AN ANALYSIS OF SEASONAL HOUSEHOLD WASTE GENERATION*

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Solid wastes that are residuals of production and consumption have steadily increased in quantity in recent years. Historically, many of these residuals have been discarded into the environment which appeared to have the capacity to handle them. However, now it is widely believed that these residuals are responsible for the degradation of environment quality by increasing air, water, and land pollution. Ecological considerations have increased the complexity of handling solid wastes and have stimulated the need for alternative methods of managing various types of wastes.

Local and municipal authorities and private industry provide waste collection and disposal services. Municipal services are generally financed out of taxation revenues, so it is in the public's interest to have an efficient, cost-minimizing operation at some publicly acceptable standard of quality of service. Provision of such services and planning for future waste management can be effective only if decision makers have reliable information on waste quantities and how these quantities are likely to change as population grows, and as shifts to higher levels of income and living standards occur.

This paper is concerned with the aggregate solid waste stream for household consumption activities and the factors underlying the volume and seasonal distribution of such wastes. The objectives were to empirically analyze the relationship of quantities of household solid wastes with selected social and economic variables and to examine the seasonality of the household solid waste production process. Underlying these objectives is a need for information on exact volumes and seasonal variations of solid wastes.

THE MODEL

The household is viewed as an appropriate decision-making unit with regard to the generation of solid wastes from consumption activities. Traditional consumer theory ends with the act of consumption, ignoring residuals. Lancaster [2] presented an alternative view that products are demanded because they possess attributes which yield most satisfying characteristics to consumers. Products generally possess more than one characteristic, and any characteristic may be shared by more than one product.[1] The waste residual may be viewed as a characteristic which is inseparable from the product until after the act of consumption. The consumption activity is a transformation of products to characteristics, and solid wastes are a subset of the characteristics.

We can combine Lancaster's approach to consumer theory with the notion of a household utility function as discussed by Becker [1] and Michael [3]. The household maximizes the utility function

(1) $U = f(Z)$

subject to the linear budget constraint

(2) $P'Q = Y$

where

Z is a (sxl) vector of most satisfying characteristics,

P and Q are (nxl) vectors of prices and quantities, and

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[1] The traditional consumer maximization model is a special case in which the number of characteristics is equal to the number of goods [1, p. 136].

Y is the budget or household income.

The transformation of products to characteristics may be represented by

(3) $Z = BC$

where

B is a (sxm) matrix of technical transformation coefficients between consumption and characteristics, and

C is a (mxl) vector of consumption activities chosen to maximize the household utility function.

The types and quantities of goods and the consumption activities are related as follows:

(4) $Q = AC$

where

A is a (nxm) matrix of technical transformation coefficients which relate the type and quantity of goods associated with each consumption activity.

In an analogous manner, the relationship between solid wastes that are residuals of consumption and the consumption activities may be expressed as:

(5) $W = RC$

where

W is a (rxl) vector of the components of solid wastes, and

R is a (rxm) matrix of technical waste transformation coefficients which relate the types and quantities of solid wastes associated with each consumption activity.

The total quantity of solid wastes from consumption produced by a household is the sum of the r elements of the W vector. This may be expressed as follows:

(6) $TW = [1]'W$

where

TW is the total quantity of solid wastes, and

[1] is an (rx1) unit vector.

The primary concern is with the elements of W which are observable and measurable, and with social and ecnomics factors that influence the choice of the consumption activities vector C. In the short run, product prices and technical waste transformation coefficients are assumed constant. The major determinants of household consumption activities in this situation are household income (Y), age structure of households (A), household size (F), and ethnic origin (E). These factors are hypothesized to influence household tastes and preferences and subsequent solid waste loads. The general form of the model is:

(7) $C = f(Y, A, F, E)$.

Substituting into equation (5) yields:

(8) $W = R \cdot f(Y, A, F, E)$

where the elements of R are non-variant. The total solid waste function is:

(9) $TW = g(Y, A, F, E)$

where TW is total solid waste as defined in equation (6).

