to take hold.

As a final point, obviously the cost-effectiveness of a vehicle retirement program will depend on the magnitude of the bonuses paid to attract vehicles. Aside from determining *costs, the size* of the bonuses will affect benefits because it will affect the type of vehicles attracted. Also, unless initial bonuses are high, there may be some trial-and-error involved in determining the size of the bonus needed to attract enough vehicles to meet program targets. Car values depend on a number of factors, but vehicle condition is particularly important in determining the value of older vehicles, and data may be lacking to allow reliable calculation of the numbers of vehicles likely to respond to any particular bonus level. Thus, program sponsors should be ready to adjust bonus levels if program targets are not met.[16]

In our analysis, we used two spreadsheet models. The first was developed by OTA and run only with assumption b1; that is, we assumed that all replacement mileage was made with new vehicles. To explore the effect of other assumptions about replacement mileage, and to examine the sensitivity of the results to changing other assumptions, we also borrowed the spreadsheet model developed by EPA to conduct its analysis of retirement programs, which was based on the MOBILE4 model.[17]

Additional New Car Sales

The new car sales stimulated by a vehicle retirement program may be an important benefit of such a program, but there is controversy about the magnitude of this benefit. Some programs-such as proposed in S. 2049, for example-seek to stimulate the sales of one new car for every older car retired. However, because most owners of old cars cannot afford to purchase a new car, and because most older cars are driven fax less than new cars, programs such as S. 2049's will likely attract only a small percentage of available older cars-those owned by a relatively wealthy driver, probably in a multicar household where the older car was not the primary means of transportation. We can also speculate that such cars might be in better condition than average, given the affluence of their owners. Because program benefits are maximized when the vehicles to be scrapped are in below-average condition and when they are the primary means of transportation, and thus driven more, one-for-one programs may not achieve hoped-for benefits.

Further, it is entirely unclear that programs such as S. 2049 will actually "replace' old cars with new ones. Although the sponsors of S. 2049 may envision auto dealers offering bounties for trade-ins that might stimulate new car sales that would otherwise not be made, the program might not work this way. Instead, dealers might simply select certain of their lower value, low fuel economy trade-ins to scrap rather than resell, pocketing the value of the CAFE credit to compensate themselves for the loss of the sales value of the traded-in vehicle. In fact, it is easy to envision this program simply substituting for each dealer's normal system of wholesaling its lower value trade-ins (new car dealers generally keep only their better trade-ins to sell in their own used car operations, wholesaling the rest). If the program works this way, the overall effects will be virtually identical to an ordinary scrappage program that does not include CAFE credits, except that the automakers will now have these credits to use in satisfying fuel economy requirements. If so, the true ''replacement vehicles, " that is, the vehicles that actually replace the VMT lost by scrapping the old cars, may not be new cars at all,[18] and the emission and fuel savings benefits will be correspondingly lower.

Other vehicle scrappage programs, not incorporating CAFE credits for new car trade-ins, cannot hope to stimulate one new car sale for every retirement-even if all of the miles ''lost' to increased scrappage are replaced by new cars. Since older cars, especially those that would be candidates for scrappage, on average are driven much less than new cars, a "one-to-one" exchange of new cars for old would imply either that total driving would increase significantly or that the new cars purchased

16 Presuming that higher bonus levels will not push the program out of the cost-effective range.

17 The spreadsheet model was developed by William Schroeer of EPA's Energy Policy Branch. EPA's analysis is discussed in W.L. Schroeer, "A Cost-Effective Accelerated Scrappage Program for Urban Automobiles," presented to the Transportation Research Board, Jan. 13, 1992.

18 Unless assumption b1 holds.

under an early retirement program will be driven much less than average. Although a newer fleet may create an increase in driving because it will have lower "per mile" gasoline costs (because of higher fuel economy) and greater reliability, it is not plausible that VMT would increase by the large amount implied by a one-to-one replacement of new cars for old. Neither does it seem likely that the new replacement cars would be driven much less than average. Finally, and most importantly, it is not clear at all that the net replacement travel will be provided by new cars-it is entirely conceivable that much, perhaps most, of the replacement miles will come from increased usage of existing cars. *Even if all replacement miles are provided by new cars, however, a likely result of an early retirement program is that only enough new cars will be purchased so that total miles driven will not change much-implying that considerably fewer new cars will be purchased than old cars scrapped.*

Using the assumption that total VMT will not change demands that data be gathered on the VMT of older vehicles of the type likely to participate in a scrappage program. Data on vehicle mileage as a function of vehicle age is somewhat spotty, however. Two sources give data on mileage for different vehicle age groups: the Nationwide Personal Transportation Study[19] and the Residential Transportation Energy Consumption Survey .20 Data in both surveys, presented in Oak Ridge National Laboratory's *Transportation Energy Data Book, Edition 10, lump* **all** vehicles equal to or greater than 10 years of age together in one group, restricting application of the data to a program aimed at pre-1980 cars. A more recent data source, apparently produced from an update of the latter Residential Transportation Energy Consumption Survey, presents mileage data that includes a value for pre-1975 vehicles.[21] Policymakers might prefer programs aimed at such an older group of cars because scrapping vehicles from model years 1975-79 will yield only moderate benefits-the new car fleet had already reached about 20 miles per gallon (mpg) by 1979, and major reductions in vehicle emissions were mandated for the 1975-76 model years.[22]

Table 3 presents the age-related vehicle mileage data from the two surveys, along with the ratio of miles driven per year for new vehicles (up to 2 years old) compared to vehicles 10 years old and older. (These are national data; wide variations among regions may exist.) The table supports the thesis that, if vehicles 10 years old and older are scrapped *randomly,* between 1.5 and a bit over 2.0 older cars will be replaced by 1 new car (or by some combination of somewhat fewer new cars than predicted and increased driving of newer used cars) .23 Figure 1 presents more recent data on age-related mileage, including a value for pre-1975 vehicles. These data support the thesis that for random scrappage of pre- 1975 vehicles, 2 or more of the scrapped cars would be replaced by 1 new car.

As noted previously, scrapping old cars under an early retirement program is not going to be at random. Instead, sellers of old vehicles will be responding to monetary incentives, and thus should tend to be more eager to sell vehicles which have less-than-average value. We expect these vehicles to be somewhat closer to retirement and to be driven less than the average, since presumably the value of the vehicle to its owner generally will be a function of the vehicle's time to retirement and degree of use. Consequently, we choose the ratio 2:1 for an estimate of the ratio of old cars scrapped to new cars purchased for a program to retire pre-1980 cars. We *hypothesize* ratios of 3:1 and 3.5:1 for programs to retire pre-1975 and pre-1970 cars, respectively. We note, however, that it is quite possible that the initial surge in new car sales associated with a vehicle retirement program may result in somewhat fewer

19 D. Klinger and J. Richard Kuzmak, COMSIS Corp., ***Personal Travel in the United States, Volume Z; 1983-84 Nationwide personal Travel Study,*** prepared for the U.S. Department of Transportation Washington DC, August 1986, table 4-22, p. 4-21.

20 Energy Information Administration, Office of Markets and End Use, Energy End Use Division, ***1985 Residential Transportation Energy Consumption Survey,*** Washington DC, unpublished data.

21 Data from U.S. Department of Energy, Energy Information Administration, ***Household Vehicles Energy Consumption, 1988,*** presented in Motor Vehicle Manufacturers Association, ***MVMA Motor Vehicle Facts & Figures '90,*** p. 44.

22 In 1975-76, allowed HC and CO were reduced from 3.4 and 39 grams per mile (gpm) to 1.5 and 15 gpm, respectively. In 1977, allowable NO_x were reduced from 3.1 to 2.0 gpm. In 1980, HC and CO were further reduced to .41 and 7.0 gpm, respectively, and CO was again reduced, to 3.4 gpm, in 1981, with NO_x reduced to 1.0 gpm that same year. Source: U.S. Environmental Protection Agency, Office of Air and Radiation, Oct. 15, 1988.

23 The lower value of 1.5, derived from the Residential Transportation Energy Consumption Survey, might be preferred because the data from that survey is based on odometer readings and is likely to be more reliable than the driver estimates collected by the Nationwide Personal Transportation Survey.

Table 3—Average Annual Miles per Automobile by Automobile Age

Vehicle age (years)	Nationwide Personal Transportation Study 1969	1977	1983	Residential Transportation Energy Consumption Survey 1983	1985
Under 1	17,500	11,800	14,200	13,400	12,700
1	16,100	13,400	17,000	13,000	13,000
2	13,200	13,400	14,000	12,700	12,600
3	11,400	12,100	12,500	12,100	12,400
4	11,700	11,300	11,400	11,300	11,100
5	10,000	10,700	11,000	9,700	10,600
6	10,300	10,500	9,900	9,700	10,000
7	8,600	9,500	9,400	9,500	9,700
8	10,900	8,600	8,700	8,700	8,900
9	8,000	8,800	8,100	8,400	8,600
10 and older	6,500	7,100	6,900	8,700	8,400
All vehicles	11,600	10,300	10,400	9,500	9,900
miles/year, 10 and older / miles/year, 2 and younger	.42	.55	.46	.67	.66

SOURCE: Oak Ridge National Laboratory, *Transportation Energy Data Book Edition 70,* ORNL-6565, September 1989. Based on: Nationwide Personal Transportation Study: D. Klinger and J. Richard Kuzmak, COMSIS Corporation, *Personal Travel in the United States, Volume 1: 1983-84 Nationwide Personal Travel* Study, prepared for the U.S. Department of Transportation, Washington, DC, August 1986, table 4-22, p. 4-21; and Residential Transportation Energy Consumption Survey: Energy information Agency, Office of Markets and End Use, Energy End Use Division, 7985 *Residential/ Transportation Energy Consumption Survey,* Washington, DC, unpublished data.

sales in later years when the scrapped vehicles *would have been* retired. If we focus more on maintaining lifetime mileage rather than on retaining annual mileage, the long-term ratio of old cars scrapped to new cars purchased *that would otherwise not have been purchased* might be closer to 4:1 for pre-1980 cars and even higher for older cars.

