J. ENVIRONMENTAL SYSTEMS, Vol. 5(3), 1975

DISTRIBUTIONAL IMPACTS OF AUTOMOTIVE POLLUTION CONTROL PROGRAMS: A MODEL FOR EVALUATION

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ABSTRACT

A model is developed for calculating the incidence of automotive pollution control costs according to the income level of the vehicle owner, for controls that are applied to the existing vehicle population. The model, which is appropriate for evaluating retrofit control programs, mandatory inspection-maintenance, and effluent charges, is applied to the evaluation of the inspection-maintenance program, drawing on data gathered in a test program several years ago. The results indicate that the program is likely to be significantly regressive—the lowest income group will experience a much larger ratio of program costs to income than the highest income group.

If widely held equity goals are to receive serious attention in environmental decisionmaking it is necessary that program alternatives be evaluated in terms of their distributional impacts as well as economic efficiency or effectiveness goals. Traditional methods of program evaluation—benefit cost analysis or cost-effectiveness analysis—have been criticized as being inadequate to the task of evaluating the incidence of program impacts [1, 2].[1] In benefit-cost analysis the assumption of equal marginal utility of benefits (or costs) regardless of income or wealth is tantamount to the neglect of equity concerns in the analysis. One solution to this defect is to assign different weights to the affected groups and

[1] Prominent criticisms have been made by Arthur Maass [1], and Robert J. Kalter and Thomas J. Stevens [2].

doi: 10.2190/AC9L-VRKB-ADNR-4HN6
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calculate weighted benefits and costs [3].[2] In theory, if the weights are correctly assigned, equity will be adequately accounted for within the efficiency calculation. Although many economists favor this approach, others have advocated separating the distributional analysis from the efficiency or cost-effectiveness analysis, primarily because they believe that such separation will better inform the affected interest groups of the impacts and will, thereby, enhance participation in the decision process [4].

Besides the normative argument that can be offered for a more prominent role for distributional information in the decision process, it is clear that equity issues are important in the current political debate over environmental programs. However, the importance of those issues to the decisionmaking process does not appear to have been matched by the attention of policy analysts to the incidence of program impacts. In the area of automotive pollution control, especially the control of used vehicles, there has been little effort to evaluate distributional impacts.

Two studies [5, 6] of the incidence of air pollution costs have concentrated on controls applied to new vehicles and did not consider the effects of controls applied to all or a large segment of the existing vehicle population.[3] The evaluation of the distributional impacts of controlling all vehicles has been addressed by this author [8] in a paper which laid the groundwork for the present analysis, and by Mikolowsky whose model appears to be marred by an error [9].[4]

The present paper presents a model for calculating the incidence of program costs according to the income class of vehicle owners. Although the model is applicable to several control alternatives, including the retrofitting of devices and the use of effluent charges, it is developed here and illustrated in detail for a mandatory inspection-maintenance program.

[2] The use of weighted benefit-cost calculations has been recommended by A. Maass [1] and Burton Weisbrod [3].

[3] The distributional effects of programs directed at the existing vehicle population are likely to be quite different since most new car buyers are in middle and upper income groups. The conclusions of the Chase Econometric Associates and the Dorfman studies—that incidence will be progressive or only slightly regressive, depending on how the costs are financed—have been used to minimize concern for the equity impacts of air pollution control [7].

[4] A recent paper by Freeman [20], which came to my attention after the present paper was in press, evaluates the impacts of a hypothetical program for control of the existing vehicle population. Freeman's results support the findings of this paper.

Inspection-Maintenance Programs

Inspection-maintenance programs have already been implemented in five cities or states and this number will undoubtedly increase.[5] The program basically requires that each vehicle owner bring his or her car to an approved inspection station, generally operated by the city or state, for measuring exhaust emissions of at least two pollutant types, hydrocarbon (HC) and carbon monoxide (CO). If emissions exceed the established standard for the pollutant and model year of vehicle the owner is required to have repairs made on the vehicle to bring the emissions into compliance with the standards.

