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FORECASTING THE COMPOSITION AND WEIGHT OF HOUSEHOLD SOLID WASTES -- An Executive Summary

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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FORECASTING THE COMPOSITION AND WEIGHT OF HOUSEHOLD SOLID WASTES USING INPUT-OUTPUT TECHNIQUES

An Executive Summary

by

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DISCLAIMER

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communication link between the researcher of the user community.

A new approach is explored for determining not only the current status but also the probable effects of new government policies or other significant economic developments on the quantity and composition of household solid waste and the implications for resource recovery. The potential of the input-output model for forecasting is discussed and results are compared with several other studies. It is hoped that the methodology and results of this study will provide planners and policymakers with additional information for efficient management of the increasing quantities of household solid waste.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

ABSTRACT

After a critique of previous methods for assessing household solid waste generation, an improved input-output model based on transactions among industries and other sectors of the economy is presented. The various adjustments and assumptions necessary in this model are explained along with its basic concept of "path products" for long-term estimation of household solid waste. The model is tested with industrial production data from earlier years and projects the household waste producing inputs for 1985.

The integration of this method of manipulating industrial production data with the INFORUM model of economic growth is shown to be a module available for the Strategic Environmental Assessment System of the Environmental Protection Agency that would have value for planning for resource recovery efforts and management of household solid waste.

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ACKNOWLEDGEMENTS

The research reported in this publication was taken from a more extensive report entitled, Forecasting the Composition and Weight of Household Solid Wastes Using Input-Output Techniques, prepared by International Research and Technology Corporation (IR&T) of Arlington, Virginia (EPA Contract No. 68-03-0261, Stedman B. Nobel, project manager). The full report is available in two volumes from the National Technical Information Service (NTIS), U.S. Department of Commerce. Volume I, PB 257 499/AS; Vol II (appendix), PB 257 500/AS.

Dr. David Kidder, assisted by Guy Hudgins, prepared this executive summary of the original report. Ebon Research Systems wishes to express thanks for the support of the EPA Project Officer, Oscar Albrecht of the Municipal Environmental Research Laboratory, Environmental Research Center, Cincinnati, Ohio.

INTRODUCTION

Effective planning for solid waste management and resource recovery has been hampered by serious problems in prior models for predicting household waste. Methodological limitations in past studies produced inadequate data for long-term forecasting of waste levels. This particular weakness presented a major problem since accurate quantitative predictions of specific materials is essential for useful planning. Furthermore, earlier studies neglected to incorporate methods for controlling such variables as income changes over time, family size, new packaging technologies and other phenomena in calculating long-range solid waste estimates.

The economic model described in this study allows the user to make more realistic predictions about the quantity and composition of household solid waste than was previously available. In addition to showing the levels of future household purchases and the quantities of particular materials embodied in the products discarded by households, the report introduces a methodology for accounting for other relevant variables in the model.

By applying the techniques of input-output analysis to the study of solid waste generation by households, the study used data collected in 1958 to 1964 to prepare estimates of waste by product group for 1971. Forecasts of solid waste generation for 1985 were made using the input-output type coefficients and the production forecasts from the INFORUM model of sectoral growth.

The IR&T estimates for 1971 showed that paper and metals were the components of household and commercial wastes, contributing 41.0 and 37.5 million metric tons respectively. Glass contributed 12.5 million, and the combination of plastics, textiles, wood and rubber contributed approximately 18 million metric tons. [p.83 of IR&T Report]

The forecast of growth in consumer expenditures and resulting waste between 1971 and 1985 was considerable for most product categories included in the study. For some product categories, the forecasts were subject to prediction errors resulting from the aggregation of sectoral data and weaknesses in productivity forecasts.

