

FEBRUARY, 1987

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Dr. Samuel A. Vigil is a Professor of Civil and Environmental Engineering at California Polytechnic State University. He has authored numerous papers and articles in the solid waste and resource recovery fields. More on page 18.

Microcomputer Model for Solid Waste Planning

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THE California Waste Management Board (CWMB) is a state agency that provides technical assistance to county and local governments in the planning of solid waste management systems. CWMB policy encourages waste reduction, resource and energy recovery, recycling, and the environmentally sound disposal of wastes that cannot be economically recovered. The evaluation of various alternatives to meet these goals requires standardized, reliable procedures for the comparison of alternatives.

The CWMB recognized that the widespread availability of relatively low cost microcomputers and powerful "spreadsheet" software could simplify these calculations. The CWMB contracted the Civil and Environmental Engineering Department of California Polytechnic State University at San Luis Obispo, to develop a spreadsheet based model to perform these calculations.

Overview of the Solid Waste Financial Model

The model, entitled "Solid Waste Financial Model" (SWF Model), is a preprogrammed "template" that uses the Lotus 1-2-3 spreadsheet program on the IBM-PC microcomputer. The SWF Model is composed of four parts or modules. The first module, BASELINE, is the entry point into the SWF Model. A menu selection system allows the user to transfer from one module to another. Data entered into the BASELINE module is automatically transferred from one module to another. The modules are briefly described below. For brevity, only the BASELINE and RECYCLE modules will be discussed in detail. The model is documented by extensive built-in HELP screens, data entry screens, a User's Guide,¹ and a detailed Programming Guide².

The BASELINE module is used to record basic data about the community, including current population, fu-

ture population estimates, solid waste quantities, and solid waste composition. The results of the BASELINE module are transferred to the other modules.

The RECYCLE module uses the solid waste and population data assembled by the BASELINE module to plan recycling centers. Several types of centers can be planned, including buyback, curbside, dropoff, and commercial.

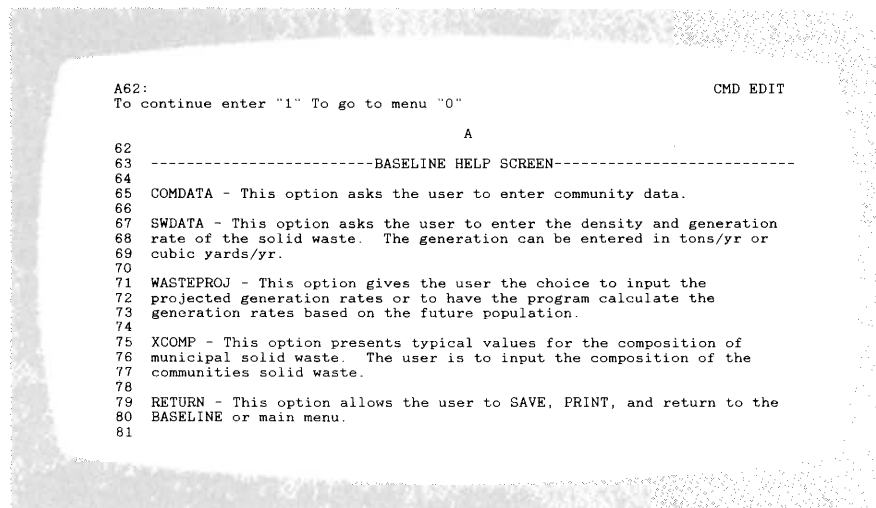
The ENERGY module uses the solid waste data from the BASELINE module to help plan waste-to-energy systems. The module will help the user assemble capital and operating cost estimates, compute a proforma income statement, and assess the effects of changing interest rates and capital costs on project feasibility.³

The LANDFILL module helps the user plan a landfill site for municipal

The HELP option provides a capsule description of each option and provides reminders on required data input formats. Figure 1 is the HELP screen for the BASELINE module. (The numbers on the side of the screen are LOTUS 1-2-3 row numbers.)

The COMDATA option is used to enter community data such as the name of the project and population projections. Two data entry screens are used to enter population data and estimates for the desired study period. COMDATA does not perform population projections. This was done purposely to allow the user to enter his own best population estimates. City, county, or regional plans are the best sources for estimates of future population.

The SWDATA option is used to enter the estimated solid waste den-



■ FIGURE 1. The HELP screen for the BASELINE module.

solid waste. The module uses solid waste data developed in the BASELINE module to estimate the acreage, equipment, and labor requirements for a landfill. Estimates of capital costs, operating expenses, closure, and postclosure costs can also be made.