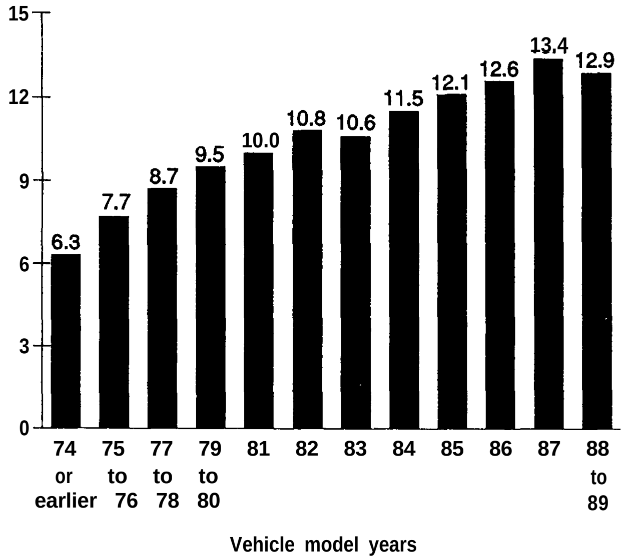
It is possible to make a case for a much lower *immediate* boost in new car sales. The values estimated above depend on the thesis that the mobility lost by early retirement of older vehicles will be replaced by additional vehicles in the fleet, i.e., more new cars (which leads to assumption bl, above). However, it is possible that the additional miles could be made up by increased VMT/year over all model years in the existing fleet (as in assumption b2). We note, however, that increasing such driving should shorten the lifetime of these vehicles, causing the need for additional new cars sometime in the future. In other words, we may add approximately the same additional new cars to the fleet, but they might be added slowly rather than in the first year or two after the program begins. An important uncertainty here: Will the lifetime of vehicles in the existing fleet be shortened in direct proportion to their increase in driving? Given the importance of maintenance as well as sheer *time* as determinants of vehicle life, is it possible that the vehicles will *not* have significantly shorter lifetimes because of their increased use, but simply last approximately the same length of time with more total miles?

The possibility that the loss of large numbers of older cars will be compensated for by increased driving in the remaining existing fleet, rather than the addition of substantial numbers of new cars, adds a significant note of uncertainty to the rest of the impact analysis as well. Both the volume of gasoline saved and the amount of emissions reduced would be lower than estimated if the existing fleet satisfied most of the VMT demand created by the increased scrappage rate of older vehicles, because the remainder of the existing fleet is both less fuel efficient and more polluting than the new car fleet. As noted above, we account for this uncertainty by examining three scenarios of vehicle replacement, ranging from all miles being replaced by new cars to virtually no miles replaced by new cars.

Fuel Savings or Losses

Another way of looking at the market shift caused by an early retirement program is that every remaining mile left in the normal lifetimes of the retired cars is replaced by a "mile driven" at the higher efficiency of the replacement car. This concept can be used to calculate the fuel savings of a program that simply attempts to retire older cars without

Figure l—Average Miles Traveled per Vehicle in 1988 by Model Year (thousands)



SOURCE: Motor Vehicle Manufacturing Association, *MVMA Motor Vehicle Facts* and *Figures '90.* Based on: U.S. Department of Energy, Energy Information Administration, *Household Vehicles Energy Consumption, 1988.*

granting any compensatory adjustment in fuel efficiency regulations (CAFE credits) to those running the program: simply multiply the estimated VMT that the old car would have been driven had it not been scrapped by the difference in the fuel economies (measured in gallons/mile) of the old and replacement vehicles. This value may have to be adjusted by any bias introduced by the nature of the incentive-that is, the older cars are not selected at random. Also, the estimated average mpg of replacement vehicles must account for the increase in sales of light trucks as vehicles for personal transportation; this will decrease the expected efficiency of the replacement vehicles. As shown in box B, we estimate that a program aimed at retiring pre-1975 cars would achieve a fuel savings of 649 to 866 gallons per car if the average car retired by the program would otherwise have had a remaining lifetime of 15,000 to 20,000 miles and the vehicle miles traveled are replaced by new cars. Similarly, a fuel savings of 454 to 681 gallons per car could be achieved by retiring pre-1970 cars with an average of 10,000 to 15,000 miles remaining, and a savings of 472 to 661 gallons would be saved by retiring pre-1980 cars with 20,000 to 28,000 miles remaining.[24]

We note that, if the removal of older vehicles and additional purchase of new vehicles does lead to increases in driving-due to lower gasoline costs per mile and improved reliability of the new vehicles—the actual fuel savings will be reduced. Although there is no consensus about the magnitude of this effect, a typical value would be about a 10 percent reduction in the gasoline savings expected. This would reduce the expected fuel savings from retiring pre-1975 cars to 613to817 gallons, from 681 to 908 gallons.

By awarding CAFE credits to automakers who retire old cars taken in trade for new cars, bills like S. 2049 and S. 2237 will allow the automakers to produce cars of lower efficiency than required without the program. For these programs, the fuel savings must be calculated differently. Because the CAFE credit theoretically creates a fuel loss—the decrease in fuel economy of new cars using the credit from what the cars' fuel economy *would have been* without the credit-the calculation of net fuel savings must account for this loss over the lifetime of the new cars.[25]

The auto industry disagrees with the argument that CAFE credits create actual fuel losses. It argues that the CAFE regulations play little role in determining fleet fuel economy levels, but instead these levels are determined primarily by market forces. As an extension of this argument, the industry claims that CAFE credits would be used only when compliance with CAFE regulations was essentially impossible for a company, i.e., when the company has run out of engineering and marketing options. In other words, removing such credits would yield violations of the CAFE regulations, not a more efficient fleet.

It is beyond the scope of this paper to ascertain the relative merits of the various arguments about the

24 The fuel savings for the pre-1980 cars is lower than for the earlier model cars despite the longer remaining life of these cars, because there is less difference between the replacement vehicles and those being scrapped-the average fuel economy of pre-1980 cars is better than the earlier models due to the influence of CAFE standards and rising fuel prices in the late 1970s.

25 The CAFE credit gained from the retirement of one vehicle is not applied to an individual new car, but is spread out over a company's entire fleet and incorporated into the company's corporate average fuel economy. If, for example, a company retires 100,000 vehicles and gets an average of 15 mpg CAFE credit for each, it can reduce the fuel economy of a 1,000,000 vehicle fleet by about 1.0 mpg. (The value is not 1.5 mpg because fleet fuel economy is averaged harmonically, that is, the inverse of fuel economy, in gpm, is averaged arithmetically.)

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Box B—Fuel Balance Calculations for Retiring Pre-1975 Cars

The change in fuel use associated with early retirement of a pre-1975 car, its replacement with another, newer vehicle, and possibly, application of a full Corporate Average Fuel Economy (CAFE) credit (as in proposed S. 2049) obtained by the destruction of the older car can be estimated if a number of assumptions are made based on available data:

1. Actual fuel economy of average pre-1975 car= mpg.old = 11 mpg,[1]
2. Recorded test value for average pre-1975 car = mpg.oldr = 12 mpg[2]
3. For scrappage program without CAFE credits, actual fuel economy of new replacement vehicle[3] = mpg.new =21 mpg (assuming 30 percent light truck sales[4])
4. For scrappage program with CAFE credits, recorded fuel economy of replacement vehicle= mpg.rec = 24 mpg (current new car fleet average),[5]
5. Actual value of CAFE credit= mpg.rec - mpg.oldr = 24- 12= 12 mpg/vehicle,
6. Remaining miles of old vehicle without early retirement= 15,000 to 20,000 miles, and
7. Lifetime miles of new vehicle= 100,000 miles.

Fuel savings associated with early retirement of one vehicle

For a scrappage program without CAFE credits, under assumption b1 in text (that is, new cars replace all of the VMT lost to scrapped old cars):

Fuel = miles X (1/mpg. old - l/mpg.new)
= 20,000x (1/11 - 1/21)
= 866 gallons for an assumed 20,000 mile lifetime
= 649 gallons for an assumed 15,000 mile lifetime.[6]

For a scrappage program without CAFE credits, under assumption b2 (that is, scrapped old cars are replaced by an average of the fleet, say about 18 mpg):

Fuel = 20,000X (1/11 - 1/18)
= *707* gallons for an assumed 20,000 mile lifetime
= 530 gallons for an assumed 15,000 mile lifetime.

For a scrappage program with CAFE credits (assuming that a full credit is awarded), if the program actually stimulates the sale of a new replacement vehicle[7]:

Fuel = miles X (1/mpg.old - l/mpg.rec)
= 20,000x (1/11 - 1/24)
= 985 gallons for an assumed 20,000 mile lifetime
= 739 gallons for an assumed 15,000 mile lifetime.

1 Assuming a 10 percent loss in fuel economy due to performance deterioration. Based on an assumed (EPA) test rating of 14 mpg when new. This latter value may be a bit low, because Federal Highway Administration data show total fleet fuel economy dropping during the 1950s, 1960s, and first few years of the 1970s—implying that the early 1970s mpg rating of 14 may represent a minimum, and earlier model years may have attained higher fuel economies.

2 On-road, EPA test value of about 14 mpg.

3 Note that we do not assume that each retired vehicle is replaced with one new vehicle. Given the lower rate of driving generally experienced with pre-1975 cars, we estimate that 1 new vehicle would replace 3 pre-1975 cars *if all of the VMT "lost" by scrapping the vehicle is regained by new cars. If* some of this VMT is regained by increased driving of the existing fleet-without shortening the lifetimes of the fleet-the replacement vehicles will be composites of that fleet rather than new vehicles.

4 That is, the average gpm is .7 times the new car fleet average gpm plus .3 times the new light truck fleet average gpm. Here, gpm is used to obtain the harmonic average of fleet fuel economy, in mpg.

5 This assumes that there is no bias in the dealers' selection of cars to include in the CAFE credit scrappage program toward lower mpg cars. Note also that the *actual* replacement vehicle for the scrapped car will not necessarily be the new car purchased by the former owner of the scrapped car-since the scrapped car would otherwise have *either stayed* with that owner *or* have been traded in for a new car anyway but then sold to another buyer. In the latter case, the actual replacement vehicle is that vehicle that substitutes for the miles that would have been driven by the potential buyer of the scrapped car.

6 Note that the EPA alternative to our assigning all "replacement miles" to new vehicles assigns these miles to earlier model cars that will be, on average, less efficient than new cars. Consequently, the EPA method will estimate lower gasoline savings than obtained with our approach.

7 This may be a very optimistic assumption, since many of the new cars would have been bought anyway.

If the program does not actually stimulate the new car sale, the new car is then not the actual replacement vehicle for the old one. In this case, fuel saved is the same as for a vehicle retirement program *without CAFE* **credits.**

Fuel loss associated with CAFE credit gained for retiring one vehicle

Fuel loss = (lifetime of new vehicles for which CAFE credit is used)

X (1/mpg.rec - l/mpg.credit)

where mpg.rec is the actual measured fuel economy value of the new replacement vehicle and mpg.credit is the fuel economy value that the replacement vehicle is credited with in CAFE calculations:

= 100,000 miles X (1/24 -1/36)
= 1,389 gallons.

Net loss associated with retirement program/vehicle = **fuel loss - fuel savings**

1. Replacement vehicle is actual new vehicle purchased. = 404 gallons for assumed 20,000 mile lifetime for retired vehicle
   = 652 gallons for assumed 15,000 mile lifetime
2. Replacement vehicle is an entirely different new vehicle = 523 gallons for assumed 20,000 mile lifetime
   = 740 gallons for assumed 15,000 mile lifetime
3. Replacement vehicle is an entirely different vehicle representative of the fleet as a whole. = 682 gallons for assumed 20,000 mile lifetime
   = 859 gallons for assumed 15,000 mile lifetime

Partial CAFE credit needed to achieve a net fuel balance

Need fuel loss to equal fuel savings

1. Replacement vehicle is actual vehicle purchased:
   for 20,000 mile lifetime
   985 = 100,000X (l/u - l/(24+C)) where C = credit needed for fuel balance
   C = 6.5 out of a full credit of 12, or 54 percent of full credit

   for 15,000 mile lifetime
   739 = 100,000 x (1/24 - l/(24+c))
   C = 5.2 out of ***12,*** or 43 percent of full credit.