RATIONALE FOR THE STUDY

This study tested the feasibility of using input-output analysis among numerous industries to estimate and project the future volume of household wastes. Moreover, it compared input-output to other methods for estimation and projection of waste volume. The quantity and composition of household solid waste were forecasted to 1985 using (1) a model for the economy described in terms of materials embodied in products purchased by households as a baseline, and (2) INFORUM model's extrapolations of inter-industry coefficients. If the input-output system documented by this study proves useful, it can provide a "module" in the Strategic Environmental Assessment System [SEAS] of EPA that would forecast solid waste production in the future.

THE NATURE OF INPUT-OUTPUT ANALYSIS

Input-output analysis looks at the inter-relationships among (1) industries as producers, and (2) users of raw materials and semi-finished goods. It also shows inter-relationships among industries and users -- households, capital goods buyers, governments and foreign buyers -- of final products. The structure of inter-relationships among sectors is defined in a variety of ways:

1. the dollar values of goods flowing from INDUSTRY A to INDUSTRY B or from INDUSTRY A to FINAL USE;
2. the ratios of INDUSTRY A's product used to make a dollar's worth of B's product. These are the "technical coefficients" that, along with other industry input coefficients, comprise the components of INDUSTRY B's production technology and
3. the multiplier values that show the total direct and indirect impact of a specific dollar value of final use (or a change in this value) on production volumes. These values result from an "inversion" of any array of technical coefficients that describe production technologies for an entire economy.

In order to illustrate input-output analysis, consider machine tools as they relate to production. Machine tools are a component part of the manufacturing process in many industries. Along the "row" of machine tool technical coefficients, one usually finds high coefficients between the machine tool and other industries, and a low coefficient relating machine tools to household use. The direct effect of an increase in final demand by households on machine tools would depend on the size of the coefficient:

$$\frac{\text{"machine tools — household"}}{\text{total machine tools production}}$$

But the total effective change in machine tool production would depend on all the relationships specified as occurring among industries. For example, automobiles require more machine tools, according to the coefficient:

$$\frac{\text{"machine tools -- autos"}}{\text{total machine tools}} .$$

Machine tools use steel; therefore, higher production levels in machine tools will lead to more orders and increased production in the steel industry. Other "ripple effects" that create business for machine tools add to a multiplied indirect effect on production. The final total effect of a dollar's increase in household demand on machine tool production will include the dollar value of additional tools bought by households and the total increase in machine tool sales to other industires.

A complete set of technological coefficients and associated multiplier values similar to those included in this study can provide the user with a tool that satisfies two goals: (1) it shows how projected increases in final demand expand production requirements in the related industries, and (2) it gives a structure for analysis that is adaptable to adjustment and change if necessary.

Although an input-output table identifies money flows among sectors, by a series of adjustments it is possibe to convert the model for use in estimating flows of physical product weights and the technical coefficients that reflect these flows. In this form, waste volume estimation for industries, households and the commercial sector becomes feasible.

METHODOLOGY

This study used a "minimal adjustment" approach to convert the basic input-output system from a description of market value relationships to a description of flows of product by weight among sectors. Further adjustments, beyond the minimum, were subsequently made to increase estimating accuracy and realism in the model's structure.

MINIMAL ADJUSTMENTS

The analysis identified 16 two-digit industries (classified by the Department of Commerce's SIC codes) plus two one-digit industries (wool and cotton) as major producers of outputs that would become household waste. "Final use" waste included waste from the commercial sector, wholesale and retail trades. The primary goal of minimal adjustment was to show how much poundage of each product group becomes embodied in products that households buy and discard.

The input-output bench mark figures used in computations were from the INFORUM model, developed at the University of Maryland, that included 182 separately-identified industries. The model's technical coefficients were adjusted to calculate physical flows in pounds or tons (all values were divided by unit prices). Input flows not embodied in the weight of the products used by households and flows to users other than households or the commercial sector were removed. For example, service inputs that have no effect on the disposal of a final product that used them were excluded.