The Model

The distributional analysis is conducted according to household (family) income of the affected owners. Measurement of the benefits and costs to each income group is the major task of the distributional analysis. In some situations, especially where a program is already in progress, it may be possible to measure the incidence of benefits and costs by direct methods, for example, by a survey of a sample of the affected population or from census data or other records. Such direct methods cannot be used when the analysis is done prior to the implementation of the program for purposes of evaluating proposed alternatives. Even when a program is in operation and direct methods such as a survey could be used there may be advantages to indirect methods. Foremost among these, in our situation, is the opportunity to calculate future impacts of the program and obtain an estimate of its long-term value. The model presented here allows us to treat changes in costs and vehicle population characteristics while using survey data to initialize and refine the model.

It is often difficult to calculate both the costs and benefits to each income group, especially in air pollution control, where most of the benefits are of a nonmarket variety—reduced morbidity and mortality, reduced sensory irritation, and improved aesthetic and other psychological conditions. The measurement of these benefits in economic terms is quite difficult and is a subject of

[5] The only statewide program in operation is in New Jersey. The California program was authorized by the legislature in 1973 (SB 479) for the South Coast (Los Angeles) air basin. A trial demonstration program was started in Riverside county in September 1975. Other programs are currently in operation in Chicago, Portland, and Cincinnatti. The implementation plans for meeting air quality standards in 27 metropolitan areas require the use of inspection-maintenance programs. Personal Communication, Joe Cutro, Environmental Protection Agency, October 1, 1975.

contention [10].[6] The model presented here concentrates on the calculation of the program costs and their distribution, leaving the analysis of benefit distribution for a future date. Analyzing the cost side will indicate the extent of subsidy or compensation needed (if any) to eliminate inequitable cost impacts.

DETAILS OF THE CALCULATION

The desired output of the calculation is the total cost of the program to each income group in each year of the program. If program-related costs vary with vehicle age, then the model should account for differences in the vehicle age distribution among income groups. Since certain maintenance costs are a function of use rate (vehicle miles traveled per year), which varies greatly with vehicle age, a persuasive *a priori* argument can be made for using vehicle age as a key variable in the model. The available data also support the hypothesis that costs vary with vehicle age.[7]

THE COST EQUATION

The derivation of the basic cost equation starts with the equation for the expected value of cost per vehicle owned by a member of income group i. Cost and vehicle age (age group) are the random variables over which the expected value is calculated. The conditional form of the expected value calculation is convenient.
We assume the discrete conditional probability function for cost given vehicle age, $f(c|k)$, and the vehicle age distribution $f_i(k)$, are known. The expected cost for vehicles owned by members of income group i, $E_i(c)$ is calculated from:

$$E_i(c) = \sum_k \sum_c c f_i(c|k) f_i(k) \qquad (1)$$

where

$f_i(c|k)$ = conditional probability (frequency) function for program cost given vehicle age, for vehicles owned by members of income group i.

$f_i(k)$ = probability (frequency) function for age of vehicles owned by members of income group i.

6 Although quantification in economic terms of the benefit distribution may not be possible, it may be possible to link spatial patterns of air quality improvement to income levels by using census tract data and air quality maps, and, thereby, obtain a rough idea of the distribution of program benefits.

7 The vehicle repair cost data obtained by the Northrop Corporation in their study for the California Air Resources Board supports this hypothesis. When additional factors related to vehicle age are considered, the dependence on age is even stronger. Tables 1 and 2 of this paper show this dependence.

The probability function is subscripted in equation 1 to allow for different cost distributions among income groups. Since the existing data do not permit the construction of different probability functions for each income group, the subscript will be dropped. The summation over c of the inner term is simply the average program cost for vehicles in age group k,[8] which we denote by E(c|k):

$$E(c|k) = \sum_{c} cf(c|k) \tag{2}$$

Thus,

$$E_i(c) = \sum_{k} E(c|k)f_i(k) \tag{3}$$

The total cost to members of income group i, TC_i, is then given by

$$TC_i = N_{iT}\, E_i(c) = N_{iT} \sum_{k} E(c|k)f_i(k) \tag{4}$$

where N_{iT} = total number of vehicles owned by members of income group i.[9]