STATISTICAL MODEL, HYPOTHESES, AND DATA

The statistical model is of a single equation form and is estimated using ordinary least squares estimation procedures. There are 13 equations, one for each four-week period of year, and for the p^{th} period the equation form is:

$$(10)\ TW_p = \beta_0 + \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \beta_6 Z_6 + \beta_7 Z_7 + \epsilon_p$$

where

TW_p = total waste quantity of pounds per household for the p^{th} four-week period ($p = 1, 2, ..., 13$);

Z_1 = median household income for 1969;

Z_2 = median income squared;

Z_3 = household size in numbers of persons;

Z_4 = household size squared;

Z_5 = percent of people of 18 to 61 years of age at June 30, 1970;

Z_6 = percent of black people, and

Z_7 = zero-one dummy variable to identify 1970 from 1971 observations.

β's are regression parameters and ϵ's are stochastic disturbances. Alternate formulations of this model were estimated to further evaluate the performance of explanatory variables and more fully utilize data collected.

The income variable was expected to have a positive coefficient since aggregate consumption increases with income. With rises in income, the demand increases for convenience factors and services embodied in products. It was also hypothesized that consumption increases at a diminishing rate as income rises, i.e., that the marginal propensity to consume declines. This suggests that beyond a certain point, the derived supply of wastes increases at a declining rate with increases in income. The coefficient signs for Z_1 and Z_2 were therefore expected to be positive and negative, respectively.

Larger household size was expected to result in increased quantities of household wastes, because more individuals are included in the decision unit. The coefficient sign for Z_3 was therefore expected to be positive. As household size increases, we hypothesize that total consumption per household increases at a decreasing rate, so the coefficient on Z_4 was expected to be negative. The hypothesis suggests that some items are consumed jointly in larger households.

Age structure was hypothesized to have important impacts on tastes and preferences, and therefore on aggregate waste quantities. It was hypothesized that the individual's consumption bundle and the associated residuals change in quantity over the life span. Total waste generated by the individual was hypothesized to be low in the early stages of life, increase through middle age, then decline in old age.

The ethnic origin variable was included in the model to identify the consequences for waste generation of possible differences between blacks and whites in tastes and preferences and in selection of consumption activities. No prior expectation on the signs for coefficients on this variable was made.

Data for this study was collected in Indianapolis, Ind., and comes from two principal sources, the 1970 census and the collection records of the Solid Waste Division of the Indianapolis Sanitary District. To get a correspondence between waste quantities and census data series, the waste quantity data was aggregated to conform to the boundaries of census tracts from the 1970 census. To aggregate for any census tract, the percent of each collection route population falling in the tract was recorded. These percentages were applied to total collections for that route to derive an estimate of total waste output of the population of that census tract.

Several correspondence problems occurred in the data. Census data was for June 30, 1970, while waste quantity data was for January 1970 to December 1971. Income data is an estimate for 1969 based on sampling rather than full enumeration. No method for correcting these correspondence problems was available.

Each observation covered the population of a census tract. Census tracts varied in size from 150 to 3,000 household units with an average size of about 1,055 households. Since the city collection trucks collect wastes only from single family dwellings and duplexes, census tracts containing one or more apartment complexes were not included in the data base. The total number of census tracts appearing as observations in the data is 33 out of a possible 179 census tracts. For each of these 33 tracts there are 26 waste quantity observations, one for each four-week period from Jan. 1, 1970, to Dec. 31, 1971. There were 66 observations of total waste quantity for each of 13 successive four-week periods of the year. For data and data sources see Richardson [2, pp. 129-142].

THE RESULTS

Seasonal Waste Generation Rates

Average waste quantity results for the period Jan. 1, 1970, to Dec. 31, 1971, appear in Table 1. The largest quantities of wastes occurred in the spring and fall with a slight reduction in quantities in the summer. Lowest rates of total waste generation were in January and February. This seasonal variation in waste quantities appears to be associated with variations in quantities of grass clippings, tree cuttings, and yard wastes in the spring, and with leaves from trees in autumn. The average per period quantity was 115.31 lbs. per household. Waste quantities were lowest for the first 12 weeks (three periods) of the year and highest in periods 6 and 8.