2. Replacement vehicle is different new vehicle:
   for 20,000 mile lifetime
   866 = 100,000 X (1/24 - l/(24+C))
   C = 6.3 out of 12, or 53 percent of full credit.

   for 15,000 mile lifetime
   649 = 100,000 x (1/24 - l/(24+c))
   C.= 4.4 out of 12, or 37 percent of full credit.

3. Replacement vehicle is different existing vehicle
   for 20,000 mile lifetime
   C = 4.9 out of 12, or 41 percent

   for 15,000 mile lifetime
   C = 3.5 out of 12, or 29 percent.

ability of CAFE regulations to stimulate increases in fleet fuel economy that would otherwise not occur. Instead, we assume for the sake of this exercise that the manufacturers *do* have the means to achieve a higher fuel economy to comply with CAFE standards but instead exercise the credits because it is cheaper to do so.

When a CAFE credit is applied to a new car, that credit will effectively lower that car's fuel economy for its lifetime-at least 100,000 miles, many times as long as the older car's remaining lifetime (had it not been retired by the program). Consequently, the net fuel savings of a vehicle retirement program with a CAFE credit incentive will equal the savings associated with the replacement of the older vehicle with a more efficient newer vehicle[26] (equal to the difference in the gallons per mile of the old and replacement vehicles multiplied by the older car's lifetime of perhaps 15,000 to 20,000 miles), *minus the* fuel loss associated with the CAFE credit over the lifetime of a new vehicle (or several vehicles) to which the credit is applied (perhaps 100,000 miles).

As shown in box B, awarding a full CAFE credit based on the difference in fuel economy between a new vehicle and the vehicle to be retired yields a net increase in fuel use, rather than a savings. OTA believes it unlikely that Congress would accept a program that resulted in a net increase in U.S. oil use. One possible compromise would be to award a partial CAFE credit that would yield no net increase in use. For the net change in fuel use to equal zero over the long term, that is, *no fuel savings or loss, the* CAFE credit would have to be equal to a fraction of the differential fuel economy between the old and new car. For example, as shown in box B, we estimate that a retirement program for pre-1975 cars that offered a full CAFE credit for the fuel economy difference between retired and purchased vehicles when a customer traded in an older vehicle and bought anew one would suffer a net loss of 404 to 859 gallons of gasoline for every vehicle scrapped. For such a program to ''break even" in terms of fuel use, it would have to reduce the value of the CAFE credit awarded to .3 to .5 times the difference between the fuel economies of the old and new vehicles. Similarly, this type of program applied to pre-1970 vehicles would lose 708 to 935 gallons and break even only with a CAFE credit of *.3* to.5 times the fuel economy difference of old and new vehicles. Applied to pre-1980 vehicles, the net loss would be 529 to 718 gallons, with a breakeven achieved if the CAFE credit were .4 to .5 times the fuel economy difference.

As noted earlier, it is possible that the changes in fuel economy caused by both the early retirement of the older vehicles and the application of the CAFE credits will cause small changes in vehicle miles traveled. According to our calculations, adjusting for such changes yields only modest changes in the breakeven CAFE credit.

The remaining potential years of operation of the cars attracted to an accelerated scrappage program are a critical determinant of the benefits of the program. The value for the remaining lifetime assumed here—15,000 to 20,000 miles for pre- 1975 vehicles—seems in line with the annual mileage figures used in the EPA MOBILE4 model discussed below. It appears low, however, in comparison with the annual mileage figures given in figure 1, since a 15,000 mile lifetime implies retirement within 2 years and 4 months at the pre-1975 annual mileage value of 6,300. On the other hand, it seems reasonable to assume that the program will tend to disproportionately attract vehicles whose lifetime is somewhat below the average.

Reductions in Vehicle Emissions

Retiring old vehicles will have a positive impact on vehicle emissions because the vehicles being retired were originally subject to emissions standards that were weaker than those required of new vehicles, and because mechanical breakdowns and effects of general wear and tear in the engines, exhausts, and pollution control systems of the older vehicles will likely have increased their on-road emissions substantially.

Table 4 shows the Federal automobile tailpipe emissions standards for 1968 to the present. Assuming that the relationship between on-road emissions and the appropriate standard (generally, average on-road emissions are expected to be somewhat higher than the standard) remained the same over the years and poor maintenance did not affect older cars more than younger ones, we might have expected pre-1970 HC and CO emissions to be about 20 times

[26] Note: as discussed above, we do not consider it likely that the true replacement miles will be driven only by new cars, despite the structure of the proposed legislation.

Table 4—Federal Motor Vehicle Tailpipe Emission Standards (grams per mile)

Model year	Automobile emissions			Light-duty truck emissions		
	HC	CO	NO_x	HC	CO	NO_x
1966 precontrol	10.60’	84.0				
1968	6.30	51.0	(6.0)[b]			
1970	4.10	34.0				
1971	4.10	34.0				
1972	3.00	28.0				
1973	3.00	28.0	3.0			
1974	3.00	28.0	3.0			
1975..	1.50	15.0	3.1[c]	2.00	20.0	3.1
1976	1.50	15.0	3.1	2.00	20.0	3.1
1977	1.50	15.0	2.0	2.00	20.0	3.1
1978	1.50	15.0	2.0	2.00	20.0	3.1
1979	1.50	15.0	2.0	1.70	18.0	2.3
1980	0.41	7.0	2.0	1.70	18.0	2.3
1981	0.41	3.4	1.0	1.70	18.0	2.3
1982	0.41	3.4	1.0	1.70	18.0	2.3
1983	0.41	3.4	1.0	1.70	17.0	2.3
1984	0.41	3.4	1.0	0.80	10.0	2.3
1985	0.41	3.4	1.0	0.80	10.0	2.3
1986[d]	0.41	3.4	1.0	0.80	10.0	2.3
1987	0.41	3.4	1.0	0.80	10.0	2.3
1988”	0.41	3.4	1.0	0.80	10.0	1.7[f]
1989[g]	0.41	3.4	1.0	0.80	10.0	1.7

[a]Crankcase emissions of 4.1 g/mi not included; fully controlled.
[b]NO_x emissions (no standard) increased with control of HC and CO.
[c]Change in test procedure.
[d]Full useful life requirement = 11yr/120,000 mi (was 5yr/50,000 mi).
[e]NO_x Federal standard = 1.2 g/mi under 3,751-lb loaded vehicle weight (LVW), 1.7 g/mi for ≥ 3,751-lb LVW, and *2.3* g/mi for ≥ 6,000-lb LVW.
‘1.2 for > 3,751 lb.
[g]These values hold until 1994, when more stringent standards apply. In 1994, automobile standards are .25g/mi for HC, 3.4 g/mi for CO, and .4 g/mmi for NO_x. For light-duty trucks, 40 percent of the trucks larger than 3,751 lb must meet .32 g/mi for HC, 4.4 g/mi for CO, and .7 g/mi for NO_x. By 1996, 100 percent of the fleet must meet these standards.

SOURCE: Adapted from Johnson, 1988; in R. Andersen, “Reducing Emissions From Older Vehicles,” American Petroleum Institute Research Study #053, August 1990, Washington, DC.

higher than 1990 emissions, and NOx emissions to be about 5 times higher. Presumably, a higher ratio of pre-1970 emissions to 1990 emissions would imply that inadequate maintenance of engines and controls also plays a significant role in the emissions imbalance between the two groups of vehicles.

Table 5 shows the emissions, as measured with the Federal Test Procedure used by EPA to certify new automobiles, of 74 of the approximately 8,400 cars scrapped under the Unocal program. According to Unocal, these emissions should be a conservative representation of the whole set of vehicles because some of the worst examples could not be tested.[27]

The Unocal cam’ emissions were far higher than the expected emissions level of new 1990 automobiles: for tailpipe emissions, 65 times for HC,[28] over 50 times for CO, and over 10 times for NOx. These values imply that a similar program conducted on a nationwide scale would substantially reduce vehicle emissions.

The Unocal experiment focuses on pre-1970 vehicles not only because they represent the worst’ group of vehicles from an emissions standpoint but because California, with its warm climate (and thus, lack of salt use for icy roads), has an unusually large number of such vehicles. It is likely that a national early retirement program would focus on vehicles of more recent vintage, because pre-1970 vehicles represent a very small fraction of vehicles in the fleet. In fact, *in 1985* pre-1970 cars represented only 6.7 percent of the total automobile fleet, and a much smaller percentage of the mileage driven; today, the value must be much lower, about 2 percent of the fleet if General Motors’ “20 percent per year’ rule of thumb for scrappage is approximately correct.

[27] Unocal brochure, op. cit., footnote 3.

[28] Unocal claims 99 times, but it did not realize that the .25 grams/mile figure for new cars applies to tailpipe emissions only.

Table 5-Federal Test Procedure (FTP) Test Results vs. Projections (grams per mile)

	HC	CO	NOx
SCRAP test results			
HP results	16.28	84.3	2.96
Adjustments[a]	8.49	16.5	-0.02
"in-use" emissions	24.77	100.8	2.94
Air quality model EMFAC-7D			
1966-70 cars	8.34[b]	50.1	4.39
1975 cars	3.88[b]	23.4	2.53
1990 cars	0.25[b]	1.8	0.27

[a]To reflect nontailpipe emissions and scale to 16 mph.
[b]Tailpipe only.
SOURCE: Unocal, 1991.

Table 6—Estimated Auto Emissions by Model Year, in 1990 (grams per mile)

Model year	Average miles	HC[a]	BEF NO.	CO
1971	4,562	13.450	3.902	63.56
1972	4,823	10.856	3.902	59.27
1973	5,099	10.408	3.104	62.92
1974	5,390	10.218	3.103	62.54
1975	5,608	9.428	3.384	70.31
1976	6,024	9.074	3.336	67.63
1977	6,369	8.835	2.899	64.28
1978	6,733	6.997	2.818	61.76
1979	7,117	6.763	2.733	59.13
1980	7,524	4.028	2.943	20.03
1981	7,954	2.506	1.442	19.80
1982	8,409	2.295	1.370	16.96
1983	8,889	2.017	1.061	10.90
1984	9,398	1.878	1.011	9.48
1985	9,935	1.703	0.929	8.10
1986	10,503	1.554	0.857	6.81
1987	11,103	1.438	0.808	5.91
1988	11,737	1.327	0.756	5.03
1989	12,408	1.228	0.701	4.17
1990	13,118	1.173	0.667	3.51

[a]Total emissions, including evaporative losses.
NOTE: BEF = basic tailpipe emission factor.
SOURCE: MOBILE4; R. Anderson, "Reducing Emissions From Older Vehicles," American Petroleum institute Research Study'#053, Washington, DC, August 1990.