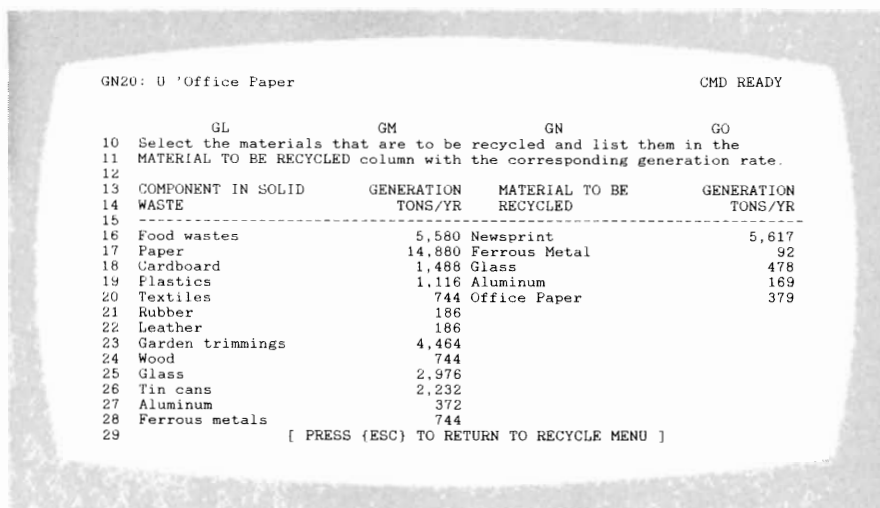
The BASELINE Module

The BASELINE module prepares data input for the RECYCLE, ENERGY, and LANDFILL modules. The module has six options for data input including population projections, solid waste generation rates, and solid waste composition. The data is automatically transferred to the other modules when needed.

sity and solid waste generation rate. Data input includes solid waste density (lb/cu yd), the numerals 1 or 2 to indicate the units of solid waste generation (tons/years or cu yd/year), and the solid waste generation rate in the selected units.

These data are important because the SWF Model uses solid waste data in tons/year in the other modules. The solid waste density is used to convert from volumetric data (cu yd/year) to weight data (tons/year).

The WASTEPROJ option is used to generate solid waste generation rates for the study years defined in COMDATA. This can be accomplished by two methods. Method 1 allows the user to input his own generation rate



■ FIGURE 2. Data entry screen for the MATERIALS option.

for each study year based on solid waste studies or other information. Method 2 automatically calculates the generation rate for each year based on the population and solid waste generation in study year zero. For example, if the population in 1984 is 38,000 and the generation rate is 5,500 tons/year, then the generation rate in the year 2010 (estimated population of 55,000) is 7,961 tons/year (5,500 tons/year times 55,000 divided by 38,000).

The XCOMP option is used to enter solid waste composition data. This is used in the RECYCLE module for estimating quantities of recyclable material available in a community. A list of typical solid waste components and compositions from the literature is provided. The user can use the typical data as a guide or enter data from a local solid waste composition study.

The RETURN option in each module is similar. Selection of the RETURN option produces a submenu with four sub-options:

- ◆ The SAVE option allows BASELINE to be saved as the default filename AUTO123, or allows the user to select his own filename. This can be useful to build multiple case studies for sensitivity analyses as discussed later.

- ◆ The PRINT option prints summary tables of all BASELINE data entries.

- ◆ The RETURN option transfers to the main menu so that other SWF modules can be selected.

- ◆ The BASELINE option returns to the BASELINE menu.

The RECYCLE Module

The RECYCLE module uses data transferred from the BASELINE module and user input data to plan recycling centers. Several types of centers can be planned, including

buyback, curbside, dropoff, and commercial. Seven user selected options are available to assist in data input.

The HELP option provides abbreviated descriptions of each option in the module and provides information on data input formats.

The MATERIALS option is used to enter the quantities of recyclable materials. As shown in Figure 2, the data entry screen has four columns. The two left hand columns list the potential recyclable materials in the community waste stream based on the solid waste generation rate (TONS/YEAR) and solid waste composition () entered in the BASELINE module. These columns have been automatically transferred from BASELINE and cannot be changed in the RECYCLE module.