Average total waste quantities per household per period in 1970 and 1971 appear in Table 2. Per period average quantities increased from 108.58 lbs. per household in 1970 to 122.74 lbs. per household in 1971. This is an average increase of 11 percent between 1970 and 1971. Part of this increase resulted from increased waste production per household, and part may be attributed to increased population. The latter effect was not considered in subsequent analysis because only June 30, 1970, census data was available, and the effect may be minimal because only well-established areas of the city, where waste collection routes have changed very little, were included in the total quantity data.

Some differences in the seasonality of total quantity data between 1970 and 1971 can be observed in Table 2. In 1970 the waste production peaks were 130.54 lbs. per household in period 5 and 126.62 lbs. per household in period 8. In 1971, on the other hand, largest quantities of total waste occurred in period 6 (135.24 lbs.) and period 8 (138.98 lbs). Seasonal differences between years may be due to random climatic changes from year to year and their impact on quantities of grass clippings, tree cuttings, and other yard wastes.

Table 1. MEAN AND STANDARD ERRORS OF QUANTITIES OF WASTES COLLECTED FOR SELECTED CENSUS TRACTS IN INDIANAPOLIS, JAN. 1, 1970, TO DEC. 31, 1971

	Per Person		Per Household	
Period[a]	Mean	Standard Error	Mean	Standard Error
		(P O U N D S)		
Jan. 1 - Jan. 28	28.75	6.77	82.30	18.20
Jan. 29 - Feb. 25	30.96	5.92	88.72	15.33
Feb. 26 - March 25	34.64	6.84	99.12	17.12
March 26 - April 23	41.48	7.79	118.66	18.67
April 24 - May 19	44.49	8.88	127.06	21.12
May 20 - June 17	45.55	10.32	129.98	24.87
June 18 - July 15	42.90	9.04	122.50	21.86
July 16 - Aug. 12	45.91	9.26	131.05	21.59
Aug. 13 - Sept. 9	44.41	9.19	126.87	22.45
Sept. 10 - Oct. 7	43.36	9.65	123.80	23.71
Oct. 8 - Nov. 4	43.52	9.51	124.28	23.29
Nov. 5 - Dec. 2	41.91	9.51	119.64	22.91
Dec. 3 - Dec. 31	36.74	8.03	105.05	20.73
Average Per Period	40.36	8.52	115.31	20.91

[a]Each period covers four weeks and involves four separate waste collections for each household.

Estimated Equation Results

Multiple linear regression equations were estimated for each of 13 periods of the year. Results of two alternate model formulations appear in Tables 3 and 4. Table 3 contains results for a model including quadratic terms for income and household size. In Table 4 these two terms are deleted from the model. In both models, linear income and household size terms are measured in deviations from the mean. This was done to avoid problems of multicollinearity due to the high correlation of linear and quadratic terms when the quadratic terms were included in the model. Coefficient magnitudes are not changed by this variable definition, but solving the equations requires coding of values for independent variables.

In Table 3 the estimated coefficients, standard errors, coefficients of determination (R^2), coefficients of determination corrected for the degrees of freedom ($\bar{R}^2$) and F value for tests of significance are presented. These results indicate a generally low level of explanation as measured by the R^2. Values of R^2 range from .23 in period 2 to .51 in period 10. Based on an F test at the .05 level of significance, all equations except the one for period 2 explain significant amounts of variation in total waste quantities. The explanatory power of the equations

Table 2. **MEAN QUANTITIES OF WASTES PER HOUSEHOLD PER FOUR-WEEK PERIOD COLLECTED FOR SELECTED CENSUS TRACTS IN INDIANAPOLIS IN 1970 AND 1971**