Table 6 presents estimates of 1990 automobile emissions/mile for different vintages of autos from 1971 to 1990 models. These estimates are obtained from EPA's MOBILE4 model which is derived from tests of vehicles with unhampered emission control systems. These data do not appear to show as large a variance between new and old vehicles as obtained from the Unocal tests, primarily because the EPA model is considering average 1990 on-road

Table 7—Number of Older Cars Still in Operation in 1990, by Model Year

Model year	Number of cars (thousands)
1961	23
1962	45
1963	70
1964	105
1965	163
1966	222
1967	270
1968	392
1969	528
1970	706
1971	832
1972	1,244
1973	1,600
1974	1,742
1975	1,780
1976	2,957
1977	4,147
1978	4,911
1979	5,281

SOURCE: Adapted from Motor Vehicle Manufacturing Association, *MVMA Motor Vehicle Facts* &Figures '89, extrapolated from 1988 to 1990 by assuming 20 percent/year scrappage rate.

models, whereas Unocal compares its emissions to 1990 newcars.[29]

Table 6 also contains estimates for annual miles driven per vehicle for each model year. These values are lower than the values shown in Table 3 and figure 1 for the older cars.

The average volume of emissions per vehicle changes sharply from model year to model year, so that estimating the emissions reductions obtained from an early retirement program must account for the likely differences in numbers of vehicles remaining in each model year and average miles driven per vehicle. The data we located for the number of vehicles remaining in each model year are somewhat outdated; we updated them to 1990 values by assuming a 20 percent annual scrappage rate for each model year. Table 7 presents our estimates for the number of cars in operation in 1990 by model year, for model years 1960 through 1979 (to allow us to calculate weighted average emission rates for pre-1980 autos). If there is a second phase to this project, we will attempt during that phase to obtain better data.[30]

29 Also, the values for *1990* cars in table *5* do not include evaporative emissions. The HC comparison in that table should compare tailpipe emissions only, thus yielding a ratio of 65:1, not the 99:1 ratio that Unocal has claimed in its written material.

30 For example, the Motor Vehicle Manufacturers Association has published additional, more recent data since we conducted this analysis.

Table 8a—Auto Emissions "Saved" by Scrapping Older Vehicles

	Emissions (grams/mile)	Emission reductions upon replacement (grams/mile)	(lb/vehicle/yr)[a]	(lb/vehicle)[b]	Cost-effectiveness ($/ton)[c]
Hydrocarbons					
1990	*1.2*				
Pre-1970	16.5	15.3	126	337 to 506	2,900 to 4,900
Pre-1975	12.1	10.9	113	240 to 361	3,700 to 4,700
Pre-1980	8.8	7.6	101	335 to 469	5,500 to 7,300
Carbon monoxide					
1990	*3.5*				
Pre-1970	86.5	83.0	686	1,830 to 2,745	600 to 900
Pre-1975	66.8	63.3	654	2,094 to 2,792	600 to 800
Pre-1980	63.9	60.4	800	2,664 to 3,730	700 to 900
***Nitrogen* oxides**					
1990	.67				
Pre-1 970	3.90	3.23	27	71 to 107	16,000 to 23,000
Pre-1975	3.53	2.86	30	95 to 126	14,000 to 18,000
Pre-1 980	3.07	2.40	32	106 to 148	17,000 to 23,000

[a]Estimated VMT/yr: pre-1970-3,747; pre-1975-4,684; pre-1 980-6,004.
[b]Assumed vehicle lifetimes: pre-1970—1 0,000 to 15,000 miles/2.7-4.0 yrs; pre-1975—15,000 to 20,000 miles/3.2-4.3 yrs; pre-1980-20,000 to 28,000 miles/3 .3-4.7 yrs.
[c]Bonus = $700/car for Pre-1 970 and pre-1975, and $1,000/car for pre-1 980, assumed 10 percent interest.

SOURCE: Office of Technology Assessment.

Table 8b—Auto Emissions "Saved" by Scrapping Older Vehicles Assuming Older Vehicles Driven More, Last Longer

	Emissions (grams/mile)	Emission reductions upon replacement (grams/mile)	(lb/vehicle/yr)[a]	(lb/vehicle)[b]	Cost-effectiveness ($/ton)
Hydrocarbons					
1990	*1.2*				
Pre-1970	16.4	15.2	149	402 to 603	3,000 to 4,100
Pre-1975	12.1	10.9	136	325 to 529	3,300 to 4,400
Pre-1980	8.8	7.6	121	369 to 503	5,000 to 6,500
Carbon monoxide					
1990	*3.5*				
Pre-1970	86.3	82.8	812	2,191 to 3,286	500 to 800
Pre-1975	66.6	63.1	786	2,226 to 3,061	600 to 800
Pre-1980	63.9	60.4	958	2,930 to 3,995	600 to 800
***Nitrogen* oxides**					
1990	.67				
Pre-1970	3.90	3.23	32	85 to 128	14,000 to 19,000
Pre-1975	3.52	2.85	35	101 to 138	13,000 to 17,000
Pre-1980	3.07	2.40	38	116 to 159	16,000 to 21,000

[a]Estimated VMT/yr: pre-1970-4,450; pre-1975-5,648; pre-1 980-7,194.
[b]Assumed vehicle lifetimes: pre-1 97&l 2,000 to 18,000 miles/2.7-4.0 yrs; pre-1 97&l 6,000 to 22,000 miles/2 .8-3.9 yrs; pre-1980-22,000 to 30,000 miles/3.1 -4.2 yrs.

SOURCE: Office of Technology Assessment.

The data in tables 6 and 7 can be combined to produce average emission rates (averaged over a variety of model years, e.g. for all pre- 1980 vehicles) for HC, CO, and NO_x weighted by total miles driven by vehicles from each model year (total miles is the product of miles driven/vehicle and the number of vehicles in that model year) .31 As shown in table 8, the 1990 weighted average emission rates for pre-1970 vehicles are only 14, 25, and 6 times as large as 1990 model year values for HC, CO, and

[31] We based our estimates of emission rates for vehicles in model years 1960-70 on the precontrol values shown in table 4 and an examination of the relationships between standards and estimated on-road emission rates in later years. We estimated the mileage/vehicle/year for the same model years by assuming a 5.7 percent/model year reduction in mileage/year down to 3,500 miles/yew in 1967; we assumed that thereremaining vehicles of earlier vintage would also be driven 3,500 miles/year.

NO_x, respectively—versus 65, 56, and 10 times as large as the 1990 model year cars in the Unocal tests. As noted, the primary reason for this difference is EPA's higher estimates for 1990 emissions (Unocal's values reflect new cars, while EPA's presumably do not); the EPA and Unocal estimated emissions rates for older vehicles are not that different.

Table 8a also presents the total emissions 'saved' per vehicle retired, by assuming that pre-1970 vehicles have a remaining lifetime of 10,000 to 15,000 miles. (This strikes us as generous but is in line with some estimates of 'miles driven per year' for these vehicles; it may seem low when compared to the high VMT/year values obtained from the Unocal program, but Unocal's data reflect California vehicles, which should be expected to have longer lifetimes for each model year than the national average. Pre-1975 vehicles have a remaining lifetime of 15,000 to 20,000 miles, and pre-1980 vehicles have a remaining lifetime of 20,000 to 28,000 miles. This is a *guess* based on available data on mileage values for these vehicles and an assumed scrappage rate of 20 percent per year for the older vehicles. Table 8b presents the same values with different assumptions about the VMT/year and lifetime VMT remaining for old vehicles—12,000 to 18,000 miles remaining for pre-1970 vehicles, 16,000 to 22,000 miles for pre-1975, and 22,000 to 30,000 miles for pre-1980 vehicles.[32] (These values are more in line with the estimates in table 3 and figure 1 and with Unocal's results for the amount of driving of retired vehicles).

Note that the "per vehicle" emissions estimates used as a basis for our calculations represent estimates of *current* emissions from older cars. Changes in fuels and control programs mandated by the Clean Air Act Amendments of 1990 will likely change these emissions values, and thus this analysis applies primarily to early retirement programs scheduled for the immediate future. If a program is contemplated for a later date—say, 1995-emissions, net benefits, and overall cost-effectiveness of a retirement program maybe different. In particular, the amendments require oil companies to introduce reformulated gasoline into nonattainment areas by 1995, and this gasoline will reduce emissions from all cars, and particularly from older vehicles. This, in turn, will reduce the net emissions savings from each retired vehicle, and reduce overall program cost-effectiveness. Similarly, the amendments call for increased waiver limits for I/M programs in key nonattainment areas, to $450/vehicle (waiver limits are the dollar amount that a vehicle owner must spend in emissions repairs before he or she can be granted a waiver from State emissions standards). The increased limits should both force more repairs, with reduced emissions, and cause more retirement of high-emission vehicles, with the result likely to be a generally lower *average* emission rate for older cars. This, too, will reduce the net emissions savings/retired vehicle and reduce retirement program cost-effectiveness. Thus, unless the per ton *value* of emissions savings increases, the cost-effectiveness of vehicle retirement programs should decline somewhat after the provisions of the Clean Air Act Amendments go into effect. Of course, it is entirely possible that the value (dollars/ton) of emissions savings *will increase in the future*, and this would tend to reverse the effect of the reduced level of savings.

Emission Cost-Effectiveness

Although a vehicle scrappage program will have a variety of costs and benefits, most of these are difficult to quantify in dollar terms. We will examine program cost-effectiveness in the limited fashion of balancing emission benefits against direct program costs. There are a variety of other costs and benefits, both public and private, including gasoline savings, investment costs for replacement vehicles, changes in insurance costs, improved vehicle reliability (when the replacement vehicles are newer), and so forth. Other analyses of early retirement programs have included gasoline savings in their cost/benefit equations.[33] However, including gasoline savings, a private benefit, in our analysis would *at least* require that we also include private *costs* such as investment costs (to the extent that new vehicles are purchased), changes in insurance costs with purchases of higher value vehicles, and so forth, and possibly other private benefits (such as improved vehicle reliability) as well.

32 Chrysler's estimates for remaining vehicle lifetimes are even more optimistic than these: 18,000 miles forpre-1970 cars, 23,000 for pre-1975 cars, and 33,000 miles for pre-1980 cars, from a 1990 baseline.

33 For example, the EPA analysis.

We are not here attempting a true cost/benefit calculation, that is, balancing costs against the actual physical and financial effects of reductions in emissions levels caused by a vehicle retirement program (as well as other benefits, including jobs created by increased demand for new cars). Aside from the obvious difficulty of obtaining reliable estimates of the physical effects on health and welfare of emission reductions, or placing a monetary valuation on these effects if they were known (see OTA's report on reducing urban ozone, *Catching Our Breath*[34]*)*, a cost/benefit analysis would miss the point that the Clean Air Act *requires* that the national ambient air quality standards be met regardless of cost (in fact, the act forbids the use of cost/benefit estimates in establishing the ambient standards). Instead, our analysis simply asks whether there are other ways to accomplish similar emissions reductions more cheaply than retiring old vehicles, rather than whether or not the cost of the retirement program is truly lower than the societal benefits of the program. In other words, the emissions "benefits' that we compare to program costs are measured as the costs for *alternative* measures that would instead have to be used to reduce emissions in the absence of an early retirement program-i. e., this is an ''avoided cost" method of measuring benefits.

