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METHODS DEVELOPMENT FOR ENVIRONMENTAL CONTROL BENEFITS ASSESSMENT

Volume V

MEASURING HOUSEHOLD SOILING DAMAGES FROM SUSPENDED PARTICULATES: A METHODOLOGICAL INQUIRY

by

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OTHER VOLUMES IN THIS SERIES

volume 1, Measurinq the Benefits of Clean Air and Water, EPA-230-12-85-019.

This volume is a nontechnical report summarizing recent research for EPA on methods development for better estimates of economic benefits from environmental improvement. The repdrt'presents the basic econanic concepts and research methods underlyinq benefits estimation as well as a number of case studies, including several fran other volumes of this series. Finally, it offers insights regarding the quantitative benefits of environmental improvement.

Volume 2, Six Studies of Health Benefits fran Air Pollution Control, EPA-230-12-85-020.

This volume contains six statistical epidemiology studies. They show that large associations between health and current levels of air pollution are not robust with respect to the statistical. model specification either for mortality or morbidity. They also find that significant relationships, mostly small, occasionally appear.

Volume 3, Five Studies on Non-Market Valuation Techniques, EPA-230-12-85-021.

This volume presents analytical and empirical comparisons of alternative techniques for the valuation of non-market goods. The methodological base of the survey approach - directly asking individuals to reveal their preference in a structured hypothetical market - is examined for bias, replication, and validation characteristics.

Volume 4, Measuring the Benefits of Air Quality Changes in the San Francisco Bay Area: Property Value and Contingent Valuation Studies, EPA-230-12-85-022.

This volume replicates a property value study conducted in the Los Angeles Basin for the San Francisco Bay area. A taxonomy series of air quality types and socioeconanic typoligies are defined for cities in the area to examine how property values vary with pollution levels. The contingent valuation method surveys individuals, directly asking their willinqness to pay for changes in air quality. The survey method yields benefit values that are about half the property value benefits in both the Bay area and Los Angeles.

Volume 6, The Value of Air Pollution Damages to Agricultural Activities in Southern California, EPA-230-12-85-024.

This volume contains three papers that address the economic implications of air pollution-induced output, input pricing, cropping, and location pattern adjustments for Southern California agriculture. The first paper estimates the econanic losses to fourteen highly valued vegetable and field crops due to pollution. The second estimates earnings losses to field workers exposed to oxidants. The last uses an econometric model to measure the reduction of economic surpluses in Scuthern California due to oxidants.

Volume 7, Methods Development for Assessing Acid Deposition Control Benefits, EPA-230-12-85-O 25.

This volume suggests types of natural science research that would be most useful. to the economist faced with the task of assessing the economic benefits of controlling acid precipitation. Part of the report is devoted to development of a resource allocation process framework for explaining the behavior of ecosystems that can be'integrated into a benefit/cost analysis, addressing diversity and stability.

Volume 8, The Benefits of Preserving Visibility in the National Parklands of the Southwest, EPA-230-12-85-026.

This volume examines the willingness-to-pay responses of individuals surveyed in several U.S. cities for visibility improvements or preservation in several National Parks. The respondents were asked to state their willingness to pay in the form of higher utility bills to prevent visibility deterioration. The sampled responses were extrapolated to the entire U.S. to estimate the national benefits of visibility preservation.

Volume 9, Evaluation of Decision Models for Environmental Management, EPA-230-12-85-027.

This volume discusses how EPA can use decision models to achieve the proper role of the government in a market economy. The report recommends three models useful for environmental management with a focus on those that allow for a consideration of all tradeoffs.

Volume 10, Executive Summary, EPA-230-12-85-028.

This volume summarizes the methodological and empirical findings of the series. The concensus of the empirical reports is the benefits of air pollution control appear to be sufficient to warrant current ambient air quality standards. The report indicates the greatest proportion of benefits fran control resides, not in health benefits, but in aesthetic improvements, maintenance of the ecosystem for recreation, and the reduction of damages to artifacts and materials.

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ABSTRACT

Major conclusions from this study are as follows. As measured by the "frequency" approach to estimating household cleaning costs, annual household soiling damages in the Pennsylvania-New Jersey-Delaware area range from $762 per household (1980 dollars) to $1,386 per household in "do-it-yourself" households as air particulate concentrations range from 40 micrograms per cubic meter ($\mu g/m^3$) to 123 $\mu g/m^3$; such damages for households that hire others to perform household cleaning tasks range from $1,531/household to $2,683/household in the same range for particulate concentrations. Marginal household soiling damages attributablee to air particulate are estimated at $6.63/household per $\mu g/m^3$.

The "willingness to pay approach to estimating particulate-related household soiling damages is found to be infeasible. Average annual contingent valuations related to the <u>total</u> elimination of air particulate were some $7.32/household in the Los Angeles area and $2.68/household in the Philadelphia area.

Individuals in the Los Angeles and Philadelphia areas indicated a maximum willingness to pay of $32.83/month and $12.59/month, respectively, for the elimination of all air pollutants. These total "bids" are allocated to pollution effects as follows: 66-76% health; 13-18% visibility; and 0-16% household soiling.

A modified "frequency" approach to estimating household soiling damages would likely be very effective in terms of providing consistent estimates.

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EXECUTIVE SUMMARY

A. PURPOSE OF THE STUDY

This study is a final report for research funded by the U.S. Environmental Protection Agency (USEPA-R805-9010). The purpose of the research is to test two alternative methods for estimating household soiling damages attributable to suspended particulate air pollution.

B. SUMMARY OF CONCLUSIONS

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C. DESCRIPTION OF RESEARCH

A review of received technical literature is given In Part I of this study. Conclusions drawn from this review are: (i) the present state of the technical arts does not allow for quantitative estimates for the relationship between particulate concentration and the accumulation of dust/grime in households; in qualitative terns, however, the particulate-selling effect is demonstrable; (ii) related to (i), one cannot qualtify, with any precision", the relationship between outdoor particulate concentrations and indoor concentrations; (iii) little can be said in terms of differentiating between soiling effects from "large" (greater than 15 micrograms) and "small" (less than 15 micrograms) particulate.

One can, however, identify a dominant relationship between particulate level and soiling effects; likewise between gaseous pollutants and materials damages. Therefore, while one cannot quantitatively specify the soiling effects that result from alternative particulate levels, it is at least conceptually possible to look to household soiling damages via observed behavioral responses in different pollution (particulate) environments.

Economic theory suggests two alternative approaches to measuring such responses. The first approach involves focus on specific adjustments by households to different particulate environments; adjustments of interest are: changes in expenditures, changes in time spent in cleaning activities and changes in household utility, or satisfaction, related to changes in the average state of household cleanliness. This approach, referred to here as the "frequency" approach, was followed in the 1968 study by Booz - Allen and Hamilton, Inc. The second approach involves focus on the amount of income which would compensate an individual for any change in particulate level; this "compensating variation" in income is the individual's maximum willingness to pay for any imporvement (reduction) in particulate level and is referred to as the "willingness to pay" or "contingent valuation" approach. In theory, the frequency approach and the willingness to pay or contingent valuation approach would yield identical results.

The 1968 Booz-Allen and Hamilton study represents an effort to implement the frequency approach to estimating household soiling damages. This study involved interviews with some 1800 households in the Pennsylvania-New Jersey-Delaware (PENJERDEL) area, wherein individuals were queried as to the frequency with which they performed 27 specific household cleaning tasks. Households were dichotomized into those which paid others to perform cleaning tasks (HIRE households) and "do it yourself" (DIY households). Household soiling costs (damages) for HIRE households were given as the product of contract costs and task frequencies; household soiling costs for DIY households are given as the product of "out of pocket" costs (for cleaning materials) and task frequencies. Conclusions suggested in the B-A study are that: ". . the range of annual air particulate levels experienced in the PENJERDEL area (some 60-140 Micrograms (ug) per cubic meter (m^3)) has no measurable effect on out of pocket cleaning and maintenance costs . . . . Direct economic effects, as far as residential structures are concerned, appear unimportant".

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household soiling damages was shown to be deficient in a number of ways. Particularly important deficiencies included the following. First, the bulk of B-A's tasks were of the "materials damage" type rather than the "soiling" type; materials damage effects are more directly related to gaseous pollutants than to particulate level. Second, B-A's tasks were not comprehensive; particularly important soiling-related tasks excluded in the B-A study are household dusting and vacuuming. Further, considerable ambiguity exists in terms of the scope of B-A cleaning tasks. Third, and especially important, the B-A study abstracts from those costs which, on a priori grounds, one would expect to be most important for household cleaning activities: the imputed cost of household time spent in cleaning activities. Fourth, and finally, B-A's conclusions are seemingly based on the "small", trivial, magnitude of out of pocket costs per operation for soiling tasks which are shown to indeed vary with particulate level. However, these tasks have high annual frequencies. When annual costs for these tasks are compared with annual costs for other tasks (with "nontrivial" costs/operation), the "triviality" of such costs is an open issue.

The original intent of the present study was to simply revise the B-A estimates for household soiling damages to include the imputed value of household labor (the third point described above); task frequencies, HIRE costs and DIY out of pocket costs as given in the B-A study were to be used to the end of developing a revised estimate of 1968 household soiling damages in the PENJERDEL area. It turns out, however, that particulate level in this area has been dramatically reduced over the last twelve years. It then became necessary to generate current task frequency estimates when possible, and to cast our damage estimates as relevant for 1980 rather than 1968.

Estimates are developed here for task frequency, time spent cleaning and the value of household labor for DIY households. These data, in conjunction with B-A's estimated frequencies for HIRE households and dollar costs, are used to estimate total cleaning costs for 1,654,000 households in the PENJERDEL area for current average particulate levels in B-A's four "pollution zones": Zone 1, (40 $\mu g/m^3$); Zone 2, 81 $\mu g/m^3$); Zone 3, (102 $\mu g/m^3$); and Zone 4, (123 $\mu g/m^3$). These estimates are given in Tables A-C. Referring to Tables A and B, average household soiling damages per household increase from \$763 (\$1,531) to \$1,385 (\$2,683) in DIY(HIRE) households as particulate level increases from 40 $\mu g/m^3$ to 123 $\mu g/m^3$ for the ten tasks identified in the B-A study as varying (in frequency) with particulate level.[1] When damages per household are multiplied by HIRE and DIY households in each particulate zone, total soiling damages are derived as given in Table C (there are more than 700,000 households per Zone 1 (40 $\mu g/m^3$) compared with only some 250,000 households in Zone 4 (123 $\mu g/m^3$)). A crude estimate of marginal household soiling damages is estimated at \$6.63/household/$\mu g/m^3$).

Turning now to the WTP approach to estimating household soiling damages, the Contingent Valuation (CV) method was used as a vehicle for estimating the compensating variation" in income associated with changes in particulate level (and, therefore, household soiling). The essence of the Contingent Valuation method is the simulation of a "market" in which a "good''-reductions in air

TABLE A

ESIMATION FOR 1980 SOILING COSTS FOR FOUR PARTICULATE LEVELS:

DIY HOUSEHOLDS[1/]

	SOILING COSTS (PER HOUSEHOLD. MILLIONS OF 1980 DOLLARS) WHEN PARTICULATE LEVEL ($\mu g/m^3$)			
TASKS	40	81	102	123
Wash Floors	$372.71	S387.07	$424.71	$544.77
Wax Floors	177.69	233.23	154.33	205.30
Clean Outside Furniture	0	16.38	46.87	64.05
Clean Gutters	7.32	10.83	6.50	30.08
Wash Inside Windows	51.43	120.67	159.10	199.99
Clean Venetian Blinds	107.75	17.44	73.54	73.45
Wash Outside Windows	34.10	83.49	110.47	138.34
Clean Storm Windows	3.66	27.63	43.62	60.19
Replace Air Conditioning Filters	4.29	4.75	4.52	10.40
Clean/Repair Screens	3.66	3.66	43.62	60.19
TOTAL	S762.71	$905.15	$1,067.28	S1,386.26

1/ Table 18 in text

TABLE B

COMPONENTS OF ESTIMATED SOILING COSTS: WIRE NOUSENOLDS 1/

TASK	COST PER OPIMATION ($ 1980)	MEAN ANNUAL FREQUENCY WITH PARTICULATE LEVEL (µg/m³)				TOTAL ANNUAL COST PER HOUSEHOLD BY PARTICULATE LEVEL ($ 1980):			
		40	81	102	123	40	81	102	123
Wash Floors	$22.60	16.3	40.8	37.9	41.5	$ 368.38	$ 922.08	$ 856.54	$ 936.90
Wax Floors	84.75	6.5	13.9	9.9	6.3	550.87	1,178.03	839.02	533.93
Clean Outside Furniture	27.12	2.6	5.7	5.8	---	70.51	154.56	157.30	---
Clean Cutters	40.68	.4	.6	.5	.03	16.27	24.41	20.34	1.22
Wash Inside Windows	25.43	7.6	11.2	7.7	18.5	193.26	284.82	195.81	470.46
Clean Venetian Blinds	25.43	4.1	4.1	9.3	7.8	111.89	111.89	236.50	198.35
Wash Outside Windows	40.68	3.5	3.3	3.3	8.1	142.38	134.24	134.24	329.51
Clean Storm Windows	40.68	1.4	.7	1.7	3.7	56.95	28.48	69.16	150.52
Replace Air Conditioner Filter	30.51	.4	.8	.3	.8	16.27	32.54	12.20	32.54
Clean/Repair Screens	40.68	.1	.4	.4	.7	4.07	16.27	36.61	28.48
					TOTAL	$1,530.85	$2,886.94	$2,557.72	$2,682.91

1/ Table 19 in text.

TABLE C

ECONOMIC DAMAGE ESTIMATES IN THE PENJERDEL AREA FOR FOUR PARTICULATE LEVELS (1980)[1/]

"TASK	HIRE HOUSEHOLDS WITN PARTICULATE LEVEL (μg/m³) 40	81	102	123	DYI HOUSEHOLDS WITH PARTICULATE LEVEL (μg/m³) 40	81	102	123
	($ millions, 1980)				($ millions, 1980)			
Wash Floors	$12.6	$33.7	$11.0	$ 9.6	$181.0	$167.3	$1-33.9	$144.4
Wax Floors	17.1	24.4	7.8	5.4	57.2	57.9	28.9	28.1
Clean Outside Furniture	.7	1.6	.5	0	0	2.2	3.5	1.2
Clean Gutters	.6	1.0	.4	.01	1.6	1.7	.4	1.5
Wash Inside Windows	8.0	11.1	4.5	6.6	36.8	40.5	47.1	31.5
Clean Venetian Blinds	1.7	1.9	2.3	3.4	26.9	3.7	11.6	11.1
Wash outside Windows	4.6	11.3	5.0	14.5	15.4	29.1	29.1	28.9
Clean Storm Windows	1.3	.9	1.8	2.9	1.0	5.6	6.1	5.8
Replace Air Conditioner Filters	.2	.6	.1	.1	.4	.5	.2	.6
Clean/Repair Screens	.1	.4	.7	.2	1.1	.8	6.0	8.0

HOUSEHOLDS	TOTAL DAMAGES ($ HILLIONS, 1980) PARTICULATE LEVEL (μg/m³): 40	81	102	133
DIY	$321.4	$309.3	$266.8	$261.1
WIRE	46.9	86.9	34.1	42.7
TOTAL	$368.3	$396.2	$300.9	$303.8

1/ Table 20 In text

particulates--is traded. As noted above, however, we are unable to specify the change in physical soiling effects (E) that would result from any given change in particulate level given the current state of the technical arts. This being the case, what is the "commodity" to be traded in the Contingent Valuation's simulated market? One might simply obtain Contingent Valuation measures for arbitrarily selected values for E. This approach lacks appeal, however, inasmuch as the data would remain valueless until some means are developed which allows one to relate EPA policy (in terms of reduced particulate level) to changes in average cleanliness, to which the Contingent Valuation measures apply. Our only alternative then was to obtain Contingent Valuation measures where income is traded directly for reduced particulate level. The major weakness here, however, is that the individual must then transform the particulate level change involved in the Contingent Valuation "market" to his (her) perception of the E that would result. This is the case inasmuch as the individual's Contingent Valuation response for any given change in particulate level reflects his valuation not for the particulate change per se but for the resulting change in the average state of household cleanliness.

Obviously, the problem with leaving to the individual the technological question as to the soiling effects of a given change in particulate level is that individuals, when asked to value the same change in particulate level, may each imagine a different effect in terms of soiling Thus, we are then faced with the issue of interpreting the resulting willingness to pay measures: given two different bids (for the same particulate level change) from two different individuals, does the bid-difference reflect different valuations for the same change in cleanliness or the same (unit) valuation for different (perceived) changes in cleanliness?

Two experimental approaches for dealing with this problem are tested in this study. First, an attempt is made to elicit Contingent Valuation responses from participants for very small changes in particulate level (the "incremental approach"). The idea here is that if small, e.g., 1%, changes are posited, differences in perceived soiling effects across individuals will be sufficiently limited to allow the resulting Contingent Valuation measures to serve as marginal valuations; i.e., Contingent Valuation measures are marginal damage estimates. A damage function would then be derived by integrating the marginal measures across particulate levels; the area under the damage function between any two given values for particulate level could then be used as an estimate for the associated soiling damages.

The second experimental approach used here in an effort to deal with the particulate-soiling effect problem is to simply use the total elimination of airborn particulate (in excess of background levels) as the "commodity" traded in the Contingent Valuation market.

A further complication arises in the general WTP approach in that in offering Contingent Valuation responses, a participant may be unable to sharply differentiate between the many potential effects of particulate level. This is to say that heightened public awareness of potential health and visibility effects from air pollution in general may result in contingent Valuation responses to particulate-level questions that reflect more general attitudinal reactions to more general air pollution effects.

In light of these potential problems, it was never clear whether or not a Contingent Valuation instrument could be developed which would yield defensible estimates for soiling damages. This issue was well recognized in the research proposal which served as the funding basis for this study-the intended purpose of the WTP research efforts was limited to that of testing the feasibility of the WTP approach as a method for estimating soiling damages.

Experiments with the "incremental" approach were undertaken in Albuquerque, New Mexico; more than 300 participants were involved. Results from the "incremental" Contingent Valuation study were disappointing, however. In general, participants simply could not perceive, or relate to, posited small changes in particulate level or small reductions in all pollutants. This is reflected in data given in Table D. In terms of 1% and 10% reductions in all air pollutants, average Contingent Valuation responses were $6.31 and $4.80 (1980 dollars per household per month), respectively. More to the point, however, roughly a third of the participants gave a zero response—their maximum willingness to pay for a small reduction in air pollution was zero. Further, almost half of the nonzero responses were simply at the starting point (starting "bid") of $1.00 or $10.00.

Similar results obtained when small reductions were posited for those types of air pollution which primarily affect health, visibility and household soiling (Table D). A relatively large proportion of the participants either selected the starting bid or responded with zero bids.

Individuals who gave nonzero bids would many times express misgivings about their bid, however. The inescapable conclusion by our interviewing staff was, therefore, that individuals were generally confused in terms of the effects that might accompany any "small" change in particulate level or, more generally, all pollutants. Given our inability to obtain meaningful Contingent Valuation responses to "small" changes in air particulate, attention was then focused on Contingent Valuation responses to the total elimination of air particulate.

In the "total" approach, participants are asked for their maximum willingness to pay for the total elimination of air particulate that contribute to household accumulation of duet and grime. As discussed above, economic theory suggests that major components in any individual damage function for household soiling would include: income, as a surrogate for the opportunity cost of any cleaning expenditures and/or foregone work; cleaning time saved, reflecting the utility of leisure time; and particulate level, which series as a proxy for the average state of household cleanliness. Given the elimination of particulate, the individual's Contingent Valuation response should measure the compensating variation in income obtained as particulate level, P, "changes" from that level now existing in the individual's environment (P_o) to zero, and is therefore a measure of total damages attributable to particulate level at P_O. Again, this damage is hypothesized as determined by income, time saved and P.

There are many functional forms that one might use in testing these hypotheses. Two of the more conventional forms used for analyses of this type are a linear form and a Cobb-Douglas form; these are the functional forms

TABLE D

CV RESULTS FOR INCREMENTAL AIR POLLUTION
AND PARTICULATE LEVEL CHANGES

For the Following Reduction in ALL Air Pollutants:	Average CV Response	Percent Zero Responses
1% (N = 152)	$6.31	37.1,%
10% (N = 232)	$4.80	28.2%

For the Following Reductions in the Effects of Air Pollution:		Average CV Response	Percent Zero Responses
1% :	Heal th	$10.75	21.4%
	Visibility	$10.88	26.0%
	Soiling	$ 4.40	26.5%
10% :	Health	$ 3.00	38.1%
	Visibility	$ 3.98	33.3%
	Soiling	$ 2.55	41.3%

used here. Define Y as individual income, S as cleaning hours saved (per week) from the total elimination of particulates, p as the existing particulate level and D as the individual's maximum willingness to pay for the elimination of P--total damages. Our experiments then focus on the following equations.

$$D_1 = AP^{\alpha_1} Y^{\beta_1} S^{\gamma_1}$$

$$D_2 = \alpha_2 P + \beta_2 Y + \gamma_2 S$$

Data used for testing these hypothesized damage relationships were obtained from Contingent Valuation responses by study areas in Los Angeles, California and the Pennsylvania-New Jersey-Delaware area (referred to as simply Pennsylvania). Criteria for statistical analyses concerning the damage relationships was the F-test at a 95% confidence level. From data in Table E (groups 1 and 2), both the log form and the linear form for the damage function was found to be statistically significant based on data from the Los Angeles study; only the linear form was significant for the Pennsylvania data (compare F-statistics with the critical value for F given by $F_{.05}$). This implies that, for these regressions, one rejects the hypotheses that the coefficient for P and Y and S are not significantly different from zero at a 95% confidence level. In homey terms, then, one might accept any of these three equations as a basis for estimating damages.

Given the purposes of this study, however, it was necessary to go further with statistical analyses. In particular, concern here is with the significance of the variable P (Particulate level) in these equations. For each equation D_1 and D_2 for Los Angeles, D_2 for Pennsylvania), the hypothesis a = O (a is the relevant coefficient for the variable P) was tested; results of these tests are given in groups 3 and 4 in Table E. In all cases the relevant F-statistic is less than the critical value $F_{.05}$, in which case one <u>cannot</u> reject the hypothesis $\alpha = 0$ in any of the three euqations. Similar tests on Y and S result in the rejection of the null hypothesis.

These results may be interpreted in several ways. It may be the case that individual perceptions of soiling damages related to air quality are unaffected by particulate level per se. Individuals are willing to pay for the elimination of particulate in average monthly amounts of $2.69 in Philadelphia and $6.61 in Los Angeles, but it is not clear that individuals in fact differentiate between particulate level changes (and associated soiling effects) and air pollution levels in general (with associated effects on health, visibility and soiling). Further, one may argue that the relationship between Contingent Valuation responses and P is distorted due to the perception problem discussed above; i.e., differences in individual perceptions of the effect on household soiling from the elimination of particulate may play a large role in determining the Contingent Valuation response (damage measure). Finally, it may be the case that the poor performance of P in explaining changes in damages is related to correlation between P and Y, a problem of some concern in the 1968 B-A study. Each of these issues warrant a bit more detailed consideration.

TABLE E

RESULTS FROM STATISTICAL ANALYSES OF CV DAMAGE FUNCTIONS

1. LOS ANGELES DATA ($F_{.05} = 2.71$)

$$\ln D_1 = -\underset{(-3.3)}{9.5} + \underset{(.46)}{.14} \ln P + \underset{(4.9)}{1.06} \ln Y + \underset{(2.0)}{.18} \ln S \qquad F = 10.8$$

$$'_2 = \underset{(.5)}{.007P} + \underset{(3.0)}{.0003Y} + \underset{(.3)}{.14s} \qquad F = 3.19$$

2. PHILADELPHIA DATA ($F_{.05} = 2.76$)

$$D_1 = \underset{(-1.8)}{-5.3} + \underset{(.9)}{.31} \ln P + .53 \ln Y + .09 \ln S \qquad F = 2.3$$

$$'_2 = \underset{(1.1)}{.009P} + \underset{(3.5)}{.0001Y} + \underset{(2.1)}{.23S} \qquad F = 4.9$$

3. LOS ANGELES DATA

$'_N$: $\alpha_1 = 0$, $F = .20$, $F_{.05}(1, 85) = 3.96$

H_N $\alpha_2 = 0$, $F = .22$, $'_{.05}(1,121) = 3.92$

4. PHILADELPHIA DATA

H_N : $\alpha_2 = 0$, $F = 1.23$, $F_{.05}(1, 62) = 4.0$

First, to what extent might individuals view pollutants and effects of pollutants as something of a gestalt? As a part of the Contingent Valuation study, individual[s] were queried as to their maximum willingness to pay for the elimination of all types of air pollution, after which they were asked to allocate this Contingent Valuation measure among health, visibility and soiling effects in terns of their perception of the relative importance of these effects. Results related to this question are summarized in Table F. From these data, two observations are of particular interest. First, as one might expect, the bulk of individual Contingent Valuations for the elimination of air pollution is allocated to health--some 65% to 75% of the total Contingent Valuation. Soiling effects are seen to be viewed as relevant, however, in that the allocation to soiling is 11% to 24% of the total bid. Interestingly enough, the willingness to pay for soiling effects ($2.83 in Los Angeles, $1.98 in Philadelphia) when all effects are considered is <u>less than half</u> of the Contingent Valuation response for soiling that was obtained when Contingent Valuation responses were asked for soiling alone. The higher soiling-only Contingent Valuation response may be viewed as reflecting the individual's more general (in terms of effects) perception of pollution damages; certainly when asked to allocate a general pollution-related Contingent Valuation measure to soiling, a much smaller Contingent Valuation for soiling obtains.

Secondly, when asked their willingness to pay for the total elimination of particulate, to what extent were individual perceptions of the <u>effects</u> of this change--and therefore the "benefits" received for their Contingent Valuation—-homo geneous? Were people bidding on different "goods" (changes in particulate-related effects)? The hetrogeniety of perceived effects from the postulated change in particulate level is made manifest by the fact that the variable S (reduction in household cleaning time) included in our regression equations is statistically significant in explaining estimated damages. But more, it turns out that a substantial proportion of study participants which gave positive Contingent Valuation responses for soiling gave a <u>zero</u> S - response' (approximately 25% of all participants), a phenomena which gives rise to the question: why would one indicate a positive willingness to pay for the elimination of particulate while at the same time indicating that no effect, in terms of reduced cleaning effort, is expected? Among possible explanations for this phenomena, it may be an indication of an effect suggested by Watson and Jaksch, viz., that while cleaning effort is seen by individuals as being unaffected by the reduction in particulate level, their positive bid reflects the change in consumer surplus associated with a higher average state of household cleanliness with "price" (cleaning effort) held constant. Alternatively, as suggested in the previous paragraph, the "soiling" bid (Contingent Valuation response) may in fact relate to <u>other</u> pollution-related effects of concern to the indivdual.

Of particular interest, however, is the relationship between S and P. While the correlation coefficient for P and S is small (around .2), if P is regressed against S, in a simple linear case, the following result obtains (from Los Angeles data):

$$S = .5 + .007P \qquad F = 2.29$$

$$(.8) \quad (1.15) \qquad F_{.05}(1,122) = 3.92$$

TABLE F

CV RESPONSES FOR THE TOTAL ELIMINATION
OF AIR POLLUTION AND THEIR ALLOCATION
OVER EFFECTS

Data Set	Elimination of Air Pollution	Allocation of Total CV to: Health	Visibility	Soiling	Soiling Allocation As % of Average CV for Soiling
Los Angeles	**$32.83/month**	**$25.09**	**$ 4.16**	**$2.83**	**49%**
Philadelphia	$12.59/month	$ 8.36	$ 2.23	$1.98	62%

While this equation is not statistically significant, the t-statistic for P serves to suggest (and only to suggest) a positive relation between S and P. With damages significantly related to S, the effect of P on damages may then be to some extent suppressed in S.

Finally,[2] given the persistent significance of income in explaining Contingent Valuation responses, one may well inquire as to the correlation between P and Y. The potential for correlation between P and Y differs markedly between Los Angeles data and Philadelphia data. While not "high" (usually, correlation coefficients of about .8 are considered "high"), there is some correlation between P and Y in the Philadelphia data (the correlation coefficient, e, is e = -.403). In Los Angeles, however, e = -.23, which suggests little if any correlation. Little more can be said on this topic with available data; P - Y correlation may account, to some extent, for the poor performance of P in explaining Contingent Valuation responses in the Philadelphia data.