From the adjusted technical coefficients, multiplier values were computed by summing (for each industry) all of the possible direct and indirect ways the industry's products could be embodied in the weight of the products used by households. This approach was referred to as computation by path products. Utilizing this technique, various paths by which a product could enter final consumption were specified. Fiber, for instance, could enter final consumption by the path as input embodied in clothing or by the path as input in automobile upholstery.

Using the truncation principle, the study computed 1700 significant paths. However, it was found that 214 paths accounted for approximately 75% of all output finally purchased by households. These 214 major paths were subjected to analysis for proration errors, and it was found that about 85 had no substantial error from this source. The major proration errors encountered were in plastics, fibers and non-ferrous metals.

The study stressed, throughout the analysis of errors, that thoroughly accurate corrections were not currently possible, given the form in which industry production and sales data were collected and presented. It was important to attempt corrections that could be done with some precision and to stress the type and direction of bias to be expected when quantitative changes proved impossible.

FURTHER ADJUSTMENTS

The minimally-adjusted model previously described provided an appropriate basis for the analysis, but contained a number of weaknesses that were either corrected or noted in the report. Whenever possible, the necessary corrections were made before arriving at final estimates in the study.

Many of the problems that arise in using input-output analysis for any purpose result from excessive aggregation of industry data. When describing waste generation, this is particularly true. For instance, at the two-digit level an input from one industry enters production of another in fixed proportion. In actuality, the purchasing industry may make a variety of products which use different proportions of the input it purchases. Consequently, fixed proration may cause inaccuracy in forecasting, expecially if the goods sold by the input-purchasing industry should change. Metal cans provide an example of this situation. Cans used for some purposes include a high proportion of aluminum, but for other uses different metals are preferred. Furthermore, different users of an input may not pay the same unit prices. Again, because data relative to input are too gross (e.g. "steel" rather than steel by specific grade), an adjustment that uses a single unit price of steel to convert money values to physical values will lead to misrepresentations. (A full adjustment incorporates information about price differentials when they are available.)

Assumptions about the manner in which a product is wasted may also lead to inaccuracies in the model. For instance, a car battery may be saved even though the owner scraps the car. The same kind of problem occurs in the industrial sector when some inputs sold are embodied in final product weight and some are not embodied in the final product weight. Two-digit aggregation forces the user to discard these industries or to use them and accept the resulting lack of accuracy. Informed judgment is required to adjust for errors resulting from misleading representations by the model regarding the way final products are wasted.

In developing final estimates, this study recognized the existence of such aggregation problems and attempted to make adjustments where data permitted the correction. Some problems, such as the proration of highly specialized inputs, were intractable (given the way current data are gathered). Plastics, fibers and metals estimates appeared to suffer most from the assumption of rigid proration.

THE PRODUCTION FORECASTING MODEL

To generate forecasts of solid waste weight and composition, IR&T considered a number of economic models constructed by governmental agencies and private firms. It was decided that INFORUM and the Inter-Agency Growth Model used by the Federal Government presented the details needed for analysis of household waste. The following were offered as the advantages of the INFORUM model:

1. INFORUM was part of the EPA's long-range forecasting tool, the SEAS;
2. INFORUM was free to projects sponsored or supported by EPA;
3. INFORUM forecasted 133 separate consumption categories compared with 82 by the Inter-Agency Growth Model. In addition, INFORUM's input-output table details 182 sectors compared with 129 for the Inter-Agency Model;
4. the interdependence of income, desire to work and spend, and productivity was spelled out in the INFORUM model;
5. the INFORUM model has been "purified" to eliminate inconsistencies caused by aggregation of sectors;
6. since the assumptions INFORUM's builders used were explicit, it would be possible for another user to alter the assumptions and check the sensitivity of predictions for a variety of ways of looking at the world and
7. INFORUM made projections of input-output coefficients over time.

