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To the Graduate Council:

I am submitting herewith a dissertation written by Gerald E. Smolen entitled "The Costs Associated with Milk Packaging, Delivery, and Container Disposal for Four Container Types and the Policy Implications for the Knoxville, Tennessee, Area." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

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THE COSTS ASSOCIATED WITH MILK PACKAGING, DELIVERY, AND CONTAINER
DISPOSAL FOR FOUR CONTAINER TYPES AND THE POLICY IMPLICATIONS
FOR THE KNOXVILLE, TENNESSEE, AREA

A Dissertation
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Gerald E. Smolen
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ABSTRACT

The overall objective of this study was to estimate the direct and indirect costs associated with alternative fluid milk packaging systems in the Knoxville, Tennessee, Metropolitan area and the implications to solid waste management. Also considered were the possible effects on economic efficiency by legislated policy that would elicit changes in milk packaging systems currently used.

The general procedure involved the application of an economic-engineering or synthetic cost analysis. Economic-engineering models were built for a small and a large milk packaging operation in the Knoxville area. Models were synthesized for paper, glass, disposable plastic, and returnable plastic fluid milk packaging systems, a total of eight models. Economies of scale were suggested from the synthesized packaging models. The unit packaging cost for the four packaging systems ranged from 1.12 to 2.99 cents per quart equivalent for the glass and the disposable plastic-paper container line in a small plant. For the large plant unit packaging costs ranged from 0.96 to 2.49 cents per quart equivalent for the glass and the disposable plastic-paper container line.

The wholesale and retail fluid milk delivery models used were essentially based upon existing research results. The estimated unit delivery costs were 3.84 and 5.87 cents per quart equivalent for disposable and returnable containers, respectively. The milk delivery task

proved to be the most costly among the packaging, delivery, and container collection-disposal tasks studied.

Economic-engineering models of the solid waste collection and disposal operations for six municipalities in the Knoxville Metropolitan area were synthesized. These models provided the cost data necessary to compute unit costs of the solid waste collected and disposed in the research area. A sample survey was designed and taken to augment existing solid waste data. The sampling unit was the compactor truck. Approximately 36 percent of the population was surveyed for a one week period at each of four landfill sites during October and November, 1970. The weight and volume solid waste data were standardized to a 600 pound per cubic yard density. The unit costs for solid waste collection and disposal ranged from \$9.99 to \$26.19 per ton and from \$3.59 to \$8.10 per cubic yard in the research area. Solid waste management economies of scale were suggested by the results.

The weight and volume of milk containers used in the research area were computed from published sources, including census and Federal Order publications. The collection and disposal unit costs for milk containers ranged from 0.04 to 0.69 cents per quart equivalent for paper and glass, respectively.

The fluid milk packaging delivery and container collection-disposal costs for the four types of milk containers studied were summed. The results showed that given the current efforts by the paper, glass, and plastics industries to internalize all of their costs of production, disposable containers were least cost. Therefore, the results indicate

that any effort to legislate controls of disposable milk containers could lead to economic inefficiency. Further research is needed to quantify the production costs currently shifted on to the environment by the paper, glass, and plastic milk container manufacturers.

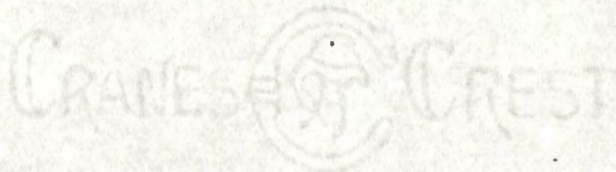


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CHAPTER I

INTRODUCTION

Recently there has been much interest focused on the environment, or industry, and on their interrelationships. The continued decline in environmental quality has caused intelligent citizens to evaluate the present trend of air, water, and landscape pollution. The questions most often asked are "Why?" and "What can be done?" The answers to questions such as these concerning the rapid deterioration of the environment and the interrelationships of the environment and industry are likely to have a profound impact on the organization of business and industry, and on the living patterns of mankind. Certainly it is with utmost urgency that researchers need to direct attention to these pressing matters. Their answers will affect not only their generation but also future generations. Hard facts must be ascertained. Reliable models must be built to test long-run implications of the direction our economic system is going in terms of the quality of life society deems desirable. From this kind of research the society's political machinery may be able to act in a manner which is most likely to optimize social welfare.

Most authorities readily agree that to just maintain the current environmental quality will cost billions of dollars. To procrastinate will, in the long run, result in clean-up operations costing many times more. These costs will necessarily be reflected in the prices of

products whose manufacture has traditionally caused much pollution, e.g., paper, steel, and automobiles. The point is that where externalities¹ once existed, there must now be some assignment of cost. However, hard facts coupled with good judgment are prerequisite to optimal trade-off.

I. THE SOLID WASTE PROBLEM

"The average city dweller, directly or indirectly, uses about 150 gallons of water per day, 4 pounds of food, and 19 pounds of fossil fuel. This is converted into roughly 120 gallons of sewage, assuming an 80 percent recovery of water input; 4.5 pounds of solid refuse, and 1.9 pounds of air pollutants."² The simple generation of these wastes is not the critical issue. Rather relatively high concentrations of population and industry in the United States have resulted in large concentrated volumes of these wastes being dumped on the environment. In localized areas, the environment's capacity to absorb pollution has approached the saturation point. The recently instituted air pollution³

¹Externalities as used in the pollution context can be defined as action by one person (or firm) which causes an unwanted upward shift in the cost curves of other persons (or firms). See Jack L. Knetsch, "Economic Aspects of Environmental Pollution," Journal of Farm Economics, 48(2):1256-1262, for a good discussion of pollution and externalities.

²Henry Still, The Dirty Animal (New York: Hawthorn Books, Inc., 1967), p. 28.

³Pollution may be defined as the "undesirable change in the physical, chemical, or biological characteristics of our air, land, and water that may or will harmfully affect human life or that of other desirable species, our industrial processes, living conditions, and cultural assets; or that may or will waste or deteriorate our raw materials." Pollutants are residues. Definition from Committee on Pollution, Waste Management and Control, Publication 1400 (Washington: National Academy of Sciences, Nation Research Council, 1966), p. 3.

surveys that "monitor air particle saturation in many major American cities is an indication of the severity of the problem of the things we make, use, and throw away."⁴

Some scientists argue that continual dumping of wastes into our environment may destroy its regenerative capabilities. The result of this would be an alteration of the terrestrial life sustaining capacity, with implications of doom for life as we know it now.

The strain put on the environment as a reservoir for waste disposal is expected to continue barring large scale efforts to control waste generation.

Properly processed or neutralized solid waste⁵ represents a relatively lesser problem to large cities in terms of environmental quality than does its physical collection, movement, and disposal. As urban areas expand outward from the city's geographical center possible disposal sites are developed for commercial or residential use. In any event, the transportation bill associated with collection and disposal is directly influenced by urban sprawl. That is,

From 20 to 40 percent of annual budgets of departments of public works is applied to the tasks of refuse collection and refuse disposal. Of this repetitive expenditure, approximately 80 percent is consumed in collection, the cost of which has

⁴Committee on Pollution, p. 3.

⁵Solid Waste is defined as useless, unused, unwanted, or discarded materials. Refuse is generally used in reference to solid wastes. Defined by American Public Works Association, Municipal Refuse Disposal (Chicago: Public Administration Service), p. 11. Hereafter referred to as APWA.

been steadily increasing with no apparent improvement in sanitary quality of service rendered.⁶

To the citizen this means more taxes just to maintain present environmental quality standards.

Not all solid waste is properly processed. Studies conducted by the American Public Works Association and the United States Department of Public Health show that fewer than 50 percent of the United States cities with population greater than 2,500 dispose of community refuse by approved sanitary and nuisance-free methods. Approximately 80 percent of urban and rural towns with populations between 1,000 and 5,000 dispose of refuse in open pits or dumps. This refuse is handled without regard to sanitation standards, health hazards, and associated community blight near the dump.⁷

The Tennessee Department of Public Health recognized the potential health problems associated with careless solid waste disposal. The Department spearheaded a drive to legislate rules and regulations on solid waste disposal. In 1971 the Solid Waste Disposal Act is to become effective (Tennessee Code Annotated, Section 53-4301 to 53-4315).⁸ However, liberal waiver provisions have been made because local governments claim that the regulations would impose an excessive financial burden on the community.

⁶Marcus M. Truitt et al., Mathematical Modeling of Solid Waste Collection Policies, Public Health Service Publication No. 2030 (Washington: Government Printing Office, 1970), p. 1.

⁷APWA, Refuse Disposal, p. v.

⁸Tennessee Code Commission, Tennessee Code Annotated, Volume 9A Cumulative Supplement (New York: The Bobbs-Merrill Company, Inc., 1970), pp. 133-141.

The response to the growing problem of solid waste at the state and national level has been sharp. Recent articles from the New York Times indicate the degree of community reaction: Senator Nelson offered a bill to require industry to pay a fee for package materials not easily disposable. The fees were to be used to pay for clean up.⁹ Representative Rosenthal issued a warning to the package industry of possible government curbs because of the unmanageable waste problem being created.¹⁰ Governor Davis of Vermont studied the possibility of a state law on non-returnable bottles.¹¹ The Philadelphia City Council recently held hearings on possible action to eliminate or control disposable beverage containers in that city.¹² An editorial in the Knoxville News-Sentinel reiterated the problem of beverage containers littering the shores of the surrounding TVA lakes and parks.¹³

The common theme prevalent in the references just mentioned is "Action, Now." However, these types of statements generally are not based on reliable quantitative data. The reason, of course, is that few reliable data have been collected in the area of solid waste management.

⁹New York Times, April 2, 1970, 79:4.

¹⁰New York Times, April 21, 1970, 37:5.

¹¹New York Times, April 22, 1970, 36:2.

¹²John Hall, "Statement to the Special Investigating Committee, City Council of Philadelphia, Hearings on Resolution #307" (Philadelphia: University of Pennsylvania, Wharton School of Finance and Commerce, undated).

¹³Knoxville News-Sentinel, March 7, 1971, F-8.

Some studies have been made (see Review of Literature below) and the quantitative results have been extrapolated to the limits of reliability.

II. THE ROLE OF PACKAGING IN SOLID WASTE MANAGEMENT

The function of a food package is to contain food in order to allow (a) safer and more efficient transportation, (b) product protection against contamination or loss, (c) product protection against damage or degradation, and (d) product dispensing.¹⁴

Another role of packaging that has become very important in recent times is related to exterior package appearance. Package printing and other exterior decoration serves: (a) to identify type and quantity of contents, (b) to identify manufacturer's brand and quality grade, (c) to attract customer interest, (d) to persuade the customer to buy, and (e) to provide product use instructions.¹⁵

The functions of the fluid milk package are the same as for the broad category of food packages. However, glass and plastic containers do not lend themselves to a great deal of exterior decoration. Traditionally, consumers have preferred a clear plain milk package that suggests product purity. Because of the ease with which the paper milk container takes printing, this type of container is more decorated than are glass or plastic containers. None of the container types used for milk is double and triple wrapped as in the case of certain other

¹⁴Stanley Sacharow and Roger C. Griffin, Jr., Food Packaging (Westport, Conn.: AVI Publishing Company, Inc., 1970), p. 50.

¹⁵Ibid.

food items. This fact saves both the consumer and the solid waste management people cost and effort.

The relative potential cost to society for disposal varies according to the type of milk container. A glass container is recyclable. Each time a glass or a returnable plastic container is purchased only the hood and stopper must be discarded. However, if a container is broken or damaged the remains will be disposed. In the case of either returnable or one-way, their initial compaction features are a problem to solid waste agencies.

The paper milk container is designed for single use. Each time a fluid milk product is purchased the whole spent container eventually is discarded.

Because they are disposable, disposable plastic milk jugs require disposal in some solid waste system. These containers are the most costly in terms of initial cost to the consumer and they require special treatment at the disposal site. Discarded plastic containers are lightweight and bulky; and because they are often blown by strong winds can cause a litter problem. Their compaction qualities are such that they tend to rebound once compaction pressure is removed. However, once disposable plastic bottles are compacted in place, they serve as good fill material. Biodegradability characteristics include relatively slow deterioration over time. The material used in disposable milk containers (high density polyethylene) will combust with only the water and carbon dioxide as residues in properly designed and operated incinerators.

III. OBJECTIVES

The general objectives of this research can be stated as follows:

To estimate the direct and the indirect costs associated with alternative fluid milk packaging systems and the implications to solid waste management. Specifically:

1. To estimate the costs of alternative packaging systems (plastic, glass, and paper) to milk processors, including delivery costs.
2. To estimate the direct and indirect costs of alternative milk package systems to public solid waste management agencies.
3. To estimate what effects, if any, policies to elicit changes in milk packaging systems would have on the fluid milk processor and solid waste management agencies.



CHAPTER II

REVIEW OF LITERATURE

Previous research has been conducted in the areas of solid waste collection and disposal, milk plant costs, economics of fluid milk processing, fluid milk distribution, and the dairy industry market structure. The purpose and scope of these studies were limited to a specific area. None grouped the three areas of (a) solid waste; (b) milk filling costs, and (c) milk distribution costs to examine the existence of and the magnitude of externalities or of pricing system breakdown as they arise from milk packaging. None has attempted to discuss the implications to the dairy industry if a legislated ban on nonreturnable containers were enacted.

The University of California Sanitary Engineering Department¹ conducted one of the first comprehensive studies in municipal solid waste collection and disposal. In a study of 13 California cities made during two summers, the research group found that 1.2 to 4.0 pound per capita per day of solid waste was generated depending on categories collected. The sample periods were one week at each site. The refuse collected had a density of 440 pounds per cubic yard and 323 pounds per cubic yard for mechanical and open-body trucks, respectively. A compaction ratio of 2.36 was observed for business refuse for mechanical

¹Sanitary Engineering Department, "An Analysis of Refuse Collection and Sanitary Landfill Disposal, Series 37, Technical Bulletin No. 8, Sanitary Engineering Research Project, University of California, 1952.

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packer trucks. Labor cost for pickup operation ranged from \$2.43 per ton to \$4.85 per ton depending on refuse pickup point. Operations and maintenance costs of mechanical packer trucks were about 29 percent per truck greater than open-bed trucks. Disposal costs varied from \$0.33 to \$1.57 per ton. Compaction ratios (ratio of volume of refuse delivered to site to volumes in completed fill) averaged 2.6. The cost of refuse collection and disposal in eleven California cities ranged from \$3.58 to \$16.26 per ton. Cost of administration varied from \$0.23 to \$3.16 per ton. No significant difference in quantity of refuse between summer and winter was found.

The United States Consumer Protection and Environmental Health Service² sponsored a research project during 1967-68 to include a comprehensive analysis of the Des Moines metropolitan area. Solid waste data were collected by weights and measurements during a one week sample period at each site in the study area. The data were tabulated to allow for seasonality and compaction. Estimated collection costs of \$10.80 per dwelling per year were calculated from an engineering-economic model subsequent to adoption of the study group's recommendations. Disposal costs were estimated for incineration of \$6.05 per ton. The sanitary landfill operation was discussed and estimated disposal cost was \$0.91 per ton and \$0.49 per cubic yard. Average weights for various types of solid wastes were computed for domestic and commercial type refuse

²United States Department of Health, Education, Welfare, Collection and Disposal of Solid Waste for the Des Moines Metropolitan Area, Public Health Service (Washington: Government Printing Office, 1968).

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at 362 to 419 pound per cubic yards for packer trucks. The densities were computed from small sample sizes.

The United States Health, Education, Welfare Department³ sponsored a study to develop a regional solid waste program in New Jersey. A comprehensive examination of solid waste collected in the study area was by component, type, source, weight, and volume. Seasonality effects on solid waste were significant but the average occurred during the autumn (late October-November-early December); per capita average was 2.7 pound per day of domestic refuse.

A study of Genesee County, Michigan, during 1967-68 sponsored by the United States Consumer Protection and Environmental Health Service⁴ used economic-engineering models to calculate expected costs of disposal on a county basis. The estimated cost per ton varied from \$2.97 to \$3.73 for a two site operation and \$3.98 to \$5.24. The higher figure reflected costs of grinding refuse prior to compaction. The researchers used Flint Department of Public Works records which showed a difference of winter to summer density of 11 pound per cubic yard; the former being 328 pound per cubic yard and the latter 339 pound per cubic yard. City volume records for 1966 and 1967 showed relatively constant seasonal refuse generation, with the exception of July and

³United States Department of Health, Education, Welfare, Quadc-city Solid Wastes Project: An Interim Report (Cincinnati: Bureau of Solid Waste Management, 1970).

⁴United States Department of Health, Education, Welfare, Solid Waste Disposal Study, Technical Report, Genesee County, Michigan, June 1968 (Cincinnati: Bureau of Solid Waste Management, 1969).

December which were approximately 6,000 cubic yards above the annual averages. The daily per capita residential refuse was 0.79 pound, considerably less than the national average.

A study conducted in Louisville, Kentucky,⁵ under sponsorship of the United States Environmental Health Service investigated the quantities and composition and distribution of solid waste in order to develop a linear programming model to optimize collection and disposal functions on the basis of least cost. A 19 month weight study was made and the autumn season had slightly above the annual average weight. The seasonal variation in volume exhibited little trend for an eleven month period. The autumn season was close to the annual average volume.

A recent study in the Great Falls area of Montana⁶ evaluated the solid waste problem, made recommendations, and developed economic-engineering models to indicate costs associated with alternative proposals. Combined collection-disposal functions varied from \$26.46 to \$17.86 per ton for twice a week pickup and once a week pickup, respectively.

A considerable amount of research effort has been directed toward the economics of dairy processing. The work can be grouped under the headings of specification and costs, costs and alternatives, and economies of size and scale. The literature dealing with specifications and costs was of particular interest in light of research objective I.

⁵United States Department of Health, Education, Welfare, Louisville, Kentucky--Individual Metropolitan Region Solid Waste Disposal Study (Cincinnati: Bureau of Solid Waste Management, 1970).

⁶United States Department of Health, Education, Welfare, Comprehensive Study of Solid Waste Disposal in Cascade County, Montana (Cincinnati: Bureau of Solid Waste Management, 1970).

Tracy's⁷ engineering-economic models utilizing two relevant size fluid milk processing plants attempted to illustrate economies possible when certain equipment is substituted for labor. The publication lists in detail the equipment items and suggested plant layout, for a plant processing 35,000 gallons per week and a plant processing 105,000 gallons per week. Tracy's basic plants have provisions to augment production to double original capacity. The equipment sizes and capacities are "matched" to minimize production bottlenecks.

Mengell et al. in 1967⁸ attempted to determine economies of size in large (100,000 quarts per day) fluid milk processing plants in New Jersey. The package stage was mixed: glass and paper. The model plant utilized four product handling system alternatives, each one more automated than the previous system as a research objective function. This objective was of no use to the present study. Also investigated was expansion of the initial plant capacity to 200,000 quarts per day. The researchers presented the budgeted costs when the plant packaged only in paper. Net cost changes were found as follows: paper daily costs increased by \$147.74 and unit costs increased by less than \$0.002. The paper containers contributed most to the net cost increase.

⁷ P. H. Tracy, Layouts and Operating Criteria for Automation of Dairy Plants Processing Milk, Half-and-Half, Cream, Chocolate Drink, and Buttermilk, United States Department of Agriculture, MRR No. 591, AMS (Washington: Government Printing Office, September 1963).

⁸ John Mengel et al., "Specifications and Costs for a 100,000 Quarts Per Day Fluid Milk Processing Plant," Rutgers Experiment Station Bulletin 825, New Brunswick, 1969.

Williams⁹ used economic-engineering models for medium and large Georgia fluid milk processing firms to determine the optimum product mix where product specialization is an operational objective and still maximize profits. The research found that containers were the single largest cost item in the packaging center. Of the two container types considered, plastic and paper, packaging two paper half gallons was 4.195 cents less per unit than gallon plastic jugs.

This study did not consider the relative cost of glass or returnable plastic containers. Williams' plant data were relevant to this study because of its currentness and because the research areas are in close proximity, thus minimizing certain regional factors that could have bearing on two widely separated plant studies. The literature review given by Williams describes the essence of major research endeavors into fluid milk plant economic analyses, should the reader be interested in more depth.

Over the past 25 years a number of studies have been done analyzing the distribution costs associated with the fluid milk product. Those which dealt with relative costs for different package types are reviewed here.

Korzan et al.¹⁰ in a 1949 Portland study of milk distribution costs found that delivery costs for wholesale paper milk quarts was

⁹ John Louis Williams, "An Economic Analysis of Fluid Milk Processing and the Changes in Net Revenue as a Result of Product Mix Adjustments" (unpublished Ph.D. dissertation, Mississippi State University, 1968).

¹⁰ G. E. Korzan et al., "Costs of Distributing Milk in the Portland Market," Oregon State Agricultural Experiment Station Bulletin 510, Orono, February, 1952.

1.65 cents and wholesale glass milk quarts was 3.40 cents. Implicit in these costs figures is time in milk delivery, a task which is highly labor intensive. One could conclude that over twice the time was required to deliver glass packages relative to paper. Processing costs were found to be greater for paper quarts relative to glass quarts. However, total unit costs of glass quarts was greater than for paper quarts.

No delivery costs were given for retail deliveries of milk quarts in paper. Glass quart retail delivery costs were 3.92 cents per unit.

Snyder and French¹¹ used linear programming and activity analysis to optimize fluid milk processing firm's product mix subject to institutional limitations, resource availabilities, and market situation. The model plant was of medium size typical of those operating in the Midwest. Although the bulk of the research centered on mixed package line, glass, and paper, a model was run to measure the effects of technological innovation. Net revenue changes between the all glass and all paper packaging was measured and found to be \$500 per day greater for all glass. However, storage requirements and delivery costs for glass run 20 percent and 15 percent, respectively, above paper. Labor requirements for the two package type situations was about equal. Working capital requirements for paper were over twice that of glass.

¹¹James C. Snyder and Charles E. French, "Selection of Product Line for a Fluid Milk Plant by Activity Analysis," Purdue Agricultural Experiment Station Research Bulletin 667, Lafayette, August, 1958.

The analysis of delivery labor found that labor requirements for all paper operations was 38 percent of the all glass operation. The delivery labor input coefficients were derived from Hicks and Wood¹² and the California Milk Control Board Modifiers.

Table 1 summarizes the percent that paper container delivery costs are of glass delivery costs for selected research publications.

Many books and research bulletins have been published on market structure. These range from Bain¹³ setting forth the theoretical framework concerning the organization of industrial markets, in general, to the Padberg and Clarke research bulletin¹⁴ on California fluid milk market structure.

The Padberg and Clarke¹⁵ study covered a period from the mid-1950's to the early 1960's. The researchers found that factors such as the secular decline in home delivered milk, rapid increases in raw milk production, centralization of wholesale milk processing, the rapid acceptance of disposable containers plus processing technology developments predetermined the trend toward larger and more specialized dairies

¹²John W. Hicks and G. B. Wood, "Operations in Retail and Wholesale Milk Routes," Purdue University Agricultural Experiment Station Bulletin 556, Lafayette, November, 1950.

¹³Joe S. Bain, Industrial Organization (New York: John Wiley and Sons, Inc., 1959).

¹⁴D. I. Padberg and D. A. Clarke, Jr., "Structural Changes in the California Fluid Milk Industry . . . Their Effects on Competition and Market Performance," California Agricultural Experiment Station Bulletin 802, Berkeley, June, 1954.

¹⁵Ibid.

Table 1. Summary of Paper Milk Container Delivery Time as a Function of Glass Milk Delivery Time from Selected Fluid Milk Retail and Wholesale Delivery Studies.

Author	Year	Geographic Location	Retail Ratio	Wholesale Ratio
Babb and Butz ^a	1957	Pennsylvania	0.87	--b
Hicks and Wood ^c	1950	Indiana	--b	0.69 (small)
			--b	0.72 (large)
Bressler ^d	1951	California	--b	0.47
Cook ^e	1953	Wisconsin	0.76 ^f	--b
Cook et al. ^g	1956	Wisconsin	--b	0.86
New York State ^h	1951	New York	--b	0.76 ^f
Clarke ⁱ	1956	California	--b	0.91 (1/2 gallon)
			--b	0.67 (quart)
			--b	0.62 (pint)
			--b	0.60 (1/2 pint)
Korzan et al. ^j	1952	Oregon	--b	0.49 ^f
			0.72 ^k	0.73 ^k

^aE. M. Babb and W. T. Butz, "Improving Fluid Milk Distribution Practices Through Economic-Engineering Techniques," Pennsylvania State Experiment Station Bulletin 622, College Park, June, 1957, p. 18.

^bSufficient data not published.

^cJ. W. Hicks and G. B. Wood, "Operations in Retail and Wholesale Milk Routes," Purdue University Agricultural Experiment Station Bulletin 556, Lafayette, November, 1950, p. 26.

^dR. G. Bressler, Jr., City Milk Distribution (Cambridge: Harvard University Press, 1952), p. 163.

^eH. L. Cook, "Paper Packaged Milk in Wisconsin--Its Part in Expanding Distribution Areas," University of Wisconsin Agricultural Experiment Station Research Bulletin 179, Madison, June, 1953, pp. 23-24.

^fRatio in terms of costs.

^gH. L. Cook et al., "Costs and Efficiency of Wholesale Milk Distribution in Milwaukee," University of Wisconsin Agricultural Experiment Station Research Bulletin 196, Madison, May, 1956, p. 12.

^hNew York State Temporary Commission on Agriculture, "The Spread Between Consumer Milk Prices in New York State Markets," Legislative Document No. 34, Part 3, Albany, 1951, p. 17.

ⁱD. A. Clarke, Jr., "Milk Delivery Costs and Volume Pricing Procedures in California," California Agricultural Experiment Station Bulletin 757, Berkeley, December, 1956, p. 74.

^jG. E. Korzan et al., "Costs of Distributing Milk in the Portland Market," Oregon State Agricultural Experiment Station Bulletin 510, Corvallis, February, 1952, p. 18.

^kComputed figures based on Hicks and Wood^l and Conner and Giles^m time data.