D. CONCLUSIONS

The conclusions of this study, in terms of the viability of the general WTP approach to establishing household soiling damages are then obvious: Further use of this method must await advances in the technical state of the arts which allow for the specifications of soiling effects from changes in particulate level (which, of course, is the "good" traded in Contingent Valuation-type "markets".

On the other hand, results from this study suggest considerable promise for the frequency approach to measuring household soiling damages. Weaknesses in the B-A effort to implement this approach notwithstanding, results from the present study which focus on ways in which the B-A implementation methods might be extended and modified provide a basis for, at worst, cautious optimism as to the potential richness of the frequency approach. Suggestions offered here as to an appropriate research design for the implementation of the frequency approach include the following. First, cleaning frequency is considered in terms of multitask household cleaning operations--such as "light" cleaning and "deep" cleaning--rather than in terms of sPecific research tasks. Second, refined estimates for time spent per operation are obtained. Third, stratified (over income) samples are used in obtaining required data. Fourth, data relevant for the value of household labor are obtained for various posited changes in household cleaning time (as opposed to but one change posited in this study). It is suggested here this method for implementing the frequency approach can be accomplished with relatively modest funding requirements.

REFERENCES

1. B-A's task "maintain driveways/walks" is excluded due to ambiguities in the scope of this task.

2. Tests for "starting point bias" were conducted for all equations; no significance was found between contingent valuation responses and starting bids .

PART I

CHAPTER I: INTRODUCTION

This study is a final report for research funded under contract with the United States Environmental Protection Agency, Contract No. USEPA-R8059010 (May 20, 1980) . The purpose of the research is to investigate methods for assessing economic damages from household soiling caused by suspended particulate air pollution. Two alternative methodological approaches are employed. The first approach adjusts soiling damage measures from an earlier study by Booz-Allen and Hamilton so as to include imputed costs of household labor. The second approach employs contingent valuation techniques to assess the economic damages associated with suspended particulate related household soiling. The balance of Part I of this report develops the rationale for following these two methodological approaches for estimating these air pollution damages.

The Clean Air Act of 1970 (Public Law 91-604) is a landmark piece of legislation in terms of establishing the public and government's awareness of the problems of air pollution and manifesting the body politic's determination to promulgate ways and means for improving and protecting the nation's environment. The 1970 Act established the Environmental Protection Agency (EPA) with the mandate to establish and enforce air quality standards as well as to promote scientific research concerning the effects of air pollution and the means of controlling air pollution.

Initial air quality standards established in the 1970 Act, summarized in Table 1, included restrictions on sulfur oxides, carbon monoxide, particulate, nitrogen dioxide and hydrocarbons. The EPA must periodically review these standards to the end of making recommendations to the Congress as to desirable changes and/or extensions. In addressing the question of "desirable'''changes in EPA standards, two interrelated technical and economic issues are of primary importance: what is the relationship between pollution levels (as would result, e.g., from alternative standards) and adverse effects; what is the relationship between pollution-related effects and economic "damages"? The importance of these two issues stems from the fact that if changes in standards are to be viewed as "desirable," it must be demonstrated that, among other things, reductions in economic damages that may result from lower pollution levels will more than offset any costs that may be associated with more stringent air quality standards.

A host of perplexing questions underlie the issues described above; for example, what does one mean by "pollution," what is meant by an "effect" and when does an effect become a "damage"? A response to these issues is required, however, if one is to assess the relative impacts of alternative air quality standards.

Table 1

Review of Ambient Air Standards[1/]

Tempera ture: 25°C (77°F)

Pressure: 760 millimeters of mercury

Agent	Time	PPM[2/]	ug/m³	Measurement Method	Standard
Sulfur Oxidea (Sulfur Dioxides)	Annual -	.03	80	equivalent[3/]	primary
	24 hour (max) not more than once a year -	.14	365	equivalent	primary[5/]
	3 hr. -	.3	750	reference[4/]	secondary[6/]
Particulate	Annual (Geo mean)		75	ref/equiv.	primary
	24 hour (max) not more than once a year		260	ref/equiv.	primary
	24 hour (Gem mean)		60	ref/equiv.	secondary
	24 hour (max) concentration once a year		150	ref/equiv.	secondary
Carbon Monoxide	8 hour (max) once a year -	9	10,000	ref/equiv.	primary and secondary
	1 hour - once a year	35	40,000	ref/equiv.	primary and secondary
Photo chemical Oxidants	1 hour (more then once a year)	.08	160	reference	primary and secondary
Hydrocarbon	3 hour (max once a year) (6 to 9 a.m.)	.24	160	reference	primary and secondary
Nitrogen Dioxide	1 year	.05	Loo	reference	primary and secondary

1/ Source: "National Primary and Secondary Ambient Air Quality Standards" E.P.A.

2/ Parts per million.

3/ "Reference Method" means a method of sampling and analyzing the ambient air for an air pollutant that is specified as a reference method in an appendix to this part, or a method that has been designated" in Title 40, part 53 of the Federal Register, p.4.

4/ "Equivalent method" means a method of sampling and analyzing the ambient air for which an equivalent method" as designated in Title 40, part 53 of the Federal Register, p.4.

5/ "Natural Primary ambient air quality standards define levels of air quality the administrative Judges deem necessary, with an adequate margin of safety; co protect the public health", p.4, Federal Register, Title 40, part 50.

6/ "Natural Secondary ambient air quality standard define levels of air quality which the Administrative Judges deem necessary co protect the public welfare from any known or anticipated adverse effects of a pollutant." Federal Register, Title 40, part 50, p.4.

Concern in this study is with a particular type of air pollution, namely suspended particulate. As is developed below, in so limiting one's focus, one encounters serious problems in separating out pollution effects attributable solely to particulate. Also, "effects"--damages--of concern in this study are primarily household soiling damages caused by particulate and these specific damages are difficult to define. The rationale for limiting the focus here to household soiling damages attributable to particulate is a reflection of the relative poverty of the current state of the arts in terms of assessing such damages. Methodologies for estimating pollution-related damages for such things as health/morbidity, aesthetics and labor productivity are at a <u>relatively</u> advanced state. [1]

Given (as is developed below] that, first, considerable uncertainty exists as to the technological basis for hypothesizing specific cause-effect relationships between particulate and household soiling effects and, secondly, that related economic studies have essentially failed to quantify such damages in any convincing way, any study that pretends to provide a methodology for estimating household soiling damages attributable to particulate must begin by directly addressing the following interrelated questions:

(A) What is the current state of understanding concerning the cause and effect relationship between particulate pollution and household soiling?

(B) If our technological understanding of this cause-effect relationship is weak (as is in fact the case) on what basis can one then proceed to inquire as to the potential "magnitude of economic damages? This is to say that if one cannot establish in some compelling and quantifiable way that particulate concentrations do indeed result in (quantifiable) soiling effects, how then can one pretend to estimate economic damages that attend such effects?

A response to these questions is the topic of Part I of this study; this response serves to set the stage for the plan of research and research results reported in Part 11 of this study. In what follows, question A posed above is considered below in Chapter II. Question B is the topic of Chapters 111 and IV. Results from these discussions are considered in Chapter V wherein the plan of this report is set out for the reader.

PART I

CHAPTER II: SOILING AND MATERIALS-DAMAGE EFFECTS FROM AIR POLLUTION: A TECHNICAL SKETCH

A. INTRODUCTION

Although the concern of this study is with suspended particulate, an accurate assessment of our current understanding of particulate-related effects is initially best seen within a context where other pollutants are considered. This follows from the important interactions between suspended particulate and gaseous pollutants and environmental valuables. For example: (1) particulate can act as nuclei for adsorbed and absorbed gases either while the particulate is airborne or after it has settled; the potential for damage then depends on the chemical effects of the particle in conjunction with its synergistic reaction with other pollutants such as S02, H2S, NO_2, etc.; unfortunately, relatively little is known about these reactions; (2) gaseous pollutants can convert directly to liquid acids or salts, which are then deemed to be particulate, or interact with moisture in the air or on a material surface (e.g., SO_2 reacts with moisture to form liquid SO_3, H_2SO_4 and sulfate salts); likewise, little is known about the effects of liquid particulate. 2 Thus, in initial discussions that follow, gaseous pollutants are considered along with particulate.

Further, in these introductory sections it is important to distinguish between two types of household damages attributable to air pollution: materials damage and soiling. "Materials damage" refers to such things as corrosion and deterioration of materials per se; "soiling" refers to the accumulation of dust and grime in the household. While the distinction between these two effects may often become blurred in terms of assessing some air pollution effects, it is useful, as is argued below, in terms of limiting focus to damages strictly attributable to suspended particulate.

In section B, a brief sketch of the technical literature is given as it relates to the effects of gaseous pollutants and suspended particulate on the following materials:[3] metals, masonry and concrete, paints and finishes, polymeric materials, textiles, porcelain, asphalt, and paper and leather. The order in which these materials are listed reflects the relative volume of research that has been conducted which is, in our judgment, relevant for the questions at hand. Prior to 1970 the bulk of research concerning the impacts of pollution was financed and conducted by private industry which had as its motivation the reduction of maintenance and replacement costs for materials used in machinery and construction; corrosion of metals led to costly replacement/maintenance, thus its prominent role in pollution-related research. The existing imbalance in physical research over materials-types is therefore not surprising.

As will be obvious from the review that follows, the methodology used in a large part of the research for varying pollution levels is that of testing materials in different sites--usually rural-industrial environments and/or different cities; some studies, of course, are based on laboratory experiments (chamber studies). The point is that, with few exceptions (e.g., a few studies of textiles), the focus of existing physical research is on the effects of pollution on materials most often found out-of-doors--household damages per se are not at issue. Little has been done concerning the relationship between outdoor pollution levels, which affects households via effects on paint, woodwork, etc., and pollution levels indoors. This issue is touched on below in Section C. In Section D, an attempt is made to summarize these reviews to the end of examining their implications for suspended particle-related effects on households.

B. REVIEW OF TECHNICAL LITERATURE

A comprehensive review of **all** studies concerning pollution-related effects would, of course, be a massive undertaking (see e.g., Airborne Particles, 1978) and no pretense is made here for presenting such a review. The intent here is to demonstrate the general methodology used to date in such studies to the end of responding to the question as to the general state of our understanding of the household soiling (and, to some extent materials-damage) effects of different levels of pollution, particularly suspended particulate. In this vein, a general literature review of the above listed eight material categories follows.

Metals

The literature concerning pollution effects on metals concerns primarily materials-damages--corrosion. The general methodology used is that of comparing corrosion effects on metals in an urban and industrial environment and attributing differences in corrosion rates to the differences in pollution levels, with particular focus on SO_2. For example, Haynie and Upham (1971) found that variability of the concentrations of both sulfur dioxide, which increases corrosion rates, and oxidants, which decrease them, account for 90% of the variability of corrosion in steel. Their procedure was to place three types of steel in a number of urban and rural areas. Because pollutants are counteractive, they concluded that steel corrosion behavior could vary considerably among cities as cleanliness of the environment was improved. A national reduction in pollution would result in less steel corrosion; however, in cities where sulfur dioxide concentrations are low and oxidant concentrations are high, lowering the total pollution level would increase steel corrosion.

In similar tests with steel plates, conducted by Yocum and McCaldin (1968) in Chicago and St. Louis, corrosion rates were 30% and 80% greater in urban and industrial locations than in suburban rural sites. At Chicago sites, a relationship between SO_2 and corrosion was detected, but dust fall (particulate) had little effect on corrosion levels.

Pushing the industrial environment a bit further, Simpson and Horrobin (1970) found that the exposure of aluminum to an industrial atmosphere resulted in the formation of white crystalline corrosion products on the surface. Increases in amount of soot in the atmosphere affected aesthetic appearance by acquiring a greyish or darkish appearance.

In an effort to get more variations in pollution levels and, perhaps, the composition of pollutants (including environmental variables, discussed below), the effects of increases in levels of atmospheric smoke and sulfur dioxide on the corrosion of steel were studied by Chandler and Kilcullen (1968). Two mild steels with different copper contents were observed at 11 sites near Sheffield, England. The high correlations between the corrosion caused by the smoke and that caused by the sulfur dioxide made any separate analysis of corrosion attributable to each pollutant undiscernible, however.

This multiple environmental approach was extended by Gibbons (1972a) who tested corrosion rates on three aluminum alloys, two magnesium alloys, three steel alloys, stainless steel and rolled zinc at eight sites of varying environmental settings (rural, semi-rural, marine, industrial). The industrial and marine atmospheres produced the highest corrosion rate and steel and magnesium alloys suffered the highest level of corrosion among the metals at all sites. Stainless steel was affected only in the industrial-marine atmosphere. The corrosion rate in zinc was correlated with the degree of SO_2 in the atmosphere.

Two lead alloys, a copper sheet and a copper alloy were tested by Gibbons (1972b) in a similar manner. Although corrosive rates were low at all sites, a marine-industrial atmosphere caused the most damage. SO_2 was the predominant pollutant, while other variables such as wetness, temperature and time increased the corrosion rates. Guttman and Gibbons (1971), following Gibbons' procedure, exposed nine metal-coated panels in varied environments. A thin metallic coating plus a sealant afforded the most effective protection. A cadmium coating had the shortest life in all but the rural site.

Finally, and somewhat more generally, the relative corrosion of open hearth iron, steel and zinc were observed for a number of atmospheres at different locations by Hudson (1943) and Larrabee (1959).

Turning now to the materials-damage effects on metals from suspended particulate in particular, a number of studies point to the importance of suspended particulate in causing corrosion, but only within the context of the interaction of suspended particulate with gaseous pollutants and/or environmental variables. Severity of corrosion is dependent on the level of pollution. It relates specifically to concentrations of sulfur dioxide in the ambient air and sulfates and chloride ions in falling dust. This was verified in tests conducted by Hukui and Yamamoto (1969) on 29 metals. in 13 randomly chosen sites in Japan. Iron and steel had the highest degree of corrosion. Laboratory tests performed on the metals with SO_2, clean water (an attempt to eliminate the particulate) and ultraviolet light produced low levels of corrosion. Their results suggested the importance of including particulate matter.

Research results by Elliot and Franks (1954) related the effects of alternative levels of H_2S, and indirectly suspended particulates, in various metals. Fink et al. (1971), following a similar line of inquiry, reported that corrosion rates on metal surfaces were increased by contact with hydroscopic particles that had absorbed nitric acid reacting with ammonia.

The importance of suspended particulate in their interaction with gaseous pollutants was further verified by the Chemical Research Laboratory in Teddington, England (Beaver, 1954), who concluded that particulate matter was an important factor in the corrosion of metals, especially in the presence of acidic, gaseous pollutants. Particulate matter in the atmosphere was filtered by muslin cloth on one of two samples of iron. Samples were exposed to moist atmospheres containing traces of sulfur dioxide and particulate. Because the filter protected the sample, rusting was negligible. No measure of $S0_2$ and moisture absorbed in muslin was determined; therefore, decreases in rusting could have been due to absorption of S02 by the muslin cloth. Also, Tajiri (1972) reported that, in an atmosphere in which charcoal particles accompany S02, corrosion increases. Fink et al. (1971), in a similar context, stated that accumulation of hydroscopic particles on a surface increased corrosion rates, especially in the presence of SO_2. Stainless steel oxide film could also be disrupted and corrosion could result by the collection of dust on the surface, further supporting the effects of the particulate matter on corrosion.

Finally, studies were conducted by Hermance (1966) and McKinney and Hermance (1967) in Los Angeles, New York and Philadelphia, Baltimore and Chicago, and subsequently in laboratory tests, on the relationship between airborne particles with high levels of nitrates and stress corrosion cracking on electrical equipment with nickel-brass composition. Humidity and temperature levels were also found to be significant however. The study indicated that critical humidity levels above 40% - 50% activated the nitrate ion and produced stress corrosion in nickel-brass alloys.

In closing the discussion of pollution effects on metals, we wish to emphasize the findings suggested above as to the critical importance of environmental variables for materials-damages. In the most general terms, most studies show that the corrosive effects of pollutants on metals, especially from $S0_2$, will not occur without the presence of moisture as a catalyst. Other critical variables affecting the corrosion of metals are temperature and salt. Rates of corrosion and S02 concentration in the atmosphere over an average period are deceptive, however. Corrosion continues even during low concentration levels; once sulfates or sulfites are present in metals, corrosion continues. Thus, in terms of average corrosion, peak concentration levels of pollutants may be more critical than average concentration levels.

Two studies concerning the interaction between pollution and environmental factors may be of interest. The relative effects of humidity on metals is summarized by Yocum and McCaldin (1968). Above a critical humidity level of 80% for aluminum, 75% mild steel, 70% nickel, 63% copper, 70% zinc and 90%

magnesium, in the presence of SO_2, corrosion increased sharply. A more general study provides the results of a chamber study concerning the effects of gaseous pollutants conducted by Haynie, Spence and Upham (no date). The exposure system was a combination of chambers designed to alter the composition of the air and separate pollutants by filtering. Natural environmental variables such as humidity and light were controlled artificially. The interaction of environmental variables with pollutants appear to be a determining factor as to the extent of materials-damage and household soiling.

Masonry and Concrete

Masonry and concrete product categories include such items as clay tiles, bricks, poured concrete and stone. The potential pollution effects on masonry and concrete range from simple discoloration or staining to erosion and corrosion. The pollutants affecting soiling and materials-damage most significantly are particulate matter and SO_2.

While masonry and concrete are used extensively as building materials, there is a very limited amount of technical research concerning pollution-related effects on these materials. A number of rather general studies exist. For example, Schaffer (1932) reports that the darkening of sandstone is a result of soot filling the surface pores. This process is a uniform process on sandstone, while with other stones, such as limestone, darkening occurs only in sheltered areas since the darkening is caused by an interaction between atmospheric smoke and moisture. The chemical composition of stone would also seem to influence the materials-damage and soiling effects. Stones containing no carbonates, well-baked brick and glazed tiles, are relatively unaffected by SO_2 (.Sterling, 1977 and Wilson, 1965). Particulate acids and salts at high temperatures affected refactory bricks, and sodium metavanadate reduces the strength of magnesium brick; discoloring of masonry can be produced by water carrying hydrochloric acid. Finally, Wilson (1965) reported that irregular shapes and the nature of the surface of bricks affect materials-damage and soiling due to accumulations of dirt, while Adams (1961) reports that stains on flat rock simply are more apparent--show up more easily--on irregular shaped rocks. Spedding (1969) reports that, at higher levels of humidity, limestone becomes saturated with S02 resulting in a continuous erosion process.

The major comprehensive study concerning pollution effects on masonry products is that by Beloin and Haynie (1975). Beloin and Haynie reported on the soiling of 6 types of building materials: (1) painted cedar siding; (2) concrete block; (3) brick; (4) limestone; (5) asphalt shingles and (6) window glass. Five sites were chosen in Alabama, reflecting increasing levels of suspended particulates in the atmosphere. Atmospheric measurements were determined by collecting 24-hour particulate samples on 10 random days each month. Other variables monitored were rainfall, temperature, dew duration and relative humidity. Beloin and Haynie conclude that soiling is a continuous function of time and particulate concentration.

Thus, unlike the case with metals wherein damages were primarily of the materials-type, pollution-related damages for masonry products would seem to be primarily of soiling-type. Of course, environmental variables seem to be important here too; such variables can work as a catalyst to initiate and increase rates of materials-damage and soiling on masonry products. Rain can work as a cleaning process for masonry and concrete; washing ameliorates aesthetic degradation. However, moisture can also act as a catalyst for chemical reaction. When high humidity prevents evaporation in the presence of atmospheric acids, the clacareous elements in concrete and masonry dissolve (Stedman, 1972). Wind velocity in atmospheres with particulate matter can also affect the rate of erosion. The greater the wind velocity, and the larger the size of the particles, the greater the erosion. Yocum and McCaldin (1968) compared this erosive process in masonry materials to sandblasting.

Paints and Finishes

Paints and finishes serve two purposes: as a protective coating for materials and as a decorative addition. Composition of the paint product determines the ability of the paint or finish to withstand environmental impact. Pollutants as well as natural environmental factors can affect the appearance and protective ability of the paint or finish. The effects of pollutants on finished or painted surfaces are loss of gloss, scratch resistance, adhesion, and strength, discoloration, increased drying time, and unattractive dirty appearances.

Aesthetic quality of paints are primarily affected by particulate matter. That is, the accumulation of soot on painted surfaces--a “soiling” effect--gives paint a dirty appearance. Unfortunately, however, remedial efforts to counteract soiling effects can give rise to materials-types of damages. Thus, Spence and Haynie (1972), in studying soot accumulation on painted fences around the U.S., note that attempts to clean or remove deposits from fences results in a loss of protective film.

Here again, however, the interaction between suspended particulate, gaseous pollutants, and particularly, environmental variables, seems to be critical in terms of soiling-type damages in paints. As examples, paints and finishes exposed to airborne particles containing iron salts and copper are shown to result in brown stains.

Drying time of paint at high humidity levels was shown to be increased by the presence of sulfur dioxide in concentrations of 1 to 2 ppm (Copson, 1955); with 7 to 10 ppm, drying time was delayed from 2 to 3 days. Potter et al. (1967) report that, in the presence of sulfur dioxide, together with high humidity at the time of application (or with washing), paint may dry tackily, thus facilitating contamination with particulate.

Finally, Campbell et al. (1974) report laboratory tests and field studies which suggest a relationship between erosion rates in paint and pollutant concentrations. Both chamber and field exposures resulted in similar degress of thickness loss of the exposed paints. A seven year service life in rural areas, compared with a five year service life in industrial areas is suggested. This difference in service life is attributed to relative SO_2 concentrations.

Polymeric Material

Polymeric materials used in buildings are mainly vinyls but also include floor tiles, wall covering and paneling, siding, piping, vapor barriers, protective coating, cladding, window frames and electrical insulation. Polymeric materials include anything made of plastics or elastomers (rubber). The composition of the products are varied resulting in numerous types and variations. Polyvinyl chloride (PVC), the main chemical ingredient in vinyls, has drawn the most attention in the relatively limited research concerning pollution effects on polymeric materials.

The effect of particulate on polymeric material is to dirty the surface while liquid and gaseous acids cause fading, loss of gloss or disintegration. In a laboratory experiment, Stedman (1972) exposed strips of white, rigid PVC to ammonia, carbon monoxide, hydrogen sulfide, sulfur dioxide and atmospheric air in separate sealed test tubes. An unsealed set of tubes, containing the same substances, was exposed to sunlight after 22 hours. In the tube containing S02, the PVC strip started to darken; after 144 hours the strip was black. The reverse side (face away from sun) was only slightly yellowed. Similar tests were performed on PVC strips of different compositions. Similar results were recorded with minor differences in the type of discoloration.

In the sealed set of test tubes with nitrogen dioxide, the first reaction of discoloration--a yellowish tan--was recorded on the 29th day. When exposed to fluorescent sunlamp/blacklamp radiation, discoloration was evident differing only with different compounds of PVC. Addition of the lamps to PVC strips of the same compound only produced a small increase in yellowish color although in some cases cracking occurred.

A study by Jellinek (1970) demonstrated a significant change in tensil-strength of PVC after two to six months exposure to 100 ppm of sulfur dioxide. Berger (1970) exposed plastic films including PVC to an industrial urban environment and the rural environment free of S02. The rural samples were least affected; while the industrial sample was affected, deterioration was less than that of controlled weatherized samples in the laboratory. The composition of the vinyls seem to have a critical effect on the deterioration and loss of gloss.

The evidence shows that suspended particulate, interacting with gaseous pollutants, can be expected to give rise to materials-types of effects on polymeric materials; the quantitative nature of these effects remains an open question, however. The demonstrations of soiling-types of effects on polymeric materials from particulate seem to be limited to the almost casual observation that the materials become dirty.

Textiles

Textiles considered in the pollution-effect literature are generally not those directly used in the building industry; included products are almost exclusively accessories such as drapes, rugs, and upholstery which are subject to material-soiling types of damages from air pollution. Clothing is also affected by pollution and any material or soiling damage to clothing results in increased cost to the individual in terms of cleaning or replacement. Textiles are generally dichotomized into natural fibers (wool, cotton, etc.) and synthetic fiber (nylons, polyesters, etc.). Additives to textiles, such as dyes and protective coating, influence the overall effect of pollutants on the fabric. Environmental factors (sunlight, moisture, etc.) also play a critical role in discoloration and the deterioration to the article in conjunction with pollutants.

Cellulose fibers such as linens, hemp and cotton are shown to be weatherized by acid aerosols (U.S. Department of Health, Education, and Welfare; 1970) and sulfuric acid. Particulate can result in the soiling of textiles, and will damage textiles only when the particles are abrasive and textiles are flexed frequently. Attempts to measure particulate-related damages by frequency of cleaning have been attempted and are discussed below in Chapter III. Similar to the case of paints, the frequency of cleaning affects the deterioration of the textile (U.S. Department of Health, Education, and Welfare; 1970).

A number of factors other than pollutants and "normal" environmental variables seem to be relevant in explaining damages to textiles. As examples, the electrostatic property of the textile affects the level of soiling. Rayon, for example, becomes electrostatically charged by friction during manufacturing and attracts more particulate during use. The location of curtains affects the level of soiling. Located at open windows, curtains and drapes act as a filter catching particulate matter as well as acid droplets (U.S. Department of Health, Education, and Welfare; 1970).

Nylon, when exposed to SO_2 exhibits a high degree of degradation. Zeronian et al. (1971) experimented with polymeric fabrics (modacrylic, acrylic, nylon and polyester). The fabrics were exposed to polluted air containing 0.2 ppm nitrogen dioxide, 0.2 ppm sulfur dioxide, or ozone, respectively, in a laboratory. Control specimens were also observed, and all specimens were exposed to sunlight. While the modacrylic was unaffected by any pollutants, nitrogen dioxide and ozone affected acrylic and nylon, and the polyester was the only one affected by nitrogen dioxide. In a study by Hosking (1960), the major conclusion was that nitrogen dioxide is the most damaging pollutant to fabrics.

Dyes are additive to fabrics and are subject to degradation by both particulates and gaseous pollutants. In both cases, the resultant effect is fading of the fabric. While the chemical proportions of the dye are correlated with fading, the level of fading is also affected by the method by which the dye is applied (direct, dispersed and acidic) to fabric and the type of material involved. That is, the same dye applied in similar manners to different fabrics may have different results when exposed to pollutants. Fujii and Tsuda (1971) reported that dispersed dyes were affected most by nitrogen dioxide and particulate, direct dye by sulfur dioxide, acidic dyes were most affected by gaseous pollutants.

Beloin (1973) examined the effects of common air pollutants, in the absence of light, on the color fastness of several representative, dyed fabrics. Samples were exposed to varying levels of sulfur dioxide, nitric oxide, nitrogen dioxide and ozone for 12 weeks. High and low ranges of humidity and temperature were introduced as variables. Beloin concludes that the same dye on different materials will not necessarily fade the same . . . both temperature and relative humidity are important in determining fading . . . nitrogen and sulfur dioxide, as well as ozone to a lesser degree, can cause appreciable fading; nitric oxide has little or not effect. Fading as a function of exposed time appeared to be nonlinear (1973, pp. 132-133).

Fujii and Hirate (1970) determined that particulate caused a greater degree of fading on dyed fabrics than SO_2 in conducting experiments on viscous rayons, acetate, tetron and wool fabrics dyed blue. Ray et al. (1948) tested rayon fabrics and found minimal color fade with S02 alone; when combined with nitrous oxide, a small increase in fading was observed. Nitrous oxide alone caused the highest degree of fading.

Thus, suspended particulate can give rise to textile damages, particularly in terms of affecting types used with textiles--essentially a soiling-type effect. Evidence of materials-types of damages to textiles which might be attributable to suspended particulate is compelling only when looking at the interaction between suspended particulate, gaseous pollutants, environmental variables and factors peculiar to textile products.

Porcelain Enamels

Rushmer and Burdick (1966) reported on a National Bureau of Standards study which was designed to determine the weathering ability of post-war enamels. A post-war enamel is a glossy coating, composed chiefly of quartz, felspar, clay, soda and borax which is fired on some metals. Seven locations were selected representing different environmental combinations of pollutants, temperature, humidity and salt environments. Rushmer and Burdick suggest that observed constant declines in color retention and gloss are probably attributable mostly to high salt content in the air.