CALCULATION OF THE FRACTION OF THE POPULATION EXCEEDING A SPECIFIED COST

Although the result of equation 4 is needed for the evaluation of distributional impacts by income class, another measure can provide additional distributional information—the fraction of vehicles in each income group that is likely to incur more than a specified cost. This fraction is equivalent to the probability that the value of the random variable, c, exceeds c_s—the specified amount. For income group i the probability is given by equation 5 [11].

$$\Pr\,[c > c_s] = 1 - \Pr[c \leqslant c_s] = 1 - \sum_{k} \Big(\sum_{c=o}^{c_s} f(c|k)\Big)f_i(k) \tag{5}$$

INFORMATION REQUIREMENTS

To carry out the full calculation prescribed by Equations 3 and 4 requires the conditional probability density functions for program cost for each age grouping of vehicles and the density function for the age distribution of vehicles owned by each income

[8] If the data were adequate to construct separate distributions for each income group, then the inner term would be the average cost for vehicles in age group k owned by members of income group i, and would be denoted as $E_i(c|k)$.

[9] If N_{iT} is taken inside the summation and multiplied by $f_i(k)$, the result is simply the number of vehicles in age group k owned by members of income group i. Thus, a simpler form of the calculation is possible.

group. Ideally, the probability density functions are revised for each year of the calculation to reflect expected changes in vehicle ownership and costs to the owner. The change in the cost distribution for future years should be estimated, if possible, to reflect changes in repair practices and consequent cost changes. There is reasonable basis for expecting an inspection-maintenance program to cause an "upgrading" of the quality of maintenance and of replacement parts in order to meet emission test standards [12]. Such an upgrading will cause increased costs beyond those attributable to inflation. If the recent past is an accurate indicator, automobile repair and maintenance costs will continue to rise at a higher rate than the general inflation rate.[10]

VEHICLE OWNERSHIP DATA

Although the decennial census obtains household income and ages of vehicles owned by the household, vehicle age distribution by income is not tabulated by the Census. Neither is such information recorded by a state agency in California. Therefore, short of an independent survey of vehicle age distribution by income class, there is no way to obtain these data for specific regions. Fortunately, however, the Bureau of the Census does report such data for a national sample in its Current Population Reports [13]. As a result of these limitations we necessarily assume that the national age distribution applies to the specific areas for which our analysis is undertaken.

COST DISTRIBUTION BY VEHICLE AGE AND INCOME GROUP

For maximum accuracy, where the data permit, a different cost distribution should be constructed for each vehicle age class, for each income group. The general structure of the model permits us to account for differences in direct costs between income groups, such as might result from different repair practices or labor rates between low and higher income areas. At present, however, the data do not permit such fine distinctions to be incorporated.

The basic data from which the cost distribution curves are constructed are the *net annual cost attributable to the program.* Since the available maintenance/repair (m/r) cost data simply report the total m/r cost that resulted from failure of the inspection test, the analyst is faced with the task of estimating what portion of those

[10] The price index for automobile maintenance and repair increased by 52.5 per cent from December 1970 to September 1975. U.S. Department of Labor, Consumer Price Index.

costs are attributable to the I-M program. It will be difficult to determine which repairs were done specifically because of the I-M program and would not have been performed otherwise, and which repairs would have been performed eventually but were performed sooner because of the I-M program. In the former case the entire cost of the repair should be charged to the program but in the latter case only the portion that represents the added cost due to increasing the frequency of the repair should be counted. The percentage of the cost of a specified repair procedure to be attributed to the program may be calculated as

$$\% \text{ due to program} = \frac{T_n - T_p}{T_n} \tag{6}$$

where T_n = Normal period between specified repair or maintenance procedure, before program

T_p = Period between specified repair or maintenance procedure, after I-M program.

COST COMPONENTS

Certain major repairs are typically infrequent (engine overhaul, carburetor replacement) and are treated as capital investments. Such costs are amortized or distributed over either the remaining useful life of the automobile, or the useful life of the components that have been replaced. This calculation simply requires applying the interest factor that translates a current charge to an equivalent annual charge over the specified period [14].[11]

In the category of recurring or regular costs are items such as tuneups and other minor electrical or fuel system adjustments. If m/r results in lower fuel consumption, as is generally claimed for tuneups or carburetor adjustments, then part of that saving should be credited to the I-M program. The difference in the duration between the performance of the procedure with and without the program is the basis for attributing a fraction of the fuel savings to the program. Additional recurring costs that are attributable to the program are the inspection fee, the travel cost for inspection and repair, and the cost of lost time.