Retail Ratio: $\frac{\text{Paper}}{\text{Glass}} = \frac{84.6 \text{ min.}}{116.9 \text{ min.}} = 0.724$; where Purdue data = 116.9 min. per day to deliver
VPI data = 84.6 min. per day to deliver

Wholesale Ratio: $\frac{\text{Paper}}{\text{Glass}} = \frac{48.2}{66.1} = 0.729$; where Purdue data = 66.1 per day to deliver
VPI data = 48.2

^lHicks and Wood, pp. 9 and 25.

^mM. C. Conner and Edward J. Giles, "Milk Delivery Practices-- Alternatives and Costs," Virginia Agricultural Experiment Station Bulletin 515, Blacksburg, July, 1960, pp. 9 and 12.

requiring large capital investments. The result was that during the period 1943-60 the number of small plants decreased while the number of large-volume plants increased. Home delivery declined from 71.3 percent of total retail sales in 1950 to 56.0 percent in 1962.

The researchers could make only generalized statements concerning market conduct since this variable does not lend itself to quantification. The authors conclude that although market structure changes have occurred in California there has not been a trend toward monopolistic exploitation or a sluggish rate of new technology adoption. However, the analysis is not able to indicate whether future performance can be improved given further structural and/or institutional changes.

Manchester¹⁶ gathered fluid milk market structure data on a national scale. He found for the period 1948 to 1965 the number of bottling plants in the United States declined 53 percent while sales increased 63 percent. About 33 percent of the handlers in Federal Order jurisdiction left the business during 1945 to 1957. Forty percent of those handlers regulated by Federal Orders during the period 1958 and 1965 ceased operations.

In the smallest markets the average share of the four largest firms increased from 67 percent in 1950 to 88 percent in 1965. In the largest markets the market share of the "largest four" increased from 45 percent in 1950 to 48 percent in 1965. Manchester's analysis of

¹⁶ Alden C. Manchester, The Structure of Fluid Milk Markets: Two Decades of Change, USDA, AER No. 137 (Washington: Government Printing Office, July 1968).

dairy market structure data offers no conclusions regarding market conduct or market performance within the dairy industry nationally.

Moore¹⁷ discusses, in depth, the market structure, conduct, and performance of the United States dairy industry in recent times. A substantial portion of Moore's discussion centers on the topic: competitive behavior in the fluid milk industry. Through the use of prior research and court case transcripts the author shows that price fixing and price leadership are quite common practices. However, joint-profit maximization has not been found to any great degree. Moore nowhere discusses the market situation where a legislated ban on disposable milk containers is enacted.

A list of dairy market structure references can be found in Moore¹⁸ or Williams et al.¹⁹ for the reader desiring a more comprehensive review of the literature on the subject.

I. PURPOSE OF THE STUDY

This analysis attempts to analyze the statement "Because of prohibitive collection and disposal costs some policy must be enacted to impose a control on the manufacture and distribution of disposable beverage containers." Implicit in the above statement is that (1) milk

¹⁷ John R. Moore and Richard G. Walsh (eds.), Market Structure of the Agricultural Industries (Ames: Iowa State University Press, 1966).

¹⁸ Ibid., footnote references.

¹⁹ Sheldon W. Williams and David A. Vose et al., Organization and Competition in the Midwest Dairy Industries (Ames: Iowa State University Press, 1970), pp. 309-326.

being a beverage would fall into the category of legislated policy and (2) the actual use of nonreturnable beverage containers by the consumer is in fact more costly in terms of collection and disposal than the possible loss of economic efficiency in the beverage marketing system including the administration of some policy to ban or control disposable containers. Legislation to control disposable containers could affect consumer sovereignty assuming that consumer preference promoted the widespread use of disposables in packaging.

Figures 1 and 2 present the container problem as a graphic model. This study attempted to determine if there is economic justification to legislate a ban or control on disposable containers in the fluid milk industry (Figure 1) and utilize only returnable containers (Figure 2).

Figure 1 illustrates the flow of milk containers from the milk processor through the consumer to final disposal. The sewer or waste water function was included to illustrate that milk which is destroyed because of accident or design. The heavy flow lines indicate flow toward disposal; whereas, the broken line indicates recycle flow of used disposable milk containers through the market system.

Figure 2 illustrates the flow of returnable milk containers from the processor through the consumer back to the processor for reuse. The flow lines to the sewer system follow the path of milk residue where the empty containers are washed and rinsed. The flow of materials to the collection and disposal function is much less than the corresponding flows of Figure 1 because of container recycle. A possible externality is illustrated in Figure 2 for the processor; that is, in the form of

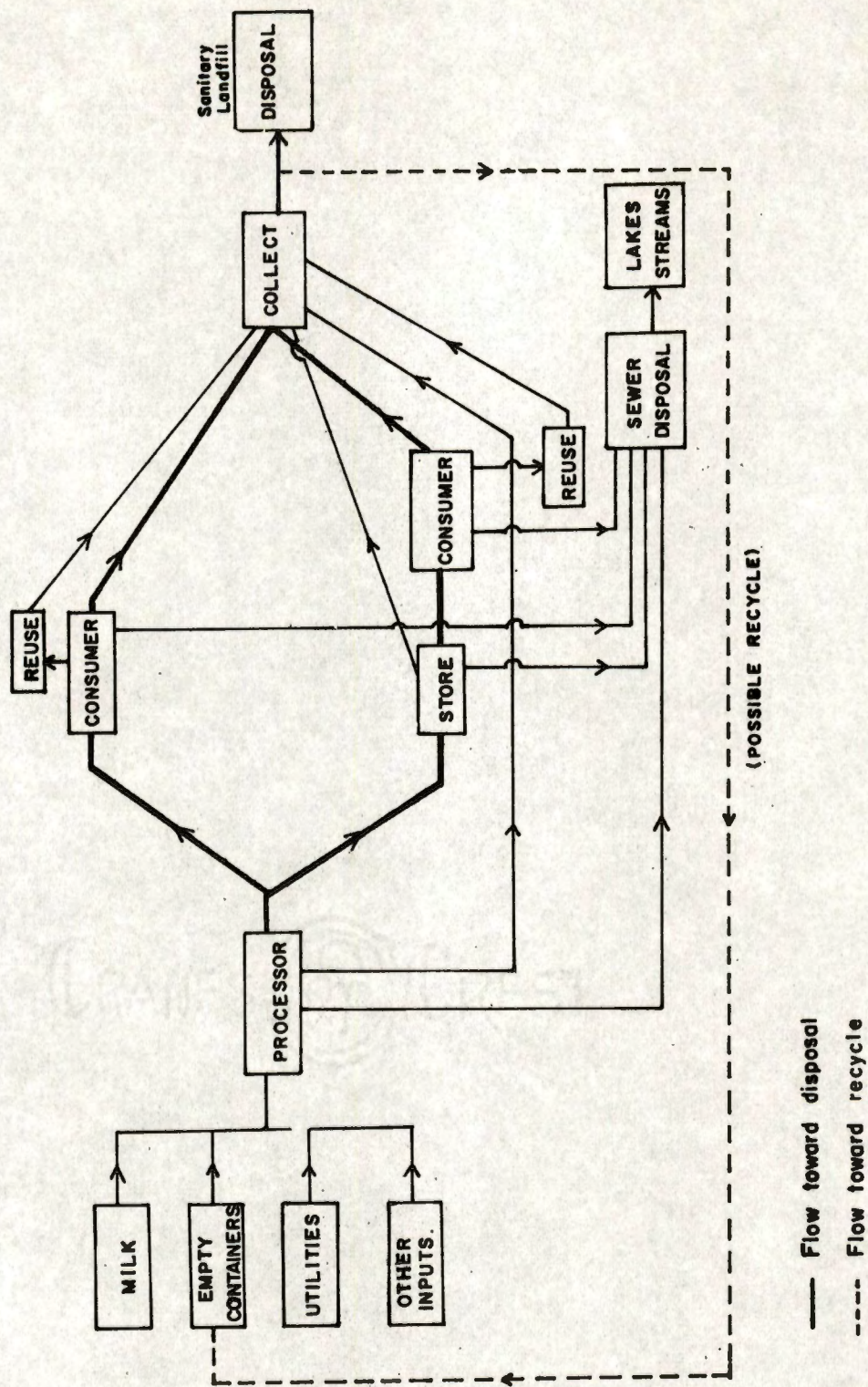


Figure 1. Flow of disposable milk containers from milk processor to disposal.

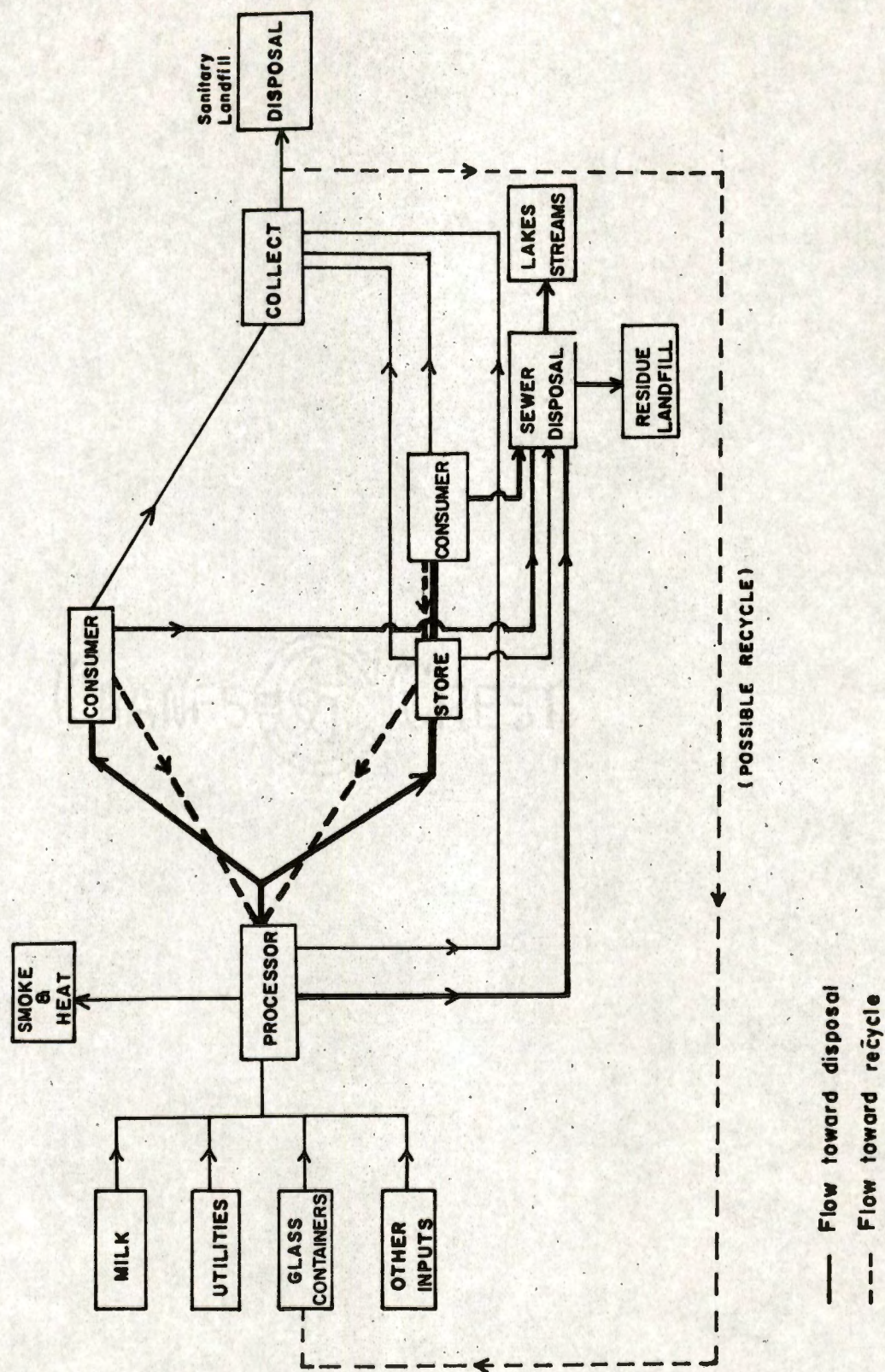


Figure 2. Flow of returnable milk containers.

heat and/or smoke emitted from additional boilers required to heat water to sanitize milk bottles before filling.

In both models the assumption was made that the landfills and sewer systems are operated effectively to minimize the occurrence of externalities in the form of leaching, odor, and unclean water flowing into streams and lakes.

II. ANALYTICAL FRAMEWORK

Objectives I and II

The general procedure used to reach the research objectives involves the use of economic-engineering models. Economic-engineering models were built for two representative sized fluid milk packaging plants in the Knoxville area. Since it was assumed that the milk plant would require the same type and size of processing equipment regardless of the packaging technique used, a partial budgeting procedure was deemed adequate to estimate unit packaging costs associated with a particular milk packaging technique. To supplement published research on milk packaging operations, the author obtained technical advice from milk processing equipment distributors, dairy engineers, and dairy processors.

The procedure used to develop retail and wholesale fluid milk distribution models borrowed heavily from past research. The objective of the delivery model was to quantify the relative costs for distributing wholesale and retail fluid milk. However, obtaining reliable primary data for delivery model synthesis posed a formidable task since neither

cost records nor engineering coefficients were readily available for returnable and disposable container delivery operations in the research area.

The administrative function of the municipal solid waste agency and solid waste disposal function were synthesized to provide reliable cost figures associated with solid waste collection and disposal. Models were constructed for each municipality located in the study area that operated collection and disposal facilities. The technical coefficients used in the models were obtained from municipal records, published sources, and professional consultation. Accurate unit costs were based upon obtaining reliable statistical data for the quantities of solid waste collected and disposed at each landfill site in the research area. Because existing quantitative data were unreliable a stratified random sampling procedure was designed and taken. The population sampled was compactor collection trucks; the mode of transportation delivering most of the solid waste to the landfill.

The budgetary or synthetic model is a preferable alternative analytical technique with which to evaluate the operation of a firm. With this latter technique a model plant is "constructed" to given standards determined from actual plants in operation and from specifications published by equipment manufacturers regarding manpower, fuel, raw product, electricity, etc., requirements. Costs are then estimated from a plant where all internal bottlenecks or limiting factors are removed. The plant has been "built" with sufficient capacity to handle the expected volumes of product, whether milk or solid waste, over some

preselected planning horizon. On this basis the components of the synthesized plant, equipment, building, storage, and other facilities can be organized into a more efficient organization. Partial budget analysis is the analysis of relative costs associated with alternative systems, organizations, or methods for a given plant stage or operations center.

Average costs can be calculated and average cost curves can be derived from the synthesized plants for varied levels of plant utilization where economies of size are of primary interest. Synthesized plants operating at high efficiency constructed for different levels of output will indicate economies of scale prevailing in that particular industry.

An economic-engineering analysis is based on the specific model constructed. The research results and conclusions are valid only for the model analyzed. However, the analytical technique incorporates a great deal of flexibility.²⁰ For example, a manager attempting to relate his dairy processing firm to the dairy processing firm in the research project need only be aware of differences such as efficiency, size, and bottlenecks to adapt or modify the synthesized model to his plant operation. Once appropriate adjustments are made valid conclusions can follow. Likewise models constructed at an earlier date can be adjusted for price changes and technology changes. Once price and

²⁰The reader may want to refer to B. C. French, L. L. Sammet, and R. G. Bressler, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," Hilgardia, 24(19), July, 1956, for a thorough discussion of the theory and methodology of economic-engineering models.

technology are revised the model can serve as a foundation for further research.

One criticism leveled at the economic-engineering approach is that it cannot incorporate managerial ability. The researcher must assume some degree of management capacity for his model. The solid waste agency model is best suited to small scale microeconomic analyses rather than large governmental studies of economies of scale.²¹ This research project assumes that managerial capacity was "average" in the various economic-engineering models developed because the models are not to be identified with a specific government or firm. The solid waste models were to represent operations upon enforcement of Tennessee's Solid Waste Disposal Regulations.

Objective III

The analytical framework for Objective III is allied with the market structure model. The three elements generally associated with this model are market structure, conduct, and performance. Market structure is defined as the organizational characteristics of the market.²² This can include the market entry conditions, degree of product differentiation, and the number of buyers and sellers (for sellers monopoly, oligopoly, atomistic industries). Market conduct of sellers is defined as the composite of "acts, practices, and policies"

²¹A. A. Walters, "Production and Cost Functions: An Econometric Survey," Econometrica, 31:11, January-April, 1963.

²²Bain, p. 7.

used to determine and coordinate industry decisions concerning price and output determination, product policy, and predatory and exclusionary action.²³ Parallels of market conduct can be drawn for buyers but buyers conduct is not within the scope of this research project and will not be discussed further. Market performance is construed to mean the economic end results occurring in the market-place. Market performance is interrelated to structure and conduct, in that structure determines what conduct will be and conduct in turn determines performance. The existing market structure prevailing in a given industry has direct bearing on the market performance in that industry. However, the fewness of firms within an industry does not allow one to define the degree of collusion that exists. But where conduct is such that performance is affected for the private benefit of a single firm or group of firms, market efficiency, profit rates, and selling and advertising costs.

The fluid milk processing industry is undergoing market structural changes.²⁴ The trend has been to decrease in the number of fluid milk processing firms; the relative market shares (concentration) of existing firms has generally tended to increase. With the decline in firm numbers goes the possibility of monopolization and economic exploitation. This leads to economic inefficiency, a condition counter to maximum social welfare.

The perishable nature of raw milk and the rapid decline in the number of milk processing firms were two important reasons which lead

²³Bain, p. 268.

²⁴Padberg and Clarke, pp. 20-34; Williams and Vose et al., Organization . . . in Dairy Industries, pp. 92-94.

to the enactment of strict regulations governing the fluid processing industry. Society, including milk producers, noted instances of questionable market conduct by processors who operated as a local monopoly before the days of high speed refrigerated trucks. Political pressure was applied to create a healthy agricultural economic base. The milk marketing order was designed as an equitable remedy. Where milk producers desired regulation, a referendum could be held on a local or regional basis.

This study synthesized two processing plant sizes to determine economies of scale and to analyze the implications on market structure if disposable milk container legislation was enacted and enforced on the fluid milk industry.

III. DESCRIPTION OF THE STUDY AREA

The research project was conducted in the Knoxville Metropolitan area. Specifically, data were collected in Anderson, Knox, and Blount counties, Tennessee. The area in many ways typifies other urban-rural areas in Tennessee and in the South. That is, Knoxville serves as the commercial, industrial, and cultural center for the population but in keeping with current social trends a substantial portion of the population lives in the suburbs or rural area and commutes to the inner city. Furthermore, these "bedroom communities" surrounding the main city are incorporated municipal units providing their own services and generating their own revenue to pay for the services. Diseconomies of scale are generally inherent in the production functions of smaller cities relative to larger cities.

The United States Bureau of the Census has defined the Anderson, Knox, and Blount counties area as a Standard Metropolitan Statistical Area (SMSA). The 1970 population in the three county area was numbered at 400,337.²⁵ However, as will be discussed later, a portion of the total population is omitted from the study because they did not have municipal or private garbage collection. The number of persons residing in the same household in the study area (2.73) closely corresponds to the state average, 2.8. The median value of households in the Knoxville SMSA was \$12,700 and for the state, \$12,700.²⁶ Approximately 13.5 percent of the population in the Knoxville SMSA is nonwhite; whereas, for the state the percentage is approximately 16.3 percent.²⁷

The quantity of milk containers used per unit of time was a data input in this research project. A superior source of data to actual solid waste sampling for milk containers are the milk processing statistics published by the Federal Milk Market Administrator. Milk container data are compiled for each Federal Order area. The data include monthly totals by container size and package type. Knoxville Federal Order 101.

²⁵United States Department of Commerce, 1970 Census of Population, Tennessee, Final Population Counts, PC(V1)-44; Bureau of the Census (Washington: Government Printing Office, December, 1970), p. 3.

²⁶United States Department of Commerce, 1970 Census of Population, General Housing Characteristics, HC(V1)-44, Bureau of the Census (Washington: Government Printing Office, February, 1971), p. 5.

²⁷United States Department of Commerce, 1970 Census of Population Advance Report, Tennessee, General Population Characteristics, PC(V2)-44, Bureau of the Census (Washington: Government Printing Office, February, 1971), p. 4.

includes a 15-county region in East Tennessee of which the research area is a part.²⁸ The manner of allocating milk consumption to the research area will be discussed subsequently.

The location of fluid milk processing plants selling in a specific area is not restricted to the local market. Low cost transportation with efficient cooling equipment to some extent has allowed milk to be moved greater distances from the processing plant to the buyer. Milk companies ship their product to the consumer in the research area from dairies located inside the Knoxville city limits, and from as distant as Central Tennessee and Northwestern Georgia²⁹ some 200 miles.

Solid wastes are generally disposed by the sanitary landfill method in the study area. The municipalities provide collection and disposal functions for residents located within the respective boundaries. One community, however, contracted with a private corporation to provide collection and disposal services. In the latter instance the contractual fee was paid by the city from tax revenue rather than directly by individual resident subscribers. The individual resident subscriber method of refuse collection was observed in rural and suburban areas located outside municipal serviced areas. This service was on a voluntary basis with the householder paying from two to three dollars per month for one or two times a week pickup. The surrounding

²⁸Compilation of Federal Order No. 101 Regulating the Handling of Milk in Knoxville, Tennessee, Marketing Area (Knoxville: Market Administrator's Office, January, 1970), p. 3.

²⁹Compilation of Statistical Material for the Knoxville, Tennessee, Marketing Area for the Year, 1969, Federal Order No. 101 (Knoxville: Market Administrator's Office, 1969), Tables 1 and 15.

municipalities or the county in which the subscriber resided provided a centrally located disposal site. Those households not served by municipal collection and choosing not to subscribe to pickup service could either haul their refuse to the county landfill or dispose of it in some other manner. Collective participation in the latter method of disposal has caused the emergence of many roadside and backyard dumps throughout the area. Associated with these dumps and improperly operated landfills are landscape, water, and air pollution. Efforts have begun at the state and local level to clean up roadside dumps and prohibit their future occurrence. As stated earlier, Tennessee has adopted regulations governing landfill operations that will aid in minimizing environmental pollution. However, their enforcement has not yet begun. Specifically due to the Tennessee refuse disposal regulations, there exists uncertainty as to the future location of many of the existing landfills. All data collected concerning solid waste disposed was at four landfill locations of which, in all likelihood, two must be closed to further disposal because the landfill location contributes to water pollution. Exploratory efforts are underway to find more suitable disposal sites.

Tennessee has adopted air pollution legislation resulting from burning of solid wastes. Enforcement efforts are underway to eliminate all unnecessary burning as defined by this law to include solid waste dumps.

IV. USEFULNESS OF THE STUDY

Because the three problem areas covered by this study (milk packaging, milk delivery, and solid waste collection and disposal),

traditionally treated as separate research projects, were combined in this study, the data and results should be relevant for a diversity of special interest groups. The dairy processor should find the economic-engineering models of the four packaging techniques for a large and small sized plant helpful in answering such questions as the following: Should I change my fluid milk packaging system from glass to disposable or returnable plastic? What are the relevant costs for delivering returnable fluid milk containers relative to disposable containers? How do delivery costs associated with specific types of packages compare to their associated packaging costs?

Local solid waste agencies and regional planners should find the solid waste collection and disposal costs useful in terms of gauging their own relative efficiency, where comparison is possible, and for estimating future solid waste collection and disposal requirements.

The legislator may be interested in the total costs of collecting and disposing solid waste in a metropolitan area which is divided into several municipalities each operating its own solid waste agency. Meriting additional interest of the legislator is the estimated proportion in terms of quantity and costs that discarded milk containers contribute to the total solid waste aggregate. The implications of such research results should aid private individuals and groups and legislators to make decisions regarding suggested controls for disposable containers.

Finally, the researcher could find the study useful as a departure point for further research into solid waste generated by other agriculturally based industries.

CHAPTER III

ANALYSIS FOR OBJECTIVE I

This part of the analysis focused on two sets of activities:

(1) fluid milk container filling and (2) fluid milk distribution. The purpose was to obtain cost estimates that would be appropriate when milk plants were operated at efficient levels with typical or average entrepreneurial capacity.

I. FLUID MILK CONTAINER FILLING

Description of the Fluid Milk Packaging Operations

The criterion of plant size used was the average daily volume of milk packaged. The model plants assumed were of two sizes, 13,000 and 27,000 gallons per day. These plant sizes were chosen because they most closely approximate the limits of plant sizes in the geographical bounds of the area covered by this study. Plant sizes within this area--based on daily volume--ranged from 5,000 to 26,000 gallons per day. The proportion of milk packaged by container size was determined from data supplied by the Knoxville Milk Market Administrator. (See Table 30, Appendix A.) The plant layouts came from previous studies¹ and milk filling equipment suppliers.

¹John Louis Williams, "Economic Analysis of Processing"; Mengel, Devino, and Bradfield, "Plant Specifications"; and Tracy, "Plant Layouts".

An 8-hour day, 5-day work week was assumed because this is typical among East Tennessee dairies. Only the large model with a disposable plastic and paper container combination deviated from the 40-hour work week. Wage rates were obtained from union pay scales currently in effect.² Filling stage models were synthesized for these combinations of container systems: (1) the small size plant--paper, glass, disposable plastic and paper, and returnable plastic and glass; (2) the large size plant--paper, glass, disposable plastic and paper, and returnable plastic and glass. A technological constraint imposed by not yet perfected blowmold plastic container extrusion systems resulted in the returnable and disposable plastic being matched with glass and paper, respectively. That is, because of the high production costs associated with both types of plastic containers the manufacturers of plastic containers were limiting the container sizes marketed to gallons and half gallons. The in-plant blowmolding equipment for making disposable containers was limited to gallons only. A major supplier of this equipment indicated it would be "some time" before a half gallon in-plant system would be marketed on a production basis.³ It appears that the manufacturers of plastic containers made of high density polyethylene resin are aggressively marketing their product, which was reason to consider that type of container in the research. However, to retain the distinction between returnable and single service containers for analytical purposes, glass and paper were used to represent those sizes having no plastic

²Wage Rate Schedule, 1970-1971 (Johnson City, Tennessee: Teamsters Local No. 23, 1970).