Rushmer and Burdick's results do not allow for conclusions of the sort that would attribute effects on enamels to pollution in general, and certainly not to suspended particulate. Little more can be said.

Asphalt

Asphalt has a wide range of uses, including its use in roofing, waterproofing paper, electrical insulation and adhesives, etc. Unfortunately, very little research has taken place in this area. The only study that we mention here is that by Hamada et al. (1964) wherein asphalts of different composition were exposed to sulfuric acid, hydrochloric acid and ammonia. The study's results simply point to associated rates of chemical transformations, exfoliation and/or crumbling.

Paper and Leather

Paper and leather products considered are primarily used as decorative items. Paper is used to cover walls and in books. Leather is mostly used in upholstery and clothing. Here again, however, there is a dearth of technical studies concerning the effects of pollution on these products. We find little more than general observations of the following types: uncoated wall paper absorbs greater quantities of SO_2 than vinyl coated types; the coating of paper with polymers prevents wear and soiling and averts S02 damage; leather is aged by the build up of sulfuric acid which correlates with its deterioration (Plenderlieth, 1946).

C. INDOOR-OUTDOOR AIR POLLUTION RELATIONSHIPS

The summary of ambient air standards, presented as Table 1 in the previous section, represent "acceptable" levels of pollution as of the year 1970. One might prefer to describe the prescribed limits alternatively as "damage threshold" values, although, given the disparity of results observed in the previous section concerning only materials-damage and soiling, it is clear that a certain vagueness must attend any notion of acceptability as it concerns these standards, especially when the notion of damages is broadened to include health, aesthetics, etc.

However, there is even a more fundamental problem in attempting to assess household soiling damages associated with varying air pollution levels. This problem arises from a general lack of knowledge concerning the relationship between ambient (outdoor) pollution levels and those which might be observed inside households. As individuals spend, on the average, about 80% of their time indoors, much physical property which may be subjected to materials damage, and the bulk of soiling effects, are found indoors; some knowledge of outdoor/indoor pollution relationships is then highly desirable for the purpose "of promulgating meaningful standards for suspended particulate.

The indoor/outdoor pollution index (IOPI) is usually expressed as

$$\text{IOPI} = \frac{\text{indoor concentration}}{\text{outdoor concentration}} \cdot 100\% .$$

Observe that a low index does not necessarily imply a low pollution concentration. For example, an indoor concentration of, say, .1 ppm SO_2 and outdoor concentration of .2 ppm yields an IOPI = 50%. On the other hand an indoor concentration of 2 ppm and an outdoor concentration of 8 ppm yields an IOPI = 25%. In this case the lower IOPI is associated with a <u>higher</u> indoor pollution concentration.

IOPI may exceed 100% when outdoor concentrations are low due to highly concentrated indoor pollutants related to human activity. Human produced gases, such as CO_2, may result in IOPI's which exceed 100% over a large range of concentrations. Particulate IOPI may be characterized by relative weight or particulate count. The IOPI's of many pollutants may be affected by faulty indoor machinery and car appliances; e.g., a leaky exhaust pipe can raise concentrations inside a car to fatal levels even though the bulk of the gas, which is released outside, has little effect on outdoor concentrations. Indoor particulate concentrations are enhanced by activities such as smoking, cooking, etc. and often lead to IOPI's which exceed 100%.

We think it fair to say that no real concensus exists as to the value of IOPI's. Thompson et al. (1973) provide an estimate of .67 for total oxidant levels and Spengler et al. (no date) provide a similar estimate for the IOPI of around .7; in the more recent HUD-EPA study (Indoor Air Pollution in Residential Environment, 1978), however, it is suggested that a constant value for an IOPI may be meaningless in that the ratio varies substantially throughout the day, possibly ranging from .3 to 3.6 over a 24-hour period (Indoor Air Pollution in Residential Environment, 1978, p. 27). The dependence of indoor concentrations of suspended particulate on human activity is emphasized in most all reported works, e.g., ". . . many indoor particulate are generated by the activity of people and the concentration . . . is often much higher than that of outdoor concentrations" (Spengler, p.160); in this regard, considerable effort has been expended on the impacts of cigarette smoking on indoor total suspended particulate concentrations (see Spengler; and Sterling, 1977). We should emphasize the fact that IOPI's, at some times during a day, may substantially exceed unity; viz., "A number of residences . . . show indoor concentrations that exceed current standards (260 micrograms/m^3 for a 24-hour maximum) . . . current standards for particulate matter are exceeded in the indoor residential environment when corresponding <u>ambient</u> (author's emphasis) levels are below the standard" (Indoor Air Pollution in Residential Environment, 1978, pp. 27-28).

Virtually nothing is reported in the literature which differentiates between "large" (greater than 15 micrograms) and small particulate. Sterling and Kabayashi (1977), in looking to indoor total suspended particulate effects from smoking,suggest that "more"s submicrogram particulate may be found indoors, but offer no real empirical support for this assertion.

Thus, while there is unquestionably a relationship between outdoor and indoor concentrations of suspended particulates--and an IOPI of .6 to .7 would seem to be a best available estimate as a daily <u>average</u>—considerable uncertainty remains as to the value of an IOPI or, indeed, whether a single (average) measure for an IOPI is in fact meaningful. In "explaining" indoor concentrations of suspended particulate, considerable work remains in separating out those concentrations attributable to ambient concentrations from those attributable to other factors, e.g., internal human activities, natural ventilation, time (season, day/night, etc.) and air conditioning. The National Research Council (Board on Toxicology and Environmental Health Hazards) has recently initiated a comprehensive study on indoor pollutants which could well result in an improvement in our understanding of IOPI's; in the meantime, however, the outdoor/indoor relationship must be viewed as an open issue as must the "size" (large/small particulate) question.

D. SUMMARY AND CONCLUSIONS

Given the above discussions, we now re-address Question A posed above in Chapter I, viz.: how well do we understand the relationship between levels of suspended particulate and household soiling effects? Laying aside issues of particulate size and the IOPI for the moment, it would seem that these relationships are not at all well understood in quantitative terms. The complexities involved in the myriad interrelationships between gaseous pollutants, suspended particulate and environmental variables will require a great deal more research before meaningful characterizations of pollution-effect relationships can be set out quantitatively.

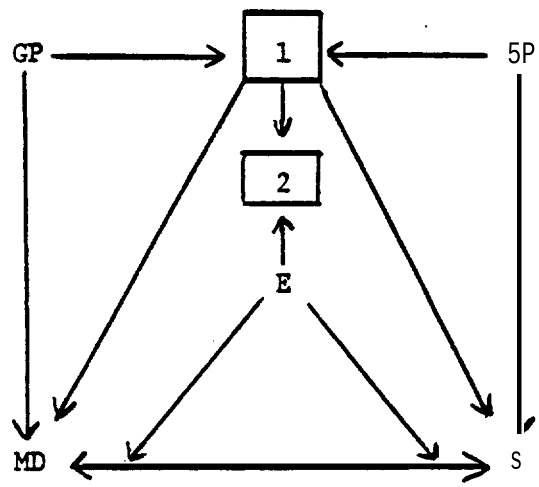
We can, however, define qualitative relationships as sketched in Figure 1. Results to date from research do serve to establish the direct relationship between gaseous pollutants and household effects of the materials type. Gaseous pollutants, interacting with suspended particulate and environmental factors, may also result in effects of the soiling type. On the other hand, a direct relationship is suggested between suspended particulate and household soiling effects; more indirectly, suspended particulate may result in materials-damage types of household effects via their interaction with gaseous pollutants and environmental factors.

The argument is made more succinct by reference to Figure 2. While the current state of research results does not allow unambiguous quantification of pollution-household-effect relationships, one can, relying upon a preponderance of evidence, look to dominant and weak relationships. Thus, dominant relationships are those for which lines of cause and effect are relatively certain in qualitative terms, while weak relationships are those which are more indirect and which are hypothesized but lack substantial supportive evidence. In Figure 2, the double arrows indicate dominant relationships and single arrows indicate weak relationships. Thus, a dominant cause/effect relationship exists between gaseous pollutants and materials damage effects; likewise between suspended particulate and soiling. We also “know,” in the dominant sense, that suspended particulates-soiling and gaseous pollutants-materials effects on households, particularly in terms of materials effects, are interdependent with environmental factors, and gaseous pollutants-suspended particulate interactions are critical. Direct soiling effects from gaseous pollutants and direct materials effects from suspended particulate are posited “weakly” as are materials-soiling interactive effects.

This dominant-weak dichotomization of pollution-effect relationships would seem to support research designed to estimate particulate-related economic damages to households from soiling; of course, given the dominant interactions between gaseous pollutants, suspended particulate and environmental variables, it would be desirable to include gaseous pollutants and environmental variables in statistical analyses when possible. Therefore, attention is now turned to problems associated with efforts to estimate these economic damages.

FIGURE 1

The Pollution Cause and Effect Relationship



GP = Gaseous Pollutant

SP = Suspended Particulate

$\boxed{1}$ = GP and SP interactions

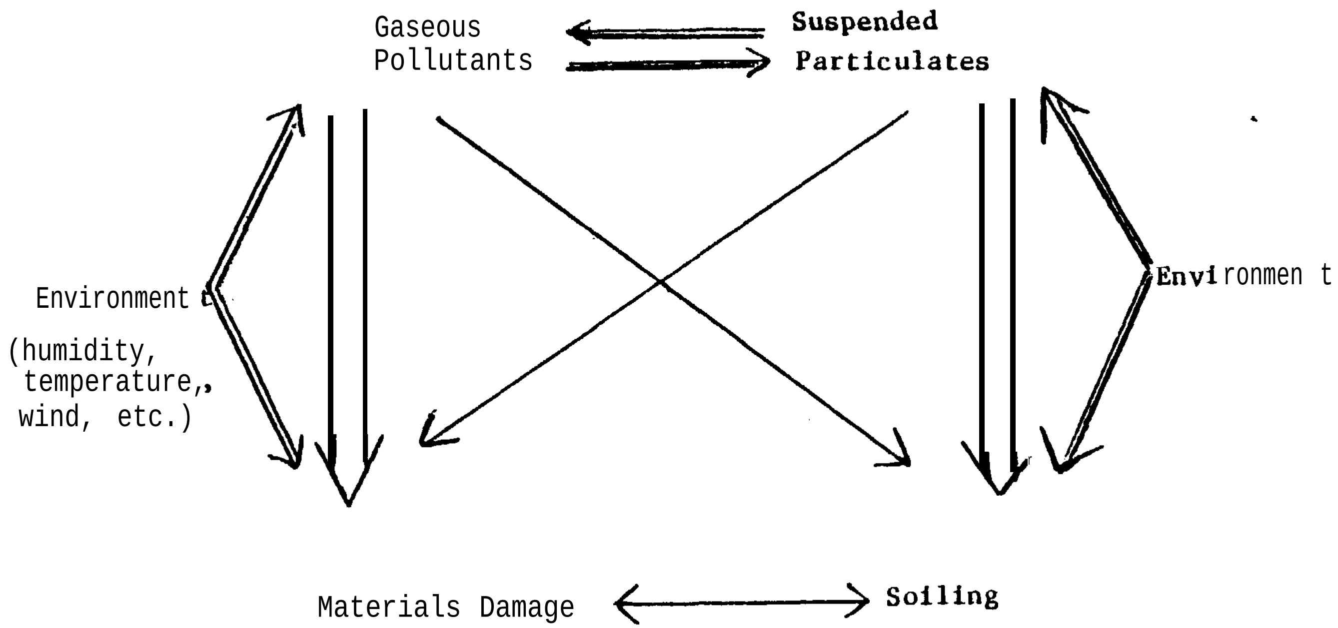
$\boxed{2}$ = GP, SP, Environment Interactions

MD = “Materials-Damage”

S = “soiling”

E = Environmental Factors: temperature, wind, humidity, sunlight, etc.

FIGURE 2: Pollution Cause and Effect Structure



PART I

CHAPTER III: ECONOMIC ASSESSMENTS OF POLLUTION-RELATED HOUSEHOLD EFFECTS

A. INTRODUCTION

As evidenced in the previous section, there is a vast literature concerning the technical aspects of materials-damage and, to a limited extent, soiling which result from air pollution. More often than not, this physical research has been guided toward determining physical effects from pollution so that scientific goals, such as damage prevention or avoidance, might be achieved. However, these studies generally abstract from any economic assessment of materials-damage and soiling effects attributable to air pollution.

Economic assessments of air pollution-related effects most often take the form of attempts to estimate "damage functions," where "damage functions" relate estimated dollar values for relevant damages to levels of air quality. While such damage functions have been estimated in a number of studies (as is detailed below), those offered to date in the literature suffer from a number of shortcomings; e.g., damage functions are usually assumed to be linear and those based on results from laboratory experiments often reflect the use of pollution levels which far exceed conditions one might expect to encounter in the real world. But an even greater problem exists in that bulk of the technical literature is micro in nature, dealing often with only a single pollutant and a single material. Given the number of actual pollutants and the broad possibilities for synergistic interactions, photoactivation, absorption, etc. , it would be extremely difficult to aggregate micro data in order to get, say, national or regional estimates of materials-damages and/or soiling damages.

This fact has naturally led to a line of research attempting, in some way or another, to attain some degree of aggregation. Generally, received research can be dichotomized into either a materials-damage or soiling classification as is the case for the technical literature reviewed in Chapter II.

Studies concerning damage functions for materials-damage are generally hedonic in nature and employ received technical and economic data to generate estimates for damage costs; unfortunately, it is often the case that key parameters must be assigned values on the vasis of little more than guesswork, unknown technological relationships must be assumed, and important economic variables are often ignored.

Soiling usually attends particulate pollution in the form of surface collection of particulate which necessitates a certain amount of effort in order to return the household to a "clean" state; however, particulate pollution may also have health and/or aesthetic (e.g., visibility) effects as well. In conjunction with pollutant gases such as SO_X NO_X, O_3, and CO_2, particulate may cause materials-damage which may involve premature replacement, loss of serviceability, or preventive actions. The important fact here is that the effects of particulate and pollutant gases with respect to materials-damage are generally inseparable.

Studies concerning soiling damages have been more varied in nature, (relative to those for materials-damage), but still might be considered as hedonic or at least quasi-hedonic in nature. Informal surveys and questionnaires are frequently employed along with traditional research methods in order to identify and isolate key parameters. The literature has dealt primarily with household soiling and generally has not considered costs associated with commercial cleaning, car washing, maintenance of municipal facilities and public goods, etc.

In order to get some feel for state of the art in each of these respective areas, we present a brief sketch of the literature concerning efforts to provide economic assessments for materials-damage and soiling from suspended particulate in Sections B and C of this chapter, respectively. Section D notes some discrepancies. in the Booz-Al.len data. A brief summary is given in Section E.

B. MATERIALS-DAMAGE FUNCTIONS

This sub-section summarizes the literature pertaining to materials-damage from air pollution as it relates to efforts to go beyond the component research efforts detailed in Chapter II. As efforts to aggregate usually tend to come in a cumulative fashion, some overlap is unavoidable. However,- this does not lead to duplication as the focus of this chapter considers economic methodologies rather than the technical aspects of the studies.

Uhlig 1950

In 1950 Uhlig undertook a partial attempt to aggregate materials-damage as related to the corrosion of metals. The costs of corrosion damage were separated as to direct costs resulting from the necessity to replace corroded equipment or use preventative measures, and indirect costs arising from plant downtime, loss of efficiency, output loss, etc. While the estimate for annual economic costs from corrosion came to over five billion dollars, the meaning of the estimate was unclear as no effort was made to determine quantitatively the role of pollution in the corrosion costs incurred. Further, no distinction is made in this study between corrosion costs to household and other sectors of the economy.

Rust-Oleum Corporation (1964)

From exposed metal plates placed in 25 cities, the Rust-Oleum Corporation (The Rust Index and What it means, 1964) acquired data used to update the

Uhlig study. The estimated costs of corrosion damage was over seven billion dollars for 1958. While air pollution was further implicated as a cause for corrosion damages, ostensibly because of the absence of industrial fumes and acids in rural areas, none-the-less, no effect was made to determine the part of the rust-corrosion bill attributable to polluion.

Hudson Painting and Decorating Company (1967)

Using gross sales for paint and related materials in New York and New Jersey, the Hudson Painting and Decorating Company (Private Communication, 1967) estimated the increased costs of painting resulting from air pollution in New York in 1963. The study employed somewhat of a "back of envelope" methodology in using a number of questionable, but at least potentially verifiable, assumptions. As examples: two-thirds of gross expenditures are in metropolitan New York; the cost of labor is three times the cost of paint, etc. While such an approach could have led to a least order of magnitude estimates of damages, the credibility of the study was compromised by: (i) the unverified assumption that one-third of the cost of painting was due to air pollution; and more importantly, (ii) the failure to observe that only the fraction of paint purchased for "replacement" purposes is related to air pollution . . . the volume of paint sold for "new" use is in no way related to air pollution.

SRI (1970)

The SRI study (Standord Research Institute, 1970) purports to examine the cause and effect relationships of air pollution on damaged electrical contracts. Estimated annual damages were in the neighborhood of 65 million dollars. The most important observation to be drawn from this study is that when the externalities of air pollution are internalized privately, through technology changes (air purification and air conditioning) and the use of less expensive material (plated contacts) that are more resistant to the effects of air pollution, reductions in pollution levels should not be thought of as leading to benefits in the form of avoided costs unless a technology reversal is expected.

Battelle (1970)

The Battelle study (1970) attempted to estimate annual damages of air pollution on rubber products (for other materials, see Salmon, 1970; Liu and Yu, 1978; and Spence and Haynie, 1972). Costs measured were increased costs associated with producing products with higher atmospheric pollutant resistance and costs associated with loss of product life. Literature review questionnaires were sent to 60 firms, 30 of which responded, some incompletely. The total estimated bill was some 380 million dollars annually. However, as little is known on damage thresholds for rubber, little can be said concerning the construction of a meaningful damage function.

C. SOILING

We continue with a brief review of the economics literature related to soiling. As mentioned earlier, soiling is highly correlated with particulate pollution, but none-the-less overlaps with materials damage.

Mellon Institute (1913)

In 1913 the Mellon Institute (O'Connor, 1913) estimated that the economic cost of the smoke nuisance in the city of Pittsburg was 9.9 million dollars annually, about $20 per capita. Cost estimates were based on literature searches, observations and informal surveys. Corrosion costs as well as losses from particulate pollution were included. Costs were estimated by comparing Pittsburg with other cities.

Beaver Report (1953)

As a result of the London smog episode in 1953, a committee was appointed to study the causes and effects of air pollution. A report authored by H. Beaver was submitted to Parliament in 1954. The methodology was similar to that of the Mellon report with the difference that polluted areas were compared with unpolluted areas rather than comparison across cities. Costs, totalling 707 million dollars annually, included laundering, painting, depreciation of buildings and textile damages. Indirect costs, losses in efficiency, comprised some 30% of the total. Costs per person were $14 per year in nonpolluted areas versus $28 per year in polluted areas.

Ridker (1965)

In 1965 Ridker (Ridker and Henning, 1967) conducted a cross sectional study of high, medium and low pollution zones in Philadelphia in order to identify costs associated with soiling. Perhaps the most important result was identifying the problems in using length of time expended in household cleaning as a basis for cost estimates rather than relative frequency.

He later conducted a similar survey in Syracuse with a time-series analysis of a pollution episode. Although results were much better, the approach could not be generalized to other than the particular episode considered.

Michelson-Tourin (1966)

In this study (Battelle-Columbus Laboratories, 1970; see also, Michelson and Tourin, 1966) two cities in the Upper Ohio River Valley, Steubenville, Ohio, and Uniontown, Pennsylvania, were compared on the basis of: (1) outside maintenance of houses; (2) inside maintenance of houses and apartments; (3) laundry and dry cleaning; (4) women's hair and facial care; (5) store operation and maintenance. The two communities differed substantially with respect to air pollution; Steubenville was more than three times as polluted. cost of pollution in Steubenville was found by taking the difference in the two cities. It came to $83 for households (not including category 5). The per capita income in Steubenville was about $100.00 greater than in Uniontown. Economic losses in Steubenville were estimated to be 3.1 million dollars annually in excess of those in Uniontown, some $84 per capita.

Booz-Allen and Hamilton (1970)

To date, the most comprehensive study of pollution-related household damages is the study by Booz-Allen and Hamilton, Inc. in 1970 (referred to here as the B-A study). A detailed questionnaire designed to determine frequency of various household cleaning tasks was administered to 1800 people in several pollution zones. Results suggested that frequency of cleaning was relatively insensitive to pollution levels. This study, which stands as the best effort thus far to quantify household soiling damages from suspended particulates--thereby reflecting the current state of the arts—is central to the research reported here. Therefore, a detailed analysis of this study is deferred to Chapter IV.

Liu and Yu (undated)

In this study (Liu and Yu, no date) the B-A data were used in a Monte Carlo model to generate observations on cleaning frequency and pollution levels in B-A's four pollution zones. These observations were fitted by both linear and nonlinear regression techniques to obtain cleaning frequency equations. Using cleaning costs data for the Kansas City area, bothnet and gross soiling costs were obtained which were then aggregated over 148 SMSAts. National estimates for 1970 were 5,033 and 17,367 million dollars annually for net and gross costs, respectively. Weakness in these reported estimates reflect weakness in their data source: the B-A study, which is examined below.

Watson and Jaksch (1978)

From the B-A suggestion that cleaning frequency is relatively constant across pollution levels, Watson and Jaksch (1978) attempt to estimate the demand function for cleanliness in order to calculate utility losses attendant to increased pollution. Benefits from reduced pollution, i.e., costs of pollution related soiling, reanged from 626 million dollars at a 100 $\mu g/m^3$ level to 3.4 billion dollars at a 55 $\mu g/m^3$ level.

There are some interesting dimensions of results reported in the Watson-Jaksch (W-J) study which warrant a bit more detailed analysis here. The major contribution of the W-J study relates to tehir criticism of the B-A study's use of cleaning task frequency as a measure for behavioral responses to pollution and, therefore, soiling damages. The essence of the W-J argument of interest here is that utility losses to the public (and therefore soiling damages) may occur even if, in fact, frequency of cleaning tasks is invariant with pollution levels.

While there are some problems with W-J's conceptual development of a cleaning technology, which we will examine in a moments, the basic idea of the W-J approach is quite innovative and proceeds as follows: given some technology such that (i) marginal costs of cleaning are constant for a given pollution level and (ii) doubling the pollution level doubles the marginal cost of cleaning, then the cost of cleaning function can be written as

$$A(C, P) = aCP,$$

where a is a positive constant, C is "units" of cleanliness, and P is the pollution level. The marginal cost of cleaning is:

$$\frac{\partial A}{\partial C} = \alpha P$$

which satisfies (i) and clearly (ii) is satisfied.

Let D_c in Figure 3 be an individual's demand curve for cleanliness. At a pollution level P. the marginal costs of cleaning are given by $MC(P_0)$. The general competitive decision rule for determining optimal cleaning levels requires that equilibrium occurs in this case at the point d, where $D_c = MC(PO)$, so that the level of cleanliness C_1 is chosen, and total cleaning costs are represented by the area of OC_1da. Let pollution levels double to $2P_0$. The cost for each unit of cleanliness doubles with the doubling of pollution, and marginal cleaning costs are $MC(2P_0)$. By the W-J assumptions (i) and (ii) above, constant cleaning frequency implies that any change in pollution leaves <u>total</u> cleaning expenditures unchanged, so that, in this case, the new equilibrium is at the point e, with one area of OC_2eb equal to that of OC_1da. One can fit the consumer's demand curve through the points d and e, and clearly it must be a rectangular hyperbola of the form $D = D^*/C$ where E^* is total (<u>constant</u>) cleaning expenditures. Soiling damages are thus shown to obtain with constant cleaning frequency; such damages are the losses in consumer surplus--the (at least conceputally measurable) are B + D in Figure 3.

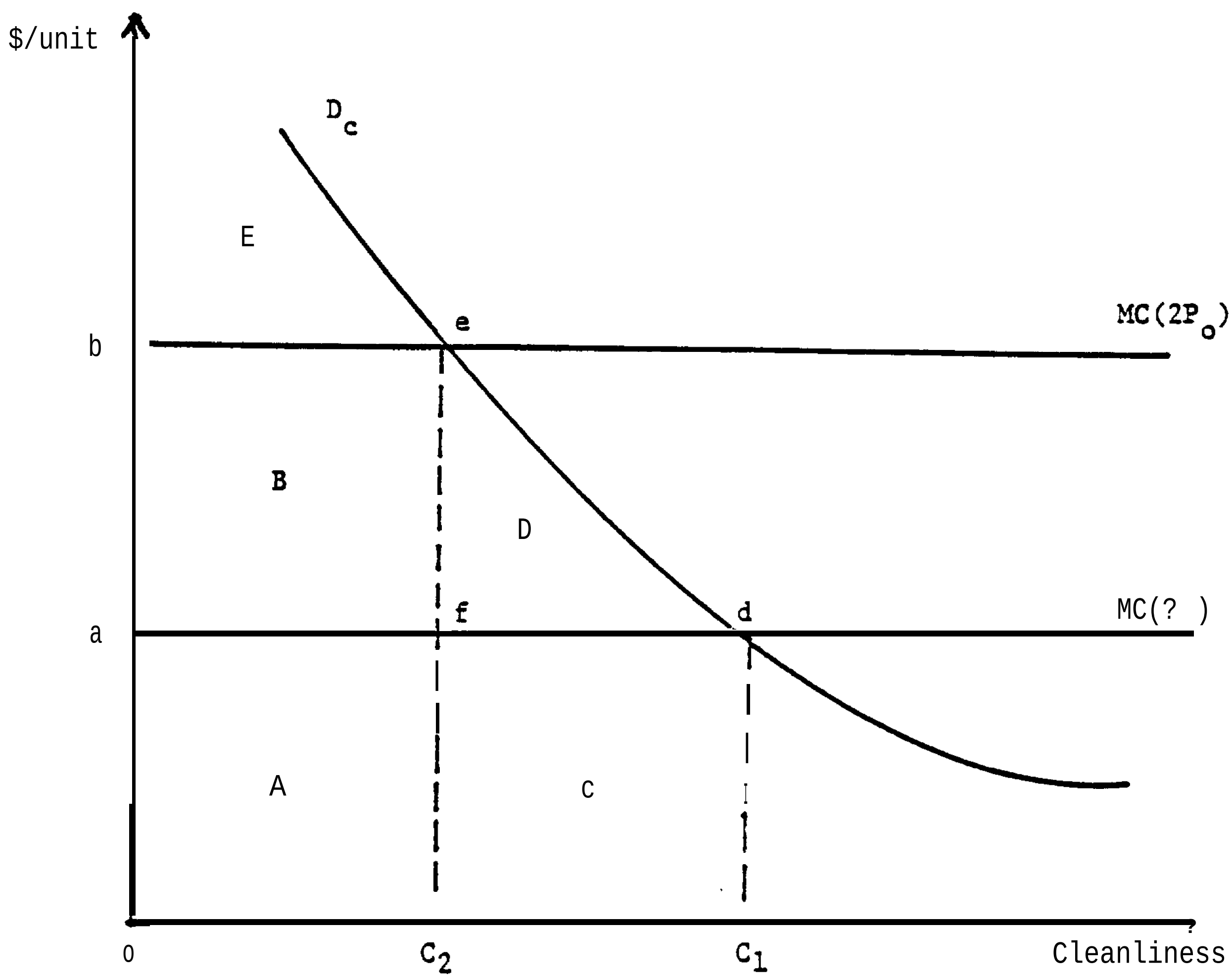
In evaluating the W-J analysis several observations should be made. First, assumptions (i) and (ii) are not consistent with the cleaning technology posited. Second, these assumptions should be verified empirically independent of assumed cleaning technologies, since, as has been documented above, knowledge of these cleaning technologies is almost non-existent. In spite of these observations the W-J represents perhaps the best analytically supported effort to empirically measure a class of soiling costs; i.e., soiling utility losses when cleaning frequency is constant. Obvious and necessary extensions require the estimation of soiling costs (including out-of-pocket costs, household cleaning time, and utility losses).

D. SUMMARY

The brief literature sketch given above indicates the relative poverty of the state of the arts for developing damage functions for household effects related to air pollution; this is particularly instructive in terms of efforts to estimate household <u>soiling</u> damages related specifically to suspended particulate.