Some large coefficients in INFORUM were projected individually. The coefficients used to describe the use of some metal in auto production is representative of an individual projection. Other projections were made "across the row". An example of the latter projection is that it seemed generally true that less cotton would be used in production, and therefore the cotton input coefficients for all industries were reduced by a constant proportion that generally extrapolated a past trend. The extrapolations permit an increase or decrease in the rate of change, but no trend reversal. The weakness of this approach is apparent when one considers that in the long-run material substitutions do occur and consumption patterns also change.

INFORUM's basic data on personal consumption expenditures came from Census of Manufactures' yearly figures from 1958 to 1971. Data from 1958 to 1964 were used to estimate statistically how consumption should relate to other "explaining" factors.

The assumed relationships were basically of two types. In one instance, changes in consumption were related to earlier changes in income, assuming that it takes some time to adjust spending patterns to new living standards. The second type of relationship added the assumption that installment buying could break down the income-expenditure link and cause some over-reaction in spending to changes in income. These relationships, based on time series spending-income data, were checked against cross-section budget data that looked at how families at different income levels made expenditures. In the final analysis, predictions for specific spending categories were based on (1) information derived from time series and cross-section data and (2) from a careful reading of "what works" in a particular forecasting exercise.

The study attempted to take into account productivity forecasts using techniques developed by the U.S. Department of Labor, Bureau of Labor Statistics in The Structure of the U.S. Economy in 1980 and 1985 (1975). This publication was based on the Inter-Agency Growth Model projections. The underlying rationale for productivity estimates was the supply of workers available to the economy over the relevant time period. Steps used by the Labor Department included the following:

1. estimation of base line numbers of U.S. Citizens of working age and Census projections of populations to 1985;
2. estimation of base line labor force participation rates, for the appropriate age categories. Projections of these rates were more difficult to obtain than projections of the working age population because participation habits have changed for both men and women;
3. adjustments for normal unemployment. Recent years have demonstrated that a "normal" level of unemployment, consistent with a reasonable level of mobility among jobs and an acceptable break-in period for inexperienced new job seekers (e.g. teenagers) is difficult to define and
4. projection of average wages. What the employed worker in 1985 will have available for spending depends, in part, on productivity since incomes that the economy makes available derive basically from productive activity. Productivity forecasting is a difficult art, however, the long-run trend of 3-4% a year has been used often as a bench mark. INFORUM projections tended to be pessimistic about productivity growth and, by implication, slower growth in the income-spending-waste generation system in the near future. This was based on the INFORUM assumption that two well-established trends would continue:

    (1) more spending for services rather than consumer and producer durables. Productivity was difficult to measure in services but all indications suggest that productivity will grow slowly in this very labor-intensive sector and
    (2) labor productivity increased at a decreasing rate in all

sectors in the 1970's after a rapid increase in the 1960's.

FINDINGS

The IR&T study provided estimates of 1971 solid waste and forecasts of 1985 waste. In addition, "path products" that related materials to household waste were computed. The forecasts by INFORUM and the Inter-Agency Growth Model were used to make projections of the weight and composition of 1985 waste.

Figure 1 compares 1971 estimates of household and commercial waste with estimates resulting from two other studies. In order to make this comparison possible, some of the industry-level detail in the IR&T study had to be sacrificed. There was considerable agreement among the three studies on waste estimates by industry, except for a sizeable difference in the "metals" sector. IR&T's estimate of 37.5 million metric tons of scrap metal was considerably higher than the 8.1 and 10.8 million metric tons shown by the other studies. Paper scrap was estimated at 41 million metric tons by IR&T, compared with 34.6 and 35.5 by NCRR and EPA. There was general agreement on glass, plastic, textiles and rubber that contributed less to waste, but some divergence on wood (IR&T's 9.9 million metric tons, compared with EPA's 4.2).

Figure 2 shows waste producing input estimates for 1971 and forecasts for 1985. The estimates of "waste" as defined took into account the fact that time from purchase to discard differed among products. Thus, not all inputs in 1985 would become waste in that year.