³M. J. Rayikes, Research and Sales Division, Celanese Plastics Company, Newark, New Jersey, telephone interview, June 7, 1971.

counterpart. Half-gallon disposable plastic containers were assumed to be purchased from plastics manufacturers.

The model plants were assumed to operate at full design capacity through a contractual milk purchase agreement with the regional dairy producers' cooperative.

Investment in Land and Buildings

Building costs were determined from several published sources.⁴ Price indices developed from the E. H. Boeckh and Associates⁵ were used to neutralize the effects of secular price rise. Building maintenance and equipment maintenance rates came from previous research,⁶ equipment distributors, and other sources. Building repairs and maintenance

⁴Paul O'Connell and W. E. Snyder, "Cost Analysis of Fluid Milk Processing and Distribution in Colorado," Colorado State University Technical Bulletin 86, Fort Collins, 1964; Aaron C. Johnson, Olan D. Forker, and D. A. Clarke, Jr., "Operations and Costs of Manufacturing Dairy Products in California," Giannini Foundation Research Report No. 272, Berkeley, January, 1964; Tracy, "Layouts and Operating Criteria for Automation of Dairy Plants . . ."; Henry A. Homme and Richard L. Simmons, "Planning Agricultural Processing for the South: Butter and Milk Powder Manufacturing Costs," North Carolina State University Agricultural Policy Institute, July, 1965; and Fred Webster et al., "Economies of Size in Fluid Milk Processing Plants," University of Vermont Agricultural Experiment Station Bulletin 636, June, 1963.

⁵United States Department of Commerce, Statistical Abstract of the United States, 1969, 90th edition (Washington: Government Printing Office, 1969), p. 692.

⁶O'Connell and Snyder, "Cost Analysis of Fluid Milk Processing and Distribution in Colorado"; Johnson, Forker, and Clarke, "Operations and Costs of Manufacturing Dairy Products in California"; Webster et al., "Economies of Size in Fluid Milk Processing Plants"; and J. R. Strain and S. K. Christensen, "Relationship Between Plant Size and Cost of Processing Fluid Milk in Oregon," Oregon State College Agricultural Experiment Station Technical Bulletin 55, Corvallis, November, 1960.

factors of 2 percent of original investment was assumed. The construction of the fluid milk processing plant was assumed to include modern techniques and materials. Incorporated into the building design are automatic fire sprinkler systems, modern air conditioning and heating systems, and in-floor conveyor systems where applicable.

The relevant costs associated with the investment in buildings include depreciation, interest, repairs and maintenance, taxes, and insurance. Costs associated with land include interest on investment and taxes. A building cost of \$22.12 per square foot including land cost was used in this study. This building cost appeared appropriate after checking with building contractors in the study area of this project. The cost of the land was assumed at \$0.05 per square foot or \$2,178 per acre. Land is available surrounding the high population density areas in the research area. The plant site would include city water and sewage service and hard surface highway access. The summary of daily building costs by components is given in Table 2. Since this is a partial budget model, the figures presented are only for those building items that were expected to change when different package techniques were incorporated.

Annual depreciation was calculated for the building based on an estimated building life of 33.3 years. The straight line method was used to compute depreciation. Annual depreciation cost was 3.0 percent of the total building investment.⁷ No effort was made to separate depreciation due to obsolescence and depreciation due to physical wear on the building.

⁷M. C. Conner and Edward J. Giles, "Milk Delivery Practices-- Alternatives and Costs," Virginia Agricultural Experiment Station Bulletin 515, Blacksburg, July, 1960, p. 15.

Table 2. Daily Building Costs for Filling; Empty Case and Empty Container Storage Area for Small and Large Model Fluid Milk Processing Plant by Cost Component for Four Packaging Systems

Type of Plant	Depreciation	Interest	Repairs and Maintenance	Taxes and Fire Insurance ^a	Daily Total	Per Unit Total ^b
-----Dollars-----						
Small, paper	9.16	9.15	6.10	4.88	29.29	0.00056
Small, glass	9.00	8.99	5.99	4.79	28.77	0.00055
Small, disposable plastic	11.15	11.13	7.42	5.93	35.63	0.00069
Small, returnable plastic	9.00	8.99	5.99	4.79	28.77	0.00055
Large, paper	13.04	8.69	13.05	6.96	41.74	0.00037
Large, glass	13.23	8.81	13.24	7.06	42.34	0.00039
Large, disposable plastic	12.01	7.31	12.01	5.09	36.42	0.00034
Large, returnable plastic	13.23	9.06	13.24	7.06	42.59	0.00039

^aBased on effective tax rate of \$1.30 per \$100 appraised value and fire insurance rate of \$0.30 per \$100 building investment.

^bPer unit costs are computed on quart equivalents for each size of model plant.

Interest is defined as the cost of using capital. As such it is a cost of doing business and should be included in plant cost analysis. The opportunity cost of capital should be the cost of capital to the firm. An interest rate of 6 percent was used in this study.⁸ Because it was assumed that the value of the building would be zero at the end of its life the interest rate was applied to one-half of the initial investment.

Property taxes are based on the appraised value of the property including the percent of assessment. The appraised value as determined by a local tax appraiser is theoretically the market value of the property but in reality only a functioning marketplace can establish a market value. The rate of assessment of actual value may range from 20 to 100 percent depending on the area. The need for comparability among the tax schedules of different areas lead to the use of effective tax rates. For example, if the tax rate is \$4.00 per \$100 and the assessed valuation is 50 percent, the effective tax rate is \$2.00 per \$100. The average effective tax rate used in this study was \$1.30 per \$100 valuation.⁹

The insurance costs, a cost that reflects certain business risks, were estimated for fire only. Different plants may react to risks of the commercially insurable nature with varying degrees of concern. A

⁸ Anyone using results of this study, of course, would need to adjust the findings to reflect local prevailing interest rates.

⁹ Tennessee Taxpayers Association, The 1969 Annual Survey of County, City, and Town Government in Tennessee, Research Report No. 180, Nashville, September 15, 1970.

fire insurance rate of \$0.30 per \$100 was used for the model plant buildings.¹⁰

Equipment Costs

Equipment descriptions used in this study were obtained from results of previous research, from dairy equipment manufacturers, and from personal observation. Machine specifications were obtained from equipment manufacturers' literature. Where pieces of equipment were related in the packaging process, equipment was selected to allow a harmonious flow of product from each operation to the next.

Previous research and industry sources provided the expected equipment life and initial costs, respectively. Because of the size and complexity of most of the packaging and related equipment, freight and installation are important costs. A common practice in the research literature is to add a fixed factor to f.o.b. cost to reflect an average freight and installation charge. In keeping with this practice a 20 percent freight and installation cost was added to f.o.b. prices.

The principal costs associated with the equipment investment are depreciation, interest, repairs and maintenance, taxes and insurance. A summary of owned equipment costs is given in Table 3. An equipment listing is given in Appendix A, Tables 32-39.

Depreciation was assumed to be an allowance to cover costs of durable capital used up in the production process per unit of time.

¹⁰Charles Powell, Jr., Powell Insurors, Knoxville, Tennessee, personal interview, May 28, 1971.

Table 3. Daily Costs: Summary of Packaging and Related Equipment by Component for Small and Large Fluid Milk Processing Plants

Type of Plant	Depreciation	Interest	Repairs and Maintenance	Taxes and Insurance	Daily Total	Per Unit Total ^a
-----Dollars-----						
Small, paper	14.04	7.72	11.70	3.74	37.20	0.00072
Small, glass	32.24	17.73	26.87	8.60	85.44	0.00164
Small, disposable plastic	16.28	8.95	13.56	4.34	43.13	0.00083
Small, returnable plastic	35.81	19.70	29.84	9.55	94.90	0.00183
Large, paper	14.64	8.05	12.20	3.90	38.79	0.00036
Large, glass	34.79	19.13	28.99	9.28	92.19	0.00085
Large, disposable plastic	88.59	25.16	38.12	13.04	164.91	0.00153
Large, returnable plastic	38.19	21.01	31.83	10.18	101.21	0.00094

^aPer unit total calculated on basis of quart equivalents.

Equipment depreciation was computed on a per annum basis. A 365-day year was assumed to reflect depreciation due to obsolescence and use. No effort was made to separate total depreciation into its components. Also computed was a quart equivalent per unit depreciation cost. A salvage value of 10 percent of initial investment was assumed because old machinery sold generally has some usefulness for its designed purpose remaining in addition to its junk value. The annual rate of depreciation used for equipment amounted to 6.7 percent of initial cost. The interest rate used was 6 percent. The 10 percent salvage value was added to initial equipment costs and the interest cost was calculated for half the estimated useful life. The property tax rate and fire insurance rate applied to the equipment inventory is the same as that used for the building, \$1.30 per \$100 and \$0.30 per \$100 valuation, respectively.

Some pieces of packaging equipment can be purchased by a processing firm, but with Pure Pac fillers, for example, existing patent rights require leasing of these filling machines. Occasionally firms lease equipment because less capital is required initially, although on the average the total cost of either practice is equal. Table 4 gives the filler rental payments for the plants utilizing paper containers in their package mix. Average unit costs are inversely proportional to volume processed when total cost is constant. Total cost or rental fee for each filler was computed from the following equation:¹¹

¹¹Pure-Pac Milk Processing Equipment Catalog (Detroit: Ex-Cell-O Corporation, 1970).

Table 4. Daily Costs: Royalties on Paper Fillers Used in Small and Large Model Fluid Milk Processing Plants, 1970 Prices

Plant	Gallon	Half Gallon	Quart, 1/3 Quart, Pint, 1/2 Pint	Daily Total	Per Unit Total
-----Dollars-----					
Small, paper	62.34 ^a	23.72	119.54	205.60	0.00395 ^b
Large, paper	86.96	50.53	131.05	268.54	0.00249
Small, disposable plastic and paper	c	c	73.11	73.11	0.00141
Large, disposable plastic and paper	c	c	128.60	128.60	0.00119

^aIncludes production rental and minimum fixed rental.

^bExpressed in quart equivalents units.

^cNo rental filler used for this size package.

$$R = MN + F - D + T$$

where:

R = rental fee

M = rental charge per 1,000 containers processed

N = number of units processed

F = fixed monthly rental fee

D = allowable discount

T = sales tax

Each filling machine was charged a production rental based on volume processed and a base rental fee. The latter fee generally is paid monthly for the first five years of operation. Table 4 shows daily filler rental costs and total per unit costs for large and small plants. Table 5 gives the daily and unit costs for renting a hooder; a machine used to put a paper cover over the lip of glass bottles.

Labor Costs

The labor requirements for fluid milk plants can be divided into three functional categories: line, staff, and supervising. Because only the packaging function is considered in this study, it is assumed that regardless of which package system is used there will be no change in staff and supervisory personnel. The wage rates used were obtained from a labor union contract in effect at local dairies that have a "union shop".¹² The wages were adjusted 11.5 percent to reflect estimated fringe benefits paid by the company. These fringe benefits

¹²Wage Rate Schedule, 1970-1971.

Table 5. Daily and Unit Royalty Costs of Hooder Machines^a Used in Small and Large Model Fluid Milk Processing Plants Using Glass Containers, 1970 Prices

Type of Plant	Daily Cost ^b	Per Unit Cost ^c
	-----Dollars-----	
Small, glass only	0.99	0.00002
Large, glass only	1.38	0.00001
Small, returnable plastic and glass	0.49	0.00001
Large, returnable plastic and glass	2.62	0.00002

^aMachine used for putting a disposable cap over the lip of the bottle for sanitary purposes.

^bIncludes a fixed charge per month only.

^cComputed on a quart equivalent basis.

include retirement, social security, workman's compensation, and uniform costs. The amount of labor used in packaging functions was adapted from other studies, equipment manufacturers recommendations, and personal observation. The plant rates used are given as follows:

1. paper filler operators - \$2.78 per hour
2. other filler operators - \$2.46 per hour
3. general plant labor - \$2.36 per hour
4. engineers - \$3.00 per hour

The plant packaging labor is employed on an 8-hour day, 40-hour week based on a 5-day week. This operating schedule minimizes hiring extra labor for "fill-in" work. Because of institutional requirements of the labor market, a man hired for fill-in work would necessarily be paid for a 40-hour week plus fringe benefits. This lumpy feature of labor costs combined with rising wage rates has been a major factor causing milk plants to automate.

The only model plant which departs from the 40-hour week in the packaging center is the large plant that blowmolds gallon disposable containers. The production of gallon containers is at a lesser rate than the rate of the gallon filler. To minimize stockpiling newly made gallon containers the blowmold process must begin operation at 5:00 a.m. and the gallon filling operation begins at 1:30 p.m. to allow both operations to shut down at 4:30 p.m. without running out of gallon containers. The higher paid blowmold personnel who double as filler operators are considered as full-time blowmold operators for pay purposes. Table 6 summarizes the labor costs. The results indicate

Table 6. Summarized Daily and Unit Labor Costs for Four Package Systems for Small and Large Model Fluid Milk Processing Plants in East Tennessee, 1970 Prices

Type of Plant	Daily Cost ^a	Per Unit Cost ^b
	-----Dollars-----	
Small, paper	89.74	0.00173
Small, glass	86.88	0.00167
Small, disposable plastic and paper	86.88	0.00167
Small, returnable plastic and glass	86.88	0.00167
Large, paper	100.71	0.00093
Large, glass	118.90	0.00110
Large, disposable plastic and paper	175.63	0.00163
Large, returnable plastic and glass	118.90	0.00110

^aIncludes 11.5 percent fringe benefits.

^bComputed on quart equivalent basis.

a degree of economies of scale exist for packaging center labor.

Table 40, Appendix A, itemizes the labor requirements in the package center.

Utility Costs

Utility rates were obtained for the Knoxville Utilities Board (KUB) which supplies electric, water, and gas service to Knoxville and immediate suburbs. Areas surrounding Knoxville are generally serviced by utilities companies or cooperatives. These firms have differing utility rates; however, for this study the KUB rates were used. The sewage rates were obtained from the Knoxville Waste Water Control System.

Electricity is priced on a demand charge and an energy charge. The demand charge is based on maximum estimated quantity that energy will be used per month. The energy charge is based on the rate that energy will be used per month. The energy charge is established on a quantity discount step rate schedule. Thus, the more energy a buyer uses the cheaper the rate he will pay for the last increment. The demand requirements can be computed by reading electrical specifications from manufacturers' literature or from the plate attached to the machine. The researcher can use the Kilo Volt-Amperes (KVA) directly to calculate total KVA or alternatively, the motor horsepower rating can be converted to KVA on the basis of a "rule of thumb" that one installed horsepower equals one KVA consumer per hour of use. The KVA for the packaging stage were aggregated and an electric bill was computed based on the assumption that the plant would be in the lower energy charge

rates. Electric consumption by motors powering compressors was adjusted to reflect the fact that these motors operate only 40 percent of the time.¹³

Water consumption rates were obtained from manufacturers' specifications for each machine using water. The total water quantity used was multiplied by a price from the KUB water rate schedule. The water schedule was constructed with a quantity discount feature. A quantity discount was assumed to apply for the model plants.

Natural gas consumption rates were determined from machine specifications. Gas costs are determined by summation of the demand charge and the commodity charge. In principal a gas bill is computed the same way as an electric bill, except that the unit of charge is the therm.

Sewer costs are based on the water consumption of the plant. More specifically, the charge is based on 75 percent of the water consumption. The sewer rate is a quantity discount service. A surcharge is applied to firms whose waste water contains above a set amount of biochemical oxygen demand (BOD), grease, and suspended solids as determined by the Waste Water Lab.¹⁴ This study used no surcharge because of the difficulty in allocating it to the packaging function. In the Knoxville System the surcharge is a relatively new phenomena and long-term records are not available for milk plants to determine a charge trend.

¹³Johnson, Forker, and Clarke, p. 19.

¹⁴Waste Water Control System, Ordinance No. 4055, Rate Schedule C (Knoxville: City of Knoxville, February 18, 1971).

Table 7 summarizes the daily and per unit costs associated with utilities. Some rural plants use water from wells and dispose of waste water through owned sewage treatment facilities. The costs associated with these facilities are variable and often difficult to estimate. The utility rates in effect by KUB are intended to serve as proxy variables for plants with their own facilities.

Package Costs

The package costs were computed for four types of containers used in the model plants--paper, glass, disposable plastic, and returnable plastic. The disposable plastic containers came from two sources: a manufacturer-supplier and an in-plant blowmold extruder installation. All purchased containers were priced f.o.b. plus freight to Knoxville. Table 50, Appendix A, gives a costed out blowmold installation.

Because of container ordering costs, quantity discounts, and possible shipping delays, plants keep a stock of empty containers in storage. Prior to exhausting the empty container stock a reorder will be made. The stock of new disposable containers are used much more rapidly than are returnable containers requiring more frequent reorders. Returnable containers spend a relatively large part of their life in stores, delivery trucks, and consumer's homes. This study assumed a typical bottle makes a six-day cycle from the plant through the market system back to the plant. This requires a large bottle inventory investment. Interest on the capital invested in the container inventories is a cost of doing business. Depreciation was computed

containers exhibit the lowest unit packaging costs, glass having the lowest of all. Disposable plastic and paper containers for the large plant has the highest unit costs because the effects of the costly blowmold resin increase the total daily costs a significant amount. The computed costs are based on several assumptions. An inventory of empty containers in stock is two weeks for paper, glass, and returnable plastic; four weeks for bottle caps and bulk liners; and 6.5 weeks for paper bulk containers. A production loss rate was applied to all containers packaged to arrive at a gross package requirement. The loss rate assumed is as follows: paper, 1 percent; all other package types, 0.5 percent.¹⁶ Reusable plastic bulk container frames had an estimated life of four years.

Cleaning supplies for returnable containers, not including case washing, is a major cost input. Owens and Butz¹⁷ found that caustic and liquid chlorine was used at a rate of 1.2 pounds per 1,000 bottles and one pint per 1,000 bottles, respectively. Table 9 presents the bottle cleanser costs for the model plants.

Since the amount of cleanser used is a function of the number of bottles cleaned, ceteris paribus, the absolute cleanser cost for the small packaging operation is less than for the large packaging operation.

¹⁶Strain and Christensen, p. 19; Milk Industry Foundation, p. 701; O'Connell and Snyder, p. 12; M. C. Conner et al., "An Economic Analysis of Model Plants for Pasteurizing and Bottling Milk," Virginia Agricultural Experiment Station Bulletin 484, Blacksburg, June 1957, p. 18.

¹⁷T. R. Owens and W. T. Butz, "Specifications and Costs for Processing Operations in Small Market Milk Plants," Pennsylvania State Agricultural Experiment Station Bulletin 625, College Park, August, 1957, p. 37.

Table 9. Summarized Daily and Unit Bottle Cleanser Costs for Four Package Systems for Small and Large Model Milk Processing Plants in East Tennessee, 1970 Prices

Type of Plant	Daily Cost ^a	Per Unit Cost ^b
	-----Dollars-----	
Small, glass	10.81	0.00021
Small, returnable plastic and glass	10.81	0.00021
Large, glass	22.45	0.00021
Large, returnable plastic and glass	22.45	0.00021

^aDaily cost applicable only to plants with returnable containers.

^bQuart equivalents basis.

The unit cleanser costs are the same for the large and small plant assuming no bulk pricing discounts were obtained by either firm.

A summary of the total daily and unit costs for the four package systems in small and large plants is given in Table 10. The table shows glass and returnable plastic having lower unit costs than did paper and disposable plastic containers.

II. FLUID MILK DISTRIBUTION

Delivery Costs

As stated in the literature review, a relatively large number of studies have been done to measure delivery costs associated with fluid milk. The studies indicated there are relative savings for wholesale delivery to retail or home delivery. Furthermore, these studies show that costs were lower to deliver disposable containers than to deliver returnable containers. (Refer to Table 1, Chapter 1, page 17.)

Previous research results for fluid milk delivery costs were used to develop a reasonable estimate of milk delivery costs that could be integrated into the plant packaging cost computations. Granted, the "average" delivery cost developed may not represent the precise conditions existing in East Tennessee, but using the "average" cost figure permits an efficient determination of relative packaging plus delivery costs. To attempt an economic-engineering study of delivery costs for (a) disposable and (b) nondisposable containers might prove difficult since no dairy in this area is delivering returnable containers exclusively. With this data limitation, possible measurement errors in the

Table 10. Summary of Daily and Unit Total Costs for Four Package Systems for Small and Large Model Milk Processing Plants in East Tennessee, 1970 Prices^a

Type of Plant	Daily Costs	Per
		Unit Costs ^b
	-----Dollars-----	
Small, paper	1,203.37	0.0231
Small, glass	581.43	0.0112
Small, disposable plastic and paper	1,553.14	0.0299
Small, returnable plastic and glass	689.69	0.0133
Large, paper	2,193.53	0.0203
Large, glass	1,034.50	0.0096
Large, disposable plastic and paper	2,684.08	0.0249
Large, returnable plastic and glass	1,236.76	0.0115

^aSummation of Tables 2-9, pages 38, 41, 43, 45, 47, 51, 53, and 55.

^bQuart equivalents.

computed delivery cost figure may be an acceptable trade-off. To further minimize the chance of error in the delivery cost figure, results of several prior studies were converted to a 1970 price basis and averaged.

The price deflators used were those published in the 1971 Economic Report of the President.¹⁸ An advantage of using these indices was that the relevant range of years for this study has the same base. Discontinuity of price change trend frequently encountered when splicing price deflators for a common base is eliminated. Additionally, the price variables published in the Report¹⁹ are acceptable proxy variables for this research.

These price variables "deflated" were delivery wages, vehicle or truck costs, and a category consisting of administrative, general credit, advertising, and "other" depending on the particular study. By separating the delivery costs into major cost components and deflating them, a logical weighting scheme is introduced, with possibilities of increased accuracy for the final results. Delivery wages were deflated by using Wholesale Trade Average Gross Hourly Earnings in Private Nonagricultural Industries and in Agriculture.²⁰ The author developed a price index for the Wholesale Trade Hourly Earnings published in order to transform absolute wages into relative weights. The year 1970 was used as a base for wage index computation. Truck costs were "deflated" by the consumer.

¹⁸ Council of Economic Advisors, Economic Report of the President, February 1971 (Washington: Government Printing Office, 1971).

¹⁹ Ibid., pp. 231, 249, and 250.

²⁰ Ibid., p. 231.

price index for transportation.²¹ The transportation category includes such vehicle costs as vehicle prices, fuel, oil, insurance, tires, repairs, and registration,²² thereby reflecting vehicle costs associated with delivery truck fleet operation. The third cost category, administrative general credit, advertising, and "other", is most closely approximated by the consumer price index, All Services Less Rent.²³

The milk delivery costs include retail routes for glass and paper, and wholesale routes for glass and paper. The inclusive route grouping overcame variations in research procedure in the studies used to develop the delivery cost figures. The alternative was simply to group all the delivery costs disregarding container type or delivery destination.

The average price deflated cost for milk delivery used in this research was 5.8713 cents per quart. See Table 51, Appendix A, for computations of the average delivery cost value.

Table 11 indicates that paper delivery costs were 65.4 percent of glass delivery costs. The relationship between paper and glass container types reflected the additional labor, both line and staff, required to handle returnable containers. The extra labor required for returnable relative to disposable containers was the research objective in the Babb and Butz study.²⁴ A limitation of the Babb and Butz study

²¹Ibid., p. 249.

²²United States Department of Labor, Monthly Labor Review, 94(6):250, June, 1971.

²³Council of Economic Advisors, p. 250.

²⁴E. M. Babb and W. T. Butz, "Improving Fluid Milk Distribution Practices Through Economic-Engineering Techniques," Pennsylvania State Experiment Station Bulletin 622, College Park, June 1957.

Table 11. Relative Percentages of Paper Container Delivery Costs to Glass Container Delivery Costs Based on Previous Research

Publication	Relative Weight ^a
	----Percent----
Williams ^b	68.6
Korzan et al. ^c	51.5
Cook ^d	<u>76.0</u>
Average weight	65.4

^aRelative weight is percentage that paper delivery costs is of glass delivery cost, i.e., paper costs .
glass costs

^bSheldon W. Williams, "Costs and Returns to Alabama Milk Distributors," Agricultural Experiment Station of the Alabama Polytechnic Institute Bulletin 287, Auburn, June, 1953, p. 33.

^cKorzan et al., "Costs of Distributing Milk in the Portland Market," Oregon State Agricultural Experiment Station Bulletin 510, Orano, February, 1952, p. 18.

^dHugh L. Cook, "Paper Packaged Milk in Wisconsin--Its Part in Expanding Distribution Areas," University of Wisconsin Agricultural Experiment Station Research Bulletin 179, Madison, June, 1953, p. 23.

and the Hicks and Wood study²⁵ was that labor costs are explicitly examined; whereas, relative vehicle costs associated with the heavier and bulkier returnable containers were not studied. Cook et al.²⁶ acknowledged volume and weight differences between given cases of glass and paper containers but did not pursue the implications of their findings in terms of truck costs associated with each type of container. Reliable quantitative data on truck costs for each type of container could not be easily and efficiently obtained, causing Cook et al.²⁷ to disregard differences in this cost category.

The paper and glass delivery costs were computed from published data.²⁸ The delivery costs given were averaged to establish a single relative factor for returnable and disposable containers. Table 12 presents the relative costs for the two types of containers. In addition to the basic cost data presented in Table 11, the basic costs have been augmented by 10 percent and 20 percent to study the effects of underestimating the computed delivery costs on overall costs to the plant. Reference to Table 12 indicates that if the basic delivery cost was underestimated by as much as 20 percent or 1.17 cents, the relative

²⁵ Hicks and Wood, Operations of Routes.

²⁶ Hugh L. Cook et al., "Costs and Efficiency of Wholesale Milk Distribution in Milwaukee," University of Wisconsin Agricultural Experiment Station Research Bulletin 196, Madison, May, 1956.

²⁷ Ibid.

²⁸ Korzan et al.; Hugh L. Cook, "Paper Packaged Milk in Wisconsin-- Its Part in Expanding Distribution Areas," University of Wisconsin Agricultural Experiment Station Research Bulletin 179, Madison, June, 1953; and Sheldon W. Williams, "Costs and Returns to Alabama Milk Distributors," Agricultural Experiment Station of the Alabama Polytechnic Institute Bulletin 287, Auburn, June, 1953.