Period	1970 Quantities	1971 Quantities
	(pounds)	(pounds)
Jan. 1 - Jan. 28	72.53	92.53
Jan. 29 - Feb. 25	82.86	94.58
Feb. 26 - March 25	90.31	107.93
March 26 - April 23	112.88	124.45
April 24 - May 19	130.54	123.57
May 20 - June 17	124.74	135.24
June 18 - July 15	113.24	131.77
July 16 - Aug. 12	126.62	138.98
Aug. 13 - Sept. 9	117.86	135.88
Sept. 10 - Oct. 7	111.54	136.06
Oct. 8 - Nov. 4	115.22	133.34
Nov. 5 - Dec. 2	113.00	126.29
Dec. 3 - Dec. 31	95.14	114.96
Average Per Period	108.58	122.74

may be acceptable, given that the data are cross sectional, but the predictive power of equations exhibiting such a large amount of unexplained variation in the dependent variable is questionable.

An alternate form of the model, in which the quadratic terms for income and household size were deleted from the previous model, is presented in Table 4. In this form of the model, explanatory power based on R^2 is generally lower than for the previous model and ranges from .19 in period 2 to .45 in period 10. The F test indicates that the explanatory power is significant at the .05 level for all equations.

Deletion of the quadratic terms from the model did not greatly change the results. Intercept terms were lowered in value for all equations, indicating a shift in the level of the regression surface. The magnitude of the income coefficient also was reduced by the deletion of quadratic terms. Household size and percent black, on the other hand, had larger (i.e., mory positive) coefficient values when the quadratic terms were deleted. The zero-one variable for the year has zero correlation with other variables, and coefficient magnitudes are unchanged between the alternate models.[2]

Results in Tables 3 and 4 were used to test

[2]The year variable is almost orthogonal with respect to all other exogenous variables, as its gross correlation with them is .00000000 in all cases.

Table 3. **ESTIMATED COEFFICIENTS, STANDARD ERRORS AND COEFFICIENTS OF DETERMINATION FOR TOTAL WASTE QUANTITY EQUATIONS-MODEL 1**

Equation Number	Intercept	Household Income	Household Income Squared	Household Size	Household Size Squared
1	19.8887	2.7114 (1.3057)**	.0551 (.4711)	3.5375 (6.8926)	-32.6222 (15.4678)**
2	59.6199	.8197 (1.3129)	-.3752 (.4736)	5.0476 (6.9303)	-22.5731 (15.5523)
3	62.6305	2.2427 (1.2944)*	-.5066 (.4670)	-1.4779 (6.8327)	-32.5559 (15.3333)**
4	76.6646	3.2239 (1.5348)**	.1143 (.5537)	-3.1511 (8.1017)	-47.4052 (18.1811)**
5	67.2070	7.4842 (1.4653)**	.0755 (.5286)	-5.1888 (7.7350)	-49.9376 (17.3583)**
6	94.6435	9.5157 (1.7811)**	.1415 (.6426)	-9.0183 (9.4022)	-55.8298 (21.0995)**
7	67.7651	5.9207 (1.5674)**	-.1877 (.5655)	-6.0965 (8.2736)	-47.8536 (18.5669)**
8	93.7615	6.1050 (1.6955)**	-.3379 (.6617)	-4.3206 (8.9498)	-34.8088 (20.0844)*
9	72.3390	5.5443 (1.6680)**	-.3393 (.6018)	-.7451 (8.8048)	-41.7566 (19.7589)**
10	68.8002	5.4322 (1.6096)**	-.4883 (.5807)	-4.0304 (8.4966)	-54.1263 (19.0673)**
11	89.0031	7.5857 (1.6293)**	-.3531 (.5878)	-6.7314 (8.6005)	-56.8946 (19.3005)**
12	81.7251	7.8269 (1.5971)**	-.2926 (.5762)	-8.8069 (8.4308)	-65.0887 (18.9196)**
13	51.6350	5.1719 (1.4492)**	.2794 (.5228)	-.6754 (7.6500)	-49.5964 (17.1675)**