Tables 9 and 10 and figures 2 and 3 show the cost/ton of emissions removed for various strategies to reduce HC and NO_x, estimated by OTA.[35] As shown, strategies to reduce HC are available to nonattainment cities for less than $4,000/ton through 1994; generally, only measures costing less than about $1,000/ton will be applied in atttainment cities during that time period. The results in Table 8 indicate that retirement programs aiming at pre-1970 or pre-1975 vehicles registered and/or driven in nonattainment cities may be cost-competitive with other HC reduction measures *even if the full cost of retirement is borne by HC control.*

NO_x reduction is available in all but southern California cities for $3,300/ton or less through 1994. Although NO_x reduction from vehicle retirement is thus not cost-effective *by itself, the* value of the reduction is an important component of overall cost-effectiveness.

EPA, in recent published analyses of the cost of future CO controls, estimates that new vehicle controls will cost about $200/ton of CO removed, but will save enough fuel to more than compensate for this cost—yielding a net cost *savings* associated with CO control.[36] CO control is also accomplished by adding various oxygenates to gasoline; EPA estimates their cost at $208 to $905/ton of CO reduction. ETBE, an ether made from ethanol, is the most expensive of the likely oxygenates slated to be used; if its use can be avoided, the cost range is somewhat lower, about $208 to $576/ton of CO reduction.[37]

The EPA report on accelerated scrappage[38] cites EPA values for the dollar benefits (or, more precisely, the alternative control costs) of reductions in HC, NO_x, and CO as $3,050, $2,750, and $300/ton, respectively. These values are generally consistent with OTA's values for available control measures in nonattainment cities. Coupled with estimated bounty costs, the values can provide the basis for an estimate of emissions cost-effectiveness of a vehicle scrappage program.

The above "benefits" should not be applied to most attainment areas. The Clean Air Act does not require the same kind of expensive controls in attainment areas, and many of the control measures that *are* applied there are simply part of nationwide programs. In fact, it might be argued that the emissions benefits in most attainment areas are zero, since complying with the air quality standards is supposed to protect against all adverse health effects. However, there may be some chronic health effects from long-term exposure to ozone levels lower than the primary standard.[39] Moreover, attainment areas may still experience adverse effects on materials, agriculture, and the natural environment, and emissions in some attainment areas may adversely impact downwind nonattainment areas as

34 U.S. Congress, Office of Technology Assessment, *Catching Our Breath: Next Steps for Reducing Urban Ozone*, OTA-O-412 (Washington, DC: U.S. Government Printing Office, July 1989).

35 Ibid.

36 *Federal* Register, Sept. 17, 1990, pp. 38263-38264.

37 EPA, technical support document for CO rulemaking, ch. 7; Joseph Somers, EPA, personal communication, Nov. 6, 1990.

38 W.L. Schroeer, op. cit., footnote 15.

39 Catching *Our Breath,* op. cit., footnote 34.

Table 9—Estimated Cost-Effectiveness of Selected Control Strategies Analyzed by OTA (dollars per ton of VOC[a] reduced)[b]

	1994			1999			2004		
	Nonattainment cities	Attainment areas	Total	Nonattainment cities	Attainment areas	Total	Nonattainment cities	Attainment areas	Total
RACT	2,200-6,600	—[c]	—	2,300-6,700	—	—	2,400-6,800	—	—
New CTGs	5,300-6,600	—	—	5,400-6,700	—	—	5,400-6,700	—	—
TSDFs	900	—	—	900			900		
Architectural coatings	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Onboard	-not effective in 1994-			1,000-1,200	1,100	1,000-1,200	1,000-1,200	1,100	1,000-1,200
Stage Ii	1,000	—	—	1,000	—		1,000	—	—
Combined onboard and Stage II	1,000	—	—	1,200-1,700	1,100	1,100-1,700	1,200-1,900	1,100	1,100-1,900
Enhanced I/M[d]	2,100-5,800	—	—	3,000-8,500	—	—	3,300-9,700	—	—
Gasoline volatility[e]	120-760	120-770	"1 20-770	120-730	120-750	120-740	120-740	120-750	120-750
New highway vehicle standards[d]	-not effective in 1994-			2,700	2,700	2,700	2,700	2,700	2,700
Methanol fuels	8,700 to 51,000	—	—	8,700-51,000	—	—	8,700-51,000	—	

[a]avm = Volatile organic compounds.
[b]Ranges represent variability among nonattainment cities and should not be construed as uncertainty in our estimates.
[c]"—" means control strategy applied only in nonattainment cities.
[d]Estimates reflect costs associated with VOC control only. We assume that one-third of the total cost of enhanced I/M programs is attributable to VOC control, with one-half and one-sixth to carbon monoxide and NO_x control, respectively. Range in I/M costs represents uncertainty in repair cost and frequency.
estimates reflect cost-effectiveness during the 5-month summertime period when controls are required.

Strategy Descriptions
RACT = "Reasonably Available Control Technology" on all existing stationary sources that emit more than 25 tons per year ofVOC.
New CTGs = new Control Technique Guidelines for existing stationary sources that emit more than 25 tons per year of VOC.
TSDFs = controls on hazardous waste treatment, storage, and disposal facilities.
Federal controls on architectural coatings.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
Stage II control devices on gas pumps to capture gasoline vapor during motor vehicle refueling.
Gasoline volatility controls which limit the rate of gasoline evaporation.
Enhanced inspection and maintenance (I/M) programs for cars and light-duty trucks.
New highway-vehicle emission standards for passenger cars and light-duty gasoline trucks.
Methanol fuels as a substitute for gasoline as a motor vehicle fuel.

SOURCE: U.S. Congress, Office of Technology Assessment, *Catching Our Breath: Next Steps for Reducing Urban Ozone, OTA-O-412* (Washington, DC: U.S. Government Printing Office, July 1989).

Table 10-Estimated Cost-Effectiveness of Selected NO_x Control Methods in Nonattainment Cities in 1994 and 2004 (In dollars per ton of NO_x reduced)[a]

	Cost-effectiveness	
	1994	2004
Stationary source controls		
Electric utility boilers	240-5,500[b]	240-5,500[b]
Industrial boilers, stationary engines, gas turbines, process heaters	690-1,400	670-1,400
	370-2,700	390-2,500
Enhanced I/M	1,200-3,300	1,400-4,400
New highway-vehicle emission standards	—	1.600

[a]Totals are rounded.
[b]Excluding the southern California cities, the upper-bound estimate is about $1,000 per ton of NO_x reduced.
[c]Includes costs of NO_x only.

Strategy Descriptions

Stationary sources controls = moderately stringent controls on all existing stationary sources that emit more than 100 tons per year of NO,. Considered to be "reasonably available control technologies."

Enhanced inspection and maintenance (I/M) programs for cars and light-duty trucks.

New highway-vehicle emission standards for passenger cars and light-duty gasoline trucks.

SOURCE: U.S. Congress, Office of Technology Assessment, *Catching Our Breath: Next Steps for Reducing Urban Ozone, OTA-O-41 2* (Washington, DC: U.S. Government Printing Office, July 1989).

well. In fact, emission reductions virtually anywhere in the Northeast corridor, for example, probably should be valued highly because of the effects of regional transport of pollutants.

As shown in Table 11, unless administrative costs are large, total benefits will modestly exceed costs for vehicle retirement programs aimed at pre-1970 and pre-1975 model years; projected costs straddle projected benefits for the pre-1980 models. The results are, however, quite sensitive to a variety of assumptions including remaining lifetime of scrapped vehicles, condition of the vehicles retired by the program (average fuel economy and emissions levels), type of replacement vehicles, and so forth.

The EPA dollar values for emissions controls are unlikely to hold for the longer term, that is, more than a few years. According to *Catching Our Breath, the* currently available HC and NO_x controls will leave many cities short of meeting national ambient air quality standards for ozone. Current controls will allow good progress up to the middle of this decade, but afterwards, if the standards are to be met, new

Table 1 l—" Per Vehicle" Costs and Benefits of Retiring Older Vehicles

Model years included	Value of emissions reductions ($/year)	Program costs,[b] excluding administrative ($/year)	Value of gasoline savings,[c] ($/year)
Pre-1970	332	221 to 312	205
Pre-1975	311	209 to 266	256
Pre-1980	318	279 to 368	170

[a]HC valued at $3,050/ton, NO_x at $2,750/ton, CO at $300/ton.
[b]Bonuses @d $700/car for pre-1970 or pre-1975, $1,000 for Pre 1980. Interest rate of 10 percent applied over remaining lifetime scrapped cars would have attained.
[c]Gasoline valued at $1 .20/gallon.

SOURCE: Office of Technology Assessment.

controls will have to be added to our arsenal, at unknown costs. Although it is likely that new controls will be more expensive than those in current use, this is not certain because of the potential for technological innovation.

Further Analysis Based on EPA Scrappage Model

OTA's initial analysis, described above, assumed that all replacement miles were driven by new cars. Criticism of this assumption during our review process led us to borrow EPA's scrappage model[40] to evaluate the effects of using other assumptions about the replacement miles. In addition, we used the EPA model to examine the effect of changing assumptions about the emission rates of both the replacement vehicles and the vehicles being scrapped.

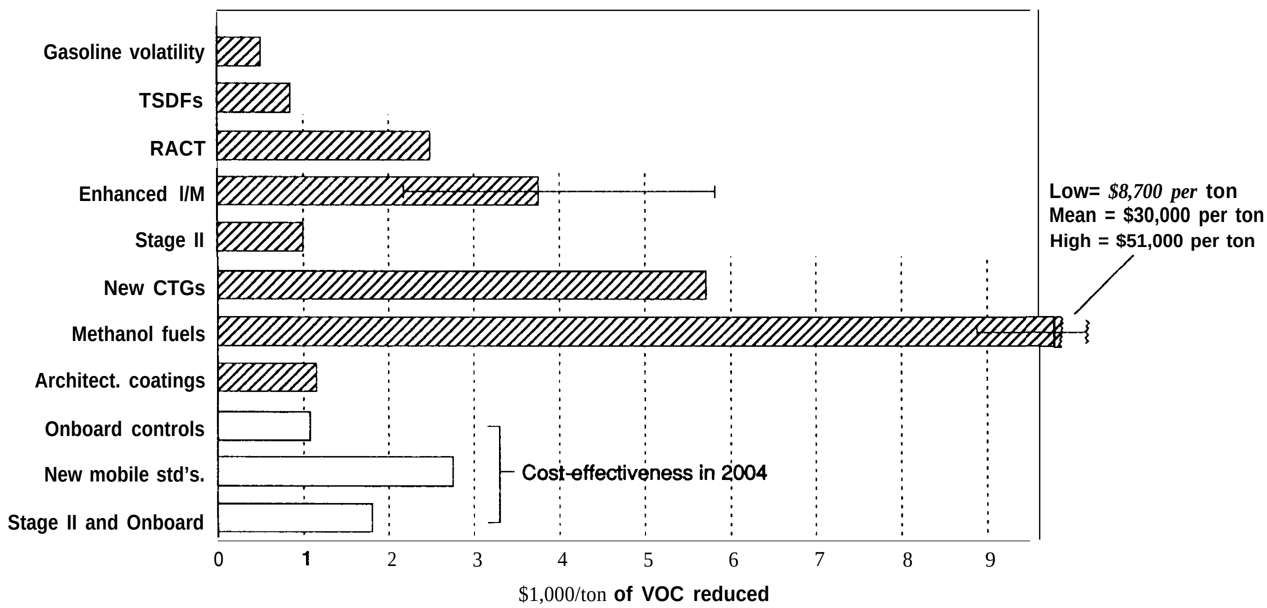
Table 12 displays the results of four model runs, each examining a scenario reflecting different assumptions about either or both the scrapped vehicles and the replacement vehicles:

Scenario 1. This scenario reflects EPA's assumption that scrapping large numbers of older vehicles will result in greater use of the existing fleet rather than the purchase and use of new vehicles. As in EPA's analysis, additional miles are assigned to each model year according to its existing share of total VMT.