Table 12. Relative Fluid Milk Distribution Costs for Returnable and Nonreturnable Containers for Three Absolute Cost Levels, 1970 Prices

Type of Container	Unit Cost	Relative Cost
	-----Cents-----	
Returnable ^a	5.8713	+2.0315
Disposable	3.8398	0
Returnable ^b	6.4584	+2.2346
Disposable	4.2238	0
Returnable ^c	7.0456	+2.4378
Disposable	4.6078	0

^aBasic unit cost derived from an average of previous studies. See Table 50, Appendix A.

^bBasic unit costs increased by 10 percent to offset possible underestimation.

^cBasic unit costs increased by 20 percent to offset possible underestimation.

differential will be affected by only 0.4693 cents per unit, a relatively small amount in the context of this study.

This study assumes no economies of scale to exist in milk delivery. Cook²⁹ stated that distribution costs vary from route organization, quantity per stop, and so forth rather than from scale of the bottling plant or total volumes distributed.

The packaging costs and the delivery costs will be aggregated in the discussion for Objective III in conjunction with the implications to the consumer.

²⁹Cook, p. 24.

CHAPTER IV

ANALYSIS FOR OBJECTIVE II

I. SCOPE OF THE ANALYSIS

The analysis for Objective II attempted to determine the weight and volume of solid waste generated and to quantify the costs of municipal solid waste collection and disposal for the municipalities in the study area. Specific answers to the question of total economic costs for operating city or community residential, commercial, and industrial garbage service per unit of waste processed were sought.

Primary and secondary data provided quantity and cost inputs in the partial budgeting analysis performed.

Initially this chapter sets forth the method by which the basic quantitative solid waste data were gathered; i.e., the weights and volumes generated per unit of time. Later an economic-engineering analysis is made of the three disposal or landfill sites operating within the geographical bounds of the study area. The three sites include those operated by the Knoxville, Knox County, and the Maryville, Alcoa, and Blount County disposal agencies. Knox and Blount counties provide only disposal services, whereas Knoxville, Alcoa, and Maryville provide collection services. Oak Ridge provides solid waste collection and disposal services via contract with a private firm for a given cost.

II. SOLID WASTE QUANTITY

Adequate data are not available on the quantities of solid waste generated in the areas covered by this study. Therefore, a sample survey was made to obtain these figures. Most solid waste is collected in compactor trucks, and so, these were the items sampled. Initially, all other vehicles (private cars, private trucks, and business-owned trucks) were to be included in addition to the compactor trucks for purposes of data gathering.¹ However, at the beginning of the survey to gather the data, cars and private trucks had to be omitted from the weighing plan because the typical nonprofessional driver did not exhibit the driving skill necessary to position the vehicle on the portable scales in a safe manner. During inclement weather the risk of a nonprofessional driver being the cause of an accident at the scales was compounded. The procedure used to compensate for omission of these vehicles will be discussed shortly.

The sample size was constrained, of course, by the time and resources available for data gathering. However, research in solid waste conducted in other areas of the United States indicate amounts collected during the autumn season to be near the mean for quantity generated.² Although published data were expressed in pounds per unit, a measure having less variability between time periods and between delivery

¹That is to say, there would be a complete enumeration of data from these vehicles in addition to the data gathered from the sample of compactor trucks.

²American Public Works Association, p. 30.

vehicles would be preferable for extrapolative purposes. Volume was, ex ante, believed to be this "ideal" measure. However, volume varies with compression force, moisture content of the refuse compressed, and density of the component materials comprising the particular heterogeneous mass of refuse being studied. Rather than attempting to reconcile these factors and their causal relationships affecting volume and weight, a task beyond the scope of this study, both weights and volumes were carried through the analysis. A further reason to justify retaining both measures was that costs can be compared for unit weight and volumes for the same waste materials, thus adding greater range to the utility for the analysis.

The American Public Works Association (APWA)³ stated that it is relatively easy to determine accurate weights and volumes of solid waste when the material is in the transporting vehicle ready to be discharged. In the geographic study area the greatest proportion of solid waste collected and deposited arrives at landfills in compaction (packer) trucks. Accordingly, the sample design was structured as follows.

The sample was used to estimate the average weight per cubic yard (CY) of solid waste delivered in packer trucks with a 95 percent confidence level desired. It was assumed that any one week at each of the four landfills surveyed is representative of the other weeks during the year. One compacted truckload was a sampling unit and all such loads per day in a six-day week constitute the population of interest at each of the four landfills.

³Ibid., p. 42.

Let X = pounds per CY of solid waste on one truck out of the population. The population mean expressed in pounds per CY per load, $\mu = E(X)$, is the sample objective. Records from the respective solid waste agencies indicated that a total of 551 packer vehicles could be expected over a one week period at all four sites covered by the study. The expected subtotals by landfill site are as follows: Knoxville, 355; Blount County, 90; Knox County, 40; and Oak Ridge, 66 vehicles per week.

Snedecor and Cochran⁴ state that if homogeneous strata within a heterogeneous population can be delineated, a gain in precision will result over simple random sampling. Stratified sampling requires a choice with respect to the size of sample to be taken from any stratum. Therefore, a proportional allocation was used which samples the same fraction from every stratum.

The sample size was computed from $n = \frac{Z^2 \hat{\sigma}^2 x^2}{L^2}$, where Z is the confidence level desired (or the probability the error in the mean will exceed L); $\hat{\sigma}^2 x^2$ is the sample variance of the population; and L is the allowable error in the sample mean⁵ measured in pounds; and n is the sample size for sites.

A sample of size, $n = 10$, was drawn from the population to establish a standard deviation for the population. (See Appendix B, pp. 184-185, for procedure.)⁶ The stratified sample using a proportional

⁴G. W. Snedecor and William G. Cochran, Statistical Methods, 6th edition (Ames: The Iowa State University Press, 1967), p. 520.

⁵Snedecor and Cochran, p. 521.

⁶Sampling procedure used was discussed with Dr. H. A. Lasater, University of Tennessee Statistics Department, Knoxville, October 30, 1970.

allocation with 5 percent probability of an error exceeding ± 10 pound per CY indicated a sample size, n , at Knoxville of 129; Blount County, 33, Knox County, 15; and Oak Ridge, 24.

A random number table was used to select the garbage packer trucks to be weighed.

All vehicles entering the landfill were stopped and questioned as to the origin of solid waste, i.e., residential, industrial, commercial, or agricultural. The type of material to be discarded was noted, along with vehicle identification and estimated cubic yardage of refuse. Solid waste volume was determined by measuring the inside dimensions of the carrier vehicle's load area. Refuse not lending itself to the simplified code used in the questionnaire was descriptively noted. (See Appendix B, p. 177, for sample questionnaire.) The data on the questionnaires formed the inputs for computing the mean weights per cubic yard of packer truck solid waste. The volume data collected from those vehicles not weighed were transformed into weights using published engineering information.⁷ Compaction factors for each waste category were applied to arrive at a standardized solid waste density for vehicles hauling loose waste.⁸ A compaction factor of 0.8, for example, means that the volume of loose solid waste material will decrease to 80 percent of original when sufficient compaction force is applied and a specific

⁷United States Department of Health, Education, and Welfare, Collection and Disposal of Solid Wastes for the Des Moines Metropolitan Area, p. 2-30.

⁸Ibid.

material density is attained. The standardized density has the advantage of allowing solid waste receipts of the landfill sites to be compared and/or aggregated.

The collected data were punched on data cards and standardized unit weights were computed by an electronic computer and the results summed for each site. The resultant weight and volume output from the computer was expanded to a 52 week basis. Table 13 presents the solid waste quantity estimated for the 52 week periods on the basis of the one week sample at each site. Knoxville processed approximately two-thirds of the total solid waste collected and disposed of in the study according to Table 13 totals.

III. SOLID WASTE MANAGEMENT COSTS

The organization of the municipal solid waste analysis is divided into cost categories for model collection and disposal agencies, assuming conformity to Tennessee Solid Waste Disposal Regulations.⁹ Cost data and equipment specifications were obtained from the respective municipalities located in the research area to permit model synthesis which simulated existing size and operational environment. The models assumed an efficiently run operation. Table 14 presents the cost stages relevant to each of the municipalities in the study area. Knox and Blount counties do not operate collection services. Oak Ridge contracts its solid waste management to a private firm.

⁹ Tennessee Code Commission, Tennessee Code Annotated, pp. 131-141.

Table 13. Expected Annual Weight and Standardized Volume Totals of Solid Waste Collected and Disposed of in the Seven Municipalities Located in Research Area, 1970

Location	Weight	Standardized Volume ^a
	Tons	Cubic Yards
Knoxville	119,467.40	385,231.6
Knox County	6,736.08	20,433.4
Blount County ^b	9,110.27	26,233.0
Maryville ^b	6,308.15	21,005.9
City of Alcoa ^b	5,813.12	19,066.3
Oak Ridge	22,520.16	57,610.8

^aDensity of standardized volume is 600 pound per CY.

^bThe total material disposed at the City of Alcoa operated landfill is 42,499,080 pounds and 66,305.2 CY. This total is the sum of the solid waste by weight and volume for Blount County, Maryville, and City of Alcoa; any discrepancy is due to rounding errors.

Table 14. Cost Stages Operated by Knoxville, Knox County, Alcoa, Maryville, Blount County, and Oak Ridge, 1970

Municipality	City Hall	Collection	Disposal
Knoxville	X	X	X
Knox County	X	a	X
Alcoa	X	X	X
Maryville	X	X	b
Blount County	c	c	c
Oak Ridge	X	d	d

^aKnox County does not perform collection service.

^bMaryville and Blount County contract to use Alcoa's landfill.

^cBlount County does not perform collection or disposal services. Administrative costs generated by Blount County officials in solid waste disposal management is of such small magnitude that their omission seemed reasonable.

^dOak Ridge contracts collection and disposal services with a private firm. Public Health Department acts as inspector and community relations coordinator.

Cost Stages--Collection

Land and building costs. Building costs allocated to solid waste management were determined for the respective agencies by a floorspace allocation technique when more than one department shared a building. Building space allocation was especially critical for the "city hall structure," since this building generally housed the majority of the staff organization for the local government. The actual floor space for specific office areas and total building floor area was obtained from the individual assigned to the office and from engineering records. The percentage of the total building unit used for the solid waste service was computed and the resulting rate was the basis for allocating costs normally assigned by the municipality to the general operating fund, such as telephone and utilities.

The Knox County solid waste building cost allocation presented a unique problem in that the County Clerk, who is administrator of the landfill, is housed with most other county agencies in a huge, old building. The landfill inspector for Knox County is headquartered in another building. Rather than attempt to cost out these two buildings, it appeared more efficient to determine the cost of comparable rental office space and to use rental rates as proxy costs. Rental rates used covered the economic costs associated with resources in office space use. Prices ranged from \$3.96 per square foot to \$4.56 per square foot without utilities; an average rental price of \$4.36 per square foot was chosen based on four rates supplied by local building rental agencies. If new building costs could not be obtained from current insurance appraisals

or other sources, a construction cost rate from the National Construction Estimator¹⁰ for military building costs was selected. The National Construction Estimator provides a guide for completed building space including fixtures and equipment normally considered built-in or attached to the structure, e.g., window screens, Venetian blinds, and drinking water coolers.¹¹ An administrative building of the type approved for military installations would cost \$26.62 per square foot, adjusted for location factors and size.¹² Personal observation indicates that new military administrative buildings built by the Federal Government in recent years differ little architecturally and functionally from civilian counterparts constructed by local governments.

Table 15 gives the costing inputs associated with the municipal city hall and garage buildings for Maryville, Alcoa, Knox County, Oak Ridge, and Knoxville. The land plot owned by specific municipalities surrounding the buildings varies in size. From the table it is noted that Maryville has four garages. Three are of the low cost pole barn variety, serving as storage facilities and the fourth, a more permanent structure housing the repair shops. The municipal garage complex existing at Knoxville is a series of antiquated buildings. To facilitate synthesizing the garage complex, a single structure was envisioned with office space provided to the side. The synthesized garage was patterned

¹⁰Gary Moselle (ed.), National Construction Estimator (18th edition; Los Angeles: Craftsman Book Company, 1970-1971), p. 174.

¹¹Ibid., p. 175.

¹²Ibid., pp. 176-177.

Table 15. Municipal Building and Land Costs and Percentages Allocatable to Solid Waste Task for Five Located in the Research Area, 1970 Prices

Location	Land Area	Land Value	Space Occu- pied for Solid Waste Agency ^a	Initial Building Cost	Estimated Building Life
	Acres	Square ft.	Percent	Dollars	Years
Maryville					
Municipal Building	3.50	98,010	0.633	300,000.00	50
Municipal Garage	b	b	25.000	3,472.00	33.3
Municipal Garage	2.00	2,000	70.000	6,240.00	33.3
Municipal Garage	b	b	75.000	2,184.00	33.3
Municipal Garage	b	b	33.333	2,000.00	33.3
Alcoa					
Municipal Building	2.50	2,500	1.666	150,000.00	50
Municipal Garage	3.00 ^b	2,000	90.000	220,000.00	50
Municipal Garage	b	b	100.000	4,960.00	33.3
Knox County					
Municipal Building	c	c	3.000	1,098.72 ^c	c
Municipal Building	c	c	40.000	627.84 ^c	c
Oak Ridge					
Municipal Building	6.68	20,500	0.694	565,331.72	50
Knoxville					
Municipal Building	6.00 ^b	174,240	15.000 ^b	54,091.84 ^d	50
Municipal Garage	7.09	65,340	70.000	105,925.00	50

^aSpace allocation determined from percentage office floor space of total building floor space or from usage estimates by the office or building user.

^bLand allocated to garage at rate of 70 percent for Maryville and 50 percent for Alcoa Garages, and 0.132 percent for Knoxville Municipal Building.

^cInitial building cost is based on office space required times current office space rental rates. Rental cost includes capital costs such as depreciation and interest which are due on owned capital.

^dInitial building cost based on public works division area only.

after maintenance facilities observed by the author while serving in the military.

The building costs for the Knoxville City Hall are for the public works department only as shown in Table 15. Engineering records provided the floor space allotted to public works. The average percentage of time devoted to solid waste management by the office staff was the basis for allocation of intradepartmental building costs. The 0.132 percent of city hall rate land allocation was determined from the ratio of solid waste management floor area to total city hall floor area.

The data given in Table 15 are of sufficient detail to allow computation of building depreciation, interest, and maintenance costs. The latter two costs are based on 6 percent interest rate¹³ and 1 percent of initial building cost¹⁴ per year. Insurance costs¹⁵ are based on the following rates:

Building, all risk, broad peril	\$0.20/\$100 value
Building and premises liability	\$1.25/100 square feet of floor space
Building contents	\$0.25/\$100 value

Office equipment costs. Office equipment constitutes are a significant cost group. The inventory of equipment in the model offices was established on the basis of personal observation during data collection visits. Prices of equipment pieces were obtained from local office

¹³See footnote 9, page 39.

¹⁴Conner et al., p. 15; Webster et al., pp. 24, 30.

¹⁵Charles Powell, Jr., Powell Insurors, Knoxville, Tennessee, personal interview, May 28, 1971.

equipment suppliers. Table 16 has listed the quantity of office equipment items for each municipality. The City of Alcoa provided a lump sum estimate of office costs associated with solid waste management. The lump sum given for Alcoa was \$916.30 which compares closely with other similar sized solid waste management offices. Blount County has not been included because of the difficulties involved in costing out the relatively small amount of total effort that goes into solid waste management. The county neither operates a collection service nor a disposal service, rather private collection contractors deal directly with the resident or business for refuse removal services. The Blount County officials negotiated a contract for Alcoa to completely operate a joint Blount County, Maryville, Alcoa landfill agreeing to pay 40 percent of the total disposal costs, whereas Maryville and Alcoa each pay 30 percent.

Office equipment depreciation, interest, maintenance, and insurance costs were computed from the information given in Table 16. Equipment life was estimated at 15 years with zero salvage value. Maintenance rate was estimated at 1.5 percent per year of new cost and a 6 percent interest rate was assumed.

Garage equipment costs. Knoxville, Maryville, and Alcoa operate municipal equipment repair and storage facilities. There are costs associated with equipping a repair garage adequately to enable vehicle maintenance. Table 17 lists estimated garage equipment costs for Knoxville, Maryville, and Alcoa. Only the City of Alcoa retains an inventory of spare parts and equipment to meet emergency needs. The

Table 16. Office Equipment Inventory for Four^a Municipalities in the Research Area, 1970 Prices

Item	Purchase Cost ^b	Knox County	Knoxville ^c	Oak Ridge	Maryville
	Dollars	-----Quantity in Units-----			
Secretary desk	250	1	2	1	1
Secretary chair	70	0	2	1	1
Side chair	60	4	17	2	8
Vertical file	75	3	20	1	4
Executive desk	225	2	11	0	1
Executive chair	90	2	9	0	1
Typewriter	400	1	7	1	2
Electronic calculator	800	1	4	0	2
Work table	130	0	0	0	2
2-way radio	2,350	0	1	0	1
Floor mat	10	1	0	1	2
Bookshelf	23	1	0	2	1
Adding machine	550	0	5	0	1
Letter file	2	1	5	1	2
Wastebasket	5	1	10	1	3

^aCity of Alcoa office equipment cost was obtained unitemized; the total was \$916.30 allocated to solid waste.

^bAverage life estimated at 15 years; maintenance rate is 1.5 percent per year of new cost; interest rate assumed at 6 percent per annum; and zero salvage value.

^cIncludes both city hall and garage office equipment.

average annual cost of the Alcoa inventory related to solid waste is estimated at \$2,200, according to city accounting records. The data given in Table 17 are the basis for computation of depreciation assuming zero salvage value, interest on capital invested assuming 6 percent interest, maintenance costs assuming 1 percent on new equipment cost per year. Insurance costs were computed from rates given on page 75.

Vehicle costs. One of the largest cost categories associated with solid waste management is that associated with the collection vehicles. Although the solid waste collection service has traditionally been labor intensive, efforts have been made to increase collection efficiency through mechanization. The collection equipment currently manufactured is relatively costly to purchase and after personally inspecting municipal collection truck service records, one could conclude they are costly also in terms of maintenance. Intensive examination of city compactor truck records for the period, 1961-1970, indicated that an estimated maintenance cost of 150 percent of initial investment with a 7 year life could be justified. The author could not find published research data to verify or modify the estimated maintenance factor or vehicle life. Much of the packer equipment used in the other cities located in the research are of relatively late model; however, initial repair costs do not appear to refute the 150 percent rate. Specific costs included in the maintenance rate are parts, lubricants, tires, and labor. Trashmobiles and the GRD truck¹⁶ used by Knoxville have

¹⁶ A truck used to lift and empty large solid waste containers into the compaction trailer.

a 90 percent maintenance rate and a 4 and 10 year estimated life, respectively, according to the records check. Automobile and pick-up truck maintenance rates were estimated at 50 percent of new cost and an estimated life of 10 years based on published data.¹⁷ Purchase prices used for the various types of vehicles were from published municipal bid price lists.¹⁸ Depreciation, interest, and maintenance costs were computed from the data in Table 18. Supplementary assumptions to those given are a 10 percent salvage value on equipment and a 6 percent interest rate on capital invested. Insurance rates given by a regional insurance firm familiar with municipal vehicle insurance, estimated that liability per automobile is \$156; trashmaster sized truck, \$568; and large packer type truck is \$912 per year.¹⁹ This is a cost assigned to the average degree of risk the vehicles face while performing collection services. In reality some municipalities do not purchase commercial insurance, but rather insure the vehicles themselves. If a vehicle is involved in an accident, the municipality pays the costs for which it is liable from its general fund. The cost of commercial insurance, then, is a cost and is, therefore, included in the operational costs.

¹⁷Glenn H. Glover, "Costs of Farm Machinery Used for Cotton Production in Tennessee," University of Tennessee Experiment Station Bulletin 448, Knoxville, October, 1968, p. 21.

¹⁸M. U. Snoderly (ed.), "Bid Data on Current Municipal Public Works," The University of Tennessee Technical Bulletin 60, MTAS, Knoxville, July, 1969; and Frank E. Kirk (ed.), "Bid Data on Current Municipal Public Works," The University of Tennessee (Knoxville) Technical Bulletin 62, July, 1970, and Technical Bulletin 63, January, 1971.

Table 18. Type, Quantity, Initial Cost, Estimated Life, and Maintenance Factor of Municipal^a Solid Waste Collection Equipment for Knoxville, Maryville, and Alcoa, 1970 Prices

Municipality and Type	Quantity	Cost ^b	Life	Maintenance Factor
		Dollars	Years	Percent
Knoxville				
Packer truck, rear load, 20 CY ^c	26	339,612	7	150
Packer truck, front load, 25 CY	7	148,204	7	150
GRD truck, hoist	1	19,000	10	90
Tractor and trailer, 42 CY	1	37,000	7	150
Trashmobile, Datsun size	29	85,550	4	90
Automobile, sedan	3	6,990	10	50
Pick-up truck	1	1,961	10	50
Maryville				
Packer truck, front load, 25 CY	1	21,172	7	150
Packer truck, rear load, 20 CY	1	13,062	7	150
Packer truck, rear load, 16 CY	2	22,384	7	150
Packer truck, rear load, 13 CY	1	9,602	7	150
Automobile, station wagon	0.1 ^d	2,400	10	50
Alcoa				
Truck, Dempster Dinosaur, 47 CY	1	33,000	7	150
Packer truck, front load, 25 CY	1	21,172	7	150
Packer truck, rear load, 18 CY	1	9,880	7	150
Packer truck, rear load, 13 CY	1	9,602	7	150
Pick-up truck	0.7 ^d	1,961	10	50
Oak Ridge				
Automobile, sedan	1	2,330	10	50
Knox County				
Automobile, sedan	0.4 ^d	2,330	10	50



Table 18 (continued)

^aKnox County, Blount County, and Oak Ridge do not own collection vehicles.

^bTen percent salvage value assumed.

^cCY = payload capacity in cubic yards.

^dDecimal indicates allocation to solid waste management function.

Fuel costs. Fuel costs are a function of time and distance.

Accurate fuel records are generally maintained for municipal vehicles. Careful inspection of many fuel records resulted in estimated fuel consumption rates applicable to the localities covered by this study. Published research data could not be found to further update the fuel estimate used in this study.

Table 19 shows the fuel cost computation components. The gallons used per day for Knoxville were estimated for the particular vehicle from fuel fill-up receipts. The fuel costs for Maryville and Alcoa were taken from city accounting records and the rates listed in the table were imputed. The lump sum fuel costs appear reasonable when checked against simulated fuel utilization rates and times of operation. Oak Ridge and Knox County automobile fuel costs were imputed from estimated average fuel consumption rates and daily mileage estimates supplied by the vehicle drivers.

Labor costs. Direct and indirect labor is the largest cost item associated with solid waste collection. Wage rates paid to municipal employees, especially to the direct labor, varied according to the specific municipality. For example, wage data collected showed one city had a direct labor wage scale significantly below the other municipalities in the research area. However, there was some pressure to provide hospital insurance to employees as a basic fringe benefit. The anticipated fringe benefit increase was incorporated into the labor cost computations for this study. A second city paid its direct laborers a relatively low wage but renumerated them also with exceptionally

Table 19. Basis for Fuel Cost Computations by Type of Collection Vehicle for Municipalities^a in Research Area, 1970 Prices

Municipality and Type Vehicle	Number of Vehicles	Gallons Per Day Per Vehicle	Total Cost Per Gallon	Days Operational Per Annum
			Cents	
Knoxville				
Trashmaster	29	9	18.00	260
Automobiles	3	4	18.00	260
Pick-up truck	1	4	18.00	260
Rear packer	27	24	18.00	260
Front loader	8	35	18.00	286
Tractor-trailer	1	50	18.00	286
GRD truck	1	30	18.00	286
Maryville				
Rear packer	3	12.4285	15.25	292.5
Front loader	1	12.8821	15.00	292.5
Oak Ridge				
Automobile ^b	1	1.1835	21.00	260
Knox County				
Automobile	0.4 ^c	1.6667	18.00	260

^aAlcoa fuel costs given for lump sum annual cost of \$2,621.63.

^bOak Ridge automobile has additional \$16.00 per year charge for oil and tires.

^cFractional vehicle quantity represents the amount allocated to solid waste management when the vehicle is used in several municipal departments.

lucrative fringe benefits, including hospitalization and life insurance and retirement plans. The high fringe benefits enabled the municipality to compete better for labor with a large industrial complex located nearby.

Table 20 summarizes the wages and salaries paid by the municipalities in the areas studied for city hall, collection, and disposal labor. Included in the table are the manpower requirements, the estimated fringe benefit rates, and the hours per week for which the job category is paid. The majority of the job descriptions listed in Table 20 have annual salaries as a basis of payment; especially for staff or office personnel. However, reference to Table 20 indicates several direct labor jobs have annual salaries given. The form in which the labor costs are presented in the table reflects the accounting procedures used in the particular municipality.

The total direct and indirect wages and salaries paid by the various municipalities were computed from the information listed in Table 20. That is, the number of men times the wage rate plus the fringe benefit rate times the hours worked per week gave the weekly labor cost for a specific job description. For salaries the fringe benefit rate was added to compute total annual job cost.

The cost data given in Tables 15-20 (pages 74, 77, 78, 81, 84, and 86, respectively) were used to compute unit costs by cost stages for the municipalities in the research area. In Tables 21-23 the cost per ton and cost per cubic yard of the various cost items relevant to the city hall, municipal garage, and collection phases of municipal solid waste management are listed.