For vehicles that fail inspection the net annual cost is calculated

[11] This factor is known in the engineering economy literature as the capital recovery factor or in the finance literature as the amount of an annunity whose present value is \$1. The factor is calculated as: $\frac{i(1+i)^n}{(1+i)^n - 1}$, where i is the appropriate discount rate (per period) and n is the number of periods, assuming a compounding of interest once per period.

as the sum of the recurring component that is attributable to the program and the annual equivalent of the non-recurring costs. For vehicles that pass inspection the only costs are for inspection, travel, and lost time. From the assumption of the fraction of vehicles that pass the inspection test and a tabulation of the relative frequencies of costs in the various cost intervals for vehicles that fail the test, a probability frequency function can be constructed for the distribution of costs for each age group.

Illustrative Calculation for I-M Programs

DESCRIPTION OF THE PROGRAM

It is assumed, after the California program, that inspection will be required of each light duty vehicle once per year at a state-operated inspection station [15]. Test standards are set by the state so as to require repair and maintenance of a target percentage of the highest emitting vehicles (for hydrocarbon, carbon monoxide, and oxides of nitrogen pollutants). Different failure levels will be set by the Air Resources Board for several categories of vehicle age and type [15, p. S-4]. A motorist whose vehicle fails the test is required to have the vehicle brought into compliance with the standards within a specified period or face the loss of registration of the vehicle at the next renewal time. If the first maintenance or repair procedure does not bring the vehicle into compliance the owner will be required to have additional repairs performed, subject to a limit on the additional repair cost.[12]

DATA SOURCES AND ASSUMPTIONS

Under contract with the California Air Resources Board, the Northrop Corporation, in 1970-71, performed an extensive feasibility study of I-M program alternatives [16]. Included in the study was the testing of about 1200 vehicles by several different test procedures. Vehicles that failed the test were sent to a randomly selected set of service stations and garages in the Los Angeles area for appropriate maintenance [16].

Raw data reporting the test results and repair costs for vehicles that failed the test were obtained from the State Air Resources Board. The cost data for two test methods—key mode and idle

[12] The cost limit comes into effect where a vehicle that has had the recommended initial repairs fails reinspection. If it is then determined that additional repairs will exceed either $150 or 20 per cent of the low market value of the vehicle, a Certificate of Waiver is to be issued.

test—were used since the methods, although different in some important respects, resulted in quite similar repair costs. Since the data were used to construct probability distribution curves for cost as a function of vehicle age, combining the results of the two test methods provided a more adequate sample size—289 total points, of which thirty-six were in the vehicle age category k = 1.

The vehicle population was divided into three age groupings as defined below:

Index	*Age*
k = 1	0-1 (Present Model year and one model year old)
k = 2	2-5
k = 3	6+

These age grouping are necessitated by the format of the census survey reports, except that the census divides the population into four age groups, rather than three, reporting ages two and three separately from four and five.

ASSUMPTIONS FOR THE COST CALCULATION

We assume that costs are entirely of the recurring variety, i.e., there are no capital costs. Next, we estimate the fraction of the maintenance and repair costs that are attributable to the program. At this time, the estimates are based on assumptions of the normal repair frequency before and after the program. More detailed research is needed as to the type of repairs performed and the normal frequencies of pre- and post-program repair.

To the m/r cost we add the cost of inspection, the cost of travel to and from the inspection station and a service facility (for those who fail the test), and the cost of lost time. The latter two items differ between vehicles that pass inspection and those that fail. The inspection fee is estimated at $4.00 and reinspection, for those failing the test, is assumed to be free. The average round trip distance in major urban areas is assumed to be 8.0 miles for inspection and 6.0 miles for repair.[13] Travel costs are estimated on the basis of $0.20 per mile.