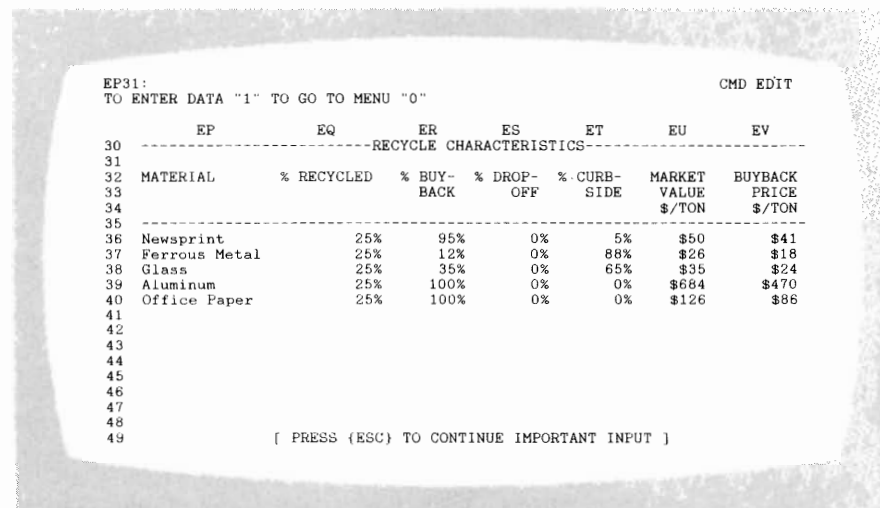
The two right hand columns are the data entry areas. They allow the user to enter up to 13 recyclable materials

and estimated generation rates. This allows the user to use the left hand columns as reference, and make a more detailed estimate for recycling. For example, paper could be divided into several categories, such as newspaper, office paper, and mixed. Quantities assigned to each recycled material category should be based on local conditions and estimates whenever possible.

The TABLE 1 option allows the user to specify the proportion of recyclable materials that are actually recycled and to allocate these materials between buyback, dropoff, and curbside type recycling centers. As shown in Figure 3, TABLE 1 is made up of seven columns. The material column has been transferred from the MATERIALS option. • RECYCLED asks the user to enter, for each material, the fraction of the generation rate that will be recycled. The following three columns — • BUYBACK, • DROPOFF, and • CURBSIDE — indicate in what way the recycled material is to be obtained. For example, if a recycling center is going to operate only buyback and dropoff programs, the user figures that the buyback program will obtain 95 percent (entered as 0.95) of the recycled newsprint leaving the other 5 percent to be collected through curbside and 0 percent for dropoff. The user enters the price that each material will be sold for in the MARKET VALUE column using no commas, no dollar signs, and rounded to the nearest dollar. The price that will be paid for material brought in through a buyback program is entered in the BUYBACK PRICE column.

The CAPCOST option allows user input of the capital or one time costs to establish a recycling center. Data are entered into two data entry screens.

■ FIGURE 3. Data entry screen for the TABLE 1 option.



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FV10: U                               CMD EDIT
TYPE "1" WHEN READY TO CONTINUE

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FV	FW	FX	FY	FZ
10				
11				
12		FIRST YEAR EXPENSES		
13		(CAPITAL COSTS INCLUDED)		
14				
15	Total Capital Costs	\$0	\$0	
16	Income from Grants or in Kind Service	\$0	\$0	
17	Annual Income from Sale of Materials	\$115,831	\$115,831	
18	Annual Replacement Expense	(\$0)	(\$0)	
19	Annual Expenses	(\$91,948)	(\$91,948)	
20	Annual Payout for Buyback	(\$83,755)	(\$83,755)	
21				
22	Annual Net Profit (Loss)	(\$59,873)	(\$59,873)	
23				
24				
25	Recycling Revenue (Cost) Per Ton of material processed annually	(\$35.56)	(\$35.56)	
26				
27	Revenue (Cost) Per Household Per Year	(\$1.58)	(\$1.58)	
28	Revenue (Cost) Per Person Per Year	(\$0.68)	(\$0.68)	
29				

■ FIGURE 4. Summary table for a typical recycling system.

The first data entry screen allows entry of typical capital cost categories, such as processing equipment and site improvements. The second screen allows eight additional user defined categories to be entered.

The ANNUAL COST option allows user input of annual recurring costs such as equipment leasing, rent, maintenance, utilities, and wages and benefits. Three data entry screens are provided. The first allows user entry of certain predefined expenses. The second allows entry of user defined expenses.

The third data entry screen allows computation of future replacement

expense for capital equipment such as trucks or processing equipment. The user enters the name of the equipment, the estimated future cost, life, and an appropriate interest rate. The annual replacement cost is then calculated. This cost represents the annual amount that would have to be invested at the specified interest to accumulate the future capital cost. It assumes annual compounding.

The SUMMARY option allows the user to view a complete summary of data entered in the RECYCLE module. It also shows "bottom line" statistics that were computed in the RECYCLE module. Figure 4 is a

summary table for a typical recycling system.