FIGURE 3

Demand and Marginal Costs for Cleanliness



In terms of data which might be used to analyze suspended particulate-related houshold soiling damages, results from the B-A study are the most comprehensive data available. Given the role that these data are to play in the research to be reported here attention is now turned to a more detailed review of the B-A study.

PART I

CHAPTER IV. THE BOOZ-ALLEN STUDY: A CRITIQUE

A. INTRODUCTION

The previous two chapters were intended to give a fairly broad-based sketch of research accomplishments to date regarding estimates of pollution-related damages in households. What has emerged so far is a distinction between appropriate methods for analyzing materials-damage and soiling in terms of data collection, particular. It would appear that materials damage--highly correlated with out of pocket expenditures--is best ascertained by well conceived experiments and tests, while soiling must rely on data gathering through survey techniques. Moreover, soiling is almost entirely related to suspended particulate. We harden our focus now on the soiling aspects of particulate pollution. In particular, one of the works sketched above needs more detailed investigation, viz. , the Booz-Allen study, in that it represents the major effort to date towards accumulating household cleaning frequency data.

B. THE BOOZ-ALLEN AND HAMILTON, INC. STUDY: AN OVERVIEW

The Booz-Allen and Hamilton (hereafter, B-A) study of 1970 involved an extensive survey and interview of residents in the Pennsylvania, New Jersey and Delaware (PENJERDEL) area. The purpose of the study was to collect data concerning the frequency of cleaning for 27 different cleaning tasks (Table 2) by participants in the survey's four pollution zones (Zone 1: less than 75 $\mu g/m^3$; Zones 2, 3 and 4: 75-100, 100-125 and greater than 125 ug/m^3, respectively). In addition to data concerning frequency of cleaning tasks by pollution zone, data were collected concerning demographic characteristics of participants (age, income, education, length of residence, etc.) as well as concerning participant attitudes regarding cleanliness.

The B-A data were then used for analyses as to the relationship between the frequency of cleaning tasks (for each of the 27 tasks; see Table 2) and pollution levels. In grief, their conclusionwas that ". . . the range of annual air particulare levels experienced in the Philadelphia area (approximately 50 to 140 $\mu g/m^3$) has no measurable effect on out of pocket cleaning and maintenance costs for residents of the over 1,500,000 households in the area." Further, "The essentially null effect cost findings (concerning soiling) imply that health and aesthetic effects of air particulate level . . . . will be required in order to quantify the impact . . . . (of alternative) . . . . air particulate levels. Direct economic effects, as far as residential structures are concerned, appear unimportant." (See Booz-Allen, 1970 pp. iii-iv).

TABLE 2

Cleaning Tasks Included in the Booz, Allen and Hamilton Study

CLEANING TASKS

A. INSIDE TASKS

Paint Walls/Ceiling
Wall-papering
Wash walls
Replace air-conditioner filter
Replace Furnace filter
Clean/oil air conditioner
Clean furnace
Dry-clean draperies
Dry-clean carpets
Shampoo carpets
Shampoo furniture
Wash floor
Wax floor
Wash Windows (inside)
Clean Venetian blinds

B. OUTSIDE TASKS

Paint outside walls
Paint outside trim
Clean/repair screens
Clean/repair awnings
Wash windows (outside)
Clean/repair storm windows
Wash auto
Wax auto
Clean outdoor furniture
Maintain driveway/walks
Clean gutters
Maintain shrubs, flowers

Source: Booz, Allen and Hamilton (1970).

The weight of the B-A conclusions is questionable on a number of grounds, however, some of the more important of which are as follows. First, the fact that frequency of cleaning is invariant across pollution levels does not necessarily imply that consumer utility (and therefore damages) is (are) unaffected by pollution levels; this is the point raised by Watson and Jaksch which was discussed above in Chapter III.

Second, the frequency of many of the cleaning tasks used in the B-A study may be expected to be either (a) detetimed by habitual and/or institutional considerations, or (b) dominated, in the sense of determination, by factors other than pollution. An example of (a) is the replacement of air conditioning and furnace filters which might, on a priori grounds, be expected to take place in the spring and/or fall, respectively, as one prepares the units for the season's use. An example of (b) is wash/wax floors, the frequency of which may be predominantly determined by the occurrence of rain/snow, house traffic, type of floor surface, etc.

Third, as mentioned earlier, the conclusion that cleaning frequency is constant across pollution levels may be questioned on the grounds that if income levels are highly (negatively) correlated with increasing pollution, then the B-A findings may be viewed as implying cleaning frequency constant across <u>income levels</u>; this interpretation of the B-A results, which is certainly plausible, would then not lead to the conclusion that, if suddenly subjected to reduced pollution levels, a given individual would fail to benefit from reduced cleaning frequency.

Fourth, referring to Table 3, the B-A study identifies household cleaning tasks which either are or are not sensitive to variations in particulate levels. Curiously enough, a large part of those activities identified as not being sensitive to suspended particulate may be viewed as activities related to materials-damages,4 rather than damages of the soiling type. From discussions above in Chapter II, these activities would be expected (in the "dominant" sense) to vary systematically with gaseous pollutants (GP), with "weak" dependence in terms of particulate levels. Tasks which are shown to vary with particulate levels (Table 3), however, are predominantly related to household soiling effects which would be expected to vary, in a dominant sense, with particulate. Thus, the implications of this B-A "finding" cannot be interpreted as demonstrating insensitivity of <u>soiling</u>-related activities to differences in particulate levels--a large part of such "insensitive" activities are of the materials-damage strip and might be <u>expected</u> to be weakly affected by particulate levels on a priori grounds.

Finally, in conjunction with the above, the B-A study treats household time spent in cleaning activities as a "free-good"; i.e., household labor inputs were not included as a cost. Thus, costs included in the B-A analysis (as related to their major conclusions) were limited to costs of purchased materials for cleaning and repair (referred to as "out of pocket" costs. Referring to Table 3, the bulk of "sensitive" activities are those for which costs of purchased materials would be very low relative to the input of household effort, while the bulk of "insensitive" activities are those for which purchased materials, relative to household efforts, would loom much larger. B-A's conclusion that out of pocket costs do not measurably vary with suspended particulate levels may result from their research design (see, parti-

Table 3

BOOZ-ALLEN OPERATIONS SEPARATED BY
SENSITIVITY TO
AIR PARTICULATE LEVEL

Sensitive to Air Particulate Level	Not Sensitive to Air Particulate Level
Inside	**Inside**
1. Replace Air-Conditioner Filter	1. Painting Walls/Ceilings
2. Wash Floor Surfaces	2. Wallpapering
3. Wax Floor Surfaces	3. Washing Walls
4. Wash Windows (inside)	4. Replacing Furnace Filter
5. Clean Venetian Blinds/Shades	5. Cleaning/Oiling Air-Conditioners
	6. Cleaning Furnace
	7. Dry-Cleaning Draperies
	8. Dry-cleaning Carpeting
	9. Shampooing Carpeting
	10. Shampooing Furniture
Outside	**Outside**
1. Clean/Repair Screens	1. Painting Outside Walls
2. Wash Windows (outside)	2. Painting Outside Trim
3. Clean/Repair Storm Windows	3. Cleaning/Repairing Awnings
4. Clean Outdoor Furniture	4. Washing Automobiles
5. Maintain Driveways,Walks	5. Waxing Automobiles
6. Clean Gutters	6. Maintaining Shrubs, Flowers, etc.

Source: Booz-Allen, “Exhibit IV”.

cularly, our second and third criticisms given above). More to the point, however, the bulk of relevant cost--the imputed value of household cleaning time--were assumed away at the outset in the B-A study; thus, with this abstraction it is not surprising to find that relevant suspended particulates-related variations in activities of the household soiling stripe do not result in significant variations in costs.

C. IMPLICATIONS OF ABSTRACTING FROM IMPUTED HOUSEHOLD COSTS

The criticisms above suggest the following line of argument. First, household cleaning tasks used in the B-A survey include tasks related to materials damages and soiling--the two effects are "mixed" in the B-A study. From our discussions above in Chapters II and III, we would expect soiling effects to vary directly with particulate; materials damage-types of effects to vary directly with particulate; materials damage-types of effects would vary directly with gaseous pollutants, but only indirectly with suspended particulate.

Second, as noted above, of the 27 tasks included in the B-A study (Table 2), 16 tasks were found to be insensitive to particulate level (Table 3), but the bulk of these tasks would be logically related to materials damages effects. The eleven tasks found to be sensitive to particulate level are, in the main, effects of the soiling type. The mean annual frequency of household cleaning tasks attributable to soiling is then essentially established in the B-A study as systematically varying with the level of suspended particulate. Mean annual frequencies for these soiling-type tasks, adjusted for households that perform these tasks with household labor ("do-it-yourselfer's", DIY, as described in B-A), are given in Table 4 (see Appendix A for the method used for adjusting DIY frequencies). These data serve to demonstrate the substantial variation of cleaning frequencies for soiling-types of tasks (with the possible exception of "Replace air conditioner filter" which might be viewed as more of a materials damage result) as suspended particulate levels vary. As one moves from B-A's pollution Zone 2 to pollution Zone 4, mean annual frequenceis more than double for all outside cleaning tasks of the soiling variety and increase from 10% (wash floor surfaces) to 82% (wash windows) for inside tasks (142% for "replace air conditioning filter").

Third, while the B-A study demonstrates that household soiling effects, as manifested by changes in individual's expenditures of time and money (changes in task frequency), vary as suspended particulate levels vary, their conclusion that economic damages attributable to suspended particulates-caused household soiling are virtually nonexistent hinges on one crucial assumption: the social cost (economic damages) of household time spent in cleaning tasks is zero.

As noted above, the B-A study argues that: "The theories of various methods of inputing labor costs to household members were rejected partly because these "costs" . . . are not direct costs. Another important reason for considering these operations as labor cost free is that over 40% of the respondents fall in the "do it yourself" attitude segment as a result of the principal factor analysis. This implies in part that a significant portion of the population takes some pleasure in performing these operations. For

TABLE 4

MEAN ANNUAL FREOUENCIES FOR "DO IT YOURSELF" HOUSEHOLDS
IN B-A STUDY FOR HOUSEHOLD CLEANING TASKS THAT
ARE SENSITIVE TO PARTICULATE LEVELS

HOUSEHOLD CLEANING TASK	MEAN ANNUAL FREQUENCY OF TASK IN POLLUTION ZONE: 1 < 75 micro/m^3	2 75-100 micro/m^3	% change from #1	3 100-125 micro/m^3	% change from #2	4 > 125' micro/m^3	Z change from #3
A. INSIDE:							
Walsh Windows (inside)	10.4	12.1	16.4%	13.2	9.1%	18.9	43.2%
Clean Venetian Blinds/Shades	12.3	13.4	9.0	14.9	11.2	16.3	9.4
Wash Floor Surfaces	.42.5	43.6	2.5	45.6	4.6	46.6	2.2
Wax Floor Surfaces	22.1	26.8	21.3	30.6	14.2	26.4	-14.0
Replace Air Conditioner Filter	1.9	2.1	10.5	2.0	-5.0	4.6	130.0
B. OUTSIDE:							
Clean/Repair Screens	1.5	2.0	33.3%	1.9	-5.0%	3.0	57.9%
Wash Windows (outside)	4.8	5.5	14.6	7.6	38.2	11.1	46.1
Clean/Repair Storm Windows	3.8	3.1	-3.0	4.8	29.7	9.9	106.3
Clean Outdoor Furniture	8.4	15.1	79.8	16.0	6.0	18.5	15.-6
Maintain Driveway/Walks	16.3	28.6	75.5	30.0	5.0	38.4	28.0
Clean Gutters	2.7	4.5	66.7	8.4	86.7	16.4	95.2

Source: See Appendix A.

example, the two 'most agree' statements for the segment were: 'working outside the house is fun' and 'I like to work with my hands around the house' " (Booz-Allen, pp. III-3 and III-4). This line of logic is questionable, at best, on the following grounds. First, it runs counter to established economic theory related to utility maximizing individuals where a work-leisure <u>trade-off</u> is basic;[5] empirical studies have demonstrated the individual's preference for leisure over work, all else equal.[6] But further, the weakest link in B-A's chain of logic is as follows. Suppose it's true that individual's enjoy puttering around outside--maintaining shrubs, washing the family car; housewives enjoy wishing and waxing floors, washing windows, etc.[7] It is one thing to suggest that some given level of "puttering around" may give the individual some satisfaction (although, again, one must establish in some convincing way that this is the case). It is quite another thing, however, to use this suggestion to imply that, as air quality diminishes, resulting in the need (as manifested by reported frequencies) to spend more time in these cleaning tasks, that this <u>increase</u> in time spent is still viewed as "puttering" types of activity that provides <u>still more</u> satisfaction to the individual. Referring to Table 4, suppose (however heroically), that the "average" housewife in Zone 1, who washes windows inside 10.4 times per year and outside 4.8 times per year, is unaffected, in a utility-loss sense, by time spent--leisure forgone--in washing windows; there are no economic damages attending the housewife's time spent washing windows implied by these frequencies. Suppose this person was now exposed to the particulate level in Zone 4. B-A's data imply that, al else equal,[8] this person's mean annual frequency for washing windows inside and outside would have to increase by 82% and 131%, respectively, in order for this person to have the same level of satisfaction with Zone 4 pollution levels that she had with Zone 1 pollution levels. Just suppose that inside and outside window washing requires 30 minutes and 1 hour, respectively. However the housewife spent "the 11 additional hours required for window washing with Zone 4 pollution levels relative to the time required in pollution with Zone 1, (10 hours/year compared with 21 hours/year), the individual's satisfaction from that 11 hours is foregone as a result of the higher suspended particulate level. The value of that foregone satisfaction must then be considered as a cost, born by that individual, which is attributed to the higher particulate level.

The implications of these criticisms of the B-A study are then obvious. If the B-A study had included the opportunity cost of household labor associated with alternative particulate levels, their conclusions concerning economic damages from particulate may well have been different. Of course, whether or not this is the case is clearly an empirical question. This empirical question may be viewed as quite important inasmuch as a response to the question may extend the usefulness of data reported in the B-A study for purposes of assessing particulate-related economic damages. We take up this empirical question in Part 11 of this study.

D. SOME IMPORTANT DISCREPANCIES IN THE B-A DATA

The reader who is somewhat familiar with the B-A study may well inquire as to why the DIY household frequency estimates, given in Table 4, are different from those given in the report (line 11 of B-A's Appendix B). To respond to this question, we begin with the following observations. Consider, for example, the task "Wax Floors". From 3-A's Exhibit III(3), we have, using Zone 3 as an example:

(i) 160 total households who perform the task.

(ii) mean annual frequency for these households is 29.73, which implies 5,024 "Wax Floor"operations per year in Zone 3.

(iii) from Exhibit III(3), there are 161 DIY households in Zone 3, and the DIY frequency (from B-A's Appendix B) in Zone 3 is 17.17, which implies 2,764 DIY operations.

From (i) through (iii), there are 8 non-DIY households In Zone 3 which accounts for (5,024-2,764) 2,260 "Wax Floor" operations, which implies a mean annual frequency for "Wax Floors" in Zone 3 for non-DIY households given in B-A (Appendix B) is 12.02 for households that hire some help (line 10, 2nd page) and 17.33 for non-DIY households that use "other" help (line 12, 3rd page).

Discrepancies of this sort abound in the B-A frequency data. As another, less dramatic example: non-DIY frequencies for "Wash Floors" in, e.g., Zone 4 given in B-A's Appendix B are:

use any hired help: 42.13,

use other help: 39.0,

whereas the frequency implied by the process (i)-(iii) above yields a frequency of 69.71.

Given these discrepancies, we opt for the method described in Appendix A (of this report) as a-means for calculating task frequencies, primarily because it places particular weight on DIY households. This choice reflects our acceptance of B-A's often repeated conclusion that DIY households dominate in terms of the particulate-sensitive tasks.

We confess to having made periodic reassessments of this choice, however, given discrepancies in the B-A study as to the DIY proportions themselves. As an example, the average (across zones) DIY fraction for the "wash inside windows" task is reported as .927 in B-A's Exhibie IX, but in Exhibit III DIY households as a percent of total households is .8997.

E. OBSERVATIONS CONCERNING B-A COSTS

Some interesting questions arise concerning B-A's analyses of the above described data. Recall that 16 of B-A's 27 cleaning/maintenance tasks were found to be invariant with air particulate levels. For the 11 tasks (Table 3 above) that were found to be sensitive to air particulate levels, however, the costs (out of pocket for cleaning/maintenance operations were judged to be "minimal and unimportant" (trivial?). (See B-A, pp. III-6 to III-10). B-A continues as follows: "Even though apparent costs of performing cleaning and maintenance operations do not vary as a function of air particulate level, computations were made of area wide costs for 11 out of 27 operations" (B-A, p. 111-11). These costs (1969 dollars, based on 1,656,400 households) are as follows: (* denotes tasks shown to vary with pollution levels:

Task	Annual "Out-of-Pocket" Cost in Millions of (1969) Dollars
Paint walls/ceilings	$56
Paint Outside Trim	50
Wash (inside) floors*	41
Paint (outside) walls	31
Shampoo Carpeting	
Wash (inside) walls*	19
Wash (inside) windows*	18
Dry-clean Carpeting	9
Shampoo Furniture	8
Dry-clean draperies	7
Clean/oil air-conditioner	2

(Source: B-A, pp. 111-11 and 111-12)

The implicit cost per operation for the above tasks is given in Table 5. Note that, for the three tasks that do vary with particulate level, costs/operation are indeed relatively low: $.60 for washing floors, $.90 for washing (inside) windows and $3.80 for washing (inside) walls.

At issue, however, is the question: do small, "trivial," costs per operation imply "trivial" social damages? The answers, of course, would depend on relative frequencies for the tasks in question. From Table 5, note that mean annual frequencies for tasks that are sensitive to air particulate level are many times higher than tasks with higher operations costs. As an example, the high cost of the "painting walls" operation, $91.40, relative to the cost of washing floors ($.60), pales in significance when one observes that walls are painted only once every three years while floors are washed 42 times per year; thus, the total annual (equivalent) cost for wall painting is $33.82 compared with $25.35 for washing floors.

Can one dismiss out of pocket costs for the particulate-sensitive tasks as "trivial?" Total annual costs for B-A's l,656,400-household area from only 3 particulate-sensitive tasks are given in Table 6 for conditions wherein the 1,656,400 "homogeneous" households are faced with four alternative particulate levels (B-A's four zones). Simply for expository purposes, let average particulate concentrations in each zone for those given by the following,

TABLE 5

ESTIMATED COST PER OPERATION FOR CLEANING/MAINTENANCE TASKS

Task	Mean Annual Frequency, All Households[1]	Total Number of Times (per year), Task is Performed[2]	Implied cost Per Frequency[3]
Paint walls/ceilings	.37	612,868	$ 91.40
Paint Outside Trim	.23	380,972	131.20
Wash (inside) floors*	42.25	69,982,900	0.60
Paint (outside) walls	.08	132,512	233.90
Shampoo Carpeting	1.28	2,120,192	12.70
Wash (inside) walls*	2.98	4,936,072	3.80
Wash (inside) windows*	12.67	20,986,588	0.90
Dry-clean Carpeting	.20	331,280	27.20
Shampoo Furniture	.59	977,276	8.20
Dry-clean draperies	.31	513,484	13.60
Clean/oil air conditioner	.39	645,996	3.10

1/ From B-A Exhibit III(3), weighted average of frequencies across the four pollution zones.

2/ Frequency, in column 2, multiplied by 1,656,400 households in B-A's "area."

3/ Annual costs, given above, divided by column 3.

TABLE 6

TOTAL CLEANING COSTS FOR THREE TASKS

Task	Frequency in Zone 1/				Total Annual Costs for Area if Pollution is at Levels:			
	1	2	3	4	1	2	3	4
					(millions)			
Wash (inside) floors	40.6	42.1	42.7	45.2	$40.4	$41.8	$42.4	$44.9
Wash (inside) walls	3.0	2.7	3.o	3.4	18.9	17.0	18.9	21.4
Wash (inside) windows	10.1	11.8	12.7	19.0	15.1	17.6	18.9	28.3
			TOTAL		$74.4	$76.4	$80.2	$94.6

1/ For all households, column 3 in B-A's Exhibit III (3).

2/ Frequency times 1, 656,400 households times cost/frequency as given in Table 5.

where midpoints of B-A ranges are used for zones 2 and 3:

Zone 1	75 $\mu g/m^3$
Zone 2	87 $\mu g/m^3$
Zone 3	112 $\mu g/m^3$
Zone 4	125 $\mu g/m^3$

Using these data in conjunction with those in Table 6, we note that if particulate concentrations are reduced from zone 4 levels to zone 3 levels, a 10% reduction, B-A's soiling costs fall by 15%--a 10% reduction in pollution yields a 15% reduction in social damages--a result which is hardly trivial. Further reductions in particulate levels, as one might expect, yield lesser savings; as such levels are further reduced by 22% and then 14%, soiling damages are reduced by 5% and then 3%, respectively.

Of course, whether or not one views damage reductions from lower particulate concentrations implied by the data in Table 6 as significant--nontrivial--depends on one's criteria for "significance." At one level, one may simply compare the reduction in soiling damages if particulate levels are reduced (e.g.) from Zone 4 levels to Zone 3 levels ($14.4 million) with the costs of attaining such reduced particulate levels. If damage reductions—social benefits--exceed costs, the result is "significant".

At another level, one may wish to focus on the "average" household whose individual damages are reduced by $8.81 for three tasks as particulate levels are reduced from Zone 4 levels to Zone 3 levels. Is the $8.81 "benefit" significant? Would it be substantial for all soiling tasks (including dusting)?

All of this is simply to argue that B-A's dismissal of out of pocket costs for particulate-sensitive household cleaning tasks on the basis of relatively low costs per operation may be viewed as spurious. Therefore, in the analyses that follow, such costs will be included with imputed labor costs in assessing economic damages from air particulate implied by the B-A frequency data.

PART I

CHAPTER V: BRINGING IT ALL TOGETHER: PLAN OF THE STUDY

A. TECHNOLOGICAL EFFECTS AND ECONOMIC DAMAGES

Relevant for any effort to measure particulate-related economic damages, the following two questions (paraphrased here) were raised above in Chapter I:

(A) What is the current state of our understanding concerning particulate-household soiling cause and effects?

(B) Do we have sufficient technological knowledge. of the particulate-effects relationship to warrant moving to the issue of assessing economic damages associated with household soiling attributable to particulate.

In terms of question (A), our review of the technical literature in Chapter 11 suggests that the state of our understanding of precise, quantifiable soiling effects attributable to particulate is very weak; we simply cannot specify the soiling effects that would attend changes in particulate levels. We can, however, specify in qualitative terms the dominant relationships between particulates and soiling effects (as well as between gaseous pollutants and materials effects), taking into consideration, of course, interactions with environmental variables.

Question (B) may then be viewed as asking: are these dominant, qualitative relationships sufficient for moving on to assessments of economic damages? In responding to this question, we note that implicit to the arguments given in Chapters II through IV is the notion that a damage-as opposed to a technological "effect"--may consist of three components: first, a loss manifested by the expenditure of income--a loss which is manifested in the market. Second, a loss of "leisure" time--in terms of increased cleaning frequency. Third, potential losses in satisfaction or utility that obtain when individuals simply "weather''the effects of higher pollution levels a la Watson-Jaksch. If all of these classes of losses can be shown to vary systematically with concentrations of particulate, one can, on behavioral grounds, move from particulate levels directly to damages, thereby skipping over the technological link in the following cause-effect chain: particulate level + effects → economic damages. Thus, in terms of effects relevant for public policy concerning environmental standards for particulate concentrations, we argue that the behavioral response to pollution effects, and not, necessarily, the technological effect of pollution per se is the relevant measure.

To fix ideas here, imagine a high pollution area with enormous concentrations of air-borne particulate in which lives a Mr. Jones. Mr. Jones responds that he would pay nothing for lesser accumulations of particulate, and we will believe Mr. Jones' response. Is there a "damage" here--is there a benefit from reducing particulates, however measures in technological terms? Alternatively, Mr. Smith lives in an area with relatively low particulate concentration levels, but expends a considerable amount of time cleaning. When asked, Mr. Smith responds that he would be willing to pay some amount if concentration levels were still further reduced. An identifiable damage associated with existing pollution levels (at the margin) is obvious in this case. At issue is that we know, at least in qualitative terms, that particulate result in soiling effects; damages, which for EPA purposes must reflect societal valuations of effects, result from behavioral responses to these effects as they are Perceived by the public. Thus, if we can measure behavioral responses related to particulate in different particulate environments, relevant damage estimates may be derived, our inability to precisely quantify relationships between particulate level and soiling effects notwithstanding.

B. PURPOSES AND PLAN OF THIS STUDY

We have argued above that behavioral responses to different particulate levels may be used as a basis for estimating socioeconomic costs. In general terms, the major purpose of this study is that of implementing this argument, which is to say that the focus is centered on methods for developing empirical measures for particulate-related household soiling damages which are based on observed behavioral responses to different particulate environments.

In more specific terms, this study reports results from research efforts wherein two different methodological approaches are used to derive estimates for household soiling damage functions, which relate soiling damages to particulate levels. The two methodological appraoches are: the use of task-frequencies developed in conjunction with frequencies reported in the B-A study to derive damage estimates which reflect the opportunity cost of household labor and, a "Contingent Valuation" approach wherein damage estimates are derived via the use of simulated markets within which individual tradeoffs between particulate levels and income are determined.

Part II of this study is concerned with the use of frequency measures as a basis for estimating household soiling damages which, for reasons argued above, consist primarily of imputed household labor costs. The components of social cost (damages) measures used in the B-A study are reviewed in Chapter VI. In Chapter VII, the methodology used here to derive imputed household labor costs is described. Since only mean annual frequencies for cleaning tasks are reported in the B-A study, at issue in this chapter is the determination of time spent per "frequency" and the value of household time; the product of these three terms--frequency, time spent per frequency and value of time--can then be used (when related to particulate) to obtain damage estimates. Chapter VIII focuses specifically on the damage estimates derived from the methods described in Chapter VII, and some tentative conclusions are suggested in Chapter IX.

As will be detailed in Chapter X, there are some conceptual difficulties associated with damage estimates which are based on task-frequency measures a la the B-A study. Most important among these are the following. First of all, a particularly important soiling-related cleaning task was not included in the B-A study, viz. dusting furniture, window sills, etc.; this omission is particularly curious given that underlying the choice of tasks included in the B-A survey is the notion that paticulates contribute to the accumulation of dust and grime in, and outside of, the home. Secondly, but related to the above, there is some question as to whether responses concerning separate cleaning tasks may not be misleading. For example, when one washes windows (inside) one may also clean shades or venetian blinds and time spent for the combined activities may be less than the sum of estimated time spent for each task; similar examples of potentially joint task include: wash windows (outside) and clean storm windows (winter) or screens (summer); wash automobiles and clean (maintain, via hosing off) driveway or walks. Potential biases from aggregating task-specific costs are obvious from these examples.

Based on participant responses, the omission of "dusting" as a cleaning task is particularly critical. This is due to the fact that participants most generally perceive particulate effects in terms of "shallow" or "light" activity, which involves weekly or hi-weekly dusting and, in some cases, wet-mopping floors. "Light" cleaning is differentiated from "deep" cleaning, wherein the latter involves waxing floors, washing windows, etc., and the timing for deep cleaning activities may well be primarily determined by cleaning habits; such habits as related to deep cleaning may certainly adjust to changes in particulate levels, but this is the empirical hypothesis tested in Part II of this study.

The potential importance of "dusting" as a central focus for soiling effects as perceived by the public, in conjunction with potential problems inherent to measures derived from individual response concerning isolated cleaning tasks (as opposed, e.g. , to frequency of more aggregate measures for "cleaning" such as shallow and deep cleaning),[10] give rise to the question: is there some alternative method for deriving estimates for particulate-related household soiling damages which would represent an improvement over those derived from the B-A method?

Part 111 of this study is concerned with an evaluation of such an alternative method, viz., the "Contingent Valuation" method. The nature of, and structure for, a Contingent Valuation study applied to the problem of estimating household soiling damages is described in Cahpter XI. Chapter XII describes results from pre-tests of valuation instruments developed in this research. Thus, as is set out in the research proposal in which funding for this research is based, a complete Contingnet Valuation study of soiling-related damages may be quite costly. Inasmuch as this method has not heretofor been applied to the soiling damages problem,[11] the intent of the research reported in Part III is that of testing the method to the end of assessing its potential as a means for deriving defensible estimates for the particulate-related damages of interest here.