Table 3. **Continued**

Equation Number	Percent 18-61	Percent Black	Year	R^2	$\bar{R}^2$ [a/]	F [b/]
1	1.0487 (.5487)*	.0976 (.0604)	19.5482 (3.4932)**	.46	.40	7.00**
2	.5007 (.5517)	.0532 (.0607)	11.7206 (3.5123)**	.23	.15	2.43**
3	.5587 (.5440)	.1364 (.0599)**	17.6209 (3.4629)**	.40	.34	5.47**
4	.6911 (.6450)	.1708 (.0710)**	11.5745 (4.1060)**	.29	.22	3.35**
5	1.2011 (.6158)*	.2292 (.0678)**	-6.9712 (3.9202)*	.49	.44	8.05**
6	.5397 (.7485)	.2299 (.0824)**	10.5294 (4.7651)**	.46	.40	7.04**
7	.8882 (.6587)	.1866 (.0725)**	18.5303 (4.1931)**	.46	.40	7.01**
8	.6190 (.7125)	.1359 (.0784)*	12.5245 (4.5358)**	.35	.28	4.47**
9	.9440 (.7010)	.1152 (.0772)	18.0212 (4.4623)**	.42	.36	5.96**
10	.9243 (.6764)	.1096 (.0775)	24.5236 (4.3061)**	.51	.46	8.77**

Table 3. **Continued**

Equation Number	Percent 18-61	Percent Black	Year	R^2	$\bar{R}^{2}$ [a]	F [b]
11	.5343 (.6847)	.1828 (.0754)**	18.1200 (4.3588)**	.48	.43	7.78**
12	.6660 (.6712)	.1593 (.0739)**	13.2897 (4.2728)**	.49	.44	7.89**
13	.8444 (.6090)	.1518 (.0671)**	19.8164 (3.8771)**	.49	.43	7.81**

**Significant at the .05 level (t = 1.96 with 58 degrees of freedom)

*Significant at the .10 level (t = 1.65 with 58 degrees of freedom)

[a] $\bar{R}^2$ is R^2 corrected for the degrees of freedom. It is computed using the fomula

$$\bar{R}^2 = 1 - \frac{n-1}{n-k-1}(1 - R^2)$$

where n = number of observations and K = number of independent variables.

[b] The F value for significance at the .05 level with (7, 58) degrees of freedom is 2.17.

Table 4. **ESTIMATED COEFFICIENTS, STANDARD ERRORS, AND COEFFICIENTS OF DETERMINATION FOR TOTAL WASTE QUANTITY EQUATIONS - MODEL 2**

Equation Number	Intercept	Household Income	Household Size	Percent 18-61	Percent Black	Year	R^2	$\bar{R}^2$	F
1	15.4740	1.9103 (1.2782)	6.1555 (6.5379)	1.0980 (.5558)**	.0653 (.0559)	19.5482 (3.5700)**	.41	.38	8.48**
2	52.8779	.2898 (1.2621)	8.5896 (6.4550)	.5905 (.5488)	.1157 (.0552)	11.7206 (3.5247)**	.19	.14	2.90**
3	53.2144	1.4764 (1.2712)	3.4864 (6.5019)	.6836 (.5527)	.0836 (.0556)	17.6209 (3.5503)**	.34	.30	6.32**
4	70.5543	2.0577 (1.5327)	.5102 (7.8391)	.7580 (.6664)	.1251 (.0671)*	11.5745 (4.2805)**	.20	.15	2.99**
5	60.3698	6.2584 (1.4795)**	-1.1440 (7.4572)	1.2776 (.6433)**	.1795 (.0647)**	-6.9712 (4.1320)*	.42	.38	8.59**
6	87.5126	8.1418 (1.7818)**	-4.7370 (9.1134)	.6175 (.7748)	.1764 (.0780)**	10.5294 (4.9763)**	.39	.35	7.67**
7	58.8929	4.7615 (1.5585)**	-1.1315 (7.9712)	.9966 (.6777)	.1293 (.0682)*	(18.5303) (4.3526)**	.40	.36	7.87**
8	85.5118	5.2737 (1.6387)**	.1339 (8.3811)	.7251 (.7125)	.0869 (.0717)	12.5245 (4.5764)	.32	.27	5.54**
9	62.4965	4.5467 (1.6317)**	4.5732 (8.3454)	1.0704 (.7095)	.0567 (.0714)	18.0212 (4.5569)	.37	.33	7.13**
10	56.3031	4.1373 (1.6196)**	2.7409 (8.2839)	1.0842 (.7042)	.0347 (.0709)	24.5236 (4.5233)**	.45	.41	9.64**