The RETURN option allows the user four sub-options:

- ◆ The SAVE sub-option gives the user the choice to save the work in the file RECYCLE, a default filename that will be retrieved by the SWF Model. A feature is provided to specify different file names. This technique allows the same BASELINE data to be used with different assumptions to perform a sensitivity analysis.

- ◆ The PRINT sub-option prints the summary tables of the RECYCLE option. It is also possible to use the print screen key [PrtSc] to print at any point in the program.

- ◆ The RETURN sub-option returns the user to the main menu.

- ◆ The XRECYCLE returns the user to the RECYCLE menu.

Sensitivity Analysis

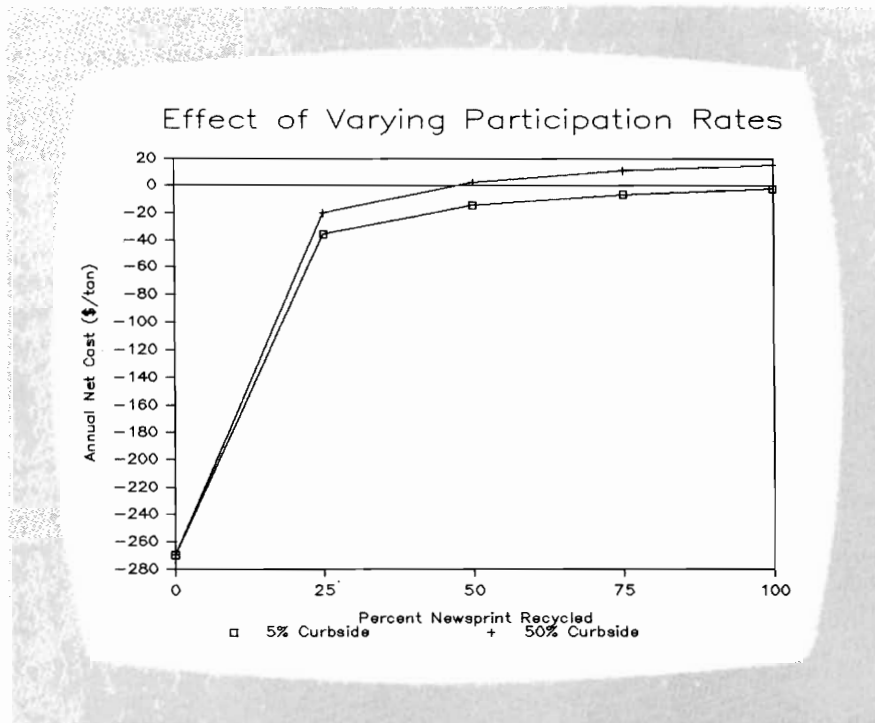
Sensitivity analysis is a planning tool used to compare several options or alternatives. Before the widespread availability of microcomputers and powerful integrated programs such as Lotus 1-2-3, sensitivity analysis was tedious and expensive. Lotus 1-2-3 has built in capabilities to simplify sensitivity analyses. These tools can be used to automatically copy data from the model onto user developed Lotus worksheets and to construct graphics from these user constructed worksheets. For example, several versions of the model could be prepared by using different values of a key variable, i.e., capital costs, interest rate, or market value of recyclables. Then the Lotus 1-2-3 File Xtract and File Combine commands could be used to copy the summary tables from RECYCLE to another worksheet for analysis. These commands are described in the Lotus User's Manual.

After data from several case studies have been stored in a worksheet, either by hand or by automatic transfer, graphics can be generated. Lotus 1-2-3 can generate circle, bar, or line charts directly from a worksheet. By a suitable choice of axes and variables, the desired sensitivity analysis can be automatically plotted. Figure 5 is an example of such a sensitivity analysis. The effect of varying participation on the net cost of recycling is plotted. Two curves have been plotted on the same graph, one for 5 percent curbside recycling and the other for 50 percent curbside recycling.

Hardware and Software

The following hardware and software are required to utilize the SWF Model:

■ FIGURE 5. Sensitivity analysis examines effect of varying participation rates.



◆ IBM-PC (or XT or AT) or other IBM-PC compatible computer capable of running LOTUS 1-2-3 and reading IBM-PC formatted 5¼-in. double side, double density (DSDD) disks.

◆ IBM-PC graphics adapter card and B&W or RGB color monitor. (Hercules Graphics Card and IBM Monochrome Display are also acceptable).