The cost of time lost in inspection and repair may be more controversial than the direct travel cost since it is not an out-of-pocket expense. It is important in political terms because of its effect on program acceptance. Research by transportation

[13] A recent estimate of the inspection cost is in the range $3.80 to $4.23. Olson Laboratories estimates the one-way travel distance for inspection as 3-5 miles in urban areas, 5-7 miles in suburban areas, and 10-15 miles in rural areas [15].

economists, although hardly conclusive, indicates that $3.00 per hour is a reasonable estimate of the economic value of lost time [17]. We further assume that the round trip travel time to an inspection station is 0.3 hours, and the wait for inspection is 0.25 hours.[14]

The final item considered is the fuel saving that results from m/r. Here, again, available data are inadequate for an accurate estimate. Widely varying claims have been made as to the beneficial effects of a tuneup on gasoline consumption [16].[15] The maximum claimed values of fuel savings that result immediately after a tune-up were reduced by a degradation factor consisting of two components. One accounts for the loss of effectiveness over time and the other accounts for the difference in frequency of the tuneup before and after the program. The percentage reductions in annual fuel consumption that resulted from these assumptions were: 1.25 per cent for $k = 1$, 2.0 per cent for $k = 2$, and 3.0 per cent for $k = 3$.

CONSTRUCTION OF COST DISTRIBUTION FUNCTION

For each age grouping of vehicles that failed the I-M test, the maintenance and repair costs were tabulated from the Northrop data. Since these data were obtained in 1970 and 1971, costs were adjusted by the average percentage increase in automotive repair costs, as reported in the Consumer Price Index. The adjusted 1975 costs (Table 1) were then multiplied by the fraction of the cost attributed to the I-M program, based on assumptions about normal repair frequencies. For age group $k = 1$, the fraction attributed is 25 per cent, for $k = 2$ it is 40 per cent, and for $k = 3$ it is 60 per cent. The fuel saving is then credited to those vehicles that incurred adjusted m/r costs above $50, since these are assumed to have had a tuneup performed. For vehicles that failed the tests, the fixed inspection costs are added. Finally, the cost distribution is completed by adding the fraction of vehicles that pass the I-M test at the cost incurred by these vehicles. The frequency of occurrence of vehicles in each cost interval is tabulated (Table 2) for the three vehicles age groupings.

[14] The average inspection time, including wait, is estimated at 15 minutes, with 6 minutes required for the actual inspection procedure [15].

[15] Claimed fuel savings from tune-ups vary widely between the Phase A and Phase B Northrop Corporation reports. Neither set of estimates is supported by empirical evidence [16]. Horowitz [18] notes a 2 per cent reduction in fuel consumption due to inspection-maintenance.

Table 1. Adjusted Maintenance and Repair Cost by Vehicle Age For Vehicles Failing Inspection Test[a]

	k = 1		*k = 2*		*k = 3*	
Cost Range	*Frequency*	*Cumulative Fraction*	*Frequency*	*Cumulative Fraction*	*Frequency*	*Cumulative Fraction*
0.00- 9.99	3	0.08	1	0.01	3	0.02
10.00- 19.99	13	0.44	30	0.32	43	0.29
20.00- 29.99	6	0.61	14	0.47	23	0.44
30.00- 39.99	2	0.67	8	0.55	10	0.50
40.00- 49.99	2	0.72	7	0.63	14	0.59
50.00- 59.00	3	0.81	7	0.70	17	0.70
60.00- 79.99	5	0.94	10	0.80	25	0.86
80.00- 99.99	2	1.00	6	0.86	6	0.90
100.00-119.99			3	0.90	7	0.94
120.00-139.99			1	0.91	4	0.97
140.00-159.99			4	0.95	2	0.98
160.00+			5	1.00	3	1.00

[a] Source: California Air Resources Board. Data adjusted by increase in automotive maintenance and repair costs as reported by U.S. Department of Labor, Consumer Price Index.