Table 20. Municipal Wages and Fringe Benefits of Solid Waste Collection and Disposal Personnel for Knoxville, Knox County, Maryville, Alcoa, and Oak Ridge, 1970 Prices

Municipality and Job Description	Number of Men	Salary or Wage ^a	Fringe Benefits	Hours Per Week ^a
		Dollars	Percent	
Knoxville				
Rear loader truck drivers	27	2.30 ^b	10	40
Front loader truck drivers	8	2.45 ^b	10	45
Front loader truck helper	8	1.85 ^b	10	45
GRD truck driver	2	2.45 ^b	10	45
Tractor-trailer drivers	4	2.45 ^b	10	45
Trashmaster drivers	29	2.80 ^b	10	40
Trashmaster helpers	29	2.15 ^b	10	40
Foremen ^d	2	5,832.00 ^c	10	a
Scraper operator ^e	1	3,312.71 ^c	11.5	a
Caterpillar operator	1	5,512.00 ^c	11.5	a
Compactor operator	1	5,512.00 ^c	11.5	a
Watchmen and scalemaster ^f	3	1.65 ^b	10	40
Gas pump operators	1	1.65 ^b	10	48
City hall personnel	g	23,905.00 ^c g	g	a
Knox County				
Caterpillar operator	1	5,355.00 ^c	11.5	a
Watchman and scalemaster ^f	2	4,762.90 ^c	h	a
County court personnel	g	2,878.20 ^c g	g	a
Maryville				
Packer drivers and helpers	15	2.351 ^{b1}	13.11	45
Engineer and staff	g	4,540.02 ^c eg	g	a
Alcoa				
Packer drivers and helpers	12	2.098 ^{b1}	31.68	40
Caterpillar operators	1.2 ^j	7,878.00 ^c	g	a
Scraper operator	0.14 ^j	909.59 ^c	g	a
Watchman and Weighmaster ^f	1	3,432.00 ^c	19.4638	a
Foreman	0.7 ^j	7,308.00 ^c	25.6	a
Engineer and staff	g	8,139.59 ^c	g	a
Oak Ridge				
Public Health Department Staff	g	9,943.25 ^c	g	a

Table 20 (continued)

^aSalary per annum; hours per week not applicable. Wages per hour; hours per week are applicable.

^bWage per hour.

^cSalary per annum.

^dForemen are assigned to collection category.

^eScraper operator wages assigned at a 60.1 percent rate to solid waste disposal.

^fWatchman-weighmaster serve dual roles.

^gMunicipal city hall personnel salary is estimated as a lump sum to include fringe benefits.

^hNo fringe benefits paid by municipal government; the individual has sole scavenger rights at the landfill.

ⁱWages are imputed from city records.

^jMan-day allocated to solid waste function in the amount of the decimal.

Table 21. Allocated Annual Total and Unit Costs of Solid Waste Collection and Disposal Functions for Knoxville, Knox County, Alcoa, Maryville, and Oak Ridge Municipal City Hall Stage, 1970 Prices

Municipality and Cost Item	Total Cost Per Year	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Knoxville			
Building depreciation	162.27	0.0014	0.0004
Building maintenance	81.14	0.0007	0.0002
Building interest	243.42	0.0020	0.0006
Building insurance	16.23	0.0001	0.0000
Land interest	6.21	0.0001	0.0000
Office equipment depreciation	29.25	0.0002	0.0001
Office equipment maintenance	6.57	0.0001	0.0000
Office equipment interest	13.17	0.0001	0.0000
Office equipment insurance	1.10	0.0000	0.0000
Staff labor ^a	23,905.00	0.2001	0.0621
Utilities	28.00	0.0002	0.0001
Supplies ^b	346.20	0.0029	0.0009
Total	24,838.56	0.2079	0.0644
Knox County			
Building rent ^c	317.06	0.0471	0.0155
Office equipment depreciation	14.64	0.0022	0.0007
Office equipment maintenance	4.88	0.0007	0.0002
Office equipment interest	8.05	0.0012	0.0004
Office equipment insurance	0.61	0.0001	0.0000
Staff labor ^a	2,878.20	0.4273	0.1409
Utilities	138.29	0.0205	0.0068
Supplies ^b	31.00	0.0046	0.0015
Automobile	252.84	0.0375	0.0124
Total	3,645.57	0.5412	0.1784
Alcoa			
Building depreciation	49.98	0.0086	0.0026
Building maintenance	25.00	0.0043	0.0013
Building interest	74.97	0.0129	0.0039
Building insurance	5.58	0.0010	0.0003

Table 21 (continued)

Municipality and Cost Item	Total Cost. Per Year	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Land interest	96.80	0.0166	0.0051
Office equipment depreciation	61.09	0.0105	0.0032
Office equipment maintenance	9.16	0.0016	0.0005
Office equipment interest	27.49	0.0047	0.0014
Office equipment insurance	2.29	0.0004	0.0001
Staff labor ^a	8,139.59	1.3959	0.4269
Utilities	112.98	0.0194	0.0059
Supplies ^b	176.00	0.0302	0.0092
Total	8,780.93	1.5061	0.4604
Maryville			
Building depreciation	37.98	0.0060	0.0018
Building maintenance	18.99	0.0030	0.0009
Building interest	56.97	0.0090	0.0027
Building insurance	5.68	0.0009	0.0003
Land interest	162.86	0.0258	0.0078
Office equipment depreciation	117.28	0.0186	0.0056
Office equipment maintenance	14.07	0.0022	0.0007
Office equipment interest	42.22	0.0067	0.0020
Office equipment insurance	3.52	0.0006	0.0002
Staff labor ^a	4,540.02	0.7197	0.2161
Utilities	114.07	0.0181	0.0054
Supplies ^b	50.00	0.0079	0.0024
Automobile	87.12	0.0138	0.0041
Total	5,250.78	0.8323	0.2500
Oak Ridge			
Building depreciation	78.47	0.0035	0.0014
Building maintenance	39.23	0.0017	0.0007
Building interest	117.70	0.0052	0.0020
Building insurance	10.17	0.0005	0.0002

Table 21 (continued)

Municipality and Cost Item	Total Cost Per Year	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Land interest	57.06	0.0025	0.0010
Office equipment depreciation	58.68	0.0026	0.0010
Office equipment maintenance	19.56	0.0009	0.0003
Office equipment interest	32.27	0.0014	0.0006
Office equipment insurance	2.45	0.0001	0.0000
Public refuse containers ^d	300.30	0.0133	0.0052
Staff labor ^a	9,943.25	0.4415	0.1726
Utilities	81.80	0.0036	0.0014
Supplies ^b	625.00	0.0290	0.0113
Automobile	639.77	0.0284	0.0111
Total	12,005.71	0.5342	0.2088

^aLabor cost does not include mayor's or city council's salary.

^bBuilding rent allocated on basis of floor space and rent includes all building and land costs.

^cSupplies include such items as pencils, paper, postage, duplication services, etc.

^dSidewalk containers furnished by the city.

Table 22. Allocated Annual Total and Unit Costs of Solid Waste Collection and Disposal Functions for Knoxville, Alcoa, and Maryville Municipal Garage Stage, 1970 Prices

Municipality and Cost Item	Total Cost Per Year	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Knoxville			
Building depreciation ^a	1,483.00	0.0124	0.0038
Building maintenance	1,059.25	0.0089	0.0027
Building interest	2,224.42	0.0186	0.0058
Building insurance	192.05	0.0016	0.0005
Land interest	19,456.95	0.1629	0.0505
Shop equipment depreciation	773.26	0.0065	0.0020
Shop equipment maintenance	210.04	0.0018	0.0005
Shop equipment interest	347.95	0.0029	0.0009
Shop equipment insurance	20.57	0.0002	0.0001
Labor	60,305.62	0.5048	0.1565
Utilities	1,110.00	0.0093	0.0029
Supplies	500.00	0.0042	0.0013
Total	87,683.11	0.7341	0.2275
Alcoa			
Building depreciation	4,229.97	0.7254	0.2219
Building maintenance	2,879.00	0.4937	0.1510
Building interest	6,279.00	1.0768	0.3293
Building insurance	535.76	0.0919	0.0281
Land interest	180.00	0.0309	0.0094
Shop equipment depreciation	100.00	0.0171	0.0052
Shop equipment maintenance	12.55	0.0022	0.0007
Shop equipment interest	37.66	0.0065	0.0020
Shop equipment insurance	59.39	0.0102	0.0031
Labor	6,537.30	1.1211	0.3429
Utilities	73.44	0.0126	0.0039
Supplies	60.43	0.0104	0.0032
Inventory interest	66.00	0.0114	0.0035
Vehicle	364.68	0.0625	0.0191
Total	21,415.18	3.6727	1.1233

Table 22 (continued)

Municipality and Cost Item	Total Cost Per Year	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Maryville			
Building depreciation	226.45	0.0359	0.0108
Building maintenance	75.41	0.0120	0.0036
Building interest	226.22	0.0359	0.0108
Building insurance	62.21	0.0099	0.0030
Land interest	168.00	0.0266	0.0080
Shop equipment depreciation	130.67	0.0207	0.0062
Shop equipment maintenance	19.60	0.0031	0.0009
Shop equipment interest	58.80	0.0093	0.0028
Shop equipment insurance	0.52	0.0001	0.0000
Labor	b	b	b
Utilities	561.10	0.0889	0.0267
Supplies	50.00	0.0079	0.0024
Total	1,578.98	0.2503	0.0752

^aBuilding life estimated at 33.3 years for Maryville; for Knoxville and Alcoa, 50 years.

^bNo administrative or supervisory labor is located in the garage.

Table 23. Allocated Annual Total and Unit Costs of Solid Waste Collection and Disposal Functions for Knoxville, Alcoa, and Maryville Collection Stage,^a 1970 Prices

Municipality and Cost Item	Total Cost Per Year	Cost Per Ton	Cost Per Cubic Yard
Knoxville	-----Dollars-----		
Collection vehicle depreciation	89,180.78	0.7465	0.2315
Collection vehicle maintenance	133,838.00	1.1305	0.3475
Collection vehicle interest	21,064.54	0.1761	0.5468
Collection vehicle insurance	49,428.00	0.4137	0.1285
Collection vehicle fuel costs	61,123.80	0.5175	0.1605
Labor	559,616.20	4.6843	1.4527
Total	914,951.32	7.6686	2.8675
Alcoa			
Collection vehicle depreciation	9,469.86	1.6240	0.4967
Collection vehicle maintenance	15,783.00	2.7067	0.8278
Collection vehicle interest	2,430.60	0.4168	0.1275
Collection vehicle insurance	3,648.00	0.6256	0.1913
Collection vehicle fuel costs	2,621.63	0.4496	0.1375
Labor	68,955.65	11.8255	3.6166
Total	102,908.74	17.6482	5.3974
Maryville			
Collection vehicle depreciation	8,514.14	1.3497	0.4053
Collection vehicle maintenance	14,189.00	2.2493	0.6755
Collection vehicle interest	2,185.32	0.3464	0.1040
Collection vehicle insurance	4,560.00	0.7229	0.2171
Collection vehicle fuel costs	2,228.37	0.3533	0.1061
Labor	93,660.31	14.8475	4.4588
Total	125,337.14	19.8691	5.9668

^aOak Ridge contracts for collection and disposal as a single bid, as such the collection and disposal functions are not separable.

The cost items appearing for the first time in Tables 21-23 requiring discussion are utilities and supplies (Table 21). Utility cost was determined from municipal records and with collaboration with respective city officials. Where only a lump sum total utility cost was available the costs were allocated in the same manner as building depreciation. That is, telephone, electric, gas, and water costs were aggregated for a period of time and the solid waste service allocation factor, computed from floor space allocation, was applied.

Office supply costs. Supplies include such cost items as postage, paper, and duplication services. The specific supply cost given in Table 21 is an estimate based on conversation with solid waste office personnel in that municipality, personal observation, and judgment. The inherent problem with determining office supply costs is that the municipalities generally purchase office supplies in bulk to gain price discounts and individuals located in the various agencies use the supplies on the basis of need. Internal cost records are not kept on these types of office supplies.

The cost item "automobiles" appears for Knox County, Maryville, and Oak Ridge in Table 21. Where no automobile cost items exist in Table 21 (Knoxville and Alcoa), the automobile cost category is included in Table 18 (page 81) and Table 23 for Knoxville and Alcoa. Cars are not assigned directly to city hall personnel in Knoxville and Alcoa; rather these municipalities have vehicles which are assigned to supervisory personnel or foremen. These personnel are considered direct labor rather than staff labor in the organizations' personnel hierarchy.

The unit costs were obtained by dividing the total cost for each cost item in a municipality by the weight and volume of solid waste produced in that municipality for 1970. Thus, each cost item total for the respective city was divided by the respective solid waste total found in Table 13 (page 70).

Table 22 (page 91) provides unit costs for the municipal garage stage in each relevant municipality. The supplies cost item of Table 22 consists of expendables such as cleaning fluids, grease wipe rags, and service record forms. Problems associated with estimating garage supply costs are similar to those for estimating office supply costs.

Labor costs attributed to the garage function consist of foremen labor or in the case of Knoxville, labor costs include wages of staff personnel located in the garage offices whose work relates directly to collection services. The labor cost listed does not include maintenance labor or mechanic's wages, for this cost is included in the maintenance factor applied to vehicle costs.

Unit costs computed for the collection stage are given in Table 23 (page 93) for Knoxville, Alcoa, and Maryville. Labor costs include direct labor only. No attempt was made to allocate overhead or city hall costs to collection or disposal where these functions exist jointly, because sufficient data were not available.

Cost Stages--Disposal

Assumptions used to develop disposal model. Disposal costs were computed for Knoxville, Knox County, and Alcoa. These municipalities

currently operate solid waste disposal sites and the research objective was to synthesize the disposal that would simulate the actual operations assuming enforcement of Tennessee Solid Waste Disposal Regulations.

Problems associated with budgeting the landfill operation include the following: (1) determination of the size and number trenches needed to handle peak refuse deliveries, (2) determination of whether it is more economical to operate owned equipment and dig trenches or to contract trench digging as needed, and (3) determination if equipment is owned what size units would be economically justifiable.

The general assumptions upon which this analysis is based are as follows: the trench method of disposal is used, although other types of landfill methods might be acceptable. The American Public Works Association provides a very informative discussion on landfill operations²⁰ if the reader desires in-depth information. Compaction density attained in the landfill was assumed as 600 pounds per cubic yard, dry weight or weight on the truck. A recent empirical study found compaction densities ranging from 515 to 613 pounds per cubic yard.²¹ Other publications have indicated higher densities;²² however, because density is a function of weight applied in compaction, duration of time of weight application, moisture content, type of solid waste, and amount of initial compaction

²⁰American Public Works Association, pp. 19-146.

²¹United States Department of Health, Education and Welfare, Solid Waste Landfill Stabilization, An Interim Report [Ralph Stone and Company] (Cincinnati: Bureau of Solid Waste Management, 1968), Table 5, pp. 1-4; Table 7, pp. 2-3.

²²American Public Works Association, p. 100.

in the truck, it is difficult to speak with assurance of a density at a particular landfill, thus, 600 pounds per CY was used.

Trench design. Reference to Table 13 (page 70) indicates the amount of refuse that must be disposed of per year. This annual quantity can be converted to daily and weekly quantities delivered as follows: Knoxville--765,816.67 pounds and 1,234.72 CY's for a six-day work week; Knox County--151,816 pounds and 78.59 CY's for a five-day work week; and Blount County--136,215 pounds and 212.52 CY's for a six-day work week.

The width of the trench required is a function of the amount of truck traffic during peak delivery periods. A trench too narrow will not allow simultaneous dumping, resulting in costly collection truck delays. On the other hand, too wide a trench creates compaction problems in that the compactor must spend time driving about spreading and compacting refuse discharged over a large area. The width of the model trenches is estimated to accommodate peak traffic loads at a particular site.

The trenches at Knoxville and Alcoa were arbitrarily set at 18 feet deep and at Knox County at 9 feet deep. A trench too deep can partially fill with water, creating compaction problems. A 30 degree grade or slope at the trench compaction face was assumed after observation of actual trench-fill operations. The purpose of calculating the compaction slope was to translate solid waste delivery data into the linear footage of trench utilized per day for disposal. The length of the compaction slope assuming a 30 degree slope and a given trench depth required the use of trigonometry. The tangency formula for an angle enabled the

adjacent side to be computed. See Figure 3.

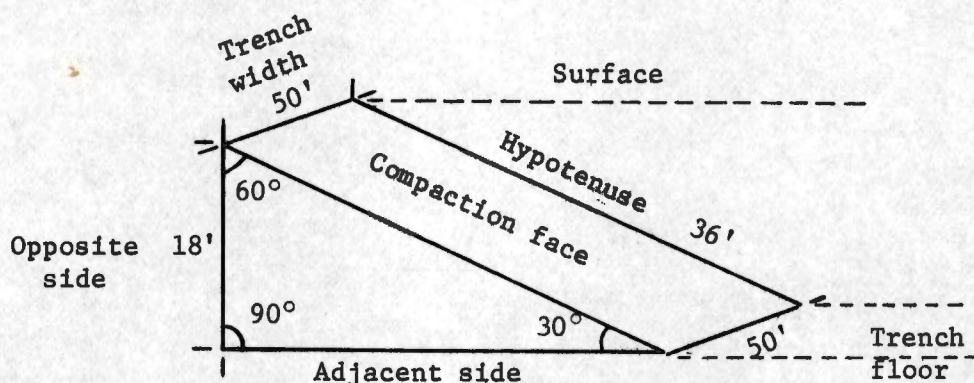


Figure 3. Cross-section of a landfill trench end.

Once the opposite and adjacent sides were calculated, the formula $a^2 + b^2 = c^2$ was used to find the length of the hypotenuse, $\sqrt{c^2}$. Thus, with the opposite side known, 18 feet, the adjacent side was computed, 31.174 feet, and both known sides were used to compute the compaction face, 35.997 feet or 36 feet. The compaction face surface, viewed from above, forms a rectangle whose area is 50 feet x 36 feet = 1,800 square feet. If a 1 foot layer of refuse is spread uniformly on the rectangular surface, the volume of solid waste necessary to fill the space whose dimensions are 50 feet x 36 feet x 1 foot = 1,800 square feet or 66.67 CY. The Alcoa (Blount County) landfill trench would fill at a rate of 3.188 feet per day plus the required six inch layer of compacted dirt

cover.²³ The amount of cover dirt necessary to cover the compaction face daily is 33.33 CY (50 feet x 36 feet x 0.5 foot).

Assuming both ends of the trench have 30 degree slopes, there would exist a space, triangular shaped, near the trench end yet to be filled whose volume can be found utilizing the formula to find the volume of a triangle, sides $(A + B + C) \div 2$. Using similar triangles, the volume of the end space was 1,039.13 CY or 4.24 day's solid waste disposal volume. See Figure 4.

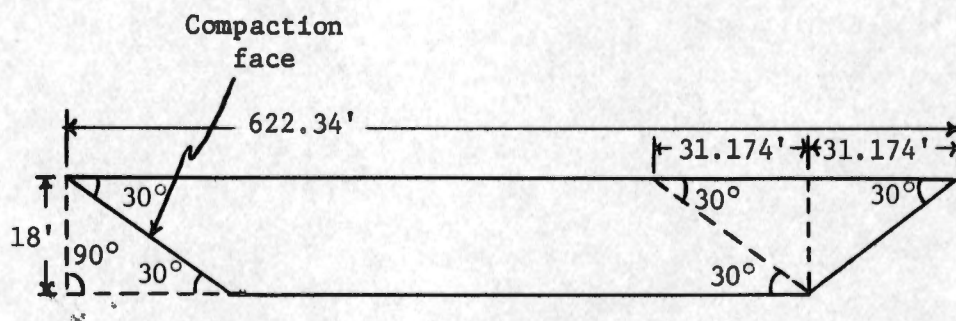


Figure 4. Cross-section of a landfill trench with a trapezoidal shape.

Assuming it is desirable to dig only two trenches per year, the length of the model trench was computed as follows: 26 weeks x 6 days per week = 156 days trench capacity. Six days is the number of days per week refuse is to be delivered. Subtracting the end fill volume of 4.24 days left a capacity for 151.76 days solid waste disposal. The trench length was 151.76 days times 3.69 feet per day equaling 559.99

²³Tennessee Department of Public Health, Regulations Governing Solid Waste Processing and Disposal in Tennessee (Nashville: Tennessee Department of Public Health, 1971), p. 10.

feet plus end length or 62.35 feet. The total trench dimensions when viewed from above are 50 feet wide x 622.34 feet long. The land area required for one trench was 0.714 acre.²⁴ Assuming that a 16 foot buffer perimeter surrounds the trench, land area requirements are increased to 0.967 acre per trench. Two trenches used in the first year would require 1.934 acres.

The decision to purchase equipment and dig trenches or to hire a contractor to excavate the trenches was determined after costing out the alternatives. Appendix B, page 186, presents the computations for commercial excavation for Alcoa landfill. Only Knox County could economically justify not owning excavation equipment, as will be discussed later.

The average round-trip (to load and unload the scraper) for excavating the Alcoa sized trench was 1,426.68 feet; that is, two times the length including the overrun length and 75 percent²⁵ of twice the trench width. The earth displaced from the trench is assumed to be piled directly adjacent to the trench so adequate cover material is available nearby. Because construction of the succeeding trench must be initiated before the one in use is filled, location of the displaced earth pile must be thoroughly preplanned.

²⁴ Computations: $622.34 \text{ feet} \times 50 \text{ feet} = 31,117 \text{ square feet} \div 43,560 \text{ square feet per acre} = 0.714 \text{ acre}.$

²⁵ The displaced earth or spoil pile is located adjacent to the trench. The scraper operator is assumed to minimize the travel or haul distance, therefore, when he excavates the left side of the trench, he can plan to deposit spoil toward the left side of the pile. The 75 percent is an estimated distance.

An excavation equipment manufacturer²⁶ suggested that where trenches are large and a great amount of material must be transported distances of 1,000 feet or more, a self-loading scraper is recommended. For the purposes of the Alcoa analysis the Caterpillar Self-Loading Scraper, Model 613, 11 CY capacity was selected.²⁷

It was assumed for computing scraper operating costs, that 50 percent of the 7,426.68 foot transport distance is uphill and loaded and 50 percent is downhill and empty. Specifications for the Model 613 scraper²⁸ indicated the following average speeds on each portion of the travel cycle: uphill, 4.5 miles per hour and downhill, 26 miles per hour. The rates of speed were converted to travel time taking into account acceleration and deceleration times, and loading and dump times. Drevdahl published formulas to compute scraper travel time.²⁹ The loaded travel time was 2.25 minutes; the empty travel time was 0.39 minutes; and the load and unload time was 0.39 minutes. Each cycle averages 3.74 minutes. This time figure was corrected for efficiency³⁰ and the corrected cycle time was 4.99 minutes. By dividing 4.99 cycle time into 480 (the minutes in an eight-hour work day) 96.19 trips or

²⁶ Caterpillar Tractor Company, Sanitary Landfill Machine Selection Guide (Peoria: Caterpillar Tractor Company, 1970), p. 4.

²⁷ Caterpillar Tractor Company, Elevating Scrapers, Publication No. AEO 20048 (Peoria: Caterpillar Tractor Company, 1970), pp. 4-6.

²⁸ Ibid.

²⁹ Elmer R. Drevdahl, Jr., Fundamentals of Excavation Equipment for Engineering and Technology (Tucson: Roadrunner Technical Publications, 1963), p. 3-32.

³⁰ Ibid.

or loads per day are possible. The operator is assumed to complete the final cycle of the day, accomplishing 97 cycles with 11 CY per load for 1,067 CY of material moved per work day.

An exogenous variable affecting the excavation rate is precipitation. Wet ground can cause material loading and unloading problems plus the possibility of a mired scraper. A precipitation factor was included into the computations based on information published by the National Climatic Center³¹ using the years 1965 and 1967-1970. The statistical data published indicated precipitation of at least 0.01 inch per day occurred 124.6 days per year for the five years observed or 34.1 percent of the days.

At the end of the day it is assumed that the scraper will load cover material from the pile adjacent to the trench, depositing the material in locations convenient to the compacting operation. The compactor will spread the material, covering the compacted solid waste with a six inch layer of earth.

The amount of time necessary for the scraper to transport cover material is time lost to constructing the trench. The cover material transportation cycle from a loading point at the spoil pile to the compaction face and return was estimated at 260 feet. Using the same procedure to calculate the time per cycle as explained in the case of digging the trench, an average speed of 5.4 miles per hour was converted to

³¹National Climatic Center, Local Climatological Data, Knoxville, Tennessee (Washington: Government Printing Office, 1965; 1967-1970), p. 1.

a cycle time of 1.65 minutes. When the efficiency factor³² is entered the corrected cycle time is 2.20 minutes.³³ The quantity of compacted cover material required is 33.33 CY. A phenomenon associated with excavating earth is its compaction characteristics. In earthmoving work it is not uncommon to compact material tighter than it occurred in a natural state according to one expert.³⁴ Compaction coefficients have been published for a variety of materials encountered in excavation work. The compacted density of "common earth" is 20 percent less than in its natural state; a characteristic referred to as shrink.³⁵ When earth in its natural state, bank earth, is loaded into a scraper it becomes less dense. This feature is known as swell and for wet or dry earth the amount of swell is 25 percent above bank measure.³⁶

The concepts of shrink and swell were used to determine the number of loads required to provide adequate quantities of cover material. The 33.3 CY compacted cover, when adjusted, equals 49.95 CY loose material. At 11 CY per load, 4 cycles taking 8.8 minutes plus travel time between work areas were required. Total intrasite travel time was estimated at 11 minutes. The additional 4.4 CY of cover material required can easily be pushed into place by the compactor. In terms of effort

³²The operating efficiency concept accounts for driver rest stops, machine breakdown, and the like. Caterpillar Tractor Company, Fundamentals of Earthmoving (Peoria: Caterpillar Tractor Company, April, 1968), p. 24.

³³Drevdahl, p. 3-32.

³⁴Caterpillar Tractor Company, Fundamentals of Earthmoving, p. 6.

³⁵Drevdahl, p. 3-6.

³⁶Ibid., p. 3-2.

lost excavating the trench, the time required to provide cover material is equivalent to four excavation loads leaving a daily maximum of 1,023 CY of trench materials excavated per day. At the rate of 1,023 CY per day, 19.26 days are required for trench excavation without precipitation. Assuming precipitation 34.1 percent of the days, the excavation period was extended to 25.83 work days or 5.2 five-day weeks.