The most rapid proportional growth in inputs was projected for plastics (1.7 to 5.2 million metric tons), glass (9.4 to 19.2 million metric tons), and other non-ferrous metals (0.2 to 0.4 million metric tons). Metals and paper are expected to remain the largest contributors to solid waste (35.5 million metric tons for all metals and 47.3 million metric tons for paper in 1985).

The study incorporated INFORUM's forecasts of consumer expenditure from 1971 to 1985. Many of the expenditure categories in the INFORUM list were not relevant to the IR&T study since they represented consumer services that do not generate household solid waste. However, some of the expenditure categories where increases were projected comprised durables made largely of metal; consequently, the projections had a direct impact upon the generation of metal in household waste. In examining the small numbers of categories that grew rapidly and had a direct effect upon the generation of household waste, it was found that most of the categories increased at a similar rate. In comparing specific consumer expenditure increases from 1971 to 1985 among the relevant categories that grew most rapidly, aircrafts led the list with a 7.5 proportion of increase, followed by communication equipment with 3.6 and guns with a 3.4 proportion of increase. [p.136 of the IR&T Report]

STRENGTHS OF THE SYSTEM

The strength of input-output analysis comes from the clarity with which inter-relationships among producers and users can be presented. The model provides greater industrial detail than other models. In addition, since technical coefficients are delineated, it is possible to test the sensitivity of waste production results with assumed changes in production technology. The study noted the difficulties involved in criticizing or correcting the techniques used in other studies:

1. composition studies of waste that suffer from choice of "atypical" time and location for sampling;
2. adjustments of production estimates that measure waste as "input" used by households. Though broadly similar in approach, most production-based studies failed to account for the full direct and indirect production impact of changes in the level and pattern of final demand and
3. adjustments of consumer spending estimates that treat waste as an "output" of the household sector. These share the lack of detail and clear structure common to other techniques that do not use input-output methodology.

LIMITATIONS OF THE MODEL

Errors in model forecasting can arise from the following two reasons: (1) the model may not have been properly built (relating consumption to income and even price may fail to capture the variety of social and personal factors that can explain why people buy more or less of a particular product) and (2) the information imbedded in the data may have been culturally or historically specific. In a sense, this point reflects poor model specification, but the limitations of time series and cross-section data are inherent in every statistical experiment in which the entire economy is the laboratory. Time series data portray behavior over time of people with vastly different social and economic characteristics. Unique historical forces affect this behavior, and to the degree that these forces cannot be "controlled", the relations estimated for one period in history will not forecast accurately the results for a succeeding time period. Cross-section data, on the other hand, "freeze" history and examine the income-spending link at a particular point in time. Moreover, incomes vary with age, and different income classes have different historical experiences that condition their behaviors. Consequently, these may not easily translate into accurate forecasts for various income classes in the future.

Weaknesses of input-output analysis come from (1) the nature of the model itself and (2) the gaps in the data used to construct the model. An input-output table is, basically, a measure of value flows. The adjustments needed to convert INFORUM or any other existing table to the requirements of solid waste estimation are, at best, crude efforts to adapt a system to a use for which it was not intended. The technical coefficients of an input-output system are necessarily fixed at any one point in time. It is, however, possible to project changes in these coefficients over time to improve the accuracy of production forecasts. It is not feasible, however, to build in an adjustment for one-time changes brought about by decisions to substitute among existing methods or materials. In practice, both the forecast and explanation of specific technology choices in an input-output framework (and elsewhere) rely heavily on intuition.

Current input-output models use data gathered by the Department of Commerce at a fairly high level of aggregation. For some uses, two-digit industrial data leave many important flows of waste-producing activity submerged and require laborious industry-by-industry adjustment of input-output coefficients to achieve usable results.