This study concludes with Part IV wherein the potential promise of the Contingent Valuation approach and the frequency approach for measuring particulate-related household soiling damages is assessed and conclusions are offered concerning the implications of our results relative to obtaining such measures.

PART II

CHAPTER VI: COMPONENTS OF B-A MEASURES FOR SOILING COSTS

A. STRUCTURE OF THE B-A STUDY

The B-A study completed in 1970, involved some 1800 interviews with individuals in eleven counties in the States of Pennsylvania, New Jersey and Delaware (the "PENJERDEL" area). The center of the study area, which extended some 45 miles on either side of the Delaware River from Wilmington, Delaware to Trenton, New Jersey, was Philadelphia, Pennsylvania and Camden, New Jersey. The purpose of the study was to determine the relationship between the frequency of selected household cleaning/maintenance tasks and the level of suspended particulate air pollution. Four pollution "zones" were defined as follows:

Zone	Concentration of Suspended Particulate (micrograms/m^3)
1	less than 75
2	75-1oo
3	100-125
4	greater than 125

The questionnaire used in the B-A survey included questions related to attitudes toward cleaning and pollution, demographic information, observations concerning neighborhod cleanliness, residence characteristics, cleaning/maintenance frequencies for 27 specific cleaning/maintenance tasks (see Table 2 above) and cleaning/maintenance costs; data collected in the B-A survey concerning residence characteristics and cleaning/maintenance costs were discarded inasmuch as these data were found to be ". . . generally fragmentary and/or unreliable . . ." (B-A, 1970, pp. II-9 to 11-10). B-A's criteria for "reliability" are not made explicit.

The primary purpose of the B-A project was that of determining residential soiling costs as a function of air particulate level (B-A, p. III-l). The essence of the method used by B-A to this end was, first, to determine how frequency of selected cleaning tasks varies with different particulate levels and, second, to estimate <u>cash outlays</u> ("out-of-pocket" costs) associated with each given cleaning/maintenance task. Frequency data were obtained via the survey described above; out-of-pocket costs (per frequency) were based on cost data obtained from professional cleaning firms, etc. However, these costs for "do-it-yourself" tasks ". . . were considered . . . (as) . . . supply costs only when these costs were non-trivial, such as for painting" (B-A, p. III-2). It would seem then that the product of ("non-trivial") out-of-pocket costs and task frequency are used to estimate soiling costs.

B. STRUCTURE OF COSTS TO BE USED FOR DAMAGE MEASURES

The B-A data provide data which relate to the following: total number of households (out of a household population of 1,656,400 in this study area in 1968) which perform each particulate-sensitive task; mean annual frequency for each task by do-it-yourself (DIY) households and by households which hire the task done (denoted HIRE). These data are given in Table 7.

If we are to analyze the relationship between soiling costs and air particulate level for the 11 particulate-sensitive tasks in the B-A study, the following costs are relevant based on the above discussions.

Cost 1(C_1): Cleaning/maintenance costs incurred by HIRE households. If N_1 is the number of HIRE households (column 2 of Table 7), F_1 is mean annual frequency for HIRE households (column 4 of Table 7) and a_1 is the cost of hiring the task performed, this cost for each task in each zone, is given by:

$$C_1 = (N o).$$

Cost 2(C_2): Cleaning/maintenance costs incurred by DIY households. If N2 is the numberer of DIY households (column 3, Table 7), F_2 is mean annual frequency for DIY households (column 5, Table 7), a2 is average out-of-pocket costs per operation for DIY households, T is household time spent (per period) and V is imputed labor costs per unit of time for DIY household labor, this cost, for each task and each zone, is given by:

$$C_2 = N_2(VT + F_2 \cdot a_2)$$

Total Soiling Costs (CT): $C_T = C_1 + C_2$.

To calculate Cost 1 and Cost 2 as given above, N_1, N_2, F_1, and F_2 are given in Table 7; as described below, alternative values for F will be estimated as a part of this work. The derivation of estimates for T and V is developed in the following two chapters.

In terms of HIRE costs/operation (a_1) and DIY out-of-pocket costs/operation (a_2), the B-A study provides such estimates for 11 tasks which include only five of the particulate-sensitive tasks (B-A Exhibits VIII and IX), viz., "replace air conditioner," "wash floors," "wash windows" (inside and outside) and "wax floors" of these 5 particulate-sensitive tasks, only one is an outside task (wash outside windows).

It is not made clear in B-A's Exhibit VIII whether unit cost data apply to the DIY or the HIRE household. For example, for "wash outside windows," one is told in Exhibit VII that "outside window washing is rarely contracted for residential structures." From Exhibit 111, however, only 1,109 out of 1,442 households (76.9%) are reported as DIY households for "washing outside windows." This would imply that some 23% of households fall into B-A's ill-defined category: "use other (non-paid) help," which would seem to be neither a DIY household nor a HIRE household. It would seem, however, that the use of non-paid help would still require DIY-type out-of-pocket costs unless, of course, the non-paid help also pays such costs.

TABLE 7

B-A AREA HOUSEHOLDS PERFORMING PARTICULATE-SENSITIVE
TASKS AND FREQUENCIES BY HIRE AND DIY

Task/Zone	No. of Households That Perform Task[1]	HIRE Households That Perform Task[2]	DIY Households That Perform Task[3]	Mean Annual Frequency for Households HIRE[4]	DIY[5]
Wash Windows (inside)					
Zone 1	756,546	41,611	714.935	9.8	10.4
Zone 2	374,548	38,954	13s,596	11.4	12.1
Zone 1	119.26S	22 ,9s7	296,281	12.2	13.2
Zone 4	172.099	13.940	15s ,159	24.2	1s.9
Clean Venetian Blinds/ Shades					
Zone 1	264,63S	14,820	249,815	4.8	12.3
Zone z	233,128	17,252	215,876	5.3	13.4
Zone 1	167,660	9,892	157,768	10.0	14.9
Zone 4	168.246	16,993	151,253	8.5	16.3
Clean/Repair Screens					
Zone 1	306,027	17,138	2ss, s89	.1	1.5
Zone 2	247,155	27,682	219,473	.4	2.0
Zone 1	1.57.22S	18.710	13s.515	.9	L.9
Zone 4	139,922	7,S36	132,0S6	3.7	3.0
Wash Floors					
Zone 1	519,976	14,119	485,657	30.7	42.5
Zone 2	$6S ,675	36,557	432,118	41.2	43.6
Zone 1	128,016	12.793	115.223	39.7	45.6
Zone 4	275,313	10,1s7	265,126	43.1	46.6
Wax Floors					
Zone 1	1S3.1S0	31,078	122,072	11.2	22.1
Zone 2	26 S.919	20,707	248,212	14.6	26. S
Zone 3	196.531	9,237	187,294	11.s	30.6
Zone 4	146.720	10,124	136,596	8.1	26.4
Wash Windows (outside)					
Zone L	484,769	31,995	452,774	1.8	4.8
Zone 2	432, ss3	83,980	348,903	3.6	5.5
Zone 3	300,189	37,224	262,36S	3.6	7.6
Zone 4	2S2.936	44,011	208,925	12.1	11.1
Clean/Repair Storm Windows					
Zone 1	301,152	21,985	279,167	2.2	3.8
Zone 2	234,579	32.13S	202,441	1.1	3.7
Zone 3	166,269	25,606	140,663	2.7	4.8
Zone 4	116.130	19,162	96,968	4.6	9.9
Clean Outdoor Furniture					
Zone 1	168.992	10,309	158,683	2.6	8.4
Zone 2	143,650	10,343	133,107	5.7	15.1
Zen, 3	78,960	3,475	75,485	5.8	16.0
Zen. 4	18,127	0	18,127	0	18.5
Maintain Driveways/Walks					
zone 1	190.657	61,964	12a, 693	1.0	16.3
Zone 2	158, 643	44,896	113,747	5.5	28.6
Zone 1	96,700	20,984	75,716	13.8	30.0
Zone 4	59,764	14,643	45,121	14.1	38.4
Clean Gutters					
Zone 1	248,614	35,801	212,813	1.1	2.7
Zone 2	202,174	42,457	159,717	.6	4.5
Zone 3	75,482	20,909	54,573	.5	8.4
Zen. 4	S5,232	6.739	48.493	.03	16.4
Replace A.C. Filter					
Zone L	110,495	10,387	100,108	.4	1.9
Zone 2	126,237	19.567	106,670	.8	2.1
Zone 3	59,481	8,149	51,332	.1	2.0
Zen. 4	62.030	2,234	59.796	.8	4.6

Notes for Table 7:

1/ B-A provides a weighted distribution for 1970 households in the 4 zones as 47%, 23.1%, 19.3% and 10.6% for zones 1 through 4, respectively. (B-A, p. IV-13). Applying these ratios to a total, 1970 household population of 1,656,400 yields: 778,508, 382,628, 319,685 and 175,578 as total households in zones 1-4, respectively B-A's Exhibit III (3) gives "percent of all households performing task" which is applied to total households for data in this column

2/ Difference between column 1 and column 3.

3/ Apply "DIY households as % of all households performing task", B-A Exhibit III (3) (last column); see, however, section B of Appendix to Chapter IV.

4/ For consistency with data in Table 4 (see Appendix to Chapter IV), total annual operations for each task in each zone as calculated from data in Exhibit III, from which DIY operations are subtracted. The difference is divided by the number of non-DIY households.

5/ Table 4 above (also, see Appendix to Chapter 4).

If we use B-A's cost of $2.00 per window and (what appears to be) nine windows per average operation, the cost per frequency for washing outdoor windows would be $18.00. With average frequency for all households that perform this task of 4.75, 5.13, 7.15 and 11.3 per year (B-A, Exhibit III) for zones 1-4, respectively, and number of households that perform the task given by (696,613), (342,410), (275,874) and (156,820) for zones 1-4, respectively (Table 7), average annual total costs for B-A's study area would be $158.6 million. This measure of $158.6 million exceeds by a factor of at least 2 any annual cost measure estimated by B-A (see above and B-A Exhibit IX). Thus, the $2.00/window operation measure given in B-A's Exhibit VIII must not apply to non-HIRE households.

In view of these problems, the implied cost/frequency given above in Table 5 are used for DIY households and unit costs given in B-A's Exhibits VIII and IX are used for HIRE households. Unit costs for all outside tasks are set at (the only available) unit cost for "wash outside windows"; "clean venetian blinds/shades" are given unit costs for "wash inside windows." The resulting estimates for al and a_2, however crude, are given in Table 8.

C. HOUSEHOLD SOILING COSTS: THE FREQUENCY APPROACH VS. THE B-A METHOD

Given the problems associated with B-A's cost data suggested above and the general critique of the B-A study given in Chapter IV, it is important for the discussions in upcoming chapters that the reader differentiate between the "frequency approach" and B-A's implementation of that approach.

As is detailed below in Appendix B, received economic theory acknowledges two conceptual approaches to identifying and measuring costs attributable to household soiling. The first would involve efforts to define a "compensating variation" in income associated with particulate-related changes in housing soiling (this approach is utilized in Part 111 of this report). The second method involves efforts to directly measure and valuate components of this compensating variation in income, which include income effects (from changes in cash outlays), changes in leisure time and changes in the average state of household cleanliness.

The B-A study is simply one way of attempting to implement this latter approach. Weakness in B-A's efforts should not be viewed as invalidating the "component" approach—referred to here as "frequency" approach—given the dominance of frequency-related leisure effects of changes in household soiling; rather, our criticisms apply simply to a particular method for measuring "components ." Indeed, as will be detailed below in Chapter IX, results from this study suggested a method for implementing the frequency approach which may have considerable promies.

TABLE 8

DOLLAR OUTLAYS FOR CLEANING/MAINTENANCE OPERATION FOR HIRE AND DIY HOUSEHOLDS

Task	Dollar Outlays Per Operation: HIRE Households (C_1)[1/]	DIY HouseHolds (C_2)[2/]
Wash Windows (inside)	$11.25	$ .90
Clean Venetian Blinds/shades	11.25	.90
Clean/repair Screens	18.00	1.44
Waah Floors	10.00[6/]	.60
Wax Floors	37.50	2.25[3/]
Wash windows (outside)	18.00	1.44[4/]
Clean/repair Storm Windows	18.00	1.44
Clean Outdoor Furniture	12.00	1.44
Maintain Driveways/walks	18.00	1.44
Clean Gutters	18.00	1.44
Replace A.C. Filters	13.50	1.00[5/]

[1/] Source: B-A Exhibits VIII and IX; "wash outaide windows" used for all outside tasks.

[2/] Source: Table 5; "Wash outside windows" ueed for all outside tasks.

[3/] From B-A's Exhibit VIII, floor waxing involves 375% higher costs than washing floors ($.04/square foot compared to $.15/square foot).

[4/] From B-A's Exhibit VIII, the cost of washing outside windows ($2.00/window) is 60% than the cost of washing inside windows ($1.25). Thus, the $.90 cost for inside windows is inflated by 1.6 to yield $1.44.

[5/] Cost of filter. B-A Exhibit VIII.

[6/] 250 sq. ft. per operation at $.04/sq. ft.

PART II

CHAPTER VII: IMPUTED COSTS FOR HOUSEHOLD LABOR

A. OVERVIEW

This chapter reports efforts to develop measures for time spent per cleaning/maintenance operation in DIY households for 10 of the 11 tasks given in Table 8, as well as for the opportunity use of household labor. As discussed above, these measures are required for the extension of B-A household soiling damages. The task "maintain driveways/walks" is excluded from our analyses inasmuch as considerable confusion was encountered in our work as to the scope of this task; in particular, participants in the Contingent Valuation study (described below) were concerned with the inclusion or exclusion of snow removal. We begin with Section B wherein a brief review of the literature related to time studies for household cleaning tasks and the "value" of household labor is given. As one might anticipate, we find little in the received literature which might be used for the measures of interest in this work.

Given the lack of available data for household time and/or value of household labor measures, attention is turned to a method for obtaining such measures in Section C. The Contingent Valuation method for obtaining data for such measures is described in this section and results from analyses of these data are presented in Section D.

B. TIME STUDIES AND THE VALUE OF HOUSEHOLD LEISURE: A LITERATURE REVIEW

In looking to the literature, one finds little of direct relevance for the measures of interest here. A good deal of research effort has been focused on household cleaning tasks--particularly the Cornell and Purdue Projects (see Walker and Woods, 1976)—but concern in these works is with cleaning tasks other than those considered in the B-A report and, more importantly, air particulate are not generally considered as a major cause for cleaning efforts.

A representative example of these works (see, e.g., Gage, 1960; Goetz, 1965 and Warren, 1940) is given (Walker and Woods, 1976). As a part of the Cornell project, 1,200 to 1,300 husband-wife households were interviewed in Syracuse, New York in the 1967-68 period concerning cleaning activities. Particulate enter the analyses only peripherally—57% of the households reported that "extra dirt from outside" contributed to "special" cleaning situations (Walker and Woods, 1976, p. 172). Interestingly enough, while specific tasks, a la the B-A study, are not considered in this work, frequencies for "general cleaning"--suggestive of "light" cleaning activities and "special house cleaning--suggestive of "deep" cleaning activities—are reported (for the previous 7 days; see Walker and Woods, 1976, p. 177). Specific tasks considered are given in Table 9; as seen from this table, there is no overlap between these tasks and those used in the B-A study.

The same applies to received time studies concerning time spent in household cleaning-available data are simply not applicable to the B-A tasks. The Cornell study (Table 9 above) is, again, representative of the state of the arts for household time studies (see, also, Reid) 1956; Warren, 1940, and the classic 1929 work by Wilson).

Typically, the value of household time spent in cleaning has been taken to be either the minimum wage or some average market wage for women (see, e.g., Gage, 1960 and Reid, 1956). In a 1973 issue of the American Economic Review, however, Gronau (1973) considers the determinants of a housewife's valuation of time. Variables considered in this work were income, race (white and non-white) and young (three or younger) children in the household. For the purpose of this work, Gronau's specification for a value function is incomplete inasmuch as a critical variable is omitted, viz., particulate level, which then reflects changes in the average state of household cleanliness (see Appendix B). Gronau's imputed value for a housewife's time is shown estimated at 80% to 114% of the housewife's potential (market) wage of $2.077 (1972 dollars, Gronau, 1973, p. 648), or between $1.66/hour and $2.37/hour. Interestingly enough, however, the range of values estimated in our work (Section D below) which, in 1972 dollars,[12] range from $1.62 to $1.89 per hour, fall almost entirely in the lower one-third of Gronau's range.

C. A CONTINGENT VALUATION STUDY: METHOD

As sketched above, existing literature provides little assistance in our search for measures for T and V. An exception, of course, is the commonly . used practice of using some sort of average market wages as a surrogate for the V measure. However, use of market wages as a measure for household labor's opportunity costs is undesirable primarily for the following sorts of reasons.

Basic economic theory suggests that individuals would derive utility, or satisfaction, from such things as goods and services, leisure and perhaps, household cleanliness. Purchased goods and services of course, require income that is derived from "work," and household cleanliness is derived from time spent cleaning (ignoring, for this purpose, out-of-pocket costs). Given constraints faced by the individual related to income and total available time, the individual allocates his time among work, cleaning and leisure (broadly used here to include all other uses of time) so as to obtain the greatest possible level of utility or satisfaction. A proposition which can be rigorously derived,[13] and which has intuitive appeal, is that the individual would allocate his (her) time so as to obtain the same measure of satisfaction from the last price adjusted unit of time spent on each activity (work, leisure, cleaning) for all activities to which time is in fact allocated. Taking the housewife (or houseperson) as an example, if, in fact, this individual does not engage in "work," as defined here, one may then reasonably assume that the

TABLE 9

FREQUENCY DATA FROM THE CORNELL STUDY

Frequency of per forming 13 household work activities, aversge daily time for each, sad percentage of each in total household work time, by employment of wives

(1,296 husband-wife households, Syracuse, N.Y., 1967-68)

	PERCENT OF DAYS ACTIVITY PERFORMED		AVERAGE HOURS PER DAY		PERCENT OF TUTAL HOUSEHOLD WORK TIME	
	NE[a]	E	NE	E	NE	E
All household work	100	100	11.1	8.7		
More Frequent Activities						
Regular meal preparation	100	99	1.6	1.3	15	15
After-meal cleanup	98	97	1.0	.8	9	9
Regular house care	97	94	1.3	1.2	12	14
Nonphysical care of family members	77	72	1.3	1.0	12	12
Physical care of family members	75	48	1.3	.5	12	6
Marketing	68	68	1.3	1.2	12	14
Washing by machine	66	56	.6	.4	5	5
Lees Frequent Activities						
Special clothing care	51	47	.4	.3	5	3
Management	49	41	.4	.3	4	3
Yard and car care	49	42	.6	.4	5	5
Ironing	43	42	.4	.3	4	3
Special house care	43	33	.7	.7	6	8
Special food preparation	23	22	.1	.1	<1	<1
Total Number of Record Days	1,958	634				

[a]NE and E indicate households with nonemployed or employed wivee.

Source: Walker and Woods [1976, Table 3-8, p.57.

satisfaction gained by the allocation of, say one (1) hour to work, which then yields the market wage and, therefore, the (satisfaction-yielding) goods and services obtained from this wage, the utility or satisfaction from that last hour in leisure and cleaning yields a higher price-adjusted level of satisfaction relative to that obtained via work. Use of the wage, as a surrogate for utility obtained from the last unit of cleaning time (and, therefore, leisure time and work)--the opportunity cost of household time--would then clearly be an underestimate for V.

If the market wage cannot be used as a means for household labor's opportunity cost, how might one obtain such a measure? At issue here is the question: What would it be "worth" to an individual to spend, e.g., one less hour per week in household cleaning, thereby freeing that hour for leisure? By "worth" reference is typically made to what the individual would be willing to pay in this case,for one hour of additional leisure. How, then, might one obtain measures for individual's willingness to pay for one hour more of leisure time, given that leisure is a non-market good, i.e., market prices for leisure do not exist?

In general, two approaches have been used in efforts to estimate prices for non-market goods. The first of these is the "hedonic price" method[14] wherein, essentially, one attempts to attribute values (hedonic prices) to specific characteristics of a particular good (for which market prices do exist) based on the good's market price, which then can be applied to the characteristics of a non-market good so as to construct an "implicit price" for the non-market good. This method has been used with some success in estimating values for leisure-related activities, particularly, outdoor recreation activities.[15] The value of outdoor recreation could hardly seine as a meaningful measure for the V measure of concern here, however, for obvious reasons. The use of such measures, would imply, e.g., that time released from household cleaning would be used for outdoor recreation (usually at National Parks, wilderness areas, beaches, etc.)[16]

The second method that has been used for estimating prices-values—for non-market goods-- is the Contingent Valuation method. The essence of Contingent Valuation is as follows. An effort is made to stimulate a market for the non-market good in question. Within this market context, responses in the form of "bids" are elicited from individuals. Individual bids are contingent on the individual's actual receipt of the quantity of the non-market good in question--thus, the bid reflects the individual's contingent valuation of the good . As such, the individual's highest bid—contingent valuation--may be used as a measure of the individual's maximum willingness to pay for the good which of course, is the value of household labor measure of interest in this work.[17]

The Contingent Valuation is used in this study as a means for obtaining measures for the opportunity cost of household labor. Measures for time spent in cleaning operations are derived by asking participants in the contingent valuation study to respond to the question given in Table 10; to minimize time required for responses to this question, each participant responds to time spent per operation for only four questions, as exemplified in Figures 4 and 5. Thus, each participant considers four of Booz-Allen's 11

TABLE 10

INSTRUMENT FOR DETERMINING

TIME SPENT PER CLEANING OPERATION

HERE IS A LIST OF SOME COMMON HOUSEHOLD TASKS. (Show Figures 4 and 5.) DO YOU OR SOMEONE IN YOUR HOUSEHOLD PERFORM THE TASK OR DO YOU PAY SOMEONE TO DO THIS TASK? (Responses in squares 2-5 → N - Do Not Do At All; M - Do Myself; P - Pay To Have It Done. If someone other than questioned person does it → H - Husband; W -Wife; C - Child; or combination, if more than one does it.) HOW LONG DOES IT TAKE TO DO TASK? (all task names)? (Go through all the tasks except ones with P in front. Fill in blanks 6-9.) HOW OFTEN DO YOU DO THIS TASK? (all task names)sm? (Go through all tasks except ones with P. Fill in blanks 10 - 13.)

FIGURE 4

(1) ☐

LIST OF CLEANING TASKS: A

			TIME TO FINISH	HOW OFTEN
(2)	☐	**WASH** FLOORS	(6) ______	(lo) ______
(3)	☐	WAX FLOORS	(7) ______	(11) ______
(4)	☐	CLEAN OUTDOOR FURNITURE	(8) ______	(12) ______
(5)	☐	CLEAN GUTTERS	(9) ______	(13) ______

(14) ☐

FIGURE 5

(1) ☐

LIST OF CLEANING TASKS: B

			TIME TO FINISH	HOW OFTEN
2)	☐	WASH WINDOWS (INSIDE)	(6) ______	(10) ______
3)	☐	CLEAN VENETIAN BLINDS/SHADES	(7) ______	(11) ______
4)	☐	WASH WINDOWS (OUTSIDE)	(8) ______	(12) ______
(5)	☐	CLEAN STORM WINDOWS	(9) ______	(13) ______

(14) ☐

particulate-sensitive cleaning operations in terms of, first how often the operation is performed (a frequency measure which may be compared with Booz-Allen's frequency measures) and, second, time spent per operation.

In applying the contingent valuation method for the purpose of deriving value of household labor measures, particular difficulty is encountered in structuring the contingent valuation instmment so as to establish simulated market conditions (Table 11). The choice of words used in this instrument is most important and the market context must be one which reflects conditions to which a participant can easily relate. The process of structuring the instrument requires considerable trial and error pre-tests; experiments with seven instruments were conducted in the development of the instrument given in Table 10. Table 12 is an example of one of the earlier instruments which was rejected. The reasons for this rejection included: individuals were confused as to the implications of a fixed-time reduction in cleaning time--the question was considered to be too hypothetical; the instrument, requiring bids for each task, required too much time to complete--the participants became impatient with the process.

Referring to the instrument actually used in our Contingent Valuation study, Table 11, our "market" is straightfoward: paying someone (in whom you have confidence--we wish to exclude potential apprehension by the participant in terms of strangers in the home) to do some, or all, of the cleaning operations. We note that while this instrument was found to be much more plausible to respondents, relative, e.g., to that given in Table 12, use of this instrument sacrifices the marginal measure for value of household labor sought in the Table 12 instrument--the resulting value of time spent cleaning is an average measure across total cleaning time and cleaning operations.

In addition to responses to instruments given in Table 10 and 11, participants, provided information concerning annual income, marital status, age, education, occupation and type of home.

Responses to the Contingent Valuation instruments described above were obtained from some 30 participants in each of Booz-Allen's four pollution zones in the Pennsylvania-New Jersey-Delaware area. Attention is turned to an analyses of these data.

D. ANALYSIS OF CONTINGENT VALUATION DATA

The contingent valuation involved 120 participants chosen randomly in B-A's four pollution zones in the PENJERDEL area (about 30 in each zone). A comparison of the characteristics of our participants with those in the B-A study is given in Table 13. Relative to the B-A study, a higher proportion of non-whites, renters and single-family households were included in our sample. Better than 40% of our sample had some college compared with 24% in the B-A study. More than 50% of our sample had fewer than 10 rooms, compared with 36% of B-A's population. Finally, the most dramatic difference in the two populations would appear to be in incomes: 45% of our sample had incomes less than $12,330 (1980 dollars). Thus, our sample included a larger proportion of low income families than did the B-A study.[18]

TABLE 11

INSTRUMENT FOR DETERMINING V

IF YOU COULD HAVE SOMEONE, IN WHOM YOU HAVE CONFIDENCE, TO DO SOME OR ALL OF THESE TASKS FOR YOU, WHAT IS THE HIGHEST AMOUNT THAT YOU WOULD PAY THEM ON AN HOURLY BASIS? WOULD YOU PAY THEM $________________ PER HOUR? (Start bid as level of box 1, Figure 4 or 5, bid them to find highest bid and put response in box 14.)

TABLE 12

EXAMPLE OF REJECTED CV INSTRUMENT

HERE IS A LIST OF SOME COMMON HOUSEHOLD TASKS (show Figure, alternating Figures 4 and 5). DO YOU DO THE TASKS OR PAY SOMEONE TO DO THEM? (For the tasks they do themselves) HOW OFTEN DO YOU __(for each task)__ AND HOW LONG DOES IT TAKE YOU TO COMPLETE IT. (Get answer in hours or minutes).

WE ARE TRYING TO FIND OUT HOW PEOPLE VALUE THE TIME SPEND IN DOING THESE COMMON HOUSEHOLD CLEANING TASKS. LET ME ASK YOU THEN: IF IT WAS POSSIBLE TO REDUCE THE TIME IT TAKES TO DO (the task) BY 1 HOUR (state the change e.g., 15 hours to 14 hours, both verbally and figuratively on the chart. In the case of minutes, look at a 10 minute reduction.) WHAT WOULD THIS BE WORTH TO YOU. WOULD YOU PAY $1.00 (alternate with $10) FOR THIS HOUR SAVED IN DOING THIS TASK? (with a yes answer bid them up, with a no answer bid them down). (in the case of minute, start at $.10 and $4). (In the case of weeks or months in how often they do the task, use the same frequency of payment, i.e. , $0.10 per week or $1.00 per month) (do this for each task separately).

TABLE 13

COMPARISON OF POPULATION CHARACTERISTICS BETWEEN

B-A SAMPLE AND THIS STUDY'S SAMPLE

HOUSEHOLD CHARACTERISTIC	B-A 1968	THIS STUDY (1980)
	(Percent of Sample)	
RACE: White	79	57
Non-White	21	43
EDUCATION:		
Less than High School	40	
High School	34	(12.98 years average)
Some College	24	
ANNUAL FAMILY INCOME: (1968 dollars)		
Under $6,000	32	45
$6,000 - $9,999	30	49
$10,000 or more	31	6
HOUSEHOLD TENURE:		
Own Home	74	67
Rent Home	26	33
DWELLING UNITS:		
Single-family	51	78
Multi-family	43	22
NUMBER OF ROOMS:		
10 or fewer	36	(8.9 average)
More than 10	64	

There is a further "difference" in the PENJERDEL area that has taken place between 1968 and 1980 of considerable relevance here. Average particulate levels, indeed, concentrations of all pollutants, have decreased dramatically over the last 12 years. Table 14 provides ranges for average concentrations for various pollutants in B-A's four pollution zones for 1968 and 1980. One is hard put to even find particulate concentrations at B-A's Zone 3 (100-125µg/m^3) and Zone 4 (over 125µg/m^3) levels in 1980.