Table 4. Continued

Equation Number	Intercept	Household Income	Household Size	Percent 18-61	Percent Black	Year	R^2	$\bar{R}^2$	F
11	77.2960	6.2151 (1.6456)	-.2846 (8.4167)	.6808 (.7155)	.1100 (.0720)	18.1200 (4.5959)**	.41	.37	8.23**
12	69.3245	6.2523 (1.6506)**	-1.8974 (8.4422)	.8186 (.7177)	.0801 (.0722)	13.2897 (4.6098)**	.38	.34	7.46**
13	46.6675	3.9424 (1.4712)**	2.4862 (7.5245)	.8928 (.6397)	.1099 (.0644)*	19.8164 (4.1087)**	.40	.36	8.06**

**Significant at the .05 level (t = 1.96 with 60 degrees of freedom).

*Significant at the .10 level (t = 1.65 with 60 degrees of freedom).

[a] $\bar{R}^2$ is R^2 corrected for the degrees of freedom. It is computed using the formula $\bar{R}^2 = 1 - \frac{n-1}{n-k-1}(1 - R^2)$ where n = number of observations and K = number of independent variables.

[b] The F value for significance at the .05 level with (5, 60) degrees of freedom is 2.37.

hypotheses about factors underlying the total waste generation process. Both sets of results confirm the hypothesis that a positive relationship exists between income levels and waste generation rates. The coefficient of the linear income term has the hypothesized positive sign in all equations, and for 12 equations in Model 1 and nine equations in Model 2, is significant at the .05 level based on a t-test.[3] The hypothesis that marginal waste loads decline with increases in income, a phenomenon analogous to the hypothesis of a declining marginal propensity to consume waste-producing products, is not clearly supported by these results. The quadratic term has a negative coefficient in eight of the 13 equations as hypothesized, but is never significant at the .05 level based on a t-test. This result may have occurred because the data did not have sufficient observations at higher levels of income to identify such declining marginal waste loads; such a hypothesized relationship may therefore exist outside the range of the data used in this study. These data do, however, indicate a strong linear relationship of waste quantities to income levels.

Tests of hypotheses about the impact of household size on the waste load are contained in linear and quadratic measures of household size. The results suggest that househola size has an important impact on waste loads and that this impact enters primarily through the quadratic term. The linear term never has a significant coefficient based on a t-test, even at the .10 level of significance, although it has the hypothesized positive coefficient sign for eight of the 13 equations in Model 2. The quadratic term for household size in Model 1 has the hypothesized negative sign in all 13 equations, is significant at the .05 level based on a t-test in 11 of these equations, at the .10 level in one equation, and is nonsignificant in one equation. Results indicate that the hypothesis concerning the effect of household size on waste quantities is supported up to about the mean value of household size (2.89 persons); even though the linear term is frequently negative, the overall value of the two terms is positive. Beyond the mean of the household size variable, the hypothesis of declining marginal waste load is not supported by these results. The results suggest that the marginal waste load at higher household size levels is negative.

The impact of age structure on waste production rates per household was included in the model to test the hypothesis that a waste production cycle is associated with the human life cycle. Age structure as measured by the percent of people from 18 to 61 years of age generally does not enter as a significant variable. Based on a t-test, the coefficient of the percent of age 18 to 61 is significant at the .10 level for two of the 13 equations in each model, and the sign of all coefficients is positive as hypothesized. These results thus reject the hypothesis that a cycle of waste generation rates exists in correspondence with the human life cycle. This result may be partly attributable to the broad nature of the variable definition. More refined measures of age structure were attempted in statistical estimation. Such measures involved the use of three or four age structure class variables together. High levels of correlation between these age structure variables and

[3] Model 1 refers to the results in Table 3, and Model 2 refers to results in Table 4.

between some age structure variables and household size presented a multicollinearity problem that precludes interpretation of individual coefficients. Models of a cross sectional type with a large amount of unexplained variation appear to be especially susceptible to such multicollinearity problems.