Table 2. Probability Frequency Function of Inspection-Maintenance Program Costs, By Vehicle Age

	Cumulative Fraction		
Cost Range	*k = 1*	*k = 2*	*k = 3*
0.00- 4.99	0.00	0.00	0.00
5.00- 9.99	0.70	0.51	0.46
10.00- 14.99	0.84	0.72	0.56
15.00- 19.99	0.88	0.78	0.68
20.00- 24.99	0.89	0.81	0.70
25.00- 29.99	0.92	0.82	0.74
30.00- 34.99	0.99	0.82	0.77
35.00- 39.99	1.00	0.86	0.78
40.00- 44.99		0.89	0.78
45.00- 49.99		0.93	0.83
50.00- 59.99		0.94	0.90
60.00- 69.99		0.95	0.94
70.00- 79.99		0.97	0.96
80.00- 89.99		0.98	0.98
90.00- 99.99		0.98	0.98
100.00-119.99		0.99	0.99
120.00-139.99		0.99	1.00
140.00+		1.00	1.00

From these results the average cost for each vehicle age group was calculated using Equation 2. Next, using vehicle age distribution data (Table 3), the average cost of the program to vehicles owned by each income group and the total cost of the program to each income group were calculated.

Table 3. Vehicle Age Distribution by Income Group

	Fraction of vehicles owned by members of each income group that is in specified age group[a] $f_i(k)$		
	Vehicle Age Group		
Income group	*k = 1 (0-1 year)*	*k = 2 (2-5 years)*	*k = 3 (6 + years)*
i = 1: < $ 5,000	0.0942	0.275	0.630
i = 2: 5,000- 9,999	0.149	0.404	0.447
i = 3: 10,000-14,999	0.192	0.458	0.350
i = 4: 15,000+	0.262	0.488	0.250

[a] For example, 0.275 of the vehicles owned by households earning less than $5,000 are in age group k = 2 (2-5 years old).

ILLUSTRATIVE CALCULATION

The calculation is illustrated for San Diego County data (Table 4). Applying equation 2 to the cost distribution for each age group (Table 2), gives the following average costs:

Age Group	*Average Cost by Age Group* $E(c\|k)$
k = 1	$11.38
k = 2	19.08
k = 3	23.68

For income group 1, the values of $f_i(k)$ are:

$$f_1(1) = 0.0942$$
$$f_1(2) = 0.275$$
$$f_1(3) = 0.630$$

From equation (4) and the values above, we calculate the average cost per vehicle owned by income group 1:

$$\begin{aligned} E_1(c) &= \sum_{k=1}^{3} E(c|k) f_1(k) \\ &= (\$11.38)(.0942) + (19.08)(0.275) + (23.68)(0.630) \\ &= \underline{\$21.24} \end{aligned}$$

Since N_{1T} = 89,622, we obtain a total cost, TC_1 = $1.903 million.

Table 4. Income and Vehicle Ownership Data, by Income Group, for San Diego SMSA

Income group	*Number of households*[a]	*Number of vehicles*	*Number of households owning vehicles*[b]	*Distribution of vehicle owning households (per cent)*	*Income, vehicle owning households*[a] *($million)*
< 5,000	112,028	89,622	69,793	19.1	181.9
5,000- 9,999	127,727	186,481	117,764	32.2	882.2
10,000-14,999	100,566	181,018	97,247	26.6	1,215.6
15,000+	82,309	164,618	80,992	22.1	1,829.2

[a] Source: Census of 1970.

[b] Calculated from data in Mikolowsky [9, p. 25].

EVALUATION OF THE DISTRIBUTION OF COSTS

Various criteria may be applied to judge the desirability of the distributional impact of a program or policy. The choice of an appropriate evaluative criterion is not clear-cut because normative considerations affect the choice—even when objective measures are sought [19].[16] Widely used measures, which are closer to the objective end of the continuum, are the Lorenz curve and the Gini concentration ratio.[17] To construct a Lorenz curve the population is arranged in increasing order of income and the cumulative percentage of income is plotted against the cumulative percentage of the population earning that income. If the income distribution is plotted before and after the program, the relative position of the two curves will indicate the direction in which the program changes the distribution of income and which segments of the population are most affected. The Gini index is an aggregate measure of income concentration based directly on the Lorenz curve and, as such, suffers several defects, most notably that the index is not sensitive. A quite regressive program may not change the index by more than a few thousandths unless the magnitude of the redistribution is large.[18]

To evaluate the results of our calculation, the distribution of program costs is compared with the distribution of income (Table 5). The program is significantly regressive since the lowest income group, which earns only 4.4 per cent of the total income pays 15.7 per cent of the total program costs. On the other hand, the highest income group, which earns 44.5 per cent of income, pays only 24.8 per cent of the program costs. When costs for each group are calculated as a percentage of income the highly regressive impact is more striking. For the lowest income group, the annual cost of the inspection-maintenance program is 1.05 per cent of total income. This percentage drops sharply to 0.42 per cent for the $5,000-$10,000 income group and to 0.16 per cent for

[16] An excellent discussion of the interaction between normative and objective considerations in the choice of evaluative criteria as well as a thorough discussion of possible criteria may be found in A. K. Sen, *On Economic Inequality* [19].