Differences in population characteristics and, particularly, the dramatic differences (relative to 1968) in air quality in the PENJERDEL area result in our abandonment of earlier planned efforts to use B-A's frequency data for "revised" estimates for B-A type economic damages in DIY households; HIRE households were not included in our study. Therefore, data collected in the contingent valuation study concerning task frequencies must be used.

Based on theoretical issues discussed below in Appendix B, we expect that economic damages from household soiling will include effects related to income (Y), the existing particulate level (P)--a surrogate for the average state of household cleanliness--and total. time required for cleaning (foregone leisure). Consider the following structure for such a damage function (D) for DIY households,

$$D = cF + (T)(V),$$

where F is task frequency (per month), T is time spent cleaning per month (in hours), V is the imputed unit (per hour) value of household labor—the opportunity cost of household labor--and c is out-of-pocket costs per F. Thus , economic damages are viewed here as the sum of out-of-pocket costs and the opportunity costs of household labor. We recognize that one might well posit T as a function of F; T is clearly the product of time spent per frequency and frequency. The use of total cleaning time, T, as a dependent variable, however, allows for the tradeoffs between frequency and time spent per frequency of interest here.

The B-A approach involves independently estimating F, T, V and c (B-A's estimates for c are given above in Table 8). At issue is the determination of F, T and V. Our experiments focus on the following hypothesized forms for these three variables which draws upon analyses of consumer behavior outlined in Appendix B.

$$F = \alpha_o + \alpha_1 P + \alpha_2 Y$$

$$T = \alpha_o + \beta_1 P + \beta_2 Y$$

$$V = \gamma_o + \gamma_1 Y + \gamma_2 P$$

Thus, F T and V are posited as being determined by particulate level and income.[19] Concern in this section is then concerned with testing the following three sets of hypotheses, where H_N is our null hypothesis and H_A is the alternative hypothesis, for each of j = 1, . . ., 8 cleaning tasks.[20]

TABLE 14

AVERAGE ANNUAL CONCENTRATION LEVELS FOR SELECTED POLLUTANTS IN THE PENJERDEL AREA, 1968 to 1979

B-A Particulate Zone:	Range of Particulate Concentrations (geometric mean)µg/m^3: 1968	1979
1. (less than 75)	42 1/ - 74 2/	38 - 51
2. ($75 \leq P < 100$)	76 2/ - 81 1/	49 - 51
3. ($100 \leq P \leq 125$)	107 - 123	68 - 72
4. ($P > 125$)	112 3/ - 125	52 - 109

1/ Data are for 1972

2/ Data are for 1969

3/ We do not find particulate levels in excess of 125µg/m^3 (geometric mean) in the PENJERDEL area in 1968.

I. H^j_{N1} : $\alpha_1, \alpha_2 = 0$, $j = 1, \ldots, 8.$

H^j_{A1} : H^j_{N1} is false

II. H^j_{N2} : $\beta_1, \beta_2 = 0$, $j = 1, \ldots, 8.$

H^j_{A2} : H^j_{N2} is false

III. H^j_{N3} : γ_1, γ_2 = 0

H^j_{A3} : H^j_{N3} is false.

Our criterion for accepting a rejecting H_N is the f-test using a 95% confidence level. The critical values for f are $f_{.05}(2,58) = 3.15$ for tasks 1-4 and $f_{.05}(2,55) = 3.17$ for tasks 5-8 with reference to the tests I and II. For the test III, the critical f is $f_{.05}(2,117) = 3.07$.

Results from these tests are given below. The estimation of damage functions is given in the following Chapter.

Results from tests of hypotheses I - III are given in Table 15. To the right of each equation, f is the f-statistic for the equation and f^1 is the f-statistic for the null hypothesis that the coefficient on P is zero; t-statistics for each variable are given in parentheses below the variable. Based on these data, the null hypotheses in I - III are accepted for frequency, F, in tasks 1, 2 and 6, and for T in tasks 1, 2, 4 and, marginally, task 6. Statistical significance (at the 95% confidence level) is demonstrated for regression equations and the coefficient for particulate level for the remaining equations.

Mid-points of particulate ranges used in B-A are used in the frequency equations given in Table 15, and the resulting estimates for task-frequency are compared with B-A's frequencies in Table 16 (note: 1980 particulate levels are used for analyses in Chapter VIII). Given the substantial reduction in particulate level since 1968 in B-A's PENJERDEL area, task frequencies estimated here are generally lower than those given by B-A, as one might reasonably expect.

Attention is now turned to the use of these data in generating damage functions for household soiling.

TABLE 15

RESULTS FROM STASTICAL TESTS FOR THE FUNCTIONS F, T AND V

A. Estimated Forms for F and T:

TASK 1: (Wash Floors)	F = 4.3 + .057P − .0002Y (.97) (1.s) (.3)	F = 1.6 (F^1 = 3.13)
	T = .06 + .029P + .0002Y (.02) (1.9)	F = 2.32 (F^1 = .17
TASK 2: (Wax Floors)	F = 1.7 − .0004P + .00004Y (1.5) (−.05) (.7)	F = .x (F^1 = 0
	T = −.01 + .0068P + .00006Y (−.02) (1.3) (1.9)	F = 2.21 (F^1 = 1.98)
TASK 3: (Clean Outside Furniture)	? = −1 + .014P + .00004Y (−1.4) (3.2) (1.0)	F = 3.03 (F^1 = 1.2
	T = −.7 + .006P + .00003Y (−2.6) (3.6) (2.9)	F = 7.76 (F^1 = .28)
TASK 4: (Clean Gutters	F = .24 + .003P . .000007Y (1.9) (3.6) (1.2)	F = 6.3 (F^1 = 13.0)
	T = −.2 + .003? + .00001Y (−.9) (1.7) (1.2)	F = 1.7s (F^1 = .14)
TASK 5: (Wash Windows Inside)	F = .07 + .017P − .00003Y (.1) (1.7) (−.9)	F = 10.8 (F^1 = 14.2)
	T = 1.1 + .03P − .00008Y (.6) (2.7) (−1.0)	F = 6.4 (F^1 = 11.5)
TASK 6: (Clean Venetian Blinds)	F = −.2 − .025P − .0002Y (2.5) (−1.7) (−La)	F = 2.17 (F^1 = 2.3)
	T = .3 − .0008P − .0001Y (2.2) (−.9) (−1.6)	F = 1.16 (F^1 = .15)
TASK 7: (Wash Windows Outside)	F = −.3 + .011P − .900003? (−.7) (4.3) (−.2)	F = 11.3 (F^1 = 18.1)
	T = .08 + .018P + .000002? (.06) (2.?) (.0s.)	F = 1.3 (F^1 = 4.7)
TASK 8: (Clean Storm Windows)	F = −.7 + .007P + .00002Y (−1.3) (5.9) (2.0)	(F = 17.9 (F^1 = 15.6)
	T = −.9 + .011P + .00004Y (2.7) (4.6) (2.2)	F = 10.6 (F^1 = 21.3)

B. Estimated Form For V:

	V = .36 + .006P + .00014Y (1.6) (1.3) (6.0)	F = 18.5

TABLE 16

COMPARISON OF FREQUENCY ESTIMATES WITH B-A FREQUENCIES

TASK	ADJUSTED B-A FREQUENCY (annual)*	ESTIMATED FREQUENCIES**
Clean Outdoor Furniture:		
Zone 1	8.4	4.5
2	15.1	7.9
3	16.0	12.0
4	18.5	15.6
Clean Gutters:		
Zone 1	2.7	,61
2	4.5	1.3
3	8.4	2.2
4	16.4	2.8
Wash Windows (inside)		
Zone 1	10.4	7.1
2	12.1	10.4
3	13.2	14.6
4	18.9	17.9
Wash Windows (outside)		
Zone 1	6.8	5.1
2	5.5	7.7
3	7.6	11.0
4	11.1	13.6
Clean Storm Windows:		
Zone 1	3.8	1.1
2	3.7	2.9
3	4.8	5.1
4	9.9	6.8

* DIY households, Table 4.

**Derived by setting P = 67.5, 87.5 , 112.5 and 132.5 (mid-points of B-A pollution ranges in 1968) in the equations given in Table 15, multiplied by 12 (estimated frequencies in Table 15 are monthly frequencies); average 1980 income, $13,951, is used for Y.

PART 11

CHAPTER VIII: SOILING DAMAGES RELATED TO PARTICULATE LEVEL

A. 1980 SOILING DAMAGES IN B-A'S POLLUTION ZONES

In this Chapter estimates for particulate-related soiling damages are developed for each of the four pollution zones used in the B-A study. Particulate levels in each of these zones are quite different in 1980 than they were in 1968, as noted above. CV estimates for household labor value, used here as a basis for estimating a part of soiling costs, were obtained in areas within B-A's from zones with average particulate levels of 40, 81, 102 and 123 $\mu g/m^3$ compared to B-A's 1968 averages of 67.5 (midpoint between 60-75 $\mu g/m^3$), 87.5, 112.5 and 132.5 (midpoints of B-A ranges) $\mu g/m^3$, respectively.

Before continuing, estimates for total cleaning costs for 10 of B-A's 11 particulate-sensitive tasks[21] are derived in what follows and, a la the B-A study, such costs are viewed here as "damages". We recognize, of course, that such costs, provided for four particulate levels, can logically be viewed as particulate-related household soiling damages only in the case where cleaning costs would be zero with particulate levels at zero; i.e. , the base level for P is zero. Obviously, even under the most stringent EPA standards one would expect that the cleaning tasks analyzed here would still be required and some level of costs would obtain. "Damages" would then be appropriately measures as the increase in cleaning costs that result from increases in particulate level above some reasonable base level. Total costs are used in this section inasmuch as we have no basis for defining this base level. In section B, however, results from analyses of section A are extended to the notion of a "damage function" which, all else equal, would allow for analyses of damages related to a base level for air particulate.

Consider, first our estimates for soiling damages for DIY households. Components for these damages are given in Table 17. Out of pocket costs (1968 dollars) are taken from the B-A study and adjusted to 1980 dollars. Average annual frequencies (columns 3-6) are estimated by the equations given in Table 15 for all tasks which satisfied f-tests described in Chapter VII. For task frequencies which cannot be estimated via these equations—tasks 1, 2 and 6-- average frequenceis in each particulate area are used. The same procedure is used in estimating time spent in performing the various cleaning tasks (columns 7-10); averages are used for tasks 1, 2, 4 and 6. Total annual cleaning costs-- damages--for a representative household in each particulate zone is the sum of: (a) out of pocket costs time task frequency and, (b) the imputed value of household labor—the product of time spent and the value of household labor (equation V in Table 15). This latter product is given in columns 11-14 in Table 17. Resulting estimates for damages are given in Table 18.

TABLE 17

COMPONENTS OF ESTIMATION OF SOILING COSTS t

o FY HOUSEHOLDS

TASK	Out-of-Pocket Cost Per Operation ($ 1980) 1/	Average Annual Frequency With Particulate Level (μ/m^3) 2/				Time Spent per Household (Annual) for Tasks (Hours) with Particulate Levels 4/				Annual Operating Cost for Household Labor ($ 1980) 5/			
		40	81	102	123	40	81	102	123	40	81	102	123
Wash Floors	1.36	136.8	133.2	142.8	162.0	60.8	62.5	61.5	79.9	186.66	205.92	230.50	283.65
Wax Floors	5.09	26.4	32.4	19.2	21.6	14.2	20.1	16.5	18.4	43.31	68.11	56.60	65.32
Clean (Nil.1,1. Furniture	3.25	0	6.6	10.2	13.7	0	2.5	4.0	4.4	0	8.25	13.72	19.52
Clean Gutters	3.25	0	1.2	9.0	2.7	2.4	2.1	0	6.0	7.32	6.93	0	21.30
Wash Inside Windows	2.03	4.0	12.3	16.1	20.9	14.2	29.0	36. S	44.1	43.31	95.70	125.20	156.56
Clean Venetian Blinds	2.03	26.6	2.9	17.1	9.6	17.5	3.5	11.2	15.2	53.15	11.55	38.42	53.96
Wash Outside Windows	1.25	1.2	6.6	9.4	12.2	9.9	18.8	23.3	27.8	20.20	62.04	19.92	98.69
Clean Storm Windows	1.25	n	1.8	1.5	5.3	1.2	6.6	9.4	12.1	3.66	21.78	32.24	42.96
Replace Air Conditioning Filter	1.26	1.9 3/	2.1 3/	2.0 3/	4.6 3/	0	0	0	0	0	0	0	0
Clean/Repair Screens	3.25	1.2	6.6	9.4	12.2	1.2	6.6	9.4	12.1	3.66	21.78	32.24	42.96

1/ # able 8; adjusted to 1980 dollars with 1979 CPI (1968 1.. ! .) of 2.055 (see [71], Table 790 (all items, May, 1979) and assuming 10% inflation for 1979-1980 (index is 226).

2/ Averages are used for tasks 1 . 2. 6; for other tasks, equations in Table 15 are used with ● "t, eg- income of $13,951 imposed. Resulting estimates for monthly frequencies are multiplied by 12 to obtain annual frequencies.

3/ Adjusted B-A frequency; Table 7.

4/ Averages for tasks 1, 2, 4 and 6; for other tasks, equations in Table 15 multiplied by 12, using average income of $13,951.

5/ Equation for V in Table 15, with Y = $13,951, multiplied by time spent per household.

TABLE 18

ESTIMATION FOR 1980 SOILING COSTS FOR FOUR PARTICULATE LEVELS:

DIY HOUSEHOLDS

TASKS	SOILING COSTS (PER HOUSEHOLD: MILLIONS OF 1980 DOLLARS) WHEN PARTICULATE LEVEL ($\mu g/m^3$) is: 40	81	102	123
Wash Floors	$372.71	$387.07	$424.71	$544.77
Wax Floors	177.69	233.23	154.33	205.80
Clean Outside Furniture	0	16.38	46.87	64.05
Clean Gutters	7.32	10.83	6.50	30.08
Wash Inside Windows	51.43	120.67	159.10	198.99
Clean Venetian Blinds	107.75	17.44	73.54	73.45
Wash Outside Windows	34.10	83.49	110.47	138.34
Clean Storm Windows	3.66	27.63	43.62	60.19
Replace Air Conditioning Filters	4.29	4.75	4.52	10.40
Clean/Repair Screens	3.66	3.66	43.62	60.19
TOTAL	$762.71	$905.15	$1,067.28	$1,386.26

1/ From Table 17, column 2 time columns 3-6 plus columns 11-14.

Of course, the resulting view of household soiling damages is quite different from that given in the B-A study. Taking the "wash inside windows" as an example, the B-A cost per frequency (in 1980 dollars) would be but \$2.03--out of pocket costs; the corresponding cost estimated here, with, e.g., a particulate level of 81 $\mu g/m^3$, would be \$10.25.

Turning now to HIRE households, soiling costs for HIRE households simply involve the product of costs per operation and mean annual frequencies. The former is taken from the B-A study and adjusted to 1980 dollars (column 2 in Table 19). Mean annual frequencies for these households are taken from the B-A study and linearily extrapolated to 1980 particulate concentrations. For example, B-A frequencies for HIRE households are 30.7 and 41.2 for particulate levels 67.5 and 87.5 $\mu g/m^3$, respectively (Table 7); frequency changes by .525 for each change in particulate level of 1 $\mu g/m^3$. Thus for P = 413, 27.5 $\mu g/m^3$ less than in B-A's zone 1, frequency is reduced from 30.6 by 14.4 (.525 times 27.5) to 16.3. Resulting estimates for HIRE household damages, in 1980 dollars, are given in columns 7-10 of Table 19.

In bringing together our damage estimates for HIRE and DIY households, a comparison with B-A damage estimates may seine to give some perspective to these data. In the B-A report, there were 1,501,969 and 120,492 DIY and HIRE households, respectively, which performed the "wash inside windows" task; these statistics for the task "wash floors" were 1,498,124 and 93,856, respectively (Table 7). B-A's estimated annual cost for these two tasks was \$133.3 million (adjusted to 1980 dollars by 2.26; B-A, pp. 111-11 and III-12). A comparable measure of annual costs for these two tasks developed here[22] would be \$97.1 million for HIRE households and \$782.5 million for DIY households, for a total of \$889 million--an almost sevenfold increase. The rational for this difference is, of course, obvious. B-A costs for DIY households-some 90% of the households that perform the tasks--was but \$2.03 and \$1.36 per frequency (1980 dollars) for the windows and floor tasks, respectively; when the imputed value of household labor is included, these costs (respectively) become \$10.25 and \$19.91.[23]

Estimates for total damages in each of B-A's zones--with 1980 particulate concentrations—-are given in Table 20; these estimates are based on B-A's estimated number of HIRE and DIY households in 1970 (Table 7). With particulate concentrations of 40, 81, 102 and 123 $\mu g/m^3$, total damages sum ,0 ,368" 3 million, \$300.9 million and \$303.8 million, respectively.[24]

B. TOWARDS A DAMAGE FUNCTION

Ideally, we would have defensible equations describing the relationship between frequency, time-spent for household cleaning and the value of household labor and income and particulate level for all tasks. If included tasks. were comprehensive (an issue discussed in the following Chapter), a damage function of the following form could be generated, where f(P,Y), T(P,Y) and V(P,Y) represent functional forms for the relevant dependent variables and c deontes out of pocket costs.

$$D = \sum_{Task} [cf(P,T) + T(P,Y)V(P,y)]$$

TABLE 19

COMPONENTS OF ESTIMATED SOILING COSTS: HIRE HOUSEHOLDS

TASK	COST PER OPERATION (\$ 1980)[1]	MEAN ANNUAL FREQUENCY WITH PARTICULATE LEVEL ($\mu g/m^3$)[2]: 40	81	102	121	TOTAL ANNUAL COST PER HOUSEHOLD BY PARTICULATE LEVEL (\$ 1980): 40	81	102	123
Wash Floors	\$22.60	16.3	40.8	37.9	41.5	\$ 368.38	\$ 922.09	\$ 856.54	\$ 936.90
Wax Floors	84.75	6.5	13.9	9.9	6.3	550.87	1,178.03	839.02	533.93
Clean Outside Furniture	27.12	2.6	5.7	5.8	---	70.51	154.58	157.30	---
Clean Gutters	40.68	.4	.6	.5	.03	16.27	24.41	20.34	1.22
Wash Inside Windows	25.43	7.6	11.2	7.7	18.5	193.26	284.82	195.81	470.46
Clean Venetian Blinds	25.43	4.1	4.1	9.3	7.8	111.219	111.89	236.50	198.35
Wash Outside Windows	40.68	3.5	3.3	3.3	8.1	142.38	134.24	134.24	329.51
Clean Storm Windows	40.68	1.4[3]	.7	1.7	3.1	56.95	28.48	69.16	150.52
Replace Air Conditioner Filter	30.51	.4[4]	.8[4]	.3[4]	.8[4]	16.27	32.54	12.20	32.54
Clean/Repair Screens	40.613	.1[4]	.4[4]	.4[4]	.7[4]	4.07	16.27	36.61	28.48
					TOTAL	\$1,530.85	\$2,886.94	\$2,557.72	\$2,682.91

[1] Table 8; adjusted to 1980 dollars using 1979 CPI (See) and assuming 10% inflation behavior 1978 - 1980.

[2] Extrapolated from data in Table 7.

[3] $(f_{81} \div f_{87.5})2.2$

[4] Data from Table 7.

TABLE 20

ECONOMIC DAMAGE ESTIMATES IN THE PENJERDEL AREA FOR FOUR PARTICULATE LEVELS (1980)

TASK	HIRE HOUSEHOLDS WITH PARTICULATE LEVEL ($\mu g/m^3$)[1] 40	81	102	123	DIY HOUSEHOLDS WITH PARTICULATE LEVEL ($\mu g/m^3$)[1] 40	81	102	121
	($ millions, 1980)				($ millions, 1980)			
Wash Floors	$12.6	$33.7	$11.0	$ 9.6	$181.0	$167.3	$133.9	$144.4
Wax Floors	1).1	14.4	7.8	5.4	51.1	51.9	28.9	28.1
Clean Outside Furniture	.1	1.6	.5	0	0	1.1	1.5	1.2
Clean Gutters	.6	1.0	.4	.01	1.6	1.?	.4	1.5
Wash Inside Windows	8.0	11.1	4.5	6.6	26.1	40.5	47.1	31.5
Clean Venetian Blinds	1.7	1.9	2.3	3.4	26.9	3.7	11.6	11.1
Wash Outside Windows	4.6	11.)	5.0	14.5	15.4	'29.1	29.1	20.9
Clean Storm Windows	1.3	.9	1.8	2.9	3.0	5,6	6.1	5.8
Replace Air Conditioner Filters	.2	.6	.3	.1	.4	.5	.2	.6
Clean/Repair Screens	.1	.4	.7	.2	1.1	.8	6.0	8.0

HOUSEHOLDS		TOTAL DAMAGES ($ MILLIONS, 1980) PARTICULATE LEVEL ($\mu g/m^3$): 40	81	10Z	133
DIY		$321.4	$209.3	$266.8	$261.1
HIRE		46.9	86.9	34.1	41.7
	TOTAL	$368.3	$396.2	$300.9	$303.8

[1] Table 7, 18 and 19.

Given any base level for particulate concentrations, estimates for damages sould be determined in a straightforward manner.

For reasons discussed in the following Chapter, we have neither a comprehensive reange of cleaning tasks nor defensible equations for all included tasks, in which case we are unable to estimate a function of this form. However, some feel for the potential nature and use of such a function can be derived by regressing total cleaning costs estimated here against particulate levels. The result is as follows.

$$D = 251.43 + 6.63P \qquad F = 35.7$$
$$(2.4) \qquad F_{.05}(1,\ 2) = 18.51$$

From the above, a linear marginal damage (MD) function can be obtained of the form:

$$MD = \frac{dD}{dP} = 6.63.$$

Marginal damages of \$6.63/μg/m^3, which is marginal damage per household, suggests that benefits attributable to an EPA standard that reduces particulate levels by, e.g., 10 μg/m^3 would be on the order of \$106 million per year, using B-A's 1.6 million households in 1970.

This linear estimate of marginal damages must be viewed as little more than of expository value, of course. One would not expect damages to be linear in P (See, Appendix B of this report). With nonlinear forms for the functions F, T and V, marginal damages would be of the form

$$MD = C + T'(P,Y)V(P,Y) + T(P,Y)V'(P,Y),$$

which would be much more robust than the simple linear form given above.

PART II

CHAPTER IX: CONCLUSIONS CONCERNING THE B-A APPROACH TO ESTIMATING SOILING DAMAGES

A. MAJOR BIASES IN DAMAGE ESTIMATES

As was explained above, the original intent of this part of the study was to simply add the imputed value of household labor to B-A's original cost estimates to the end of modifying B-A damages; the result would have been a revised estimate of 1968 household soiling damages in the PENJERDEL area. Our original proposed method involved use of the CV method to determine only time spent per frequency and the value of household labor; B-A's task frequencies were to be used.

Given the dramatic changes in air quality in the PENJERDEL area since 1968, our original methodology is simply not palatable, and a last minute effort was made to adjust to these conditions--it became necessary to develop our own frequency measures. These efforts were imperfect, at best, and a number of biases underlie our frequency estimates and, more generally, the damage estimates given in Chapter VIII which must be recognized. The first of these concerns frequencies for the HIRE households. B-A frequencies and number of households were used here for the HIRE category. Such frequencies would surely have been reduced in the PENJERDEL area over the last 12 years as a result of lower concentrations of particulate. Further, one might reasonably expect that, consistent with trends over the last decade, a smaller proportion of households would fall in the HIRE category. Both of these considerations would suggest that our damage estimates for HIRE households are overstated.

A further source for upward biases is related to the correlation between income and particulate level. While we did not find high correlation between Y and P in our sample, the two are clearly correlated in the PENJERDEL area, and more defensible damage estimates could be derived via stratified samples wherein analyses of D(P) for given income levels are performed.

A number of sources for downward biases in our damage estimates can be identified. One such source relates to the function V--the imputed value of household labor. In our efforts to reduce the size of our CV instrument--in terms of the time required to administer the instrument--participants were asked their maximum willingness to pay, per hour, to have someone do all or part of the four cleaning tasks considered. An ambiguity then exists in terms of interpreting the results. Is the CV an average measure or accomplishing one, two, three or four of the tasks?[25] If, as may be likely, the CV applies to but part of the tasks, its interpretation as a marginal measure of the opportunity costs of leisure time foregone is most appropriate. Thus, in applying the CV measures from the function V in Table 15 to total cleaning time, one underestimates damages inasmuch as one would expect diminishing marginal utility of leisure, which implies a value of V which increases at an increasing rate as particulate level (and, therefore, cleaning time) rises. In future studies, this problem might be rectified by obtaining CV responses for various levels of released cleaning time.

A further source for downward biases in our damage estimates relates to the structure of our sample for V participants. Our sample included some 30 participants in each of B-A's four pollution zones. As such, equal weight is given to responses in all four zones. Populations in each zone vary considerably, however. In particular, zones 3 and 4 have relatively smaller populations with relatively high proportions of low income and nonwhite populations. To some extent, responses from low income participants are given disproportionate weight when CV measures are aggregated. The result is most likely a downward bias in aggregate value measures.

Finally, two particularly important soiling-related cleaning tasks are not included in B-A's tasks, viz., general dusting and cleaning (vacuuming, not washing) floors. Especially when referring to the effects of air particulate, the dusting task was mentioned by the bulk of study participants. While time spent per frequency for these tasks may not be large, we have good reason to believe that these two tasks dominate "light" cleaning activities which may have high annual frequencies and, therefore, may result in relatively high damages.

B. IMPROVED FREQUENCE-BASED DAMAGE ESTIMATES

In reflecting on the lessons learned form this effort to update and extend the B-A study, the authors conclude that the approach to estimating soiling damages based on task frequency does have promise. The approach involves a mixture of frequency evaluations and willingness to pay measures that, carefully constructed, may mold into defensible measures for soiling damages. In constructing such estimates, one would begin anew, however; attempts to extend B-A's 1968 data are simply not useful. If one were to undertake the task of estimating frequency-based soiling damages the following suggestions may serve to make the Contingent Valuation process more efficient.

First of all, ambiguities in task specification should be eliminated. As an example, the "wax floor" task may involve stripping away old wax and reapplying new wax (as the task was viewed in the B-A study) or the much simpler activity of applying "instant gloss" kinds of material with a mop following the washing of floors. The bulk of participants in our Contingent Valuation study viewed "waxing" as the latter activity. As mentioned above, considerable ambiguity exists in terms of the "maintain driveways/walks", particularly in terms of whether or not snow removal is involved.

Bur further, our experience in this study suggests that individuals have considerable difficulty in separating out various tasks; participants tended to think of cleaning in terms of "light cleaning" and "deep cleaning" operations. Light cleaning primarily involves relatively frequent dusting, vacuuming carpets, and wet-mopping floors.[26] Deep cleaning involves cleaning windows, waxing floors, etc., and may involve light cleaning "tasks" in which more time is spent; e.g., floors one washed with detergents and rinsed rather than simply wet-mopped.

All of this is to suggest two considerations. First, it may be desirable to look to light and deep cleaning operations (frequencies) rather than to individual tasks as a basis for soiling-related damage estimates, particularly for inside tasks. Secondly, but related to the above, "frequency" per se may not be the variables of, interest in looking to damage estimates. Rather, one is concerned with time spent (e.g., per week or month) in light and deep cleaning operations. One then looks to variations in total cleaning time across particulate levels as the basis for damage estimates.