Percent of black people was included in the models to test the hypothesis that black and white people have different tastes and preferences in consumption and that this has impacts on the quantity of wastes generated. The coefficient of this variable is positive in all equations estimated and based on a t-test significant at the .10 level of nine equations in Model 1 and five equations in Model 2.

The zero-one variable for year of observation has a significant coefficient at the .05 level based on a t-test and has a positive sign for 12 of the 13 equations estimated in each model. The coefficient of this variable indicates the change in waste generation between the two years covered by the data. The single negative coefficient sign may be due to random climatic factors between 1970 and 1971.

In both models presented, there appears to be systematic variation, between equations, in the independent variable coefficients. A one-sample runs test was conducted to test the hypothesis of randomness between the coefficients on any independent variable between equations. This is a non-parametric test, and its use is discussed by Siegel [4]. Tests of this kind are not powerful relative to parametric tests, and therefore tend to be conservative. This means that the test is unlikely to falsely reject the null hypothesis of randomness among the coefficients.

The one-sample runs test is based on the number of runs which a sample exhibits. A run is defined as a succession of values which appear to be associated over time relative to a mean value. The occurrence of very few runs indicates a lack of randomness. The expected value of r, the number of runs, is known and tabulated for critical values of n_1 and n_2, the numbers of coefficients greater than, and less than, the mean, respectively, at the .05 level of significance [4, p. 252].

Results of the test on coefficients in Models 1 and 2 are contained in Appendix Tables A-1 and A-2. At the .05 level of significance, the null hypothesis of randomness between coefficients was rejected for the linear income term in Model 1 and the income term in Model 2. For all other variables in the models presented, the test results indicate acceptance of the null hypothesis of randomness between coefficients. On the basis of a one-sample runs test, it was concluded that a seasonal pattern exists in the income variable coefficient.

The significance and magnitude of the income coefficient varied systematically between equations, suggesting that the role of the income variable was seasonal. The first four periods of the year have "less" significant or nonsignificant coefficients on the income term; highest values of the coefficient for these periods are 3.22 in Model 1 and 2.06 in Model 2. The remaining nine periods of the year all have significant income coefficients in both model formulations; in Model 1, values of the coefficient range from 5.17 to 9.52, and in Model 2 from 3.94 to 8.14 for periods 5 to 13. These significant terms and their larger magnitudes are generally associated with periods of the year when grass and tree cuttings and yard wastes are the highest. This suggests, as one would expect, that higher income is associated with large yard and garden areas and a lower density of housing.

CONCLUSIONS AND IMPLICATIONS

This study was an attempt to analyze statistically the socioeconomic factors associated with variations in the aggregate supply of wastes. Income and household size were the most significant factors affecting the quantity of solid wastes from household consumption. The yearly zero-one variable indicated a significant increase in waste quantities between 1970 and 1971; such a variable, however, yields no information on the causes of this increase. The study indicates that waste loads will continue to increase in the future, and expanded collection and disposal will be needed.

The significant income coefficients suggest that future increases in income will result in an increasing supply of household wastes. There is also a significant seasonal waste load variation observed between equations. This variation is associated with levels of income; total waste load is larger in higher income areas, and also has a larger seasonal variation. These results indicate that higher income areas of the city put the most absolute and seasonal stress on the collection and disposal system. These results should help waste managers to plan expanded collection and disposal operations. They also may be of importance in the determination of collection route sizes and waste volumes from various parts of the city at various times of the year.

The significant household size coefficients suggest that, with increases in household size, waste quantities increase up to the mean of the household size data (2.89 persons per household), and thereafter decline in absolute value. Further research is required to verify this conclusion, since the data came from well-established neighborhoods with primarily single unit or duplex housing. Growth areas of the city and areas where there are apartment complexes may have different household sizes and waste production patterns .