Scenario 2. This scenario assumes that half of the replacement miles are driven by new vehicles, reflecting OTA's belief that removing many older vehicles will cause

[40]This model was developed by William Schroeer, Office of Planning and Policy Evaluatiom Environmental Protection Agency.

Figure 2—Estimated Cost-Effectiveness of Volatile Organic Compound Emission Control Methods in 1994 in Nonattainment Cities



The cost-effectiveness of enhanced inspection and maintenance (I/M) programs and new mobile standards include only the cost of VOC control. Since Onboard controls and new mobile standards do not take affect until after 1994, we present the cost-effectiveness in 2004. The thick horizontal bars represent the average cost-effectiveness in nonattainment cities. The thin horizontal lines for gasoline volatility, methanol fuels, and I/M programs represent ranges of uncertainty associated with assumptions we used to estimate total annual costs. The very large uncertainty associated with the methanol fuels is due to the uncertainty of methanol prices relative to gasoline prices. We were unable to estimate cost-effectiveness uncertainty for other control methods. See table 9 for description of control methods.

SOURCE: U.S. Congress, Office of Technology Assessment, *Catching Our Breath: Next Steps for Reducing Urban Ozone, OTA-O-41 2* (Washington, DC: U.S. Government Printing Office, July 1989).

changes in vehicle demand that reverberate throughout the existing fleet and work their way up to the demand for new vehicles. Also, increased driving of existing vehicles will cause some shortening of their lifetimes, also increasing demand for new vehicles.

Scenario 3. This scenario accepts scenario 2's assumption about replacement miles, and *examines the* effect of a program that begins near the introduction of the 1994 model *year. New cars* and light trucks of this model *year* must comply with tier 1 emission standards as established by the new Clean Air Act Amendments.[41]

Scenario 4. This scenario accepts scenario 2's assumption about replacement miles, and examines the effect of retiring vehicles with emissions twice as high as the (EPA-estimated) average for those years.

Each scenario contains two cases: retirement of 1971 and older vehicles only, and retirement of 1980 and older vehicles. A key assumption of this model is that the average lifetime of each retired vehicle is 3 years. Although this seems quite reasonable for the 1971 and older case, it maybe too short for the 1980 and older case. *If 1980 and older vehicles deserve a longer lifetime than assigned by this analysis, the correct value of emission benefits would be higher. The values in parentheses after the 1980 emissions benefits values in table 12 represent the emissions benefits based on a 4 year lifetime.*

As shown in the 'total value' column of table 12, the emission benefits of retiring pre-1971 vehicles exceed the assumed $750/vehicle program costs in every case. On the other hand, in none of the first

[41] Actually, we assume that total emissions from in-use vehicles equal the tier 1 *tailpipe* standards, an optimistic assumption.

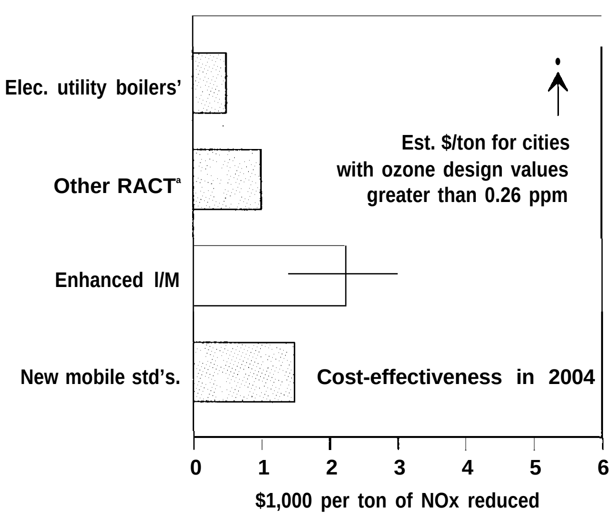
Table 12—Benefits of a Vehicle Retirement Program: Emissions Reductions and Dollar Value, Gasoline Savings

	HC		CO		NO_x		Total value[a]	Gasoline saved
	(lb/year)	($)[a]	(lb/year)	($)[a]	(lb/year)	($)[a]	($)	(gal/year)
Scenario I—miles replaced by existing fleet								
Pre-1971	107	448	707	327	29	108	883	168
Pre-1980	72	300	898	245	27	102	647 (821)	115
Scenario 2—miles replaced by existing fleet (half) and new cars (half)								
Pre-1971	119	495	895	368	33	125	988	182
Pre-1980	88	367	737	303	33	126	796 (1,010)	135
Scenario 3-as in Scenario 2, with new cars meeting tier 1 emission standards								
Pre-1971	124	520	907	373	35	131	1,024	182
Pre-1980	95	396	752	309	35	133	838 (1,063)	135
Scenario 4-as in Scenario 2, selective retirement of high emission vehicles only								
Pre-1971	261	1,090	193	790	78	294	2,174	182
Pre-1982	206	851	165	675	81	305	1,831 (2,324)	135

[a]Over *3* years at 10 percent discount rate; numbers in parentheses represent the value over 4 years at 10 percent discount rate.

SOURCE: Office of Technology Assessment.

Figure 3—Estimated Cost-Effectiveness of NO_x Emission Control Methods in 1994 in Nonattainment Cities



[a]100-ton/year "Reasonably Available Control Technology" (RACT) source-size cutoff

The cost-effectiveness of enhanced inspection and maintenance (I/M) programs and new mobile standards include only the cost of NO, control. The thick horizontal bars represent the average cost-effectiveness in nonattainment cities. The thin horizontal line for I/M programs represents the range of uncertainty associated with assumptions we used to estimate total annual costs, We were unable to estimate cost-effectiveness uncertain y for other control methods. See table 10 for description of control methods.

SOURCE: U.S. Congress, Office of Technology Assessment, Catching *Our Breath: Next Steps for Reducing Urban Ozone, OTA-O-412* (Washington, DC: U.S. Government Printing Office, July 1989).

three scenarios do the benefits of retiring pre-1980 vehicles exceed the assumed $1,050/vehicle program costs.[42] AS noted above, however, assuming slightly longer lifetimes for these vehicles would raise benefit levels. For example, if these vehicles had had 4 year instead of 3 year lifetimes, benefits would have exceeded costs in scenario 3 and would have come close in scenario 2. In OTA's view, an assumption of a longer-than-3-year lifetime for pre-1980 vehicles makes sense. Further, assigning societal benefits to gasoline savings would have increased total benefits still further.

Scenario 4 demonstrates that adding selectivity to a retirement program-for example, retiring only vehicles with higher-than-average emission rates—has the potential to significantly improve the benefit/cost ratio. The results in table 12 show that, if such emissions selectivity can be accomplished, the net benefits of the program can more than double. A caveat to this result is, however, that it assumes no relationship between emissions performance and vehicle longevity, that is, the higher emitting vehicles will continue operating about as long as low emitting vehicles. To the extent that this assumption is false, table 12 will overstate the net benefits of a retirement program selectively retiring high emission vehicles.

Scenario 4 also illustrates the potential outcome of retirement programs if the emissions estimates

[42] *Further, the* benefit values *in* scenario *3 do not account* for the effect of the reformulated gasoline and more strigent *I/M* component of the *Clean* Air Act Amendments, which would tend to reduce per vehicle emissions savings and net benefits. This is particularly important for this scenario because it contemplates waiting until 1994 or so before beginning the retirement program, and thus overlapping with those requirements of the act designed also to reduce emissions from old cars.

used in the baseline cases are significantly understated. There is important evidence that this may be the case. In particular, on-road measurements of vehicle emission rates using highway tunnels show that the predicted emission rates appear to be low, sometimes by a factor of two, three, or more.[43] Unless the relative error in emission rates is much larger for newer cars than old, this implies that the estimated emissions reduction obtained from moving from an older car to a newer one is considerably larger than predicted using MOBILE4 emissions data.

Effects on Mobility and Other Socioeconomic Impacts

To a certain extent, the used car market operates like a "trickle-down" source of mobility for lower income individuals and families: old cars provide an affordable form of transportation for those who cannot afford a new car or a late model used car. Consequently, a program designed to eliminate large numbers of older vehicles may have the potential to reduce the access to transportation of some members of these groups, specifically those who may seek such vehicles within a few years after the program takes effect. Those who already own older vehicles, on the other hand, may achieve improved mobility by using their payment to purchase later model vehicles. The net effect will depend largely on the nature of price changes in the used car market; assuming reasonably constant demand for transportation, eliminating one class of vehicles should boost prices for all others, particularly for those model years just above the years eliminated or reduced by the program. We suspect that a large program would cause some real problems for lower income drivers as a class, though we cannot quantify the effect.

We note also that an early retirement program could have strongly negative impacts on auto recyclers and spare parts dealers, by absorbing the source of their materials, and on repair shops and used car dealers. In the Unocal program, the cars were crushed on the spot, and no stripping of the car was allowed. This, of course, need not be the case, and program designers might decide to allow stripping. Some might consider stripping somewhat antithetical to the purposes of the program, because this would contribute to keeping other old cars on the road, and the early retirement program is designed to get them off. However, allowing stripping might lead to easier access to inexpensive spare parts and abetter-maintained fleet-good for safety and good for emissions performance, though bad for fleet turnover.

To the extent that an early retirement program might substitute for certain stationary source emissions controls (if pollution credits are awarded to industry participants in the program), overall pollution control costs will be reduced, with some positive economic effects on product prices and employment in the affected industries. Calculation of these effects requires a model of the national economy, and the results should be particularly sensitive to input assumptions.

A further impact of a retirement program should be to improve fleet safety. In general, the crashworthiness and crash avoidance capabilities of automobiles have improved over time despite a decrease in average vehicle weight. This improvement in safety capability is shown by the sharp declines over time in passenger fatality rates for every size class,[44] although changes in driver behavior, especially declines in drunk driving and increased seat belt usage, also play a role in these positive trends.[45] Also, the potential higher-than-average deterioration of safety systems in the older cars should add another positive component to the safety impact of a retirement program.