◆ Graphics printer and suitable cables and interface card, or typically an IBM Graphics Printer or Epson FX-80. See the LOTUS 1-2-3 User's Manual for other printers.

◆ At least 384 KB of RAM.

◆ Two DSDD floppy disk drives (or one DSDD floppy disk and hard disk).

◆ IBM-PC DOS, Version 2.0 or higher.

◆ LOTUS 1-2-3, Version 1A. The SWF Model has not been tested with Lotus 1-2-3 Version 2.0. (Note: Due to differences in macro programming commands, the SWF Model is not compatible with the LOTUS SYMPHONY program).

The Solid Waste Financial Model is being distributed on a non-profit basis by the California Waste Management Board for \$100. Distribution includes the program disk, User's Guide, and a detailed Programming Guide for the more advanced user. Contact the CWMB at the following address for further information: California Waste Management Board, 1020 Ninth Street, Suite 300, Sacramento, California 95814, Attn: Dennis Stone.

Acknowledgments. The Solid Waste Financial Model was developed under the auspices of a grant from the California Waste Management Board. The assistance of Dennis Stone and Pat Schiavo is gratefully acknowledged. Mention of commercial products or tradenames in this article does not constitute endorsement by the State of California, the California Waste Management Board, or by California Polytechnic State University. □□□

References

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2. Zevely, J. A., and Vigil, S. A., "Programming Guide to Solid Waste Financial Model," California Polytechnic State University, San Luis Obispo, CA, June 1985, (for the California Waste Management Board).
3. Vigil, S. A., and Zevely, J. A., "Microcomputer Solid Waste Financial Model," in Proceedings of the 1986 National Waste Processing Conference, American Society of Mechanical Engineers, New York City, 1986.

about our cover

Samuel A. Vigil is a Professor of Civil and Environmental Engineering at California Polytechnic State University, San Luis Obispo (Cal Poly), where he teaches courses in solid waste management, resource recovery, computer aided design, and environmental quality. He earned his bachelor's degree in civil engineering from the University of California at Berkeley in 1969. After a four-year tour as a communications and electronics officer in the Navy, Dr. Vigil earned his MSCE from Texas A&M in 1974, and a Ph.D. in Engineering in 1981 from the University of California at Davis.

After graduate school, Dr. Vigil worked as a Principal Engineer for Brown and Caldwell Consulting Engineers. He is still active as a special consultant to the firm and has also consulted for the U.S. Navy Civil Engineering Laboratory on a recycling center at Subic Bay, Philippines Naval Base, and most recently, for the U.S. Trade and Development Program on a solid waste feasibility study for the City of Surabaya, Indonesia.

Since joining Cal Poly in 1982, Dr. Vigil has concentrated on building a program in solid waste management as part of the ongoing environmental engineering program. Cal Poly is one of 19 campuses of the California State University System with an enrollment of 16,000 students, including 2,000 students in the School of Engineering. Cal Poly offers ABET accredited degrees in both Civil and Environmental Engineering. The University stresses "hands on" education with an emphasis on laboratory and design oriented courses.

Dr. Vigil believes that the teaching of solid waste management should receive more attention in environmental engineering curricula. At Cal Poly, both undergraduate and graduate solid waste courses are offered. The undergraduate course stresses the

functional elements of solid waste management and includes a laboratory with experiments in field sorting, statistical data analysis, and the proximate and calorimeter analyses of waste samples. The graduate course emphasizes the technical, institutional, and planning aspects of resource recovery and uses the case study method. Students complete a resource recovery feasibility study and preliminary design as part of the course.

Dr. Vigil is particularly interested in the application of microcomputers to solid waste problems. The Solid Waste Financial Model described in his article in this issue of PUBLIC WORKS was his first effort in this area. Developed under a grant from the California Waste Management Board, the Model is used by professionals in the field and by his graduate students in the resource recovery course. A current project involves the development of cost estimating database to accompany the Model for student use. Future projects include the development of three dimensional models for landfill design and monitoring using Cal Poly's VAX and Data General minicomputer CAD systems.

Dr. Vigil is the author of 15 articles and papers in the solid waste and resource recovery fields. He also holds a U.S. Patent in the area of energy recovery. He is a member of the American Society of Civil Engineers, the Air Pollution Control Association, the Solid Waste Processing Division of the American Society of Mechanical Engineers, and Sigma Xi. Dr. Vigil is active in the Naval Reserve and holds the rank of Commander, Civil Engineer Corps. He is a Professional Engineer in California.

The cover photograph of Dr. Vigil was taken by Joseph Codispoti, Audi-Visual Services, California Polytechnic State University, San Luis Obispo.