The urban population is a dynamically changing, waste-producing population in which total population, incomes, household size, and tastes and preferences, and the implied residuals are constantly changing. The aggregation level in the data for this study was 3,050 people, or about 1,055 households per observation. No measures of variation about the mean of the variables were available for use in the models estimated. Use of less aggregated data may reduce within-observation variance and increase the explanatory power of the equations. It also would permit the testing of alternate hypotheses about the nature of the waste generation process.

Conclusions based on the above results should be regarded as tentative, and further research is required to identify major social and economic factors associated with the quantity of household wastes generated. Waste management is one of the important areas of environmental quality causing public concern. It is a relatively new area of study for applied economists and offers a challenge to use our tools of analysis to contribute to the solution of a social problem.

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Table A-1. **RESULTS OF A ONE-SAMPLE RUNS TEST FOR RANDOMNESS OF COEFFICIENT VALUES BETWEEN REGRESSION COEFFICIENTS IN SUCCESSIVE EQUATIONS; TOTAL QUANTITY MODEL 1.**[a]

Equation Number	Income	Income Squared	Household Size	Household Size Squared	Percent 18-61	Percent Black	Year
1	-	+	+	+	+	-	+
2	-	-	+	+	-	-	-
3	-	-	+	+	-	-	-
4	-	+	+	-	-	+	-
5	+	+	-	-	+	+	-
6	+	+	-	-	-	+	-
7	+	-	-	-	+	+	+
8	+	-	-	+	-	-	-
9	+	-	+	+	+	-	+
10	+	-	-	-	+	-	+
11	+	-	-	-	-	+	+
12	+	-	-	-	-	+	-
13	-	+	+	-	+	+	+
Mean of Coefficients	5.3500	-.1704	-.32040	-45.4650	.7660	.1510	15.5220
n_1	8	5	6	5	6	7	7
n_2	5	8	7	8	7	6	6
r	2**	4	4	4	8	4	8

[a]Signs in the body of the table indicate magnitude of the coefficient relative to the mean of the 13 coefficients. Values at the bottom of the table are:

n_1 = number of positive signs,
n_2 = number of negative signs, and
r = number of runs of positive or negative signs. Where equations 1 and 13 have the same signs, they are considered part of the same run, since equation 13 is the last period of the year and equation 1 is the first period of the year.

**Indicates significance at the .05 level on the runs test. The critical value in all cases is $r \leqslant 3$.

Table A-2. **RESULTS OF A ONE-SAMPLE RUNS TEST FOR RANDOMNESS OF COEFFICIENT VALUES BETWEEN REGRESSION COEFFICIENTS IN SUCCESSIVE EQUATIONS; TOTAL QUANTITY MODEL 2.**[a]

Equation Number	Income	Household Size	Percent 18-61	Percent Black	Year
1	-	+	+	-	+
2	-	+	-	+	-
3	-	+	-	-	+
4	-	-	-	+	-
5	+	-	+	+	-
6	+	-	+	+	-
7	+	-	+	+	+
8	+	-	-	-	-
9	+	+	+	-	+
10	-	+	+	-	+
11	+	-	-	+	+
12	+	-	-	-	-
13	-	+	+	+	+
Mean of Coefficients	4.2510	1.4986	.8687	.1041	14.5268
n_1	7	6	6	7	7
n_2	6	7	7	6	6
r	3**	4	8	8	8

[a]Signs in the body of the table indicate magnitude of the coefficient relative to the mean of the 13 coefficients. Values at the bottom of the table are:

n_1 = number of positive signs,
n_2 = number of negative signs, and
r = number of runs of positive or negative signs. Where equations 1 and 13 have the same signs, they are considered part of the same run, since equation 13 is the last period of the year and equation 1 is the first period of the year.

**Indicates significance at the .05 level on the runs test. The critical value in all cases is $r \leqslant 3$.