IMPLEMENTATION OF A RETIREMENT PROGRAM

The cost-effectiveness and impacts of a vehicle retirement program will depend strongly on the method and details of the implementation program. Some choices available to designers of early retirement programs include:

[43] W.R. Pierson, A.W. Gertier, and R.L. Bradow, "Comparison of the SCAQS Tunnel Study With Other On-Road Vehicle Emission Data,' *Journal Air Waste ManagementAssoc.,* vol. 40, No. 11, November 1990.

[44] B. O'Neill, "Relationships Between Occupant Deaths and Injuries, and Car Size, Weight, and Fuel Economy, " 1992 SAE Government/Industry Meeting, Apr. 30, 1992, Washington, DC.

[45] The effects of shifts in driver behavior over time could be eliminated by doing a cross-sectional analysis of vehicle fatality rates for each model year for a given year, adjusted for differences in exposure (older cars are driven less than newer ones). We understand that the Insurance Institute for Highway Safety is beginning such an analysis (personal communication Brian O'Neill, President, III-IS, May 1, 1992).

1. *Which vehicles are selected*
   a. All vehicles in a cohort (e.g., pre-1975 or pre-1980) satisfying basic conditions such as having been registered for the previous' year and being driveable. Programs must take care to avoid the resurrection of already-junked vehicles.[46]
   b. Only those vehicles that satisfy conditions related to the primary goals of the program, for example, vehicles that emit more than a predetermined level of HC or other pollutants, or that fall below a minimum level of fuel economy, as measured by mpg or mpg adjusted by interior volume.
2. *Nature and magnitude of incentives offered*
   a. Incentives to the vehicle owner-presumably a bounty will be offered either as a uniform dollar value per vehicle or a value based on the type of vehicle.
   b. Incentives to the program sponsors
      1. Tax credits, development rights, emissions credits, or other rewards based on number of vehicles retired, possibly also based on vehicle type.
      2. CAFE credits based on fuel economy of the vehicles retired, or on the difference between fuel economies of the retired vehicle and replacement vehicle (if credit is obtained through retiring a vehicle traded in cm a new car), or simply based on the number of vehicles retired.
      3. Magnitude of incentives-at one extreme, to get a wide-ranging cross-section of the vehicle population, or instead at the other extreme, only to remove the worst-performing vehicles.

To the extent that the details of implementing the program affect the type of vehicle retired, these details are bound to affect the quantitative outcome on pollution and oil use because of the large differences among vehicles. For example, low bounties will tend to sweep only vehicles in poor condition-with high emissions or poor fuel economy, but also with minimum remaining lifetimes and low rates of use. Thus, the magnitude of the bounty paid to vehicle owners will surely affect the pollution outcome, though the net effect is not obvious since changing the bounty will change the average emission rates and rates of use (and lifetime remaining) of the vehicles brought into the program in ways that counterbalance each other.

Basing the magnitude of the bounty on the performance of the specific vehicle can avoid retiring relatively clean vehicles but will add to program costs (by requiring tests to be performed) and may cause owners to attempt to distort test results, e.g., by sabotaging their vehicles' emission controls. If significant levels of tampering occur, measured outcomes will be misleading because many of the vehicles would not have performed as badly as measured had the program not existed.

Added program costs for a retirement program based on vehicle performance can be minimized or eliminated by combining the program with existing inspection and maintenance programs. In current I/M programs, owners of vehicles that fail emission tests must repair the problem and demonstrate compliance, but many escape this requirement by spending more on repairs than a preset limit, such as $100. We understand that each year California waives about 50,000 cars-2 percent of the vehicle populatin;[47] Delaware waives about 1,000 cars each year, well under 1 percent of its vehicles.[48] In a combined retirement-I/M program, vehicles that fail inspection would have the option of either repair or scrappage with a bounty. Although such a program might entice some owners to sabotage their vehicles to deliberately fail inspection, these owners clearly would have offered their vehicles for scrappage under a more straightforward Unocal-style scrappage program. Consequently, the emission effects of such a program will *at worst be similar* to those of a simple scrappage program, and most likely will be somewhat better.

Of course, the concept of limiting a retirement program only to poor-performing vehicles raises the issue of why such vehicles are allowed to remain in service even in areas having vehicle inspection

46 Other procedural safeguards may include requirements that the vehicles be insured, that a computer hookup to the jurisdiction's motor vehicle records be maintained at the retirement site to avoid problems with forged papers, and so forth. Absence of such safeguards will provide a powerful incentive for fraud,

47 Michael Riehle, Unocal, Personal communication, Mar. 26, 1992.

48 Data from Delaware Department of Motor Vehicles and Department of Natural Resources and Environmental Control, 1991.

programs. The lifting of the very low repair cost limits of existing inspection programs would force retirement of the worst vehicles without the need for a separate retirement program paying a bounty to owners. Such a change in inspection programs would, however, have a severe economic impact on low-income drivers.

The Clean Air Act Amendments of 1990 will eliminate some of the low repair cost limits. According to the amendments, by 1992 the areas with the worst ozone problems (a design level of. 16, which applies to approximately the worst 25 urban areas) will have to enact a repair cost floor of $450. This should force the repair or retirement of many vehicles that would otherwise have escaped enforcement of emission standards under the old cost limits. As noted earlier, however, by forcing additional repairs on emission control systems and causing additional high-emission vehicles to retire, the amendments will tend to reduce the net emissions savings from a retirement program instituted late enough for the two programs to overlap.

An alternative to an absolute pass/fail system that would reduce the total impact on low-income drivers is a two-tier system: vehicles that are out of compliance but not drastically so would be subject to a dollar limit on repairs, as in today's systems, while vehicles outside of this "moderate failure" range would have to *at least* be brought within the moderate failure range, or be retired. This would get the very worst vehicles off the road.

The potential problem of owner tampering can be avoided by basing program entry or size of reward on average fuel economy or emissions of the model type rather than on the specific vehicle's performance. For example, it may be possible to screen for model types, engine families, or emission control technologies that have been shown to cause problems *as a class.* However, we are not aware of previous analysis that has defined such classes;[49] further analysis may be necessary before the practicality of this type of approach can be evaluated. Also, even basing the magnitude of the bounty on the performance of the model type has the potential to create problems or inefficiencies. For example, a retirement program that focuses particularly on fuel economy might reward higher bonuses to vehicles with low fuel economy levels. Because vehicle size is a primary determinant of fuel economy, old large cars would receive, on average, a larger bonus than small cars and might get a disproportionate share of program awards. If old large cars tend to be replaced by new large cars with lower-than-average fuel economy, the added increment to a bonus keyed to old car fuel economy might be misspent. This problem might be alleviated by basing the bonus on a combined measure of fuel economy and vehicle interior volume, so that the program would attract vehicles with lower-than-average fuel economy in each size class .50 We cannot, however, be sure of the effectiveness of this type of approach unless we can both evaluate the effect of other variables, such as vehicle performance, on fuel economy and also determine the extent to which these characteristics would tend to be ''replaced' in new car purchases. In other words, would old high performance, lower-than-average fuel economy vehicles be replaced with new high performance, lower-than-average fuel economy vehicles? If so, a higher bonus might not be justified for such cars.

An alternative option with intriguing potential is to use remote-sensing equipment to measure on-road pollution from vehicles, photograph their license plates, and invite the owners of older cars identified as high polluters by the surveillance to retire their vehicles for a bonus. The technology for such a program is relatively new and the results highly controversial,[51] but continued development and testing of the technology might well lead to a feasible method of screening for high-polluting vehicles.

Another important aspect of a retirement program is its duration. If the program lasts for more than a year or so, there will be a temptation for the owner of an old car to wait until his or her vehicle is ready to be retired anyway before bringing it in for a

49 As anecdotal evidence, EPA apparently has found that middle to late 1970s cam with air pumps tend to give less emission problems than cars without air pumps. Phil Lorang, EPA Arm Arbor, personal communication Nov. 16, 1990.

50 Such a system should still be structured to favor scrapping large cars, because average fuel economy has increased proportionately more for large cars than for small cars over the past 15 years, and because absolute fuel savings for a "large car to newer large car" substitution would still be greater than for a "small car to newer small car" substitution even if large and small cars had proportionately identical improvements in fuel economy during the period.

51 J. Carey, "IfDon Stedman Is Right, The Clean Air Act Is All Wrong," ***Business Week, Nov.*** 1, 1990.

Table 13—Benefits and Costs of Vehicle Scrappage Program Retiring 1 Million Vehicles

Model years in program	costs,[a] $million/ year	Emission reduction (1,000 tons/year) HC	CO	NO_x	Gasoline savings (million gallons/ year)	Emission benefits[b] ($million/year)	Cost-effectiveness[c] ratio
Method 1 **(assumes all miles replaced by miles** in new cars)							
Pre-1970	221 to 312	63	343	13.5	171	366	.60 to .85
Pre-1975	209 to 266	57	327	15.0	213	354	.59 to .75
Pre-1980	279 to 368	51	400	16.0	142	346	.81 to 1.06
Method 2							
Scenario 1 (miles replaced by existing fleet)							
Pre-1971	258	53.5	353	14.5	168	326	.79
Pre-1980	369	36.0	449	13.5	115	239	1 .54(1 .21)[d]
Scenario 2 (miles replaced by existing f fleet (half) and new cars (half))							
Pre-1971	258	59.5	448	16.5	182	365	.71
Pre-1980	369	44.0	369	16.5	135	294	1.26 (.99)
Scenario 3 (as in Scenario 2, with new cars meeting tier 1 emission standards)							
Pre-1971	258	62.0	454	17.5	182	378	.68
Pre-1980	369	47.5	376	17.5	135	309	1.19 (.94)
Scenario 4 (as in Scenario 2, selective retirement of high emission vehicles only)							
Pre-1971	258	130	965	39	182	802	.32
Pre-1980	369	153	825	40	135	676	.55 (.43)

[a]Excludes administrative costs. Assumes 10 percent interest rate, $700/vehicle bonus for pre-1970/71 and pre-1975 cars, $1,000/vehicle bonus for pre-1980/81 cars.
[b]HC valued at $3,050/ton, NO_x at $2,750/ton, CO at $300/ton.
[c]Includes emissions benefits only.
[d]Values in parentheses are the cost-effectiveness ratios if the pre-1980 vehicles have a 4-year rather than 3-year lifetime.

SOURCE: Office of Technology Assessment.

retirement bonus-drastically decreasing the fuel savings. Consequently, retirement programs must be of short duration to be effective. Further, the programs cannot be repeated often, because expectations of such repetition will have the same effect of promoting delays in vehicle retirement.