[17] See Sen for discussions of the Lorenz curve and the method of calculating the Gini ratio.

[18] The Gini Index for the pre-program distribution of income of vehicle-owning households in the San Diego SMSA is 0.335. The Gini Index varies from 0.00 for the situation in which all households receive the same amount of income to 1.000 in the situation where one household receives all the income. Typical values for cities in the United States are between 0.30 and 0.50.

Table 5. Distribution of Income and I-M Program Costs

Income group	*(Vehicle owning households) ($million)*	*Income distribution (percentage earned by each group)*	*Cumulative percentage*	*I-M program cost ($million)*	*I-M cost distribution (percentage to each group)*
< 5000	181.9	4.43	4.43	1.903	15.7
5,000- 9,999	882.2	21.47	25.90	3.728	30.8
10,000-14,999	1215.6	29.58	55.48	3.478	28.7
15,000+	1829.2	44.52	100.00	2.998	24.8

households earning more than $15,000 per year. Thus, the lowest income group pays at a rate that is more than six times the rate of the highest group.

It should be noted that the use of average costs and aggregation over the income group may obscure the fact that the costs borne by a portion of the population may be quite burdensome. Many individuals in the lowest income group will experience a cost in excess of one per cent of total income and some may be required to pay more than 5 per cent of annual income. From the availability of the total cost distribution by vehicle age and the vehicle age distribution by income group, we calculate, by equation 5, the fraction of vehicles in each income group that exceed a specified cost or specified fraction of income. The percentage of vehicles whose cost exceeds 1 per cent of the average group income is 20.4 per cent for the lowest income group, 4.1 per cent for the next group, 0.8 per cent for the $10,000-$15,000 group and zero for the highest group. The percentage exceeding a cost of $50 varies from 12.6 for the lowest income group to 7.7 for the highest income group (Table 6).

Table 6. Inspection-Maintenance Cost as a Percentage of Income and Fraction of Vehicles Exceeding Specified Cost, by Income Group

		Percentage of vehicles whose cost exceeds:	
Income Group	*I-M Cost as a Percentage of Income*	*$50*	*1% of Income*[a]
< 5,000	1.05	12.6	20.2
5,000- 9,999	0.42	10.4	4.1
10,000-14,999	0.29	9.2	0.8
15,000+	0.16	7.7	0.0

[a] Based on average income for each income group.

Concluding Comments

Because of the absence of important data, it is possible that the results of Table 6 could err in either direction. The true distributional effects could be more regressive than those shown if the fraction of the costs that should be attributed to the inspection-maintenance program is relatively larger for older vehicles. On the other hand, if the fuel savings are larger than estimated here or if the fraction of m/r costs attributable to the program is relatively smaller for older vehicles, then both the absolute impact and the degree of regressiveness may be smaller. However, a sensitivity calculation shows that the degree of regressiveness is quite insensitive to variations in these assumptions.

Thus, we conclude that the distributional effects of the program are likely to be highly regressive, as measured by the ratio of costs to group income. Furthermore, an analysis of the cost distribution within each income group shows that a substantial fraction of low-income individuals may face burdensome costs. If decision-makers view these consequences as undesirable—as I do—they should consider exemptions or subsidies as a means for ameliorating them. It would then be necessary to evaluate the effect of such measures on program effectiveness in order to select an appropriate type or level of subsidy.

ACKNOWLEDGMENTS

I wish to thank Linda Thorpe and Jeannette Tighe for their assistance in analyzing the data and Raymond Ingalls and Duane Seibel of the California Air Resources Board for their cooperation in making Northrop test data available. Partial support for this research was provided by a grant from the Rockefeller Foundation to the Division of Environmental Studies, University of California, Davis.

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