Before establishing the number of hours per annum the scraper will operate another assumption was required: the scraper will be utilized to provide cover material during days of no precipitation. Given machine warm-up time and travel time, the machine will operate an average of one-half hour per day including Saturdays hauling cover material. The scraper is expected to operate 92.41 hours when not doing excavation plus 231.12 hours during excavation or a total of 323.53 hours per year. See Appendix B, page 187, for computations.

Disposal Equipment Costs

Scraper. The 11 CY Self-Elevating Scraper, powered by a 150 flywheel horsepower diesel engine, has a list price of \$42,976³⁷ with standard equipment. Annual depreciation costs were computed at \$2,578.56 assuming 10 percent salvage value and a 15-year life. The estimated life for depreciation purposes assumes a 15-year life planning horizon as a constraint rather than depreciation due to wear and obsolescence.

³⁷ Grant Whitmore, Sales Representative, Stowers Machinery Corporation, Knoxville, Tennessee, personal interview, May 4, 1971.

Normally a scraper has an estimated life of 10,000 hours³⁸ at average operating conditions; whereas, the scraper in the Alcoa model will attain but approximately 4,900 operating hours in 15 years. The interest cost of capital invested in the scraper is \$1,418.21 per year at 6 percent interest rate. The maintenance and repairs cost was computed from a coefficient established from past equipment maintenance records and includes an allowance for parts and repair labor for different levels of operating conditions.³⁹ A repair factor of 0.8 of annual depreciation charges⁴⁰ was used giving a yearly repair estimate of \$2,062.85.

Fuel costs. Annual fuel costs were computed from a special formula⁴¹ based on engine horsepower (150), fuel cost per gallon (18 cents), and machine operating time (324 hours). The annual fuel cost was \$313.96. Lubricating and hydraulic oils were estimated via average consumption rates based on 0.15 gallon per hour lubricant consumption, \$1.20 per gallon lubricant cost and 324 hours operating time. A factor of 50 percent was added to the lubricating oil costs to include other lubricants, oils, and grease.⁴²

Tire costs. Tire costs are a relatively significant yet variable cost item, and are consequently considered separately from the rest of

³⁸Caterpillar Tractor Company, Fundamentals of Earthmoving, p. 50.

³⁹Ibid., p. 53.

⁴⁰Drevdahl, p. 2-8.

⁴¹Ibid., p. 2-9.

⁴²Ibid., p. 2-20, p. 6-37.

the machinery. Drevdahl⁴³ published a tire life estimating guide. Assuming average operating conditions for the type of scraper in the model, the tire life was estimated at 1,224.7 operating hours or 3.8 years of normal use for the Alcoa scraper. A local tire dealer⁴⁴ stated that the required size and type of tires for the scraper would cost \$3,685.43 for a set of four. Assuming a zero salvage value and 3.8 years expected tire life, annual depreciation was \$969.85. Tire maintenance and repairs were estimated at 15 percent of depreciation⁴⁵ or \$145.48 per year. Using 6 percent interest, the annual cost of invested capital for tires was \$110.56.

Labor costs. The scraper operator is assumed to be attached jointly to the disposal service and some other municipal department. His wages were allocated to disposal function on the basis of the average number of days spent excavating the trench, estimated 38.52 days or 14.8 percent of his total annual work year. Table 24 summarizes the disposal function cost items for the City of Alcoa, Knox County, and Knoxville.

Compactor cost. The compactor unit used in the model landfill was a Caterpillar Model 815 with blade and rated at 170 flywheel horsepower.⁴⁶ The compactor was assumed to operate during the customary

⁴³Ibid., p. 2-13.

⁴⁴Goodyear Tire Sales Representative, Knoxville, Tennessee, personal interview, June 3, 1971.

⁴⁵Drevdahl, p. 2-12.

⁴⁶Caterpillar Tractor Company, Self-Propelled Compactors, Publication No. AEO 20098 (Peoria: Caterpillar Tractor Company, 1969).

Table 24. Physical Coefficients Used to Compute Landfill Disposal Costs for Alcoa, Knox County, and Knoxville, 1970

Input	Alcoa	Knox County	Knoxville
Daily weight solid waste (pounds)	136,215.0	51,816	765,816.67
Daily cubic yardage solid waste	212.52	78.59	1,234.72
Days of operation per week	6.0	5.0	6.0
Standardized solid waste density (pound per CY) ^a	600.0	600.0	600.0
Trench width (feet)	50	36	100
Trench depth (feet)	18	9	18
Compaction face length (feet)	36	18	36
Compaction face slope (degrees)	30	30	30
CY solid waste per linear trench foot	66.67	24	133.33
CY cover material required daily	33.33	12	66.65
Number linear feet trench filled per day	3.69	3.77	9.76
Assumed length of life per trench (months)	6	6	4
Computed trench length at surface (feet)	622.34	513.47	983.69
Excess length at each end of trench (feet)	16	7	8
Distance between trenches (feet)	16	16	10
Earth displacement per trench (CY)	19,705.46	5,974.80	67,657.57
Contractual excavation charge (\$ per CY)	0.50	0.50	0.50
Annual excavation cost by contract (\$)	19,705.46	5,974.80	101,486.40
Estimated scraper travel distance: excavation (feet)	1,426.68	1,166.94	2,271.38
Scraper capacity: self-loader (CY)	11	11	21.5
Corrected time per cycle (minute)	4.99	5.84	5.43
Excavation CY per day lost when hauling cover	44	33	150.5
Estimated scraper travel distance to haul cover (feet)	260	140	270
Annual scraper operating hours for trench excavation	231.12	82.56	699.30
Annual scraper operating hours for hauling cover material	92.41	40.97	66.69
Scraper engine horsepower	150	150	300

Table 24 (continued)

Input	Alcoa	Knox County	Knoxville
Scraper list price (\$)	42,976	42,976	84,868
Scraper tire cost (\$)	3,685.43	3,685.43	10,355.90
Allocation of scraper operator's salary	909.59	349.36	3,693.67
Fuel cost per gallon (cents)	17	17 ^b	15
Bulldozer horsepower rating	c	c	270
Bulldozer new cost (\$)	c	c	77,978
Annual operating hours	c	c	1,248
Maintenance factor	c	c	0.9
Auxiliary engine cost (cents per hour)	c	c	1.0
Operator's salary			6,145.88
Compactor new cost	44,926	34,000 ^d	79,973
Compactor engine horsepower	170	170	300
Compactor maintenance factor	0.7	0.95	0.7
Annual compactor operating hours	1,560	1,250	1,560
Average population increase, 5 years (percent)	1.83	1.101	2.266
Average land requirements per trench	0.9849	0.6390	3.2494
Fence length (feet)	655	2,086.36	5,047.5
Number gates (@ \$125) 12 feet wide	3	2	3
Crushed stone (tons)	280	79.365 ^e	400
Liability insurance cost (\$)	492.45	319.50	29,244.35
Utilities cost (\$)	112.00	128.29	145.55

^aPound per CY = pounds per cubic yard.

^bKnox County scraper fuel cost is 17 cents per gallon; Knox County compactor fuel is gasoline at 19 cents per gallon.

^cNot applicable.

^dKnox County used track compactor; Alcoa and Knoxville, wheel compactor.

^eKnox County stone requirements based on actual amount used in preceding year.

times, of landfill operation, 6-day weeks or 312 days per year. The compactor price was \$44,926 including a blade.⁴⁷ The operating life of the equipment was estimated at 13,000 hours, based on estimated operating life of similar machinery.⁴⁸ The compactor was assumed to operate 5 hours per day for 312 days per year giving an estimated life of 8.3 years. Five hours of daily operation was assumed based on personal observation in the field. Assuming 10 percent salvage value, annual depreciation was \$4,871.49. At 6 percent interest rates, the cost of invested capital was \$1,482.56. Using a repair factor of 0.7 times⁴⁹ the depreciation gave an estimated maintenance and repair cost of \$3,410.04 per year.

Fuel costs. Fuel costs were computed in the same manner as for the scraper and gave an annual cost of \$1,721.96. Costs of lubrication oils and grease were estimated to be \$421.20, including an additional 50 percent for other oils.⁵⁰

Labor costs. Operator labor salary for 2,080 hours per year was established at \$6,565 per year including fringe benefits. This salary was based on current (1970) labor costs for similar jobs paid by the City of Alcoa. An additional man must be available to operate the

⁴⁷ Grant Whitmore, Sales Representative, Stowers Machinery, Inc., Knoxville, Tennessee, personal interview, May 4, 1971.

⁴⁸ Caterpillar Tractor Company, Fundamentals of Earthmoving, p. 50.

⁴⁹ Drevdahl, p. 2-8.

⁵⁰ Ibid., p. 6-37.

compactor one day per week. The services of the relief man was covered by allocating an additional annual salary of \$1,313.00 to the disposal function. It is assumed that the compactor operators are trained to operate the scraper enabling them to haul cover dirt during the times that regular trench excavations have ceased.

Land costs. This study assumes a plot of land meeting state requirements for sanitary landfill operations has been acquired by the municipality and is ready for landfill use. This assumption abstracts from several important considerations that involve time and cost to the municipality. American Public Works Association⁵¹ discusses important factors that affect landfill site suitability: (1) comprehensive land use planning, (2) thorough geological investigation to predict extent and significance of underground or surface water pollution, and to determine the depth of soil for trenching and cover material, (3) zoning regulations, and (4) the likelihood of public acceptance for a site.

The municipal planning horizon must consider its future solid waste disposal needs, including population trends, per capita solid waste generation rates, and the possibility of adopting more efficient methods of solid waste disposal in the future.

A five-year planning horizon was arbitrarily adopted for use in this study. Using 1970 population and projection data prepared by the

⁵¹American Public Works Association, p. 93.

East Tennessee Development District⁵² disposal land requirements were estimated. Interpolation indicated an average population increase for 1970-1975 of 1.83 percent. Assuming a constant rate of solid waste generation for the five-year period, the 1970 trench size of 0.96718 acre would need to be 0.9849 acre to contain all the waste collected, compacted, and covered. At \$2,000⁵³ per acre, the 9.849 acres would have an interest cost of \$1,181.88 per year based on 6 percent interest rate.

Other Costs

Scale costs. Scale costs for a 50,000 pound capacity pit scale with weight printer and simple enclosure averaged \$11,750 installed.⁵⁴ The scale suppliers suggested an expected scale life of 20 years and a 1 percent of initial cost maintenance factor. Scale depreciation with 10 percent salvage value assumed, interest based on 6 percent per annum, and maintenance costs were \$1,034.00 per year.

Fence costs. Tennessee Solid Waste Disposal Regulations specify fence requirements⁵⁵ for the landfill area. Fence requirements were

⁵²East Tennessee Development District, "Blount, Anderson, Knox County Population Projections" (Knoxville: East Tennessee Development District, 1971). (Unpublished manuscript.)

⁵³Curtis Sims, Blount County Tax Appraiser, Maryville, Tennessee, personal interview, March 12, 1971.

⁵⁴Tennessee Scale and Supply Company and Cole Scale Supply Company, Knoxville, Tennessee, personal interviews, April 6, 1971.

⁵⁵Tennessee Solid Waste Disposal Regulations, p. 8.

computed for a square plot of land containing 9.849 acres. Fence specifications are a 6 foot fence with barbed wire top and three 12-foot gates. The fence cost was \$2.90 per linear foot and the gates were \$125 each installed.⁵⁶ Assuming a 15-year fence life, 10 percent salvage value, zero maintenance costs, and 6 percent interest on investment, depreciation was \$469.12 and interest was \$258.01 per year.

Road material costs. Inclement weather can make access to the landfill dumping area impossible if an all-weather road is not maintained. It was estimated that 280 tons of crushed aggregate (stone) would be used to build the access road. The stone was estimated to cost \$3.15 per ton delivered.⁵⁷

Insurance. Liability insurance cost for a fenced landfill was \$492.45 per year based on an estimated rate of \$50.00 per one acre.⁵⁸

The costs of disposal were estimated for Knox County and Knoxville using the same computational procedures. Table 24 (page 107) summarizes the physical inputs or coefficients of the three disposal models. The table lists the coefficients in parallel to enable the Alcoa computational procedure to be used for Knox County and Knoxville with the respective data.

Table 25 is a summary of annual total unit costs of the disposal functions for the six municipalities in the study area. Reference to

⁵⁶ Moselle, p. 149.

⁵⁷ Ibid., p. 26.

⁵⁸ Powell Insurors, personal interview.

Table 25. Summary of Annual Total Unit Costs by Collection, Disposal, and Collection-Disposal Functions for Six Municipalities in the Research Area, 1970 Prices

Municipality	Collection		Disposal ^a		Collection-Disposal	
	Cost Per Ton	Cost Per CY	Cost Per Ton	Cost Per CY	Cost Per Ton	Cost Per CY
-----Dollars-----						
Knoxville	8.6106	3.1594	1.3838	0.4296	9.9944	3.5890
Knox County ^b	21.1833	6.4511	5.0100	1.6516	26.1933	8.1027
Maryville	20.9517	6.2920	1.7563	0.5276	22.7080	6.8196
Alcoa	22.8270	5.8657	1.9009	0.5813	24.7279	6.4470
Blount County ^{bc}	22.5343	6.9354	1.6215	0.5630	24.1558	7.4984
Oak Ridge ^d	0.5342	0.2088	9.9537	3.89.0	10.4879	4.0998

^aDisposal function does not include allocation of city hall costs; all city hall costs are included in collection function where there are both collection and disposal functions.

^bKnox and Blount counties do not provide solid waste collection service. County residents purchase collection services from private firms.

^cNo city hall costs are included in the above cost figures because county costs associated with administration of solid waste disposal is relatively insignificant.

^dOak Ridge contracts collection and disposal services from a private firm. No separation of collection and disposal service costs are available. The collection unit costs given are allocated costs for the Oak Ridge Public Health Department. Disposal costs are imputed unit costs based on the contractual agreement for collection and disposal services.

the table indicates a very high disposal cost for Oak Ridge; however, Oak Ridge contracts with a firm for complete collection and disposal services. No allocation of collection and disposal costs was attempted. Collection costs are by far the larger cost component of the collection-disposal totals for those municipalities having both services. Observation of the collection-disposal totals suggests that economies of scale may be present in municipal solid waste management. The Knoxville model showed significantly lower unit costs than did the smaller municipal models for Maryville and Alcoa. Furthermore, the Oak Ridge model, based on contractual arrangements with private industry has unit costs, only slightly greater than does the Knoxville model. The unit costs for the disposal function are given by cost item in Table 53, Appendix B, for the six municipalities in the study area.

IV. CONTRACT COLLECTION SERVICE COSTS

Personal interviews with the two contract garbage pick-up firms serving Knox County residents that a total of 3,280 customers are serviced per week at \$2.50 per home per month.⁵⁹ In Blount County the nine collection firms serve 9,125 per week for \$2.50 per home per month.⁶⁰

Data collected at Knox County landfill showed 4,645.16 tons having a volume of 15,253.16 CY are collected and delivered per year

⁵⁹ Personal interviews with the owners of Firms A and B providing garbage pick-up service in Knox County, November 11, 1970.

⁶⁰ Personal interviews with the owners of the nine firms providing garbage pick-up service in Blount County, October 19-21, 1970.

by the contract pick-up firms. Similarly, solid waste data collected at the Alcoa landfill showed the nine contract pick-up firms collected and disposed of 4,338.72 tons having a volume of 14,097.2 CY per year from Blount County residents. Dividing the annual receipts by the respective weights and volumes for each site, the Knox County annual cost per ton and per CY was \$21.1833 and \$6.4511, respectively. Using similar procedure the Blount County annual cost per ton and per CY was \$22.5343 and \$6.9354, respectively. Table 25 (page 113) has the unit costs for Knox and Blount counties included in the collection stage costs.

CHAPTER V

ANALYSIS FOR OBJECTIVE III

I. SCOPE OF THE ANALYSIS

The analysis for Objective III estimated the costs of collecting and disposing of discarded milk containers in the four localities covered by this research. In this chapter the allocation procedure for determining the number of milk containers used in the research area is discussed. Subsequently the discussion shifts to relative costs of collecting and disposing of used milk containers for alternative systems of packaging. The total unit costs of packaging are aggregated to include costs for the packaging in the milk plants and the collection and disposal services for alternative container systems. Finally, implications of the results for policy are discussed.

The Market Milk Administrator's reports provided statistical data on the number, type, and size of milk containers sold in the area covered by Federal Order Market No. 101, an area comprised of 15 East Tennessee counties.¹ The localities covered by this study are a part of the Federal Order Market No. 101.

An allocation procedure (explained below) was used to estimate the number, type, and size of milk containers purchased in the localities studied. The estimation procedure was simplified by assuming that in

¹Compilation of Federal Order No. 101, p. 3.

any given county of the 15 county Federal Order No. 101 area, the same proportions of milk package types and sizes were purchased by consumers.

The effects of income on milk purchases are explained by the income consumption concept which attempts to show the relationship existing between the consumption of a product and real income when the price is kept constant.² A United States Department of Agriculture publication on food consumption statistics shows that milk is a so-called "normal good", that is, as income increases so does the quantity of milk consumed.³

The most current Census data available were used to estimate the quantity of milk consumed in the research area. To account for the effects of income, county income data published in the 1967 County and City Data Book⁴ were adjusted to 1964 price levels⁵ permitting estimation of the milk consumption rates for the research area. A wage-rate index was developed from Average Gross Hourly Earnings in Private Nonagricultural Industries; a second wage-rate index was developed for Agricultural Gross Hourly Earnings.⁶ The average values of the indices differed by

²Henry Schultz, The Theory and Measurement of Demand (Chicago: University of Chicago Press, 1938), p. 115.

³United States Department of Agriculture, Food Consumption of Households in the South, ARS and AMS House Food Consumption Survey Report, No. 4, 1965-66 (Washington: Government Printing Office, 1967).

⁴United States Department of Commerce, County and City Data Book, 1967; A Statistical Abstract Supplement, Bureau of the Census (Washington: Government Printing Office, 1967), pp. 333 and 343.

⁵United States Department of Agriculture, Food Consumption, p. 12. Milk consumption rates based on 1964 family incomes.

⁶Council of Economic Advisors, p. 231.

3.1 percent for the period 1959-1964, agricultural wages being lower. The published county income data were adjusted using only the Private Nonagricultural Industries index. To verify the results from preceding calculation the same data were adjusted with the use of the Agricultural index. Only Blount County was affected in terms of milk consumption patterns. By arbitrarily weighting the nonagricultural wages 60 percent and agricultural wages 40 percent, milk consumption did not change from what it would have been if only the Nonagricultural Wage-Rate index was used. As a justification for the procedure, there were 1,501 farmers in Blount County in 1964 of which 510 were defined as commercial.⁷ The number of nonfarm workers in Blount County was 6,424 for 1963.⁸

The assumption was made that milk consumption per household has remained the same for the period 1964 to 1970.

The United States Department of Agriculture Food Consumption⁹ publication was used to estimate the quantity of milk bought and consumed per family in each of the 15 counties comprising Federal Order 101. The milk consumption rates were estimated by the use of adjusted family income data given in the County and City Data Book.¹⁰ (See Table 26 for income data.)

⁷United States Department of Commerce, County Data, p. 341.

⁸Ibid.

⁹United States Department of Agriculture, Food Consumption, p. 12.

¹⁰United States Department of Commerce, County Data, p. 341.

Table 26. Computations of Milk Consumption and Persons Per Household in the Fifteen Counties
Comprising Federal Milk Order 101, Knoxville, Tennessee, a 1970

County	Adjusted ^b Median Family Income 1965 Prices	USDA ^c Amount Milk Bought Per Household Per Week (Quarts)	1970 Occupied ^d Housing Units (Number)	Calculated ^e Amount Milk Bought Per Week Per Family (Quarts)	Average Persons Per Occupied ^f Household	Calculated Persons Per Household ^g
Campbell	2,852	5.45	8,052	0.516	3.2	0.30
Cocke	2,769	5.45	7,606	0.487	3.3	0.30
Cumberland	2,639	5.45	6,192	0.397	3.3	0.24
Grainger	2,735	5.45	4,209	0.270	3.3	0.16
Hamblin	4,349	6.95	11,990	0.980	3.2	0.45
Jefferson	3,755	6.49	7,493	0.572	3.2	0.28
Loudon	4,405	6.95	7,829	0.640	3.1	0.29
Morgan	2,553	5.45	3,795	0.243	3.4	0.15
Roane	4,957	6.95	12,124	0.991	3.2	0.46
Scott	2,528	5.45	4,238	0.272	3.5	0.17
Sevier	3,196	6.49	8,880	0.678	3.2	0.33
Union	2,669	5.45	2,647	0.170	3.4	0.11
Total			85,055	6.216		3.24
Anderson	6,488	8.38	19,125	1.266	3.1	0.47
Blount	5,068	8.10	20,305	1.299	3.1	0.50
Knox	5,326	8.10	87,164	5.577	3.0	2.07
Total			126,594	8.142		3.04

^aCompilation of Federal Order No. 101 Regulating the Handling of Milk in the Knoxville, Tennessee, Marketing Area (Knoxville: Market Administrator's Office, January, 1970), p. 3.

^bNonagricultural Wage Index computed from Council of Economic Advisors, Economic Report of the President: Transmitted to the Congress February 1971 (Washington: Government Printing Office, 1971), p. 231; the unadjusted income figure source is U.S. Dept. of Commerce, County and City Data Book, 1967: A Statistical Abstract Supplement, Bureau of the Census (Washington: Government Printing Office, 1967), p. 341.

Table 26 (continued)

^cUnited States Department of Agriculture, Food Consumption of Households in the South, ARS and AMS Household Food Consumption Survey Report No. 4, 1965-66 (Washington: Government Printing Office, 1967), p. 12.

^dUnited States Department of Commerce, 1970 Census of Population, Tennessee, General Housing Characteristics, HC(V1)-44), Bureau of the Census (Washington: Government Printing Office, February 1971), pp. 8-17.

^eWeighted averages based on occupied household units. The following is an example of the calculation procedure:

$$\text{Campbell County } \left(\frac{8,052}{85,055} \right) \times 5.45 = 0.516$$

^fUnited States Department of Commerce, 1970 Census of Housing in Tennessee, pp. 8-17.

^gWeighted averages based on occupied household units. The following is an example of the calculation procedure:

$$\text{Campbell County } \left(\frac{8,052}{85,055} \right) \times 3.2 = 0.30$$

The population residing within the research area (approximated by Anderson, Blount, and Knox counties) is predominately urban and the population in the remaining 12 counties of Federal Order 101 is predominately rural. Reference to Table 26, Average Persons Per Occupied Household, shows a marked difference in the relative family size between Anderson, Blount, and Knox counties and the remaining 12 counties.¹¹ Consequently, to compute merely an overall average family milk consumption rate for the 15-county area would create an average milk consumption rate that was biased downward for the group of three counties comprising the research area.

Weighted average milk consumption rates were estimated for the research area group of counties and the remaining 12 county group. The total number of occupied households was used as the base for the respective group of counties. Table 26 shows that household milk consumption was 6.216 quarts per week outside the research area and 8.142 inside the area. The milk consumption rates will be used subsequently to estimate what proportion of the fluid milk sold in the Federal Order 101 region per unit of time was sold in the research area to people having either municipal or contract solid waste collection-disposal services.

The total population living in the 15 counties was 678,523 persons¹² in 1970. Based on current population data¹³ and data gathered

¹¹United States Department of Commerce, 1970 Census, Tennessee General Housing Characteristics, pp. 8-17.

¹²United States Department of Commerce, 1970 Census, Tennessee Final Population Counts, pp. 3-4.

¹³Ibid., pp. 5-14.

from contract solid waste collection firms,¹⁴ 244,396 persons residing in the research area had some type of solid waste collection and disposal services other than self-provided service. For Blount and Knox counties the number of customers or residences serviced by collection firms was aggregated and the respective "persons per household" factor¹⁵ was used to estimate the population having solid waste collection and disposal services in the respective county. In reality, all of the municipality residents paying local taxes have disposal privileges at their local landfill. Where collection service is not provided by the municipality, it is a matter of personal choice whether the resident contracts for collection service. The resident choosing not to hire collection service can either haul his own solid waste to the landfill or dispose of it on his own property in a manner not to create a public nuisance.¹⁶

From data on the total quantity of milk packages sold in the Federal Order Area No. 101,¹⁷ the computational procedure used to estimate the quantity of milk packages sold inside the study area was as follows:

¹⁴Personal consultation with refuse collection firm owners, Blount and Knox counties, October and November, 1970, respectively.

¹⁵United States Department of Commerce, Tennessee General Housing Characteristics, pp. 8-17.

¹⁶Tennessee Code Commission, p. 136.

¹⁷"Milk Package Statistics by Percent of Package Units and Number of Units Sold by Pool Plants for November, 1969" (Knoxville: Federal Milk Order No. 101, May 11, 1971). (Unpublished data.)

$$\frac{P_1}{H_1} \times Q_1 = N_1; \quad \frac{P_0}{H_0} \times Q_0 = N_0; \quad \frac{N_1}{N_t} = \text{percentage of milk consumed within the research area}$$

P_1 = the population located inside the research area using either contract or municipal collection-disposal facilities.

P_0 = the population located in the 15 Federal Market counties excluding the population, P_1 .

H_1 = the weighted average "Persons Per Household" in Anderson, Blount, and Knox counties.

H_0 = the weighted average "Persons Per Household" in the remaining 12 Federal Order No. 101 counties.

Q_1 = the weighted average number of Quarts of Milk Per Household sold inside the research area.

Q_0 = the weighted average Number of Quarts of Milk Per Household sold in the 15 Federal Market counties excluding that relevant to Q_1 .

N_1 = the average Number of Quarts per unit of time sold inside the research area.

N_0 = the average Number of Quarts per unit of time sold in the 15 Federal Market counties excluding that relevant to N_1 .

N_t = the sum of N_1 and N_0 .

Solution of the preceding equations indicated that 44.01 percent of the milk package items sold within the Federal Order No. 101 area were sold in the research area. Likewise, 55.99 percent of the milk total was sold outside of the research area.