To push this argument a bit further, the appeal in looking to time spent in cleaning as the variable of interest is that one avoids a major problem which arises with a focus on task frequency. The argument implicit to the B-A approach is that task frequency increases with higher levels of particulate concentration. In fact, however, this is not the case in many instances (see Table 7); indeed, one observes higher particulate concentrations associated with lower task frequencies. Such behavior can be readily explained, however, by the fact that cleaning activity involves cleaning frequency and time spent per frequency. Lower frequencies may be associated with more time spent per frequency, and vice versa. Indeed, analyses performed as a part of this work wherein frequency and time spent per frequency (TSF) were separately regressed against particulate level indicate, in all cases, that the P-coefficient is positive for the F equation and negative for the TSF equation. Thus, households adjust to changes in F and TSF, and focus on either variable alone may result in distorted estimates. Use of the variable "time spent per (period of time)" on cleaning operations avoids this potential source for distortions.

In conclusion, it is suggested here that reasonable estimates for household soiling damages may result from an effort to determine time spent (per week or month) on light and deep cleaning activities across air particulate areas where stratified samples are used to avoid the potential correlation between income and particulate level; Contingent Valuation responses for various levels of cleaning time reductions are used to value changes in household time and price of household labor measures.

PART III

CHAPTER X: THE CONCEPTUAL PROBLEM

A. RATIONALE FOR INQUIRING AS TO AN ALTERNATIVE TO THE FREQUENCY METHOD

Setting aside the problems identified in Parts I and II concerning data derived in the B-A study per se, one may well ask as to the feasibility of simply repeating the B-A survey wherein efforts would be made to correct these problems. By this we mean to ask: what's wrong with the frequency approach?

Consider the basic method underlying the frequency approach. Basically, one simply asks people living in different particulate-level environments: how often do you do task A?; how much do you spend in accomplishing task A? Let us acknowledge B-A's point that spending responses are, in some sense, "unreliable", particularly when task-related expenditures are small. We'll then ignore expenditures for now, but more will be said regarding this matter below in section B. In addition to responses to these two sets of questions, considerable demographic and attitudinal information must be obtained from the individual. Two major sets of problems now arise.

First of all, the end sought in this method is that of estimating the manner in which task frequency changes as particulate level—only particulate level--changes. But, in fact, what are those things, in addition to particulate level, which one would expect to influence task frequencies chosen by individuals? There are simply a multitude of things which may well influence choice of task frequency, ranging across habits, upbringing, tastes, income, etc. To get some flavor for this issue, consider the following data taken from B-A's Appendix B for simply three possible determinants of frequency.[27] While one must use caution in interpreting these data,[28] frequencies are shown to vary between 10% and 27% within these few household characteristics; thus, the potential role of these characteristics in "determining" task frequencies.

	Annual Frequency for Washing Floors in Zone I
1. Education of household-head:	
Incomplete Highschool or less	40.2
Completed Highschool	43.2
Some college or more	58.7
2. Tenure of Household	
Own home	41.4
Rent home	37.7

	Annual Frequency for Washing Floors in Zone I
3. Occupation of Head of Household	
White collar	39.7
Blue collar	44.1
Not in labor force	34.6

Secondly, as has been mentioned above, it is simply not clear that individuals can accurately distinguish between cleaning tasks; this may be particularly the case if the individual is confronted with a comprehensive set of household soiling tasks including, for example, dusting, washing window sills, etc. Certainly, the individual is asked to respond to questions with which they may have serious association difficulties, inasmuch as (e.g.) housewives may seldom only dust or only sweep floors or only wipe window sills. It would seem much more plausible to expect that housepersons consider household cleaning frequencies in terms of a set of tasks: for example, sweep floors, mop floors and dust.

These points are not made to suggest that it would be impossible to set out comprehensive lists of mutually conclusive tasks or sets of tasks, and to sort through the many potential determinants of frequency to the end of isolating, in some defensible way, the frequency effects from particulate level. However, the large number of tasks and complex attitudinal variables involved (56 attitudinal questions were included in the B-A survey; B-A, p. II-5) may in fact confound efforts to attribute frequency changes to particulate level; moreover such an undertaking would involve enormous costs.

We have argued above that a "streamlined" frequency approach, in contrast to the task frequency approach of the B-A study, may have considerable promise. For completeness, however, we wish to now turn to an evaluation of a totallt different alternative approach for deriving measures for household soiling damages.

B. AN ALTERNATIVE APPROACH TO THE FREQUENCY METHOD

Suppose that we accept the proposition that "cleanliness", as related to the household, is viewed by the individual as a gestalt. Reactions to the accumulation of dust and grime in the household--curtain, window sills, furniture, floors, windows, etc--may take the form of periodic "maintenance" types of cleaning (e.g., dusting, sweep floors) and/or periodic "deep" cleaning (mop/wax floors, wash windows, etc.). Thus a cleaning "frequency" encompasses a number of tasks and we do not look for changes in particulate level to affect tasks per se; rather as particulate level falls, less time is required for all tasks performed in a given cleaning operation or,. particularly for maintenance-type operations, the multi-task operation may be required less frequently.

For an individual facing this cleaning environment, we ask: how would the utility maximizing individual react to a change in the average state of household cleanliness that would obtain , e.g., as a result of reduced particulate level? In Appendix B of this report, a simple model of consumer behavior is sketched which allows insights as to a response to this question. From the simple model we conclude:

(i) an exogenous decrease in the average state of household cleanliness would result in consumption of: (a) more cleanliness, and (b) more "other goods", and leisure, due to cost and time savings from reduced cleaning requirements.

(ii) an exogenous decrease in the average state of household cleanliness is associated with a "Compensating Variation" which, specifically, is the adjustment in income that would leave the individual just as well off at the higher level of cleanliness as he was at the lower level of cleanliness without the adjustment in income.

the empirical implications of (i) and (ii) are that, given that one wishes to measure the effects of the consumer of a given change in the state of household cleanliness, (i) and (ii) suggest that one might attempt either to estimate (a) changes in leisure time, cleaning outlays and "cleanliness", or (b) the reduction in the individuals' income that would leave the individual at the same level of satisfaction that was enjoyed prior to the exogenous change in the average state of household cleanliness.

The frequency approach is consistent with the first method in that one attempts to measure changes in household outlays of money for cleaning, changes in leisure time (via changes in frequency which would then logically be weighted by time spent or frequency and the value of time) and the value of changes in the consumption of cleanliness (this would be the Watson-Jaksch extension of B-A results to include consumer surplus).

Given the problems with implementing this method (a la the B-A approach), which have been discussed above in some detail, the method (b) is suggested as a reasonable alternative approach to deriving what is conceptually the same measure as would obtain in (a) if the B-A method could be reasonable implement ed. Of course, in (b) one simply looks to <u>the income equivalent</u> of the individual's valuation of time/money savings and increased household cleanliness. This "income equivalent" is essentially the maximum amount that an individual would be <u>willing to pay</u> to bring about such a change in the cleanliness state. We now consider a methodology for estimating this "willingness to pay".

PART III

CHAPTER XI: A CONTINGENT VALUATION APPROACH TO MEASURING HOUSEHOLD SOILING DAMAGES

A. A CONTINGENT VALUATION STUDY: PURPOSE

As developed above, an exogenous change in the average state of household cleanliness, as might result from reduced particulate levels, can be expected to result in behavioral responses by individuals in terms of: "consuming" more cleanliness, purchase of more "other goods" from any dollar savings resulting from reducing cleaning-related expenditures and the "consumption" of more leisure time. Conceptually, there is a reduction in the individual's income which would just offset--in terms of leaving the individual no worse off—these benefits from the increase in average cleanliness, and this reduction in income can be viewed as the maximum amount that the individual would be willing to pay to see such a change in cleanliness brought about.

From our discussions in Chapter VII of Part II, the Contingent Valuation (CV) method has considerable appeal in terms of a methological approach to obtaining measures for the "willingness to pay" of interest here. In applying this method to the problem, a Contingent Valuation instrument is required which would adequately simulate a market environment wherein the individual trades income for a change in the average state of cleanliness via reduced particulate level. The individual's maximum bid or "price" (real income reduction) at which he would engage in such a trade is then his maximum willingness to pay which, in turn, is his valuation of the posited change in particulate levels.

Aside from potential biases implicit to the Contingent Valuation method per se, a particularly troublesome problem arises when one considers the application of the Contingent Valuation method to soiling. Ideally, the Contingent Valuation method would proceed as follows. Participants for the Contingent Valuation study would be chosen in a number of areas with different particulate levels. For an area with particulate level, say, P_1, we would determine the average change in household cleanliness (E) that would result from a 15% reduction in P. Participants would then be asked for Contingent Valuations of E. The dollars "traded" for E are then taken as the social benefits attributable to a 15% reduction in P_1 or, alternatively, the social <u>damages</u> attributable to particulate level between .85 P_1 and P_1.

As argued in Part I of this study, however, we are simply unable to specify the change in soiling effects that would result from any given change in particulate level given the current state of the technical arts. In qualitative terms, we have good reason to believe that a change in particulate level would indeed reduce the accumulation of dust and grime--soiling—in households, but we cannot state by what amount.

This being the case, what is the "commodity" to be traded in the Contingent Valuationts simulated market? One might simply obtain Contingent Valuation measures for arbitrarily selected values for E. This approach lacks appeal, however, inasmuch as the data would remain valuless until some means are developed which allows one to relate EPA policy (in terms of reduced particulate level) to changes in average cleanliness. Our only alternative then is to obtain Contingent, Valuation measures where income is traded directly for the reduced particulate level. The major weakness here, however, is that the individual must then transform the particulate level changes involved in the Contingent Valuation "market" to his (her) perception of the E that would result. This is the case inasmuch as the individual's bid for any given change in particulate level reflects his valuation **not** for the particulate change per se but for the resulting perceived change in average household cleanliness.

Obviously, the problem of assigning individuals the technological question as to the soiling effects of a given change in particulate level, may each imagine a different effect in terms of soiling. Thus, we are then faced with the issue of interpreting the resulting willingness to pay measures: given two different bids (for the same particulate level change) from two different individuals, does the bid-difference reflect different valuations for the same change in cleanliness or the same (unit) valuation for different (anticipated) changes in cleanliness?

Two experimental approaches for dealing with this problem are tested in this study. First, an attempt is made to elicit Contingent Valuation responses from participants for very small changes in particulate level. The idea here is that if small, e.g., 1%, changes are posited, differences in perceived soiling effects across individuals will be sufficiently limited to allow the resulting Contingent Valuation measures to serve as marginal valuations; i.e. , Contingent Valuation measures are marginal damage estimates. A damage function would then be derived by integrating the marginal measures across particulate levels; the area under the damage function between any two given values for particulate level could then be used as an estimate for the associated soiling damages.[29]

The second experimental approach used here in an effort to deal with the pollution-soiling effect problem is to simply use the total elimination of airborne particulate (in excess of background levels) as the "commodity" traded in the Contingent Valuation market. Of course, here the participant must distinguish between particulate-related soiling from background particulate levels and that which would obtain from sources amenable to EPA control.

A further complication arises in that in offering Contingent Valuation responses, a participant may be unable to sharply differentiate between the many potential effects of particulate level. This is to say that heightened public awareness of potential health and visibility effects from air pollution in general may result in Contingent Valuation responses to particulate-level questions that reflect more general attitudinal reactions to more general air pollution effects.

In light of these potential problems, it is not clear at the outset whether or not a Contingent Valuation instrument can be developed which will yield defensible estimates for soiling damages. This issue was well recognized in the research proposal which serves as the funding basis for this study. Thus, the intended purpose of the research reported here is limited to that of testing the feasibility of the Contingent Valuation approach as a method for estimating soiling damages. In the remaining sections of this chapter, the development of a Contingent Valuation instrument is described. Results from pre-tests of this

bear in the central issue addressed in Part III, viz., does the Contingent Valuation method show promise as a methodology for measuring soiling damages?

B. THE CONTINGENT VALUATION INSTRUMENTS

The Contingent Valuation instruments were developed from a number of pretests conducted in Albuquerque, New Mexico. The first instrument was designed to elicit Contingent Valuation measures that relate to small, marginal changes in particulate level. This instrument consists of paragraphs (l), (2), (3), (4) and (5) given in Table 21.

The instrument given in (1)-(5) of Table 21 is the result from five pretests of similar instruments. To provide the reader with some feel for the process of developing the Contingent Valuation instrument, (2), in the final instrument, had forms similar to (2.A) in early pre-tests. Comparing (2.A) to (2), the phrast " . . . affect the atmosphere . . . ." was found to be more difficult for participants to understand than " . . . affect visibility . . . . , the question in (2.A), " . . . which of these effects are apparent to you?" seemed to confuse participants, and is eliminated in (2). Comparing (3.A) to (3), participants were unable to respond to the 1% reduction in particulate level posited in (3.A); thus, 10% and 20% are used in (3). The payment behicle "add to your utility bill", used in (3.A), elicited responses such as "utility bills are already too high", suggesting a "vehicle bias".[30] This bias was eliminated when "add to the telephone bill" was introduced, as appears in (3).

The Contingent Valuation given in Table 21 then presents a market wherein reductions in income are traded for contingent changes in all air pollutants ("small" changes, (3), and the total elimination of pollutants, (4)) and particulate level (small changes (5)). Different "starting points"--initial bids--of $1, $5, and $10 are used to allow for analyses concerning potential "starting point biases".[31] Resulting Contingent Valuation responses, obtained from participants who reside in different particulate level envionrments, may then be used to analyze the variation to individual's maximum willingness to pay for small and large changes in all pollutants and, specifically, particulate level.

A second Contingent instrument, Instrument B, is given in Table 22. For reasons that will be discussed below, focus in Instrument B is given to Contingent Valuation responses for the total elimination of air particulate. Once again, the development of Instrument B required five pre-tests. An example of the results of this process of pre-testing is given by comparing paragraphs (2) and (2.A). In earlier instruments (2.A), the transition from

TABLE 21

CV INSTRUMENT A

1. WE KNOW THAT AIR POLLUTION CAN CAUSE A NUMBER OF UNDESIRABLE EFFECTS. MAJOR EFFECTS THAT HAVE BEEN SHOWN TO RESULT FROM AIR POLLUTION ARE HEALTH EFFECTS , VISIBILITY EFFECTS, AND HOUSEHOLD SOILING EFFECTS. (Show chart 111.) POLLUTION MAY EFFECT AN INDIVIDUAL'S HEALTH EITHER BY CAUSING ILLNESS OR FURTHER IRRITATING EXISTING HEALTH PROBLEMS (GENERALLY, RESPIRATORY). (Point to Health on the chart 1.)
2. POLLUTION CAN AFFECT VISIBILITY BY CREATING A SMOG OR HAZE. (Point to visibility on the chart.) POLLUTION MAY CAUSE INCREASED HOUSEHOLD SOILING THROUGH THE COLLECTION OF DUST AND SOOT ON SUCH THINGS AS WINDOWS, FLOORS AND FURNITURE.

2a. POLLUTION CAN EFFECT HOUSEHOLD BY THE COLLECTION OF DUST, SOOT AND DIRT ON WALLS, WINDOWS, FLOORS, FURNITURE, RUGS, DRAPES, ANY ARTICLE WITHIN THE HOUSE. WE ASSUME THAT THE HIGHER THE LEVEL OF POLLUTION, THE GREATER THE EFFECT. AS YOU LOOK AT THE POLLUTION LEVELS IN ALBUQUERQUE, WHICH OF THESE EFFECTS ARE APPARENT TO YOU? YOU CAN CHOOSE ALL OF THEM OR NONE OF THEM. (Check them on the chart. If they check soiling continue with soiling. If they check only one, go with that. If they check Health and Visibility, alternate.)

3. WE ARE INTERESTED IN HOW PEOPLE VALUE REDUCTIONS IN AIR POLLUTION IN ALBUQUERQUE. LET US BEGIN BY SUPPOSING THAT WE COULD REDUCE AIR POLLUTION IN ALBUOUEROUE BY A SMALL AMOUNT.

TABLE 21 (Cont.)

LET'S SAY ABOUT (10 - 20%, as indicated in box 15). WHAT WOULD THIS SMALL REDUCTION IN AIR POLLUTION BE WORTH TO YOU? WOULD YOU BE WILLING TO PAY $(What's in box #1 A MONTH, ($1, 5, $10, as indicated in box #1 SAY, ADDED TO YOUR TELEPHONE BILL ON A CONTINUING BASIS (EVERY MONTH) . (If, "YES" bid them up; if "NO", bid them down.) (Record bid on space on chart 111 - Marked #16.)

3a. WE ARE INTERESTED IN HOW PEOPLE VALUE REDUCTIONS IN AIR POLLUTION IN ALBUQUERQUE. LET US BEGIN BY SUPPOSING THAT WE COULD REDUCE AIR POLLUTION IN ALBUQUERQUE BY A ~~VERY SMALL~~ AMOUNT. WE WON 'T WORRY ABOUT PRECISE MAGNITUDES, JUST A SMALL CHANGE , LET ' S SAY ABOUT 1%. HOW WOULD YOU VALUE THIS VERY SMALL REDUCTION IN AIR POLLUTION? WOULD YOU PAY $5 A MONTH FOR THIS SMALL REDUCTION BY WAY OF, LET ' S SAY, A $5 INCREASE IN YOUR MONTHLY UTILITY BILL? (If "yes", bid them up; if "no" , bid them down.) (Record bid on space on Chart 3 - Marked #14.)

4. WE NOW KNOW HOW YOU WOULD VALUE A SMALL REDUCTION IN AIR POLLUTION IN ALBUQUERQUE. WHAT ABOUT A LARGE REDUCTION IN AIR POLLUTION? LET'S SAY WE COULD TOTALLY ELIMINATE AIR POLLUTION AND ALL IT"S EFFECTS (point to chart 111) IN ALBUQUERQUE. WHAT WOULD THE TOTAL ELIMINATION OF AIR POLLUTION IN ALBUQUERQUE BE WORTH TO YOU? WOULD YOU BE WILLING TO PAY (start at earlier bid, plus 100%). (Bid them up or down, whichever is appropriate.) (Record result in #17).

TABLE 21 (Cont.)

5. SUPPOSE NOW THAT THE (10/20%, as indicated in box #1.5) REDUCTION IN AIR POLLUTION DID NOT REDUCE ALL OF THE EFFECTS (show chart) AND THAT THE ONLY EFFECT REDUCED IS HOUSEHOLD SOILING , WOULD YOU STILL PAY $ ________ (refer them to previous bid.) (If no bid, then bid down to where they are happy.) (Record answer #18) (If they bidded $0 to the previous ques - tion, this question is ignored.)

TABLE 22

CV INSTRUMENT B

1. ARE YOU AWARE OF THE PROBLEMS AIR POLLUTION CAUSES? SCIENTISTS WHO HAVE STUDIED THESE PROBLEMS TELL US THAT SOME KINDS OF POLLUTION ARE HAZARDOUS TO OUR HEALTH WHILE OTHER KINDS ARE NOT. SOME KINDS OF PARTICLES IN THE AIR -- TEND TO CAUSE HAZE AND REDUCE OUR VIEW. AND OTHER KINDS -- SCIENTISTS SAY THE LARGE PARTICLES -- ESPECIALLY CONTRIBUTE TO COLLECTION OF DUST AND GRIME IN OUR HOMES.

2. WE ARE PARTICULARLY INTERESTED IN THE KINDS OF AIR POLLUTION THAT CONTRIBUTE TO DUST AND GRIME IN THE HOME. THIS CAUSES LAYERS OF DUST ON FLOORS AND FURNITURE, STREAKS WINDOWS, DIRTIES DRAPES , AND SO FORTH. (HOW MUCH TIME DO YOU SPEND CLEANING YOUR HOME? FREQUENCY & TIME ______________ ______________.) SUPPOSE FOR A MOMENT THAT OUR ENGINEERS AND SCIENTISTS FOUND A WAY TO ELIMINATE <u>ONLY</u> THE KIND OF AIR POLLUTION THAT RESULTS IN DUST AND GRIME IN THE HOUSE. OF COURSE, THIS WOULD NOT ELIMINATE ALL YOUR CLEANING BUT IT OUGHT TO REDUCE IT.

2.A THIS CAUSES LAYERS OF DUST ON FLOORS AND FURNITURE, STREAKS WINDOWS, DIRTIES DRAPES, AND SO FORTH. HOW MUCH TIME DO You SPEND CLEANING? FREQUENCY & TIME ______________ ______________. SUPPOSE FOR A MOMENT THAT OUR ENGINEERS AND SCIENTISTS FOUND A WAY TO ELIMINATE ONLY THE KIND OF AIR POLLUTION THAT RESULTS IN DUST AND GRIME IN THE HOUSE. OF COURSE, THIS WOULD NOT ELIMINATE ALL YOUR CLEANING, BUT IT OUGHT TO REDUCE IT.

TABLE 22 (Cont.)

3. IF THIS KIND OF POLLUTION COULD BE ELIMINATED -- AT A COST -- HOW MUCH WOULD IT BE WORTH TO YOU? ECONOMISTS HAVE A METHOD OF DETERMINING HOW MUCH IT IS WORTH TO YOU. IT TAKES WE ASK FOR YOUR BID. SUPPOSE YOU COULD WRITE OUT A MONTHLY CHECK OR YOU " COULD ADD A CERTAIN " AMOUNT TO YOUR MONTHLY TELEPHONE BILL EACH MONTH FOREVER. WOULD YOU PAY $___________ PER MONTH TO ELIMINATE THE KIND OF POLLUTION THAT CAUSES GRIME AND DIRT? (Repeat as yearly amount and stress FOREVER in the case of large bids.)

4. NOW LET ME ASK YOU ONE FURTHER QUESTION. LET'S SUPPOSE OUR SCIENTISTS AND ENGINEERS COULD ELIMINATE ALL KINDS OF AIR POLLUTION, AGAIN AT A COST. THIS WOULD HELP WITH POLLUTION-CAUSED HEALTH PROBLEMS , IT WOULD IMPROVE THE VIEW , AND OF COURSE , IT WOULD HELP WITH HOUSEHOLD DUST AND GRIME. HOW MUCH A MONTH WOULD YOU BE WILLING TO PAY FOR THIS ? $___________ .

5. WHEN YOU INDICATED THAT YOU 'D PAY $___________ EACH MONTH TO SEE THOSE KINDS OF AIR POLLUTION THAT CAUSE DUST AND GRIME IN YOUR HOME ELIMINATED , HOW DID YOU THINK THAT YOUR HOUSEHOLD CLEANING JOBS WOULD BE AFFECTED BY THE ELIMINATION OF THIS KIND OF AIR POLLUTION? WERE YOU THINKING OF FEWER CLEANINGS EACH MONTH, OR LESS TIME SPENT IN EACH CLEANING, OR OF OTHER CONSIDERATIONS? ______________ .

TABLE 22 (Cont.)

6. IF I MAY ASK ONE FINAL QUESTION , CONSIDER THE $ ____________ PER MONTH THAT YOU HAVE INDICATED AS YOUR WILLINGNESS TO PAY FOR THE <u>TOTAL</u> ELIMINATION OF AIR POLLUTION. IN TERMS OF YOUR VALUATION OF AIR POLLUTION EFFECTS, HOW WOULD YOU ALLOCATE THIS $ ______________ AMONG THE FOLLOWING EFFECTS (you may allocate all $ ____________ to one effect, or divide the $ ___________ among the effects).

(a) VISIBILITY $______________

(b) SOILING $______________

(c) HEALTH ______________

describing different kinds of pollution and then effects to the issue of eliminating air particulate (" . . . that kind of pollution that contributed to the collection of dust and grime") was found to be too abrupt: participants attention was not focused on the soiling issue. Thus, in (2) the participant is told "we are particularly interested in . . . .", in an effort to focus the participants attention on the soiling issue. Also some confusion was encountered when Contingent Valuation questions were posed to participants. As a result, the "auction" nature of the Contingent Valuation approach is explained in ((3) in Table 22) prior to the participant's introduction to Contingent Valuation questions.

The market context and payment vehicle used here is identical to that seen in Instrument A. As is obvious from (2), (3) and (4) in Table 22, however, Instrument B gives much greater detail and emphasis on the elimination of particulate-related soiling relative to Instrument A. Given the uncertainty as to individual perceptions of the effects that might result from having all particulate-related soiling eliminated--therefore, uncertainty as to the "benefits", via reduced particulate level, to which Contingent Valuation responses apply--(5) is included to allow for analyses as to the variance in perceived <u>physical</u> effects of eliminating air particulate by individuals.

Finally, (6) is included to allow for analyses as to the relationship between individuals valuation of different pollution-related effects. These analyses are intended to speak to the possibility, discussed above in section A, that individual's perceive pollution effects as a gestalt. Attention is now turned to an anaysis of results obtained from the Contingent Valuation instruments described here.

PART III

CHAPTER XII: ANALYSIS OF CONTINGENT VALUATION RESULTS

A. OVERVIEW

The Contingent Valuation instruments described in Chapter XI were pre-tested in three locations: Los Angeles, Philadelphia and Albuquerque. Some 384 participants were involved in pre-tests of the "incremental" Contingent Valuation instrument (Table 21) in Albuquerque. The Contingent Valuation for the "total" elimination of air particulate (Table 22) involved 124, 65 and 75 participants in Los Angeles, Philadelphia and Albuquerque, respectively. Analyses are focused primarily on Philadelphia and Los Angeles data, however, inasmuch as Contingent Valutaion responses obtained in Albuquerque were used to test and refine the Contingent Valuation instrument (Table 22) ultimately used in Philadelphia and Los Angeles. Demographic characteristics of participants in the Contingent Valuation study are given in Table 23. In each city, Contingent Valuation participants were acquired in areas with different average air particulate concentrations as shown in Table 24.

As the reader will recall from discussions in Chapters X and XI, the major issue which these pre-tests are intended to address concerns individuals perceptions of the effects of air particulate. Since we cannot describe the effects, in terms of reduced accumulation of dust and grime-soiling--in the home, of any given change in the average concentration of particulate, two hypothetical changes are posited: a "small", or marginal, reduction in particulate and total elimination of air particulates (exceeding, of course, background particulate levels). If individual perceptions of the effects of these hypothetical changes do not vary significantly, it may be possible to use the Contingent Valuation responses as a means for valuing reductions in particulate level and the Contingent Valuation methodology can then be evaluated in these terms.

In section B, results from the "small change" or incremental approach are evaluated. Results from the second, or "total" approach are evaluated in section C along with results which relate directly to the perception issue.

B. THE INCREMENTAL APPROACH

The "incremental" approach involves efforts to obtain Contingent Valuation responses for "small" changes in particulate concentrations. As described in Chapter XI, a number of experiments were conducted concerning difficult word-choices to describe a small change. In the end, the phrasing given above in Table 21 was used which involved 1% and 10% reductions in "particulate level.

TABLE 23

POPULATION CHARACTERISTICS OF
CV PARTICIPANTS

Characteristics	Population (number of participants in parenthesis)		
	Los Angeles(124)	Philadelphia	Albuquerque(75)
Average age:	40.2	38.6	40.5
% that own:	74%	62. 1%	69. 4%
Average income:	$19,081	$14,740	$13,960
% non-white:	25%	60%	11%
Average Years Schooling	13.9	13.2	13.2
% Married	75%	82%	70%
% with children in household	57%	66%	60%
% Female Respondents	75%	86%	90%

TABLE 24

PARTICULATE CONCENTRATIONS IN

CV STUDY AREAs

AREA	AVERAGE ANNUAL PARTICULATE CONCENTRATION ($\mu g/m^3$, 1979)
PENJERDEL:	
1	39
2	44
LOS ANGELES:	
1	71
2	124
3	179
ALBUQUERQUE:	
1	37.5
2	87.5
3	125.0

Results from the incremental Contingent Valuation study were disappointing. In general, participants simply could not conceive, or relate to, posited small changes in particulate level or small reductions in all pollutants. This is reflected in data given in Table 25. In terms of 1% and 10% reductions in all air pollutants, average Contingent Valuation responses were $6.31 and $4.80, respectively. More to the point, however, roughly a third of the participants gave a zero response-their maximum willingness to pay for a small reduction in air pollution was zero. Further, almost half of the nonzero responses were simply at the starting point (starting "bid") of $1.00 or $10.00.

Similar results obtain when small reductions are posited for those types of air pollution which primarily affect health, visibility and household soiling (Table 25). A relatively large proportion of the participants either selected the starting bid or responded with zero bids.

Individuals who gave nonzero bids would many times express misgivings about their bid, however. The inescapable conclusion by our interviewing staff was, therefore, that individuals were generally confused in terms of the effects that might accompany any "small" change in particulate level or, more generally, all pollutants. Given our inability to obtain meaningful Contingent Valuation responses to "small" changes in air particulate, attention was then focused on Contingent Valuation responses to the <u>total</u> elimination of air particulate.