Despite OTA's optimism that an early vehicle retirement program can be a cost-effective way to control emissions, we have also stressed how sensitive program results are to a number of variables that are quite uncertain. Thus, policymakers would do well to view a national early retirement program as essentially experimental in nature. Any such program should be carefully monitored, with random examination of vehicles for operability and emissions performance and followup interviews to determine postsale behavior of participants. Information gained from such a monitoring effort will be invaluable for any future repetition of a nationwide program, and might help jurisdictions that do not participate in the initial wave of programs or that must regulate corporations that seek program entry well after the program begins.

SCENARIO FOR A VEHICLE RETIREMENT PROGRAM

This section illustrates the potential costs and benefits of early retirement programs by postulating a simple program that will retire 1 million vehicles.

The simplest, most straightforward type of retirement program would resemble that of Unocal's California experiment-a paid bonus offered to any vehicle that can be driven to the disposal facility and whose owner can prove previous registration for the past year. Presumably, such a program would focus on nonattainment areas for ozone or CO, since benefits (measured as avoided control costs) would be higher in such areas. We postulate that the program would last for a year.

Costs and benefits for the program are shown in Table 13. Total costs[52] would be $700 million for a program aimed at either pre-1975 or pre-1970 vehicles or $1 billion for a program aimed at pre-1980 vehicles, plus administrative costs.[53] At a 10 percent interest rate, under the assumptions of method 1 (see table 8a), these costs would be $221

52 NOte that we are *assuming* that we can attract a million participants with bonuses of this size. This may not be the case, and it might be necessary to offer higher bonuses, with resulting probable higher cost/benefit ratios, to attain a program this large.

53 EPA assumes that these costs can be held to about $50/vehicle, or $50 million for a 1 million vehicle program.

to $312 million/year (over the assumed remaining lifetime of the vehicles) for pre-1970 vehicles, $209 to $266 million for pre-1975 vehicles, and $279 to $368 million for pre-1980 vehicles; for method 2, costs would be $258 million/year for pre-1971 vehicles and $369 million/year for pre-1980 vehicles (or $291 million/year if the remaining lifetime was 4 years rather than 3). Depending on the scrap metal market at the time of implementation, a portion of these costs could be defrayed by the vehicles' scrap value. In rural areas of the West, scrap dealers pay approximately $40/ton for vehicles that have not been stripped and can be driven in, and about $30/ton for stripped vehicle carcasses.[54] Given the likelihood that the usable parts will *not* be salvaged, the vehicles might have salvage values even less than the $30/ton value.[55] Further, scrap values in urban areas, the more likely sites for early retirement programs, will be still less. Consequently, it seems reasonable to ignore the scrap value in cost/benefit calculations.

Using our original methodology,[56] for pre-1970 vehicles, savings/year for the average remaining lifetime of the vehicles (estimated 2.7 to 4 years) would be 63,000 tons of HC, 343,000 tons of CO, 13,500 tons of NO_x, and 171 million gallons/year of gasoline (not included among public benefits). Emissions benefits per year would equal $332 million; total public benefits would include benefits to the economy from additional new car sales (possibly as many as 300,000 over 1 or 2 years, but probably far fewer, and possibly spread out over more years) and energy security and public economic benefits from gasoline savings. The values for pre-1975 and pre-1980 vehicles are shown in table 13. Similarly, the costs and benefits for pre-1971 and pre-1980 vehicles are shown in the table for the four scenarios used in the second method, which applies EPA's spreadsheet model.

As shown in table 13, the estimated *quantified* benefits of a large Unocal-type program in nonattainment areas would exceed expected costs by a moderate margin in most cases, though extending the program to 1975-80 vehicles may tend to reduce overall benefits depending on the potential lifetime of these vehicles. If the appropriate lifetime is 3 years for pre-1980 vehicles, costs may outweigh the emissions benefits; for a *4* year expected lifetime, in most cases they are less. Adding administrative costs, not estimated here, would slightly reduce the cost-effectiveness of the program. Policymakers should, however, consider both the distribution of costs and benefits and the uncertainties associated with such a program.

The primary benefits are the reductions in emissions and the savings in gasoline. The emissions reductions are public goods and therefore basically can be considered to accrue to the government, which will bear the costs. (Or, if the program is funded by industry, the value of the emissions reductions will be the avoided costs of any alternative emission control measures that industry would otherwise have been forced to install; if emission credits are awarded on a ''ton for a ton" basis, the public gains no net environmental benefits.) On the other hand, the gasoline savings-except for any benefits countable as "national security improvements" —will accrue to the vehicle owner/participants in the program.

As discussed previously and as demonstrated by the results of table 13, the emission "benefits" and other effects of a vehicle retirement program are uncertain, highly sensitive to both assumptions about participant behavior and the physical characteristics of the fleet and assumptions about policy, that is, the precise nature of the program. Table 14 shows how the emissions benefits would change with changes in some key assumptions about policy and other factors.

Not surprisingly, both the emissions savings and the cost-effectiveness of a retirement program appear to benefit from choosing older vehicles, since these presumably would have the worst emissions performance. Complicating this, however, is the likelihood that the average remaining lifetime of these vehicles might be significantly shorter than the lifetimes of vehicles of more recent vintage. As shown, if the pre-1980 vehicles had lasted 4 rather than 3 years, the total emissions savings would be 27 percent higher; however, the higher costs of the pre-1980 program and the lower discounted value of

[54] Ken Anderson, Anderson and Associates, personal communication Greeley, CO, Nov. 28, 1990.

[55] Since nonmetal parts will either be removed, with additional labor costs, or the scrap will be worth less to metal processors because of the contaminants.

[56] Which assumes that replacement miles are driven by new cars.

Table 14—Effects on Emissions Benefits of Changes in Policies, Assumptions

Change in policy	*Effect on emissions benefits*
1. Select pre-1971 rather than pre-1980	Up 22 to 36 percent
2. Wait until tier 1 standards take effect	Up 4 to 5 percent
3. Retire only vehicles with higher-than-average emissions	Up 100 percent or more
Change in assumption	
4. Retired oars would have lasted 4 rather than 3 years	Up 27 percent
5. Miles actually replaced by half new cars/half existing cars rather than all existing cars	Up 12 to 23 percent

SOURCE: Office of Technology Assessment.

the 4th year of savings still leaves the overall cost-effectiveness of a pre-1980 program considerably lower (higher cost-effectiveness ratio) than that of a pre-1971 program.

As shown by tables 13 and 14, waiting until still-cleaner new cars are available to replace some of the retired vehicles will have only a small impact on emissions savings, primarily because the emission gap between old and current new vehicles is much larger than the gap between current and future new vehicles meeting tier 1 emissions standards.

Major increases in benefits and cost-effectiveness can be achieved if the retirement program can attract vehicles with higher-than average emissions (or lower-than-average fuel economy if the program goals are weighted heavily toward fuel savings). Programs can be designed to either screen potential candidates for high emissions/low fuel efficiency, or to *attract these* vehicles by offering rewards that vary inversely with fuel efficiency and/or emissions control effectiveness. As discussed earlier, however, testing for emissions control effectiveness might be compromised somewhat, because some owners may sabotage their vehicles to qualify them for entry to the program or a higher bonus. *If* further research indicates there is substantial variation in control effectiveness among different vehicle types, engine families, and other vehicle characteristics, then effective screening based on these differences becomes a possibility. Also, the use of remote sensing to identify high-polluting vehicles should reduce or eliminate the potential problem of owner tampering designed to win a bonus.[57]

There has been substantial controversy about the nature of the vehicles that will eventually substitute for the retired vehicles. In the Unocal study, nearly half of the study participants purchased a replacement vehicle with a median model year of 1983-84, and 36 percent were driving a previously owned vehicle (and presumably driving it more miles than before). However, as discussed earlier, these are not necessarily the true replacement vehicles. In particular, drivers who *in the absence of the program* would have purchased the vehicles bought by the study participants had to find other vehicles-setting in motion a ripple sales effect throughout the fleet. It remains unclear just what the overall impact on the fleet will be, especially the effect on new car sales. The emissions and gasoline savings will vary directly with higher impacts on new car sales. Thus, the emissions savings, gasoline savings, and cost-effectiveness all increase from scenario 1 (all replacement miles involve additional driving in the existing fleet) to scenario 2 (half of the replacement miles come from new vehicles). However, the extent of the difference in benefits depends on differences in gasoline efficiency and emission control effectiveness between the new car fleet and the existing fleet. The relative stagnation of new car fuel economy since about 1982 and the uniformity of automobile emission standards since 1981 imply that this effect should not be large, as shown in tables 13 and 14.

The above sensitivity analysis only scrapes the surface of the uncertainty associated with a large-scale vehicle retirement program. For example, the above discussion dealt with “remaining lifetime” primarily in the context of potential differences between pre-1980 and pre-1971 vehicles. The assumptions used for remaining lifetimes implicitly presumed that vehicles entering the program would be average. However, as discussed earlier, it seems more likely that the vehicle population entering the program will be skewed toward vehicles in poorer-than-average condition, whose owners value them less

57 Of course, even a remote-sensing program could be defrauded if an owner were aware of the presence of a sensor and deliberately drove within range of it with a tampered-with vehicle.

than others and thus are more willing to sell them for a relatively modest sum. Although Unocal's experience implies otherwise, we are concerned about the potential that the average lifetime of vehicles entering the program might be considerably less than the assumed 3 years. Obviously, if the program attracts primarily owners who might otherwise have soon retired their vehicles even without the program, the pollution reductions that could be credited to the program would be quite small.

PROPOSED ADMINISTRATION PROGRAM

A vehicle scrappage program offered by the Administration[58] proposes to tie emission credits to vehicle retirements, that is, allowing companies to substitute any emissions reductions they obtain from retiring old cars for reductions they would otherwise have to make in their own operations. The Administration will publish a guidance document to the States describing how such programs should be set up. The draft document envisions tying the magnitude of the credits to factors that EPA believes will affect the emissions gains from an accelerated retirement program, such as the region in which the program is sponsored (EPA expects there to be regional differences in the average lifetimes of vehicles, because of differences in climate and the use of road salt) and the vintage of the cars in the program. If done accurately, this tying of emission credits (and, thus, the magnitude of bounties) to the average emission benefits to be gained should increase the cost-effectiveness of the program. However, we are concerned about the availability of adequate data to tailor emission credits to actual benefits. Data accumulated by the Unocal program, the only existing retirement program, are unlikely to be widely applicable to a much larger nationwide program, given the small size of Unocal's program and the unique characteristics of the California fleet.

Although the Administration program is still being developed, the early documents imply that one option for the States is to allow individual companies to create their own programs for retiring vehicles, winning pollution credits to either offset their own pollution or to market to other companies. A concern about this type of system is that a profusion of individual programs within a single area may lead to an extended ''window' of time for owners to retire their vehicles, allowing them to delay retirement until the vehicles are close to their likely retirement age *without* the programs—reducing or eliminating actual emission benefits. As discussed earlier, vehicle retirement programs must be of limited time duration to achieve significant emission benefits.

[58] Press briefing of March 18, 1992 by Michael Boskin, Chairman of the Council of Economic Advisors; Richard Morganstern Assistant Admistrator for Policy and Planning, U.S. Environmental Protection Agency; and others.