Computation of Package Weights and Volumes

Table 27 summarizes the milk container specifications critical to estimating total quantities of solid waste generated by paper, glass, disposable plastic, and returnable plastic milk containers.¹⁸ The bulk dispenser container used in the solid waste analysis was the six gallon container. The bulk containers utilized in the solid waste model were of two basic types; the first was a totally disposable paper box and plastic liner unit and the other was a returnable plastic frame with a disposable plastic liner and spout. Table 27 lists the totally disposable bulk container under the paper container column and the partially recyclable frame-liner unit under the returnable plastic column. The bulk container weights and volumes are to be interpreted as the single use portion of the bulk container. The data cells left open in Table 27 indicate that no container sizes were being manufactured for the respective package type.

Table 28 summarizes the computed total unit costs associated with each container size for paper, glass, disposable plastic-paper, and returnable plastic glass. Table 28 also includes total unit costs based on volume (CY). The solid waste weight and volume relationship was discussed in the analysis for Objective II. The table shows that the disposable plastic-paper package system had lowest collection-disposal costs. Glass containers had the highest unit costs. A reason for the

¹⁸The number of glass and returnable plastic containers entering the collection-disposal system per unit of time is inversely proportional to container trippage.

Table 27. Milk Container Weight and Volume Specifications for Package Sizes by Container Types

Package Size	System of Measurement ^b	Paper ^c	Glass ^{de}	Disposable Plastic ^{gh}	Returnable Plastic ^{ih}
Dispenser	Weight	24.5	f	f	3.50
	Volume	159.41	f	f	6.816
Gallon	Weight	4.187	50	3.17466	6.70205
	Volume	8.78	36	5.81126	12.26880
Half Gallon	Weight	2.312	32	1.76370	4.40925
	Volume	4.57	23	3.22611	8.06976
Quart	Weight	1.125	17.75	f	f
	Volume	2.44	12.78	f	f
Pint	Weight	0.687	13	f	f
	Volume	1.45	9.36	f	f
Third Quart	Weight	0.593	f	f	f
	Volume	1.21	f	f	f
Half Pint	Weight	0.500	10	f	f
	Volume	1.09	7.20	f	f
Bottle caps ^j	Weight	f	0.068085	0.068085	0.068085
	Volume	f	0.045455	0.045455	0.045455

^aDispenser weights and volumes based on six gallon container size, and includes both plastic and paper construction.

^bPaper and glass container weights in ounces and volumes in cubic inches.

^cBased on personal correspondence between George B. Bondy, Pure-Pak Laboratories, The American Paper Bottle Company, Walled Lake, Michigan, and the writer.

^dBased on telephone interview with David Milky, Chattanooga Glass Company, Chattanooga, Tennessee, April 14, 1971.

^eVolume of glass in glass containers computed from 150 pound per square foot glass density. Source: Norbert Adolph Lange, Handbook of Chemistry (10th edition; New York: McGraw-Hill Book Company, Inc., 1961), pp. 878-879.

^fNot applicable.

^gBased on telephone interview with David Price, Atlanta Sales Office, Celanese Corporation, June 1, 1971.

Table 27 (continued)

^hVolume of high density polyethylene in each container was computed from 59 pound per square feet polyethylene density. Source: Arsen Darnay and William E. Franklin, The Role of Packaging in Solid Waste Management, 1966 to 1976, P. H. S. SW-5a (Washington: Government Printing Office, 1968), p. 123.

ⁱBased on telephone interview with C. H. Attabury, New York Office, Polytrip Systems, National Distillers Corporation, March 19, 1971.

^jWeights and volumes of bottle caps were assumed the same for glass and plastic containers. The weights were obtained from a Celanese Corporation mimeo, "Contribution to the Waste Stream if All Fluid Milk Were in Paper and if All Milk Were in Glass" (Celanese Corporation, unpublished, undated). The cap volume was estimated by the researcher since he could not find published data on bottle cap volumes.

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Table 28. Summary of Weight and Volume^a Total Unit Collection and Disposal Costs^b of Discarded Milk Containers for Four Package Types of Container Size in Research Area, 1970 Prices

Container Size	Paper			Glass ^c			Disposable Plastic			Returnable Plastic ^c		
	Cost Per Unit Weight	Cost Per Unit Volume	Cost Per Unit Weight	Cost Per Unit Weight	Cost Per Unit Volume	Cost Per Unit Weight	Cost Per Unit Weight	Cost Per Unit Volume	Cost Per Unit Weight	Cost Per Unit Volume	Cost Per Unit Weight	Cost Per Unit Volume
Gallon	0.163	0.080	1.949	0.329	0.124	0.053	0.261	0.112				
1/2 gallon	0.090	0.042	1.248	0.210	0.069	0.029	0.172	0.074				
Quart	0.044	0.022	0.692	0.117	0.044	0.022	0.092	0.117				
Pint	0.027	0.013	0.507	0.086	0.027	0.013	0.507	0.086				
10 ounce	0.023	0.011	d	d	0.023	0.011	d	d				
1/2 pint	0.019	0.001	0.390	0.066	0.019	0.001	0.390	0.066				
Bulk	0.955	1.457	0.136	0.062	0.954	1.457	0.136	0.062				
Caps	d	d	0.003	0.0004	0.003	0.0004	0.003	0.0004				

^aWeight and volume costs were computed from tons and cubic yards, respectively.

^bUnit costs are in cents. The unit costs were computed from a weighted average collection and disposal cost of \$12.4756 per ton and a weighted average collection and disposal cost of \$4.2651 per cubic yard. Table 56, Appendix C, shows the deviation of the average collection and disposal costs.

^cThe quantity of glass and returnable container material entering the collection-disposal system is inversely proportional to container trippage.

^dNot applicable.

difference in relative unit costs might be attributable to the heavy, bulky mass constituting a glass milk bottle, in contrast to the relatively lightweight disposable plastic container requiring very little space once compacted.

However, prior to compaction, disposable plastic containers could create a problem either at the collection stage or the disposal stage. Because of their light weight (90 grams and 50 grams for the gallon and half gallon, respectively) the individual containers are very susceptible to being blown about by the wind. At the landfill the lightweight containers may be scattered over a wide area before the compaction equipment can bury them. However, once compacted the disposable plastic containers make good landfill material.¹⁹

Theoretically a different cost per ton and cubic yard would be used to compute total unit collection-disposal costs since the solid waste management models were predicated on the existing package mix in the research area, paper and glass. Since solid waste generated from discarded milk containers is a function of the container type's physical characteristics and its trippage, an alteration of the package type mix from that currently used would change the weight and volume of solid waste collected and disposed.

¹⁹The Society of the Plastics Industry, Inc., "Los Angeles Sanitation Officials Uphold Use of Plastics in Landfill," Plastics and the Environment (New York: The Society of the Plastics Industry, Inc., March 8, 1971), p. 8; and Arsen Darnay and William E. Franklin, The Role of Packaging in Solid Waste Management, 1966 to 1976, Public Health Service Publication SW-5c (Washington: Government Printing Office, 1968).

However, close examination of the solid waste data and the collection-disposal operations indicated that different package types would alter collection-disposal costs very little. That is, collection is performed over a large geographic area and although the quantity of milk containers discarded in the research area per year is great, the quantity of discarded milk containers in terms of daily collection loads, regardless of container type, is small. Collection cost savings are obtained from collection route reorganization, a task unjustified considering the relative quantities of solid waste generated by the different types of containers.

The relative disposal costs would be slight also since the wastes are handled by four landfill operations. The relative amount of empty containers arriving daily at the sites ranged from one-half ton per day more to 2.6 ton per day (or one minute of compactor machine operating time) less than current quantities disposed, depending on the container type. For those reasons the solid waste unit costs given in Table 28, page 127, were used in all subsequent computations.

Table 29 shows the relative unit costs associated with the four milk package systems analyzed for Objective I. The unit costs were included for the milk delivery function. Finally, the unit costs for collection and disposal of discarded milk containers are presented. The unit costs were expressed in quart equivalents to facilitate interpretation.

Reference to Table 29 shows that the largest relative unit cost in the market system of the milk container was associated with the milk

Table 29. Market System Unit Costs of Four Alternative Milk Packaging Options, for Quart Container Equivalencies,^a Knoxville Area Research Project, 1970 Prices

Item Unit Costs	Paper	Glass	Disposable Plastic	Returnable Plastic
-----Cents-----				
Package costs (small) ^b	2.310	1.120	2.990	1.330
Transportation costs	3.840	5.871	3.840	5.871
Collection-disposal costs ^c	0.044	0.692	0.044	0.692
Total	6.194	7.683	6.874	7.893
Package costs (large) ^d	2.030	0.960	2.490	1.150
Transportation costs	3.840	5.871	3.840	5.871
Collection-disposal costs ^c	0.044	0.692	0.044	0.692
Total	5.914	7.523	6.374	7.713

^aQuart equivalencies based on weight.

^bUnit costs are for small milk processing firm, 52,000 quarts per day.

^cCollection-disposal costs are the same for paper and disposable plastic, and for glass and returnable plastic. The reason is that quart equivalencies are used in the table. That is, there were no plastic container sizes marketed in the quart size; therefore, the disposable plastic quart cost is for paper and the returnable plastic quart cost is for glass.

^dUnit costs are for large milk processing firm, 108,000 quarts per day.

delivery function. Collection and disposal costs are the smallest cost item in absolute terms.

In terms of the four packaging systems, the market system costs to the consumer were highest for the returnable container types. Transportation and product delivery costs were the major factor in establishing the relative cost spread among the four package types. However, the returnable containers had lowest packaging costs but the highest collection-disposal costs. The latter cost being a function of bottle trippage and discarded container weight and bulk. If trippage is assumed less than the numbers used in the analysis, the costs associated with returnable container collection and disposal would be even higher than given in Table 29.

Economies of scale were suggested in the costs associated with the large processor and the small processor for packaging costs and for total market system costs. Economies of scale in collection-disposal were not shown because an average cost for the entire study area was used in the analysis. Collection-disposal unit costs were the same for the disposable container types and the returnable container types because quart equivalents were based on only paper quarts and glass quarts. Plastic bottles were not marketed in quart sizes. Refer to Table 28, page 127, for the unit costs of collection and disposing of other sizes of containers.

The analysis presented in this study indicates quantitatively that the milk processing firms who have switched from returnable containers to disposable containers are following a least cost practice

from the viewpoint of society given the present efforts of the paper, plastic, and glass industries to internalize production costs often shifted to the environment. That is, paper containers were more costly to package but less costly to distribute in the wholesale and retail markets, and less costly to collect and dispose. The combined unit costs for packaging and distribution among the package systems indicate that the disposable containers involve lower costs. If the milk packaging market were in perfect competition, the consumer could receive milk in disposable containers at a lower cost than he would in returnable containers, ceteris paribus. Furthermore, the consumer acting in the role of the taxpayer would pay less to collect and dispose of one-way containers. The paper container would be the lowest total cost of the four types of containers. Because of economies of scale in milk packaging the largest firm had lowest total costs for the four package types.

II. POLICY IMPLICATIONS

Any type of policy action whose purpose was to control emptied milk containers, raising the average costs of the milk processor, given a competitively established milk price, would decrease the welfare of the consumer. The analysis showed that paper and disposable plastic containers had lowest costs for the firm and the taxpayer. Efforts to control solid waste production by altering the relative prices of milk containers at the marketplace could result in economic inefficiency. The results showed the small firm as having higher production costs

than the large firm. Legislation forcing up the relative price of a type of container to the processor would cause a cost shift toward the consumer. Simple demand analysis of the market would indicate a decrease in quantity taken subsequent to a price rise, assuming a relatively inelastic industry demand curve for milk. The quantity supplied would exceed the quantity demanded in the short run, price would fall, and each firm could be expected to sell less product causing the firm to operate at less than the necessary production to allow $MC = MR = AC$, assuming a competitive market structure. The firm would find itself not paying all fixed costs in the short run. With fixed capital investment payments due, the larger firms having economies of scale, could theoretically outlast the smaller firm. The smaller firm would cease operation, the quantity supplied for the industry would decrease, the price would rise to a level just sufficient to hold resources in the industry. In the process the market structure existing in the milk processing industry would become more concentrated, a characteristic, presently viewed by society as undesirable.

III. IMPLICATIONS FOR FUTURE RESEARCH

Research is needed to ascertain existing solid waste or more generally, pollution, generated by such industries as meat packing, cereal, paper, plastics, and glass industries and the economic implications of internalizing specific costs readily shifted to the environment.

Research to find the extent that efficiencies might be obtained through consolidation of the solid waste service provided by each of the outlying, adjacent communities could be done.

Also, research could be done to study the effects of continued use of paper packaging on the availability of forest resources. In conjunction with research on the economies of new paper raw material sources, study is needed on the economics of alternative systems to recycle paper and plastic packaging.

CHAPTER VI

SUMMARY

The objectives of the study were: (1) to estimate the costs of alternative returnable and nonreturnable packaging systems (plastic, glass, and paper) to milk processors; (2) to estimate the direct and indirect costs of these alternative systems to public solid waste management agencies; and (3) to estimate what effects, if any, policies to elicit changes in milk packaging systems would have on the fluid milk processor and solid waste management agencies.

The general approach used was based on synthetic cost analysis. The study focused on the milk packaging stage, the milk delivery stage, and the solid waste management agency.

The study attempted to estimate an average unit cost for packaging and delivering milk in four alternative package types--paper, glass, disposable plastic, and returnable plastic. "Small" and "large" fluid packaging operations were synthesized for each package type, representing "typical" processing plants operating in the Knoxville area. The milk packaging and delivery models were based on secondary data that was supplemented with primary data as necessary.

The solid waste management agency models were synthesized to represent operating conditions in Oak Ridge, Alcoa, Maryville, Blount County, Knox County, and Knoxville that would conform to Tennessee's Solid Waste Disposal Regulations. An average collection-disposal cost

was calculated from the costs estimated by the respective municipal models. It was necessary to collect solid waste weight and volume data at the landfill sites to establish a reliable quantity estimate to be used in estimating solid waste total unit costs. The average cost was \$12.48 per ton and \$4.27 per cubic yard for the research area, assuming a density of 600 pounds per cubic yard.

Secondary data, including 1970 Tennessee Census data, United States Department of Agriculture Food Consumption data and milk plant layout data, and Federal Milk Market No. 101 milk sales data, were used to estimate the quantity, type, and size of milk containers currently discarded in the study area. The physical specifications of each package size for each package type provided the basis for estimating the weight and volume of discarded milk containers entering the solid waste collection-disposal system in the research area. Unit costs were subsequently estimated by using the estimated average cost per ton and cubic yard.

The results indicated that disposable paper containers processed in large plants had the lowest total unit costs, 5.914 cents per quart equivalent and the returnable plastic container processed in small plants had the highest total unit costs, 7.893 cents per quart equivalent. The most important element of total unit costs was for milk transportation and handling (range, 3.84 to 5.87 cents per quart); the least important was for collection and disposal of empty containers (range, 0.04 to 0.69 cents per quart).

The policy implications were that any legislation to alter relative market prices of disposable containers and returnable containers could result in decreased economic efficiency.



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APPENDIXES

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APPENDIX A

Table 30. Assumed Distribution of Milk Package Sizes Produced in 13,000 and 27,000 Gallon Per Day Synthesized Fluid Milk Plant in East Tennessee^a Area, 1970

Item	Percent Each Item ^b	Package Mix for 13,000 Gallon Plant Per Day	Package Mix for 27,000 Gallon Plant Per Day
Gallons	46.02	5,983	12,425
Half gallons	22.55	5,863	12,177
Quarts	4.95	2,569	5,335
Pints	4.28	4,451	9,245
Third quart ^c	0.42	699	1,452
Half pint	10.58	22,006	45,706 ^d
Five gallon bulk	6.19	161 ^d	334 ^d
Six gallon bulk	4.95	107 ^e	228 ^e

^aEast Tennessee is defined to include Knox, Blount, and Anderson counties.

^bPercentages based on Knoxville Federal Order statistics for the Federal Order 101 market region, November 1970.

^cThere are no glass container sizes corresponding to the third quart size in paper; therefore, the third quart size was arbitrarily divided 50 percent to pints and 50 percent to half pints when discussing glass container mix.

^dIf all bulk containers were of five gallon size, there would be 289 units for the small plant and 608 units for the large plant.

^eIf all bulk containers were of six gallon size, there would be 241 units for the small plant and 506 units for the large plant.

Table 31. Building Area Required for Various Packaging Centers for Small and Large Model Fluid Milk Processing Plants^a

Type of Plant	Filling Center	--Square Feet--		
		Empty Case Storage Center	Empty Container Storage Center	Bulk Container Storage Center
Small, paper	1,768.0	1,951.4 ^b	1,315.7	c
Small, glass	1,768.0	1,951.4	1,000.0 ^d	225.0
Small, disposable plastic	1,768.0	1,951.4	2,405.0	c
Small, returnable plastic	1,768.0	1,951.4	1,000.0 ^d	225.0
Large, paper	2,368.0	3,085.7	1,718.7	c
Large, glass	2,368.0	3,085.7	1,418.2 ^d	400.0
Large, disposable plastic	2,368.0	3,085.7	1,150.7	c
Large, returnable plastic	2,368.0	3,085.7	1,418.2 ^d	400.0

^aRevised from P. H. Tracy, Layouts and Operating Criteria for Automation of Dairy Plants Processing Milk, Half-and-Half, Cream, Chocolate Drink, and Buttermilk, United States Department of Agriculture, MRR No. 591, AMS (Washington: Government Printing Office, September, 1963), p. 4 and 29.

^bExample of space adjustment calculation: $\frac{65,000 \text{ gallons per week}}{35,000 \text{ gallons per week}} = 0.8571 \times 795 \text{ square feet}$

= 681.4 square feet + 1,270 square feet
= 1,951.4 square feet

^cBulk containers were assumed to be stored in existing empty container storage center.

^dIncludes bottlewasher and one mouth bottle inventory storage space requirements.

Table 32. Packaging Stage Equipment Inventory and Specifications^a
for Small Model Fluid Milk Processing Plant Using
Paper Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Case unstacker	15	8,629.25	517.75
Case pusher (2)	15	826.80	49.61
Auto-casers			
Quart	15	15,000.00	900.00
Half gallon	15	13,020.00	781.20
Gallon	15	13,620.00	817.20
Case stackers			
In-line	15	5,258.40	315.50
Step-down (2)	15	14,569.49	874.17
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	6,000.00	360.00
Case washer	15	2,118.24	127.09
Air supply	15	3,484.80	209.09
Vacuum supply	15	987.60	59.26
Total		85,386.58	5,123.19

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation.

^cTen percent salvage value assumed.

Table 33. Packaging Stage Equipment Inventory and Specifications^a
for Small Model Fluid Milk Processing Plant Using Glass
Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Bottlewasher (size 20)	15	37,392.00	2,243.52
Filler			
Gallon, 1/2 gallon	15	25,467.60	1,528.06
Quart, pint, 1/2 pint	15	26,667.60	1,600.06
Cappers (2)	15	9,600.00	576.00
Case unstacker	15	5,616.00	336.96
Case pusher	15	780.00	46.80
Auto-casers			
Gallon, 1/2 gallon	15	18,000.00	1,080.00
Quart, pint, 1/2 pint	15	22,800.00	1,368.00
Case stackers (2)	15	10,518.17	631.09
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	6,000.00	360.00
Case washer	15	2,118.40	127.09
Bottle decaser	15	24,000.00	1,440.00
Air supply	15	3,484.80	209.09
Conveyor (30 feet)	15	1,800.00	108.00
Total		196,116.57	11,766.99

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation.

^cTen percent salvage value assumed.

Table 34. Packaging Stage Equipment Inventory and Specifications^a
for Small Model Fluid Milk Processing Plant Using
Disposable Plastic and Paper Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Filler: gallon, 1/2 gallon	15	25,467.60	1,528.06
Capper: gallon, 1/2 gallon	15	7,380.00	442.80
Case unstacker	15	5,616.00	336.96
Case pusher	15	780.00	46.80
Caser: quart, pint, 1/3 quart, 1/2 pint	15	15,000.00	900.00
Caser: gallon, 1/2 gallon	15	18,000.00	1,080.00
Case stackers (2)	15	10,518.17	631.09
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	6,000.00	360.00
Case washer	15	2,118.24	127.09
Air supply	15	3,484.80	209.09
Vacuum supply	15	987.60	59.26
Conveyor (30 feet)	15	1,800.00	108.00
Total		99,024.41	5,941.47

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation.

^cTen percent salvage value assumed.

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Table 35. Packaging Stage Equipment Inventory and Specifications^a
for Small Model Fluid Milk Processing Plant Using
Returnable Plastic and Glass Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Bottlewasher (size 20)	15	37,512.00	2,250.72
Filler			
Gallon, 1/2 gallon	15	25,467.60	1,528.06
Quart, pint, 1/2 pint	15	26,667.60	1,600.06
Cappers (2)	15	11,220.00	673.20
Case unstacker	15	5,616.00	336.96
Case pusher	15	780.00	46.80
Caser			
Gallon, 1/2 gallon	15	18,000.00	1,080.00
Quart, pint, 1/2 pint	15	22,800.00	1,368.00
Case stackers (2)	15	10,518.17	631.09
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	6,000.00	360.00
Case washer	15	2,118.24	127.09
Bottle decaser	15	24,000.00	1,440.00
Air supply	15	3,484.80	209.09
Hydrocarbon tester	15	20,000.00	1,200.00
Conveyor (30 feet)	15	1,800.00	108.00
Total		217,856.41	13,071.39

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation costs.

^cTen percent salvage value assumed.

Table 36. Packaging Stage Equipment Inventory and Specifications^a
for Large Model Fluid Milk Processing Plant Using
Paper Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Case unstacker	15	8,629.25	517.75
Case pusher	15	826.80	49.61
Auto-caser			
Gallon	15	13,620.00	817.20
1/2 gallon	15	13,020.00	781.20
Quart, 10 ounces, pint, 1/2 pint	15	15,000.00	900.00
Case stackers			
In-line	15	5,258.40	315.50
Step-down	15	14,561.86	873.71
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	9,000.00	540.00
Case washer	15	2,118.24	127.09
Air supply	15	3,484.80	209.09
Vacuum supply	15	1,674.00	100.44
Total		89,065.35	5,343.91

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation cost.

^cTen percent salvage value assumed.

Table 37. Packaging Stage Equipment Inventory and Specifications^a
for Large Model Fluid Milk Processing Plant Using
Glass Containers, 1970 Prices.

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Bottlewasher (size 20)	15	37,392.00	2,243.52
Filler			
Gallon, 1/2 gallon, quart	15	29,064.00	1,743.84
Pint, 1/2 pint	15	27,864.00	1,671.84
Capper			
Gallon, 1/2 gallon, quart	15	5,040.00	302.40
Pint, 1/2 pint	15	4,560.00	273.60
Case unstacker	15	5,616.00	336.96
Case pusher	15	780.00	46.80
Auto-casers			
Gallon, 1/2 gallon, quart	15	14,400.00	864.00
Pint, 1/2 pint	15	24,000.00	1,440.00
Case stackers (2)	15	12,539.38	752.36
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	9,000.00	540.00
Case washer	15	2,118.24	127.09
Bottle decaser	15	29,400.00	1,764.00
Case inverters (3)	15	4,320.00	259.20
Air and vacuum supply			
(20 percent use)	15	960.00	57.60
Conveyor (45 feet)	15	2,700.00	162.00
Total		211,625.62	12,697.53

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation cost.

^cTen percent salvage value assumed.

Table 38. Packaging Stage Equipment Inventory and Specifications^a
for Large Model Fluid Milk Processing Plant Using
Disposable Plastic and Paper Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Filler: gallon, 1/2 gallon	15	27,864.00	1,671.84
Capper: gallon, 1/2 gallon	15	6,180.00	370.80
Case unstacker	15	8,629.20	517.75
Case pusher	15	826.80	49.61
Casers (2)	15	27,600.00	1,656.00
Case stackers	15	12,539.38	752.36
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	9,000.00	540.00
Case washer	15	2,118.24	127.09
Air supply	15	3,484.80	209.09
Vacuum supply	15	1,674.00	100.44
Conveyor (45 feet)	15	2,700.00	162.00
Blowmold machine	6	173,784.00	26,067.60
Total		278,272.42	32,336.90

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation cost.

^cTen percent salvage value assumed.

Table 39. Packaging Stage Equipment Inventory and Specifications^a
for Large Model Fluid Milk Processing Plant Using
Returnable Plastic and Glass Containers, 1970 Prices

Equipment Item	Estimated Life	Installed Price ^b	Annual Depreciation ^c
	Years	-----Dollars-----	
Bottlewasher (size 20)	15	37,392.00	2,243.52
Filler			
Gallon, 1/2 gallon, quart	15	29,064.00	1,743.84
Pint, 1/2 pint	15	27,864.00	1,671.84
Capper			
Gallon, 1/2 gallon, quart	15	5,040.00	302.40
Pint, 1/2 pint	15	4,560.00	273.60
Case unstacker	15	5,616.00	336.96
Case pusher	15	780.00	46.80
Caser			
Gallon, 1/2 gallon, quart	15	14,400.00	864.00
Pint, 1/2 pint	15	24,000.00	1,440.00
Case stacker (2)	15	12,539.38	752.36
Bulk filler	15	1,872.00	112.32
Hydraulic power unit	15	9,000.00	540.00
Case washer	15	2,118.24	127.09
Bottle decaser	15	29,400.00	1,764.00
Case inverters (3)	15	4,320.00	259.20
Air and vacuum supply	15	1,674.00	100.44
Hydrocarbon tester	15	20,000.00	1,200.00
Conveyor (45 feet)	15	2,700.00	162.00
Total		232,339.62	13,940.37

^aSource: Brinks, Inc., Knoxville, Tennessee.

^bIncludes 20 percent for freight and installation cost.

^cTen percent salvage value assumed.