C. THE TOTAL APPROACH

In the "total" approach, participants are asked for their maximum willingness to pay for the <u>total</u>. elimination of air particulate that contribute to household accumulation of dust and grime. As discussed in Appendix B of this report, our theory suggests that major components in any individual damage function for household soiling would include: income, as a surrogate for the opportunity cost of any cleaning expenditures and/or foregone work; cleaning time saved, reflecting the utility of leisure time; and particulate level, which series as a proxy for the average state of household cleanliness. Given the elimination of particulate, the individual's Contingent Valuation response should measure the compensating variation in consumer income obtained as particulate level, P, "changes" from that level now existing in the individual's environment (P_o) to zero, and is therefore a measure of <u>total</u> damages attributable to particulate level at P_o. Again, this damage is hypothesized as determined by income, perceived time savings, and P.

There are many functional forms that one might use in testing these hypotheses. Two of the more conventional forms used for analyses of this type are a linear form and a Cobb-Douglas form; these are the functional forms used here. Define Y as individual income, S as perceived (ex post) cleaning hours saved (per week) from the posited total elimination of particulate, P as the existing particulate level and D as the individual's maximum willingness to pay for the elimination of P--total damages. Our experiments then focus on the following equations (A in 12.1 is a constant).

$$D_1 = AP^{\alpha_1}Y^{\beta_1}S^{\gamma_1} \qquad (12.1)$$

$$D_2 = \alpha_2 P + \beta_2 Y + S^{\gamma_2} \qquad (12.2)$$

TABLE 25

CV RESULTS FOR INCREMENTAL AIR POLLUTION AND PARTICULATE LEVEL CHANGES

For the Following Reduction in ALL Air Pollutants:	Average CV Response ($/mo.)	Percent Zero Responses
1% (N = 152)	$6.31	37.1%
10% (N = 232)	$4.80	28. 2%

For the Following Reductions in the Effects of Air Pollution:			
1% :	Health	$10.75	21.4%
	Visibility	$10.88	26.0%
	Soiling	$ 4.40	26.5%
10% :	Health	$ 3.00	38.1%
	Visibility	$ 3.98	33.3%
	Soiling	$ 2.55	41.3%

The two sets of hypotheses to be tested here are as follows, where H_N is our null hypothesis and H_N is the alternative hypothesis.

$$\text{I.}\quad H^1_N: \quad \alpha_1 = 0$$
$$\beta_1 = 0$$
$$\gamma_1 = 0$$
$$H^1_A: \quad H^1_N \text{ is false}$$

$$\text{II.}\quad H^2_N: \quad \alpha_2 = 0$$
$$\beta_2 = 0$$
$$\gamma_2 = 0$$
$$H^2_A: \quad H^2_N \text{ is false}$$

Our criterion for accepting H_N or H_A is the F-test at a 95% confidence level. For the Los Angeles and Pennsylvania experiments, the relevant critical values for F and F(3, 85) = 2.71 and F(3, 60) = 2.76, respectively. Thus, if F_1 or F_2 (corresponding to (12.1) or (12.2), respectively) for, as an example, Los Angeles exceeds 2.71, HN is rejected and we accept for our analyses of damages the estimated function (12.1) or (12.2). Data from Albuquerque are not used here for reasons described ablve.

From data in Table 26, both the log form and the linear form for the damage function are statistically significant based on data from the Los Angeles study; only the linear form is significant for the Pennsylvania data (compare F-statistics with the critical value for F given by $F_{.05}$). This implies that, for these regressions, one rejects the hypotheses that the coefficients for P and Y and S are not significantly different from zero at a 95% confidence level. In other words, one might accept any of these two equations as a basis for estimating damages.

Given the purposes of this study, however, noe must go further with statistical analyses. In particular, we are concerned with the significance of the variable P in these equations. For each equation (D_1 and D_2 for Los Angeles, D_2 for Pennsylvania) 0 (a' is the, we test the hypothesis that a = relevant coefficient for the variable P); results of these tests are given in groups 3 and 4 in Table 26. In all cases the relevant F-statistic is less than the critical value $F_{.05}$, in which case we <u>cannot</u> reject the hypothesis a = 0 in any of the three equations Similar tests on Y and S result in the rejection of the null hypothesis.

These results may be interpreted in several ways. It may be the case that individual perceptions of soiling damages related to air quality are unaffected by particulate level per se. Individuals are willing to pay for the elimination of particulate in average amounts of $2.69 in Philadelphia and $6.61 in

TABLE 26

RESULTS FROM STATISTICAL ANALYSES

OF CV DAMAGE FUNCTIONS

1. LOS ANGELES DATA ($F_{.05} = 2.71$)

$$\ln D_1 = \underset{(-3.3)}{-9.5} + \underset{(.46)}{.14} \ln p + \underset{(4.9)}{1.06} \ln Y + \underset{(2.0)}{.18} \ln S \qquad F = 10.8$$

$$'2 = \underset{(.5)}{.007P} + \underset{(3.0)}{.0003Y} + \underset{(.3)}{.14s} \qquad F = 3.19$$

2. PHILADELPHIA DATA ($F_{.05} = 2.76$)

$$D_1 = \underset{(-1.8)}{-5.3} + \underset{(.9)}{.31} \ln P + .53 \ln Y + .09 \ln S \qquad F = 2.3$$

$$D_2 = \underset{(1.1)}{.009P} + \underset{(3.5)}{.0001Y} + \underset{(2.1)}{.23S} \qquad F = 4.9$$

3. LOS ANGELES DATA

H_N : "1" 0 , F = .20 , $'_{.05}(1, 85) = 3.96$

H_N : '2" 0 , F = .22 , $'_{.05}(1,121) = 3.92$

4. PHILADELPHIA DATA

H_N : a, = 0 , F = 1.23 , $'_{.05}(1, 62) = 4.0$

Los Angeles, but it is not clear that individuals in fact differentiate between particulate level changes (and associated soiling effects) and air pollution levels in general (with associated effects on health, visibility and soiling). Further, one may argue that the relationship between Contingent Valuation responses and P is distorted due to the perception problem discussed ‘above; i.e., differences in individual perceptions of the effect on household soiling from the elimination of particulate may play a large role in determining the Contingent Valuation response (damage measure}. Finally, it may be the case that the poor performance of P in explaining changes in damages is related to correlation between P and W, a problem of some concern in the 1968 B-A study. Each of these issues warrant a bit more detailed consideration.

First, to what extent might individuals view pollutants and effects of pollutants as something of a gestalt? As a part of the Contingent Valuation study, individuals were quiried as to their maximum willingness to pay for the elimination of all types of air pollution (see Table 22), after which they were asked to allocate this Contingent Valuation measure among health, visibility and soiling effects in terms of their perception of the relative Importance of these effects. Results related to this question are summarized in Table 27. From these data, two observations are of particular interest here. First, as one might expect, the bulk of individual Contingent Valuations for the elimination of air pollution is allocated to health—some 65% to 75% of the total Contingent Valuation. Of particular interest is the allocation to soiling. Soiling effects do give rise to damages--the soiling allocation is nonzero; however, the willingness to pay for soiling effects ($2.83 in Los Angeles, $1.98 in Philadelphia) when all effects are considered Is less than half of the Contingent Valuation response for soiling that was obtained when Contingent Valuation responses were asked for soiling alone. The higher soiling-only Contingent Valuation response may be viewed as reflecting the individuals more general (in terms of effects_ perception of pollution damages; certainly when asked to allocate a general pollution-related Contingent Valuation measure to soiling, a much smaller Contingent Valuation for soiling obtains.

Secondly, when asked their willingness to pay for the total elimination of particulate, to what extent were individual perceptions of the effects of this change--and therefore the “benefits” received for their Contingent Valuation--homogeneous? Were people bidding of different “goods” (changes in particulate-related effects)? The importance of perceived effects from the postulated changes in particulate level is supported by the fact that the variable S included in our regression equations (responses as to “hours of work saved” which the participant expected to result from the change In particulate level) is statistically significant in explaining estimated damages. Interestingly enough, a substantial proportion of study participants which gave positive Contingent Valuation responses for soiling gave a zero S-response--approximately 26% of all participants. Why would one indicate a positive willingness to pay for the elimination of particulate while at the same time indicating that no effect, in terms of reduced cleaning effort, is expected? One possible explanation for this phenomena may be in terms of a Watson-Jaksch effect; i.e., while cleaning effort is unaffected, a positive bid reflects the change in consumer surplus associated with a higher average state of household cleanliness. Alternatively, as suggested in the previous paragraph, the “soiling” bid (Contingent Valuation response) may in fact relate to (nonsoiling)

TABLE 27

CV RESPONSES FOR THE TOTAL ELIMINATION
OF AIR POLLUTION AND THEIR ALLOCATION
OVER EFFECTS

Data Set	Elimination of Air Pollution	Allocation of Total CV to: Health	Visibility	Soiling	Soiling Allocation As % of Average CV for Soiling
Los Angeles	$32.83/month	$25.09	$ 4.16	$2.83	49%
Philadelphia	$12.59/month	$ 8.36	$ 2.23	$1.98	62%

pollution-related effects of concern to the individual.

Of particular interest, however, is the relationship between S and P. While the correlation coefficient for P and S is small (around .2), if P is regressed linearly against S, the following result obtains (Los Angeles data):

$$S = \underset{(.8)}{.5} + \underset{(1.51)}{.007P} \qquad F = 2.29, \quad F_{.05}(1,122) = 3.92$$

While this equation is not significant, the t-statistic for P seines to suggest (and only suggest) a positive relation between S and P. With damages significantly related to S, the effect of P on damages may then be to some extent suppressed in S.

Finally,[32] giventhe persistent significance of income in explaining Contingnet Valuation responses, one may well inquire as to the correlation between P and Y. The potential for correlation between P and Y differs markedly between Los Angeles data and Philadelphia data. While not “high” (usually, correlation coefficients of among .8 are considered “high”), there is some correlation between P and Y in the Philadelphia data (the correlation coefficient, E, is E = -.403). In Los Angeles, however, E = -.23, which suggests little if any correlation. We can say little more on this topic with our available data; P - Y correlation may account,to some extent, for the poor performance of P in explaining Contingent Valuation responses in our Philadelphia data.

PART IV

CHAPTER XIII: SUMMARY AND CONCLUSIONS

A. SUMMARY

Our overview of the current state of the technical arts in terms of measuring household soiling effects from air particulate concentrations resulted in two major conclusions which essentially set the stage for efforts here to estimate soiling damages. These were first, that we are unable at this time to quantify household soiling effects from alternative particulate levels. Therefore, any effort to estimate soiling damages must be based on: observed behavioral differences in different particulate environments wherein one attempts to attribute all or part of such behavioral differences to differences in particulate concentration; effects of different particulate levels as perceived by the public; or some combination of the two. Secondly, there is simply no basis at this time for defensible estimates for either indoor-outdoor concentration ratios or for separating out soiling effects from "large" or "small" (greater or less than 15µg) particulate.

In this work two methods for estimating household soiling damages were examined. The first of these represents a mix of the "observed behavioral differences" and "perceived effects" approaches to getting around the present void in our knowledge of particulate cause - soiling effect relationships. This method is based on the 1968 B-A study of cleaning costs wherein "observed" task frequencies for specific cleaning tasks were used as a basis for estimating soiling damages. A number of weaknesses in the B-A study were identified in this work. Among these weaknesses are the following. First, the B-A study seems to have based its conclusions that soiling damages, related to particulate level, are not important on the basis of small out-of-pocket costs per frequency. A number of observations would seem to belie the B-A conclusion: first, small unit (per frequency) costs may result in "large" costs when frequency of cleaning is high; second, household soiling costs involve the opportunity cost for foregone leisure which results from household time spent in cleaning; third, a number of inconsistencies appear to exist in the B-A estimates for DIY and HIRE household task frequencies; fourth; the specification of many of the B-A tasks is somewhat ambigous, with the result that considerable variation in time spent per frequency is possible for these tasks; last, B-A's taska are not comprehensive in terms of major soiling-related cleaning tasks.

These weaknesses aside, the original interest in this study was to simply add household labor costs, based on B-A task frequencies, to B-A's estimates for out-of-pocket costs to the end of extending B-A's measures for 1960 household soiling damages. Given the magnitude of reduction in average particulate concentrations since 1968 in B-A's PENJERDEL area, it became necessary to develop current estimates for task frequencies (for DIY households) as a part of this work. Therefore, estimates for task frequency, time spent (per year) on cleaning tasks, and the value of household time were developed and used to estimate household soiling damages for DIY households in four particulate zones; B-A frequencies were used for estimating damages for HIRE households in as much as data for HIRE households were not collected as part of this study.[33] Resulting estimates for household soiling damages are given above in Table 20. Household soiling damages are shown to vary from $762 per household to $1,386/household for DIY households, as particulate concentrations vary from 40μg/m^3 to 123μg/m^3 for HIRE households, damages vary from $1,531/household to $2,683/household in this range of air particulate.

There are a number of sources of potential upward and downward biases in the damage estimates reported in Table 20. On balance, however, we suggest that these damages estimates are <u>understated</u>. This follows from the expectation that, first, cleaning tasks excluded from B-A's sample could be expected to represent relatively large costs and, second, the use of marginal, rather than average, measures for the opportunity costs of household labor would result in much larger costs.

The second method for estimating hold soiling damages examined in this work focused on individual's maximum willingness-to-pay for contingent reductions in particulate level. Two approaches were tried in an effort to deal with the lack of particulate cause-soiling effect issue. First, efforts were made to elicit Contingent Valuation responses for "small"--marginal--reductions in particulate level; the rationale for this approach was that, with "small" changes, individual <u>perceptions</u> of resulting soiling effects might not vary substantially. After numerous tests, this approach was rejected inasmuch as study participants were generally unable to relate soiling effects to posited "small" changes in particulate concentration.

The second approach involved efforts to obtain measures for individual maximum willingness to pay for a contingent situation wherein air particulate are <u>totally</u> eliminated. Results from this approach are supported above in Table 27. In essence, "acceptable" (on the basis of statistical tests) equations are developed which relate household soiling damages (maximum willingness to pay) to particulate level and income and perceived effects (in terms of hours of cleaning time saved as a result of the elimination of air particulate). Statistical tests indicate, however, that one cannot reject the hypothesis that the particulate coefficient per se is zero. Therefore, the method does not result in a meaningful method by which particulate-related household soiling damages can be estimated. One of the major reasons for the failure of this method to produce meaningful results may well be the <u>wide</u> variation in perceived soiling effects from the elimination of air particulate among study participants. We conclude then that the use of the maximum willingness to pay approach to estimating household soiling damages must await the development of more precise particulate cause-soiling effect data.

B. CONCLUSIONS

In contrast to the B-A conclusions, the preponderance of evidence from data analyzed in this study point to the conclusion that household soiling damages which vary with particulate level exist, there is good reason to expect that they can be identified and they may be non-trivial in nature. From the analysis of B-A type damages, marginal (annual) damages for a single household from particulate-related effects are (argued to be) on the order of \$6.53 per $\mu g/m^3$ change in particulate level are suggested. Using B-A's estimate of 1.6 million households in the PENJERDEL area in 1970, air particulate concentrations in this area have been reduced, on the average, by some 26 $\mu g/m^3$ in the last decade which, using the above estimate for marginal damages, implies a reduction in annual household soiling damages on the order of \$272 million-\$170.00 per household.

Should the EPA wish to continue the search for refined estimates for particulate-related household soiling damages, the conclusions of this study suggest a simplified frequency-based methodology as a preferable approach. The approach suggested here would involve: (a) obtaining information as to periodic (month or week) time expended on light and deep cleaning operations in areas with well-defined differences in particulate level for "inside" cleaning; (b) the use of a stratified sample over income levels; (c) obtaining Contingent Valuation measures for the opportunity cost of household labor for varying levels of time expenditures; and, (d) using well defined tasks for outside soiling-related cleaning procedures. Results from analyses discussed above in Part II suggest considerable promise for such a method for estimating household soiling damages which could be accomplished at modest costs relative to extensive surveys of the B-A stripe.

REFERENCES

1. See, for example "Methods Development for Assessing Air Pollution Control Benefits," 1979.

2. See, for example, Airborn Particles, 1978.

3. A large part of this review draws on studies reported in Air Quality Criteria for Particulate Matter (1969) and Airborn Particles (1978).

4. A notable exception would be "washing automobiles".

5. See, for example, Schulze, W.D. and d'Arge, R.C., 1977.

6. See, Gronau, R., 1973.

7. Implicit to B-A's results is the notion that housewives may consider housework as a "duty"; one must wonder then why utility-losses--economic damages--that attend more "duty" as particulate levels rise, would not be relevant.

8. The above criticism concerning B-A's failure to account for income differentials between zones is particularly relevant here. If one is to attribute the change in frequencies observed in zones 1-4 to differences in particulate levels across these zones, one implies (as in this example) that the observed frequency measures apply to the "same", in an average sense, individual when faced with different pollution levels. In the simplest terms, one uses statistical techniques to sort out frequency changes attributable to **non**-particulate causes, such as income level, ethnic group, age, education, etc. in an effort to focus strictly on this "representative" person's task-frequency response to changes in particulate level.

9. For purposes of this discussion, we abstract here from the income and other household characteristics discussed in Chapter IV.

10. These issues do not in any way exhaust the conceptual problems underlying the B-A approach.

11. The Contingent Valuation method has been applied in a number of other studies; see, for example, "Methods Development for Assessing Air Pollution Control Benefits", 1979.

12. A 1979 deflater is used (U.S. Department of Commerce, Statistical Abstract of the U.S., 1979, Table 790), and a 10% inflation rate is assumed for 1979-80.

13. See, e.g., Lucas (1975) and Schulze and d'Arge (1977).

14. See, e.g., Lucas (1975).

15. See "Methods Development for Assessing Air Pollution Control Benefits," Vol. I-V, Office of Health and Ecological Effects (1979).

16. op. cit. 15.

17. The general strengths and weaknesses of the contingent valuation are discussed in works in Op. Cit. 15, Randall et al. (1974) and Schulze and d'Arge (1977).

18. This difference will also reflect different economics conditions in 1980 compared with 1968. National unemployment was 4.5 to 4.9 percent in 1968 compared with almost 8 percent in 1980. Given the large proportion of non-whites in our sample, relatively higher unemployment rates among non-whites is also relevant.

19. Our analyses would lead one to posit the dependence of V on total cleaning time (foregone leisure), i.e. , on T, as well as on P and Y. However, since T is a dependent variable with arguments P and Y, the coefficients γ_1 and γ_2 must include the foregone leisure effects **via** P and Y as they impact V.

20. "Clean/repair screens" is taken to be the summer counterpart of the "clean/repair storm windows" task; household cleaning time is excluded for the "replace air conditioner filter" task.

21. As discussed above, "maintain driveways/walks" is eliminated due to ambiguities as to the scope of this task (particularly, confusion as to whether or not snow-removal is included); clean/repair screens and *storm* windows are used as seasonal counterparts.

22. Data from Tables 18 and 19 applied to HIRE and DIY households in each B-A zone given in Table 7.

23. Table 17, data for particulate level of 81 $\mu g/m^3$.

24. The decline in damages as particulate level rises results from the smaller number of households in zones 3 and 4; see Table 7.

25. Differences in CV responses for the two sets of tasks used were not found to be statistically significant.

26. Also included in light cleaning are non-particulate related tasks such as washing bathroom and kitchen sinks, cleaning toilets, etc.

27. The reader must recall that B-A data for any characteristic are pooled over all other characteristics; thus, e.g., data for “Complete H.S.” include those who have completed High School regardless of, e.g., household tenure, income or occupation.

28. op. cit. 25.

29. To use this method for valuing total damages at a particular value for particular level would require additional information, viz., some estimate for the constant of integration (the y-axis intercept).

30. See Schulze and d’Arge (1977) for a discussion of biases in contingent valuation studies.

31. op. cit. 28.

32. Tests for “starting point bias” were conducted for all equations (see Schulze and d’Arge, 1977); no significance was found between Contingent Valuation responses and starting bids.

33. Had we have recognized, ex ante, the need to develop frequency estimates, HIRE households would have been included as a part of our Contingent Valuation study.

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APPENDIX A

The purpose of this Appendix is to explain the method used for calculating the task-frequency given in Table 4 of Chapter 4.

A.1 CALCULATING TASK FREQUENCIES FOR DIY HOUSEHOLDS

The B-A report provides mean annual frequencies for 26 cleaning tasks in four pollution zones. These data are given for all surveyed households in B-A's Appendix B.

Of interest here are those mean annual frequencies which apply to "do it yourself" (DIY) households. In B-A's Exhibit III(3), task frequencies (by pollution) for all households performing each task are given, and we are given DIY households performing the task as a percent of all households. These data are used to convert task-frequency measures for total households to those for DIY households as follows.

(a) From B-A's Exhibit III(3), multiplication of column 1 and column 5 yields total households which do each task in each pollution zone; denote this product as X_1. Multiplication of columns 1 and 9 provides the anologous measure for DIY households, denoted X_2. The difference $X_1 - X_2 = X_3$, is the number of non-DIT households that engage in the relevant task.

(b) From Appendix B in the B-A study, we are given mean annual frequencies (for each task in each pollution zone) for households that hire someone else to accomplish the frequencies-noted α_1 for non-DIY households (line 10 in Appendix B).

(c) Let Z_1 denote the total number of times (per year) that a given task is undertaken by the non-DIY households. From the above, it follows that

$$Z_1 = \alpha_1 X_3.$$

The total number of times that the task in question is undertaken by DIY households must then be

$$Z_2 - Z_1 = Z_{DIY},$$

in which case, mean annual frequency for DIY-households, denoted f, is given by

$$f = \frac{Z_{DIY}}{X_2}.$$

APPENDIX B

The purpose of this Appendix is to develop a conceptual argument that provides insights as to behavioral assumptions underlying the Contingent Valuation method outlined in Chapter X.

We begin with the following definitions.

n = number of cleaning operations in a given period

w = time spend per cleaning operation

E = average state of household cleanliness

T = total time available over period for leisure and cleaning

L = leisure time

X = all "other" purchased goods

P_1 = "price"

'2 = out of pocket cost of cleaning, per frequency; i.e. , the "price" of n

B.1 A MODEL OF CONSUMER BEHAVIOR

We consider a utility maximizing individual with utility function of the form U (X, L, E); efforts to maximize utility are constrained by budgeted constraints on time used and income expended; i.e.,

$$T = L + n \cdot w \tag{1}$$

$$Y = P_1 X + nP_2 \tag{2}$$

We assume that E is given by

$$E = f(n \cdot w, P_2 n), \tag{3}$$

where f is production for E.

Substituting (3) into the utility function and letting the Lagrangian be $G = U[X, L, f(nw, nP_2)] + \lambda_1(T - L - nw) + \lambda_2(Y - P_1X - P_2n)$, first order conditions for an interior maximum of U constrainted by (1) and (2) include the following:

$$'_X = \lambda_y P_1 \tag{4}$$

$$'_1 = \lambda_T \tag{5}$$

$$U_E = (hf_1 + P_2 f_2) = \lambda_T w + d_y P_2 \tag{6}$$

$$U_E f_1 = \lambda_T \tag{7}$$

From (2)

$$U_E = \frac{\lambda T}{f_1} \tag{8}$$

while from (6)

$$U_E = \frac{\lambda_1 w + \lambda_2 P_2}{nf_1 + P_2 f_2} \tag{8'}$$

What then is the impact, at the margin, of an increment in E on utility when the consumer is in equilibrium? One can identify two equivalent measures. The first is the marginal utility of time (T) per unit of E that results from an incremented change in a cleaning operation (which involves time and money, f^1). The second, identical measure is the marginal utility of income (λ) per unit of E that results from an incremental change in cleaning operations (f^1), weighted by the unit cleaning operation expenditure (P_2) per unit of time expenditure.

Using (8) in (5), we have

$$U_L = P_2 \frac{\lambda_1}{w} \tag{9}$$

which suggests that, anologous to (4), the marginal utility of leisure involves the price, P_2 and the marginal utility of income which is adjusted to units of time spent per cleaning operation involving the expenditure, P_2. Let us denote this time-adjusted marginal utility of income measure as λ_2. Further, define P_3 as the unit cleaning cost per increment of E **derived** from an incremental change in cleaning operations (f^1). The system (4)-(7) then reduces to the following:

$$u = P_1 \lambda_1 \tag{10}$$

$$'_L = P_2 \lambda_2 \tag{11}$$

$$'_E = P_3 \lambda_2 \tag{12}$$

In general terms, the marginal utility of goods, leisure and average household cleanliness equals the product of their respective unit costs and the marginal utility of income and (for 11 and 12) time.

B.2 THE COMPENSATING VARIATION

The idea of a "compensating variation" was introduced some time ago by Hicks (1956) and has since played a major role in studies concerning measures of gains or losses in social welfare that attend policies which effect prices (see, e.g., Lucas, 1975; Mohring, 1971; and Schulze, 1971), The essense of the compensating variation idea is that, given a fall in price of a "normal" good, thereexists a change in income (dY) at which the consumer would be indifferent between the old income and price level and the new income (Y - dY) and lower price level. Formally, if $U(Y_1 X(p_1))$ is the consumers initial state, $p_2 < p_1$ is the lower price, the compensating variation in income, dY, satisfies the condition:

$$U(Y,X(P_1)) = U(Y-dY,X(P_2)). \tag{13}$$

To apply this notion to the problem of interest here in as simple a way as possible, we ask the reader to accept the notion of a leisure "price" and a cleaning "price" wherein the opportunity of cost of time is embedded in those prices, p_2 and p_3, respectively. The underlying structure for such "prices" is implied by the developments above in section A.

We then posit a utility maximizing consumer who derives utility from three "goods", X_1, X_2, and X_3, where X_1 is the "other goods", X used above, X_2 and X_3 are leisure (L, above) and average household cleanliness (E, above).

Following Mohring (1971), we note that the effect on utility of a change in the price of any of these three goods, e.g. , P_3, is given by

$$\frac{dU}{dP_3} = \sum_{i=1}^{3} \frac{\partial U}{\partial Xi} \frac{\partial Xi}{\partial P_3} ; \tag{14}$$

the impact on income, Y, of the change in P_3 is implicit to this measure, inasmuch as " . . . $\partial X_1/\partial P_3$ is short for $(\partial X_1/\partial P_3)\ Y = Y^*$."

For utility maximization, $\partial U/\partial Xi = \gamma Pi$ (see (4) above). If we substitute this expression in (14) and assume that income is adjusted such that dU/dP_3 is zero, we obtain:

$$\sum_{i=1}^{3} \gamma Pi \frac{\partial Xi}{\partial P_3} = 0 \tag{15}$$

With $y < 0$, the sum in (15) must equal zero as the consumer moves along the indifference surface associated with some level of utility, u*.

With the income constraint $Y = \sum_{i=1}^{3} P_i X_i$, the impact on income from a change in P_3 is given by

$$\frac{dY}{*3} = X_3 + \sum_{i=1}^{2} Pi \frac{\partial Xi}{\partial P_3} \tag{16}$$

which, from (15), implies (with X_3 nonzero)

$$\left(\frac{dY}{dP_3}\right) U = U^* = X_3 \tag{17}$$

The equation (17) is more easily (however, loosely) interpreted as

$$'y = X_3 dP_3 \tag{17'}$$

Thus, the compensating variation in income that would attend a change in P_3 is the change in P_3 times the quantity of good 3 consumed, which is the area under Hick's compensated demand curve (see Hicks, 1956, pp. 74-79).

Of relevance for the subject discussed in Chapter X, the "price" is viewed here as a composite measure which reflects time (time spent per "frequency", frequence per se and the opportunity of time, see (8) and (9) above) and cash outlays. As such, a change in the "price", as would result, e.g., from a change in EPA standards for particulate levels, results in an increase in the consumptionof average household cleanliness (X3), and a reduced leisure-income "price". The value to the individual of such a change can then be measured in one of two ways. First, one may wish to attempt a measure of out of pocket dollar savings, the value of increased average household cleanliness per se (i.e., the consumer surplus a la Watson-Jaksch); this, of course, parallels the B-A approach. Alternatively, one may wish to measure the change in income that would leave the individual's level of satisfaction the same as it would have been without the change in "price". Conceptually, this compensating variation in income would be the individual's maximum willingness to pay for such a change in "price", and this maximum willingness to pay is the measure sought in the Contingent Valuation methodology described in Chapter XI.