Forecasting waste volumes accurately depends not only on the availability of complete and accurate input-output coefficients, but also on forecasts made outside the system that must be used. Contemporary predictions of personal consumption expenditure, whether done by simple trend extrapolation or by complex statistical models that relate several factors to consumption, have not performed well over long periods for disaggregated types of expenditures. Thus, major improvements in designing an input-output type system will contribute little to planning if components of final demand cannot be accurately forecast. Since personal consumption spending depends on income and many other economic and non-market factors, the accuracy of consumption forecasting depends on what is assumed will happen to these factors in the future. A crucial determinant of consumer's income is the level of productivity for the economic system. If productivity rises, the income that society's resources can produce at full employment will also rise.

Productivity forecasting is, however, a difficult job. It is not always possible to measure accurately the "state-of-the-art" levels of productivity in particular industries, because productivity indexes move as the rate of capacity utilization changes. Thus, a system coming out of a recession usually registers increased labor productivity because output in the initial recovery increases faster than the employed workforce. This growth in productivity will slow down as additional workers are employed to fill new orders and as longer hours and multiple shifts are instituted. These measures of productivity changes do not adequately reflect full-capacity resource use or the technical efficiency of productive resources for projecting secular income changes.

Bench mark productivity data are hard to find because cyclical changes distort the figures; and limitations in technological forecasting seriously restrict long-range productivity forecasts. These limitations are clearly valid for long-range projections of waste coefficients as well. Although technology has been applied consistently in the past to lowering production costs and altering the use characteristics of final products, it is reasonable to expect that in the future, as disposal costs rise, innovations will work toward reducing the volume and expense of waste.

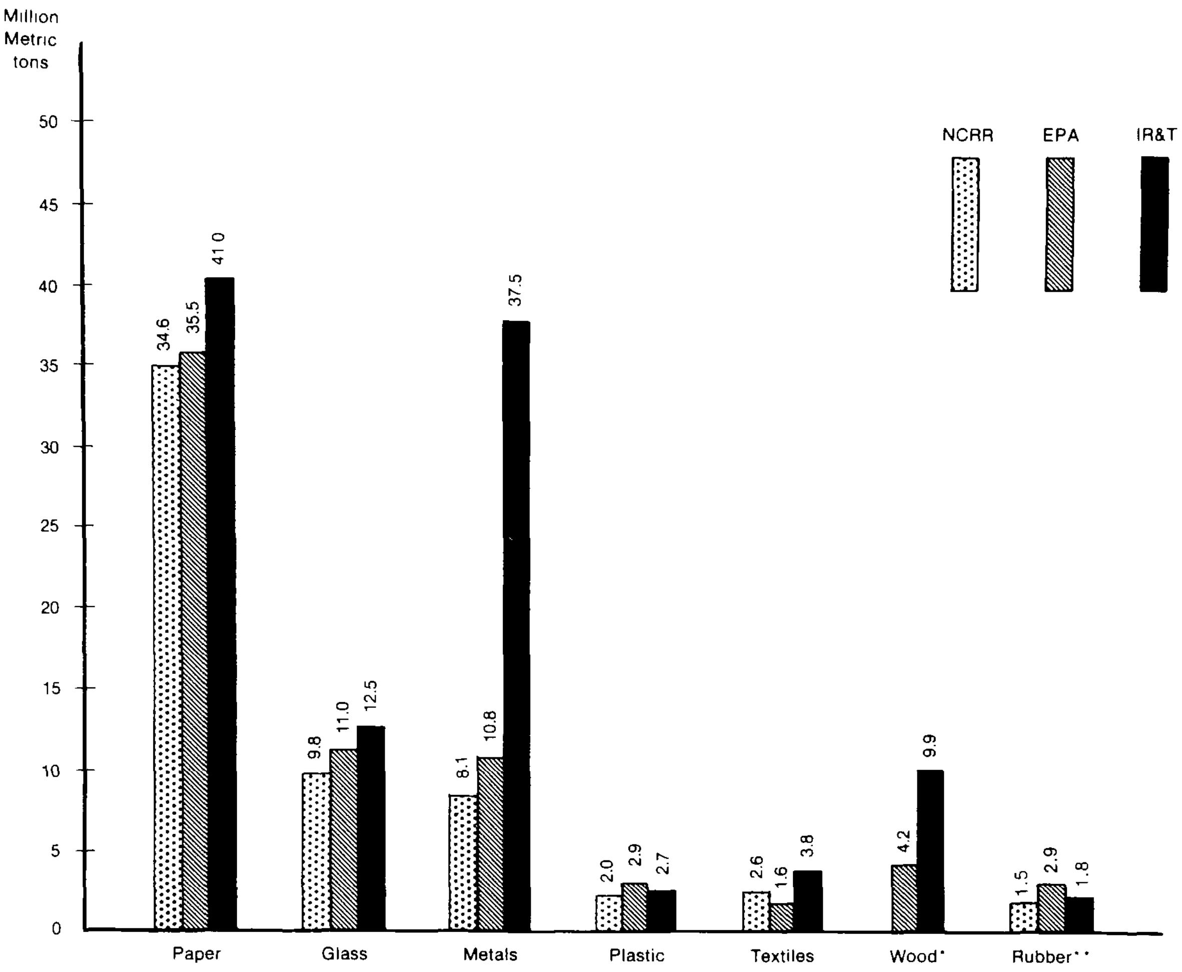
POSSIBLE USES

This study can be used by policy-makers and planners to evaluate not only the likely effects of a changing technology on future volumes of waste and the costs of disposal, but also the implications of governmental policies designed to control waste disposal. The current model offers promise for policy-makers with a national perspective. With modification and some supplementary data inputs, the approach used in this study can be applied to regional solid waste disposal problems as well.

Researchers and planners can utilize the computations in this study as a basis for improving estimates and forecasts of household solid wastes or for constructing estimates of waste volume for other sectors. How a potential user will apply the technique depends on what questions are to be answereed and what data resources are available. The minimal adjustment method, described as a crude modification of the input-output technique for use in studying waste production, is perhaps the least costly approach. But because of the many problems discussed in this report, it is also the least satisfactory. If the user chooses to make the full list of adjustments, retaining the bench mark input-output coefficients computed by the minimal adjustment technique, the cost of analysis will increase. Presumably, the accuracy of waste volume estimates will also increase.

An ambitious re-working of all the coefficients for a limited number of industries might be the best way to produce a system oriented toward the needs of waste volume analysis. Direct collection of volume data, or at least greater disaggregation of value data, would improve the structural realism of the system.

This study should be viewed not as an end in itself, but as a test application of input-output techniques for forecasting household solid wastes. The major barrier to full use of input-output in this area is not methodological, as both the theory and technique of inter-industry analysis are fairly well understood. Instead, lack of detailed data on production volume and poor consumption forecasts limit its ffective use. If it is determined that detailed industry-level production data are well worth their additional costs, the input-output method described in this study provides a powerful tool for analyzing and forecasting the quantity and composition of household solid wastes.



Source: Adapted from IR&T Final Report; Table 4.4, P. 83.

*No estimate for NCRR
**EPA estimate combines rubber and leather

Comparison studies:
—"Municipal Solid Waste" NCRR Bulletin, Vol. III, No. 2, Spring, 1973.
—"Estimates of Household and Commercial Solid Wastes Based on Production Statistics." Draft Report. Resource Recovery Division, Smith, Fred L., Jr. Office of Solid Waste Management Programs, U.S.E.P.A.

Figure 1. Comparisons of IR&T Estimates of Household and Commercial Waste (1971) with NCRR and EPA Studies

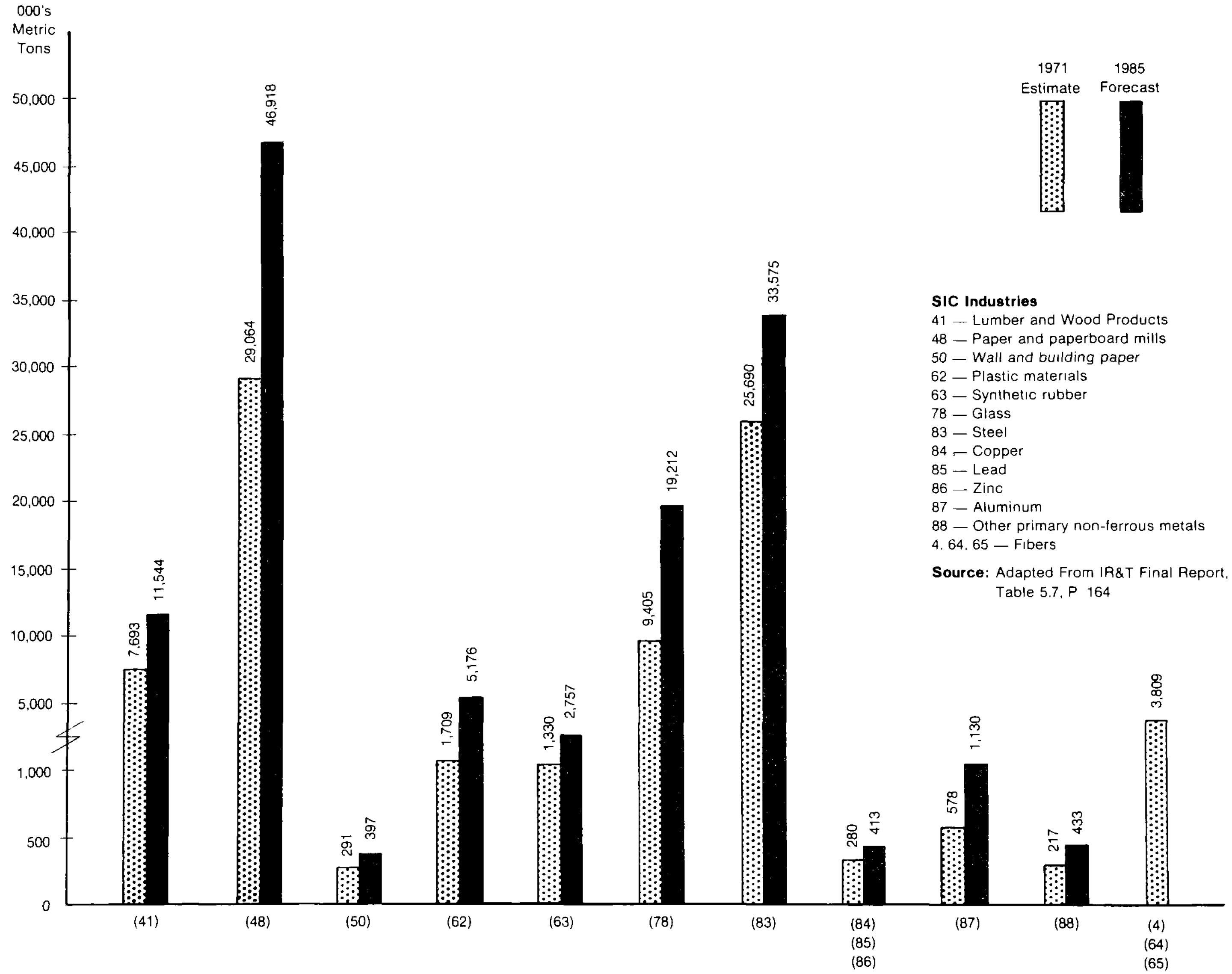


Figure 2: Waste Producing Inputs into the Household Sector: Estimates (1971), Forecasts (1985)

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16. ABSTRACT

An input-output model based on transactions among industries and other sectors of the economy is presented for assessing household solid waste composition and quantity. The various adjustments and assumptions to exercise the model are explained along with its basic concept of "path products" for estimation of household solid waste. The model is tested with industry production data and projects the household waste producing inputs for 1985.

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