Table 40. Package Stage Labor Requirements for Small Model Fluid Milk Processing Plants,
1970 Prices

Type of Plant	Manpower Quantity	Job	Hourly Rate ^a	Weekly Rate ^b
-----Dollars-----				
Small, paper	1	Empty case operator	2.46	109.72
	1	Paper filler operator	2.78	123.99
	1	Bulk filler operator	2.46	109.72
	1	General plant laborer	2.36	105.26
		Total		<u>448.68</u>
Small, glass or returnable plastic	1	Empty case operator	2.46	109.72
	1	Glass filler operator	2.46	109.72
	1	Bulk filler operator	2.46	109.72
	1	Bottle checker	2.36	105.26
		Total		<u>434.40</u>
Small, disposable plastic-paper	1	Empty case operator	2.46	109.72
	1	Bottle filler operator	2.46	109.72
	1	Bulk filler operator	2.46	109.72
	1	General plant laborer	2.36	105.26
		Total		<u>434.40</u>

^aBasic hourly wage without fringe benefits.

^bIncludes 11.5 percent fringe benefits.

Table 41. Package Stage Labor Requirements for Large Model Fluid Milk Processing Plants,
1970 Prices

Type of Plant	Manpower Quantity	Job	Hourly Rate ^a	Weekly Rate ^b
-----Dollars-----				
Large, paper	1.5	Empty case operators	2.46	164.57
	1.0	Paper filler operator	2.78	123.99
	1.0	Bulk filler operator	2.46	109.72
	1.0	General plant laborer	2.36	105.26
		Total		503.53
Large, glass or returnable plastic	1.5	Empty case operators	2.46	164.57
	1.0	Glass filler operator	2.46	109.72
	1.0	Bulk filler operator	2.46	109.72
	1.0	General plant laborer	2.36	105.26
	1.0	Bottle checker	2.36	105.26
		Total		594.52
Large, disposable plastic	1.5	Empty case operators	2.46	164.57
	1.0	Bulk filler operator	2.46	109.72
	2.0	Blowmold operators	3.23	288.12
	3.0	Machine operator helpers	2.36	315.77
		Total		878.17

^aFringe benefits not included.

^bIncludes 11.5 percent fringe benefits.

Table 42. Daily Inventory Costs on Glass Containers and Caps and Bulk Containers for Small and Large Model Fluid Milk Packaging Plants, East Tennessee, 1970 Prices

Plant Size	Container Item, Size	Daily Production	Working Inventory ^b	Unit Costs	Cost of Working Inventory	Unit Cost		
						of Disposable Part	Daily Cost ^c	Inventory Cost ^d
-----Dollars-----								
Small	Bulk, 6 gallon	241 ^a	1,446	4.56	6,593.76	0.37	89.540	1,790.80
Large	Bulk, 6 gallon	506 ^a	3,036	4.56	13,844.16	0.37	188.330	3,766.60
Small	Caps, all	41,527	e	e	e	0.0037	154.420	3,088.40
Large	Caps, all	86,250	e	e	e	0.0037	320.720	6,414.40

^aSee package mix, Table 30, page 150.

^bBased on 6 day cycle time.

^cDaily disposable cost based on daily production quantity plus 0.5 percent in-plant loss rate.

^dTwenty production day inventory assumed.

^eNot applicable.

Table 43. Daily Inventory Paper Container Requirements and Costs for Small and Large Model Fluid Packaging Plants, East Tennessee, 1970 Prices

Plant Size	Container Size	Production Per Day ^a	Cost Per Unit	Daily Cost	Inventory Cost ^b
-----Dollars-----					
Small	Gallons	6,043	0.0510	308.193	3,081.93
	Half gallons	5,922	0.0260	153.972	1,539.72
	Quarts	2,595	0.0150	38.925	389.25
	Pints	4,496	0.0100	44.960	449.60
	Third quarts	706	0.0089	6.283	62.83
	Half pints	22,226	0.0081	180.031	1,800.31
	Bulk, 5 gallon	162	0.3700	59.940	599.40
	Bulk, 6 gallon	108	0.3900	41.939	419.39
	Total			838.243	8,342.43 ^c
Large	Gallons	12,549	0.0510	639.999	6,399.99
	Half gallons	12,299	0.0260	319.774	3,197.74
	Quarts	5,388	0.0150	80.820	808.20
	Pints	9,337	0.0100	93.370	933.70
	Third quarts	1,467	0.0089	13.056	130.56
	Half pints	46,163	0.0081	373.920	3,739.20
	Bulk, 5 gallon	336	0.3700	124.320	1,243.20
	Bulk, 6 gallon	229	0.3900	89.310	893.10
	Total			1,734.569	17,345.69 ^c

^aOne percent in plant loss factor applied to market share of package mix for each size plant. One-half percent in plant loss factor applied to market share bulk container mix. See Table 30, page 150, for net market share quantities.

^bTen production day inventory assumed for nonbulk and 6M and 12M size lot order assumed for bulk small and large plants, respectively, to gain price discounts.

^cDaily interest on inventory for small and large plant at 6 percent rate is \$0.69 and \$1.43, respectively.

Table 44. Daily Inventory Glass Container Requirements and Costs for Small and Large Model Fluid Milk Packaging Plants, East Tennessee, 1970 Prices

Plant Size	Container Size	Production Per Day	Working Inventory ^a	Bottle Loss Per Day ^b	Unit Bottle Costs	Cost of Working Inventory	Cost of Replacement Inventory ^c
-----Dollars-----							
Small	Gallon	5,983	35,898	157	0.2512	9,017.58	394.38
	Half gallon	5,863	35,178	154	0.1779	6,258.17	273.97
	Quart	2,569	15,414	68	0.1000	1,541.40	68.00
	Pint	4,669	28,014	123	0.0810	2,269.13	99.63
	Half pint	22,443	134,658	591	0.0644	8,671.98	380.60
	Total	41,527				27,758.26	1,216.58
Large	Gallon	12,425	74,550	327	0.2512	18,726.96	821.42
	Half gallon	12,177	73,062	320	0.1779	12,997.73	569.28
	Quart	5,335	32,010	140	0.1000	3,201.00	140.00
	Pint	9,699	58,194	255	0.0810	4,713.71	206.55
	Half pint	46,614	279,684	1,227	0.0644	18,011.65	790.19
	Total	86,250				57,651.05	2,527.44

^a Working inventory defined as containers in daily use quantity based on six day container cycle time.

^b Bottle loss based on 2.632 percent of daily production or estimated trippage of 38.

^c Replacement inventory based on ten production day supply.

Table 45. Daily Inventory of Disposable Plastic-Paper Container and Cap Requirements and Costs for Small and Large Model Fluid Milk Packaging Plants, East Tennessee, 1970 Prices

Plant Size	Container Size ^a	Production Per Day ^b	Cost Per Unit	Daily Cost	Inventory Cost ^c	Unit Cost	Cap Cost	Daily Cost	Cap Inventory Cost ^d
Dollars									
Small	Gallons	6,013	0.0756	454.583	4,545.83	0.014	84.182	84.182	1,683.64
	Half gallons	5,892	0.0536	315.811	3,158.11	0.014	82.488	82.488	1,649.76
	Quarts	2,595	0.0150	38.925	389.25	e	e	e	e
	Pints	4,496	0.0100	44.960	449.60	e	e	e	e
	Third quarts	706	0.0089	6.283	62.83	e	e	e	e
	Half pints	22,226	0.0081	180.031	1,800.31	e	e	e	e
	Bulk, 5 gallon	162	0.3700	59.940	599.40	e	e	e	e
Large	Bulk, 6 gallon	108	0.3900	41.939	419.39	e	e	e	e
	Total			1,142.472	11,424.72		166.670	166.670	3,333.40
	Gallons	12,487	0.0298 ^e	372.113	0	0.014	174.818	174.818	3,496.36
	Half gallons	12,238	0.0536	655.957	6,559.57	0.014	171.332	171.332	3,426.64
	Quarts	5,388	0.0150	80.820	808.20	e	e	e	e
	Pints	9,337	0.0100	93.370	933.70	e	e	e	e
	Third quarts	1,467	0.0089	13.056	130.56	e	e	e	e
	Half pints	46,163	0.0081	373.920	3,739.20	e	e	e	e
	Bulk, 5 gallon	336	0.3700	124.320	1,243.20	e	e	e	e
	Bulk, 6 gallon	229	0.3900	89.310	893.10	e	e	e	e
	Total			1,802.866	14,307.53		346.150	346.150	6,923.00

^aGallons and half gallons are disposable plastic, all others are paper.

^bSource: Table 30, page 150.

^cInventory is ten production days, except for large plant. Gallons where blowmold operation eliminates inventory and half gallons where two day inventory is maintained.

^dCap costs apply to plastic containers only. Inventory is for 20 production days.

^eNot applicable.

^fUnit cost includes resin cost only. Remaining costs are included in proper fixed and variable cost categories. Unit cost based on (71, p. 8): 1.02 pound resin = 5 jugs or 0.204 pound per jug x \$0.146 per pound resin cost = \$0.0298 per unit.

Table 46. Returnable Plastic-Glass Container and Cap Inventories and Costs for Small and Large Model Fluid Milk Packaging Plants, Knoxville, Tennessee, 1970 Prices

Plant Size	Container Size ^a	Daily Production ^b	Working Inventory	Bottle Loss Per Day ^c	Unit Bottle Costs	Cost of Working Inventory	Cost of Replacement Inventory ^d
-----Dollars-----							
Small	Gallon	5,983	35,898	157	0.4000	14,359.20	628.00
	Half gallon	5,863	35,178	154	0.2500	8,794.50	385.00
	Quart	2,569	15,414	68	0.1000	1,541.40	68.00
	Pint	4,669	28,014	123	0.0810	2,269.13	99.63
	Half pint	22,443	134,658	591	0.0644	8,671.98	380.60
	Total	41,527				35,636.21	1,561.23
Large	Gallon	12,425	74,550	327	0.4000	29,820.00	1,308.00
	Half gallon	12,177	73,062	320	0.2500	18,265.50	800.00
	Quart	5,335	32,010	140	0.1000	3,201.00	140.00
	Pint	9,699	58,194	255	0.0810	4,713.71	206.55
	Half pint	46,614	279,684	1,227	0.0644	18,011.65	790.19
	Total	86,250				74,011.86	3,244.74

^aGallons and half gallons are returnable plastic, all others are glass.

^bSource: Table 30, page 150.

^cBased on 2.632 percent of daily production requirements.

^dInventory based on ten production day supply; one day cost is 10 percent of total or individual item inventory costs.

Table 47. Daily and Inventory Costs on Returnable Plastic and Glass Caps and Bulk Containers for Small and Large Model Fluid Milk Packaging Plants, East Tennessee, 1970 Prices

Plant Size	Container Item, Size	Daily Production	Working Inventory ^b	Unit Costs	Cost of Working Inventory	Unit Cost of Disposable Part	Daily Cost ^c	Inventory Cost ^d
-----Dollars-----								
Small	Bulk, 6 gallon	241 ^a	1,446	4.56	6,593.76	0.37	89,540	1,790.80
Large	Bulk, 6 gallon	506 ^a	3,036	4.56	13,844.16	0.37	188,330	3,766.60
Small	Caps, plastic Caps, stopper	11,905 29,830	e e	e e	e e	0.014 0.0037	166,670 110,371	3,333.40 2,207.42
Large	Caps, plastic Caps, stopper	24,725 61,956	e e	e e	e e	0.014 0.0037	346,150 229,237	6,923.00 4,584.74

^aSee package mix, Table 30, page 150.

^bBased on 6 day cycle time.

^cDaily disposable cost based on daily production quantity plus 0.5 percent in-plant loss rate.

^dTwenty production day inventory assumed.

^eNot applicable.

Table 48. Cost Components for Four Package Systems for Small Model Fluid Milk Packaging Plants, East Tennessee, 1970 Prices

Package System	Package Component	Inventory Total Value	Daily Depreciation ^a	Inventory Interest Per Day ^b	Daily Costs
-----Dollars-----					
Paper	Paper containers	7,323.64	c	0.60	732.365
	Bulk containers	1,018.79	c	0.08	101.879
	Total			0.68	834.243
Glass	Working inventory				
	glass containers	27,758.26	104.04	2.28	c
	New-replacement				
	glass containers	1,216.58	c	0.10	c
	Bottle stoppers				
	and hoods	3,088.40	c	0.25	154.420
	Bulk container				
	frames	6,593.76	4.52	0.54	c
	Bulk container				
	liners	1,790.80	c	0.15	89.540
	Total		108.56	3.32	243.960
Plastic-paper	Plastic containers	7,703.94	c	0.63	770.394
	Plastic caps	3,333.40	c	0.27	166.670
	Paper containers	2,701.99	c	0.22	270.199
	Bulk containers	1,018.79	c	0.08	101.879
	Total			1.20	1,309.142

Table 48 (continued)

Package System	Package Component	Inventory Total Value	Daily Depreciation ^a	Inventory Interest Per Day ^b	Daily Costs
-----Dollars-----					
Plastic-glass	Working inventory plastic containers	23,153.70	33.04	1.90	c
	New replacement plastic containers	1,013.00	c	0.08	c
	Working inventory glass containers	12,482.51	46.78	1.03	c
	New replacement glass containers	548.23	c	0.05	c
	Hoods, stoppers, and caps	5,540.82	c	0.46	277.041
	Bulk container frames	6,593.76	4.52	0.54	c
	Bulk container liners	1,790.80	c	0.15	89.540
	Total		84.34	4.21	366.581

^aDepreciation computed from 0.731 year estimated life for glass; 1.92 years for plastic; and 4 years for plastic bulk frame.

^bInterest rate of 6 percent assumed.

^cNot applicable.

Table 49. Cost Components for Four Package Systems for Large Model Fluid Milk Packaging Plants, East Tennessee, 1970 Prices

Package System	Package Component	Inventory Total Value	Daily Depreciation ^a	Inventory Interest Per Day ^b	Daily Costs
Dollars					
Paper	Paper containers	15,209.39	c	1.25	1,520.939
	Bulk containers	2,136.30	c	0.18	213.630
	Total			1.43	1,734.569
Glass	Working inventory				
	glass containers	57,651.05	216.07	4.74	c
	New replacement				
	glass containers	2,527.44	c	0.21	c
	Hoods, caps, and				
	stoppers	6,414.40	c	0.53	320.720
	Bulk container				
	frames	13,844.16	9.48	1.14	c
	Bulk container				
	liners	3,766.60	c	0.31	188.330
	Total		225.55	6.93	509.050
Plastic-paper	Plastic containers	6,559.57	c	0.54	1,027.070
	Plastic caps	6,923.00	c	0.57	346.150
	Paper containers	5,611.66	c	0.46	562.166
	Bulk containers	2,136.30	c	0.18	213.630
	Total			1.75	2,149.016

Table 49 (continued)

Package System	Package Component	Inventory Total Value	Daily Depreciation ^a	Inventory Interest Per Day ^b	Daily Costs
-----Dollars-----					
Plastic-glass	Working inventory				
	plastic containers	48,085.50	68.62	3.95	c
	New replacement				
	plastic containers	2,108.00	c	0.17	c
	Working inventory				
	glass containers	22,159.14	83.05	1.82	c
	New replacement				
	glass containers	1,136.74	c	0.09	c
	Hoods, caps, and				
	stoppers	11,507.74	c	0.95	575.387
	Bulk container				
	frames	13,844.16	9.48	1.14	c
	Bulk container				
	liners	3,766.60	c	0.31	188.330
	Total		161.15	8.43	763.717

^a Depreciation for glass based on estimated bottle life of 0.731 years; for plastic bottle, 1.92 years; and for bulk container frames, 4 years.

^b Interest rate of 6 percent assumed.

^c Not applicable.

Table 50. Economic-Engineering Costs for Disposable Plastic Gallon In-Plant Blowmold System, Large Model Fluid Milk Processing Plant, East Tennessee, 1970 Prices

Cost Item	Details	Annual Cost,
		Dollars
Building	867 square feet x \$22.12 per square foot + interest + depreciation + maintenance	1,343.04
Equipment ^a	\$173.784 + 6 percent interest + 5 years depreciation + 3 percent maintenance	42,229.51
Taxes and Insurance	\$1.30 per \$100 valuation	1,833.15
Resin	608,328 pound per year x 14.6 cents per pound delivered	88,815.89
Utilities	Electric	6,393.60
Supplies	Miscellaneous	2,000.00
Labor	20.5 manhours per day x weight average wage \$3.20 per hour x 260 days	17,054.82
Total		159,670.01

^aEquipment specifications from Uniloy Corporation.

^bAnnual bottle rate = 3,230,500 units.

^cCost per unit = $\frac{\$159,670.01}{3,230,500} = \$0.04941 = 4.94 \text{ cents}$

Table 51. Price Adjustment Procedure and Computations for Previous Research on Fluid Milk Delivery Costs Used for Developing Delivery Cost Model, Knoxville Area, 1970 Prices

Publication	Date of Price Data	Data Description and Computations ^a	
Perry ^b	1945	Labor: 2.00 x 1.712	= 3.424
		Truck: 0.74 x 1.782	= 1.245
		Other: 0.91 x 1.783	= 1.623
		Total	= 6.292
Korzan et al. ^{cd}	1949	Delivery and Selling: 3.10 x 1.605	= 4.9755
		General and Administrative: 0.48 x 1.689	= 0.8107
		Total	= 5.7862
		Delivery costs, wholesale: 3.40 x 1.617	= 5.4978
		Delivery costs, retail: 3.92 x 1.617	= 6.3386
Bressler ^e	1949	Labor: 3.00 x 1.605	= 4.815
		Truck: 1.12 x 1.459	= 1.634
		Sales and Administrative: 0.77 x 1.689	= 1.301
		Total	= 7.650
Williams ^f	1949	Labor: 1.91 x 1.605	= 3.0656
		Truck: 0.68 x 1.459	= 0.9921
		Administrative and miscellaneous: 0.81 x 1.689	= 1.3681
		Total (does not include interest on capital)	= 5.4258
Williams ^g	1948	Labor: 1.84 x 1.380	= 2.5392
		Truck: 0.64 x 1.505	= 0.9632
		Administrative and miscellaneous: 0.57 x 1.715	= 0.9776
		Total (glass only)	= 4.4800

Table 51 (continued)

Publication	Date of Price Data	Data Description and Computations ^a	
Hurt ^h	1948	Labor: 0.95×1.380	= 1.3110
		Truck: 0.67×1.505	= 1.0084
		Administrative and miscellaneous: 0.44×1.715	= 0.7546
		Total (paper only)	= 3.0740
Hurt ^h	1952-54	Salaries: 1.5357×1.504	= 2.313
		Vehicle: 1.0684×1.328	= 1.419
		Advertising and other: 0.4691×1.586	= 0.744
		Total	= 4.476
Conner and Giles ^{dl}	1958	Distribution, retail: 4.60×1.358	= 6.2468
		Distribution, wholesale: 2.53×1.358	= 3.4357
O'Connell and Snyder ^j	1963	Labor: 5.7131×1.288	= 7.3585
		Truck: 1.6502×1.193	= 1.9687
		Miscellaneous: 0.8234×1.361	= 1.1206
		Total	= 10.4476
O'Connell and Snyder ^k	1963	Labor: 1.8576×1.288	= 2.3926
		Truck: 0.4613×1.193	= 0.5503
		Miscellaneous: 0.7315×1.361	= 0.9956
		Total (for wholesale costs only)	= 3.9385
Purcell et al. ^{dl}	1967	Delivery costs, retail: 9.73×1.14	= 11.0922
		Delivery costs, wholesale: 3.41×1.14	= 3.8874

Table 51 (continued)

^aAll cost figures are in cents per quart. The source of price adjustment data was the Council of Economic Advisors, Economic Report of the President: Transmitted to the Congress, 1971 (Washington: Government Printing Office, 1971). The labor data given in the various publications listed in the table were adjusted by an index calculated from the Wholesale Wage Rates, p. 231, of the Report. In a similar manner transportation costs and miscellaneous costs (administration and advertising) were adjusted by the Transportation Cost index, p. 249, and the Service Less Rent index, p. 250, of the Report.

^bAlvah L. Perry, "Costs of Distributing Milk in Maine Markets," The Maine Agricultural Experiment Station Bulletin 451, Orono, July, 1947, p. 77.

^cG. E. Korzan et al., "Costs of Distributing Milk in the Portland Market," Oregon State Agricultural Experiment Station Bulletin 510, Corvallis, February, 1952, p. 18.

^dWeighted index developed from data expressed in footnote a in the percentages of 50, 35, and 15 percent, respectively.

^eR. G. Bressler, Jr., City Milk Distribution (Cambridge: Harvard University Press, 1952), p. 82.

^fSheldon W. Williams, "Costs and Returns to Alabama Milk Distributors," Agricultural Experiment Station of the Alabama Polytechnic Institute Bulletin No. 287, Auburn, June, 1953, p. 14.

^gWilliams, p. 33.

^hVerner G. Hurt, "Cost and Efficiency of Selected Mississippi Fluid Milk Plants," Mississippi State College Agricultural Experiment Station Bulletin 536, State College, August, 1955, pp. 21-24.

ⁱM. C. Conner and Edward J. Giles, "Milk Delivery Practices--Alternatives and Costs," Virginia Agricultural Experiment Station Bulletin 515, Blacksburg, July, 1960, pp. 25 and 41.

^jPaul O'Connell and W. E. Snyder, "Cost Analysis of Fluid Milk Processing and Distribution in Colorado," Colorado State University Technical Bulletin 86, Ft. Collins, 1964, p. 19.

^kO'Connell and Snyder, pp. 24-25.

^lJ. C. Purcell et al., "Fluid Milk Distribution in Georgia, Costs and Alternatives," University of Georgia College of Agricultural Experiment Station Research Bulletin 17, Experiment, November, 1967, pp. 14-15.



APPENDIX B

SAMPLE QUESTIONNAIRE

DAILY CARRIER WEIGHT RECORD

Site _____ Date _____ 197__

	(1)	(2)
Carrier ident.***	_____	_____
Time	_____	_____
Waste category*	_____	_____
Source**	_____	_____
Weight in	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
	_____	_____
Total	_____	_____
Weight out	_____	_____
Amt. delv.	_____	_____
Est. C.Y.	_____	_____

*Waste category: H-household, D-demolition/construction, T-tires,
B-bulky-waste (furniture, appliances, etc.)
**Source: R=residential, I-industrial, C=commercial, A=agric., etc.
***Carrier ident.: M=municipal, C=contractor, Car=private car,
Pvt.=private truck

Special Notes: _____

Table 52. Average Density of Solid Waste Arriving at Four Landfill Sites in Packer Trucks Based on Data Collected from a Random Sample Conducted in Knoxville Area, October-November, 1970

Landfill Site	Packer Truck Average Density
	Pound per CY
Knoxville	444.803
Knox County	342.866
Blount County	321.157
Oak Ridge	<u>354.086</u>
Average	365.728

^aSimple mean calculated.

Table 53. Allocated Annual Total and Unit Costs of Solid Waste Collection and Disposal Functions for Knoxville, Knox County, Alcoa, and Oak Ridge^a Disposal Stage, 1970 Prices

Municipality and Cost Item	Total Purchase Cost	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Knoxville			
Scraper depreciation	5,830.63	0.0488	0.0151
Scraper interest	2,800.64	0.0234	0.0073
Scraper maintenance	4,664.50	0.3900	0.0121
Scraper fuel	1,316.75	0.0110	0.0034
Scraper lub oils	427.43	0.0036	0.0011
Tires depreciation	6,472.44	0.5420	0.0168
Tires interest	310.68	0.0026	0.0008
Tires maintenance	970.87	0.0081	0.0025
Labor	3,693.67	0.0309	0.0096
Bulldozer depreciation	8,772.53	0.0734	0.0228
Bulldozer interest	2,573.27	0.0215	0.0067
Bulldozer maintenance	7,895.27	0.0661	0.0205
Bulldozer fuel	2,223.77	0.0186	0.0058
Bulldozer lub oils	606.53	0.0051	0.0016
Labor	6,145.88	0.0514	0.0160
Compactor depreciation	8,671.79	0.0726	0.0225
Compactor interest	2,639.11	0.0221	0.0069
Compactor maintenance	6,070.24	0.0508	0.0158
Compactor fuel	2,681.23	0.0224	0.0070
Compactor lub oils	870.48	0.0073	0.0023
Labor	6,145.88	0.0514	0.0160
Roadway crushed stone	1,260.00	0.0105	0.0033
Watchmen salaries	11,325.60	0.0948	0.0294
Land interest	35,093.22	0.2937	0.0911
Fence costs	5,470.46	0.0458	0.0142
Scale costs	1,034.00	0.0087	0.0027
Liability insurance	29,244.35	0.2448	0.0759
Utilities	145.55	0.0012	0.0004
Total	83,573.18	1.3838	0.4296
Knox County			
Compactor depreciation	3,825.00	0.5678	0.1872
Compactor interest	1,122.00	0.1666	0.0549
Compactor maintenance	3,633.75	0.5394	0.1778
Compactor fuel	1,767.00	0.2623	0.0865
Compactor lub oils	382.50	0.0568	0.0187
Labor	5,970.83	0.8864	0.2922
Roadway crushed stone	250.00	0.0371	0.0122

Table 53 (continued)

Municipality and Cost Item	Total Purchase Cost	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Watchmen salaries	4,762.90	0.7071	0.2331
Land interest	383.40	0.0569	0.0188
Trench excavation cost	5,974.80	0.8870	0.2924
Interest on trenches	44.81	0.0067	0.0022
Fence cost	504.03	0.0748	0.0247
Scale costs	1,034.00	0.1535	0.0506
Liability insurance	319.50	0.0474	0.0156
Utilities	128.29	0.0190	0.0063
Total	30,102.81	4.4688	1.4732
Alcoa ^b			
Scraper depreciation	2,578.56	0.1327	0.0406
Scraper interest	1,418.21	0.0730	0.0223
Scraper maintenance	2,062.85	0.1061	0.0325
Scraper fuel	313.96	0.0162	0.0049
Scraper lub oils	87.48	0.0045	0.0014
Tire depreciation	969.85	0.0501	0.0153
Tire interest	110.56	0.0057	0.0017
Tire maintenance	145.48	0.0075	0.0023
Labor	919.10	0.0473	0.0145
Compactor depreciation	4,871.49	0.2506	0.0767
Compactor interest	1,482.56	0.0763	0.0233
Compactor maintenance	3,410.04	0.1754	0.0537
Compactor fuel	1,721.96	0.0889	0.0271
Compactor lub oils	421.20	0.0217	0.0066
Labor	7,878.00	0.4053	0.1240
Roadway crushed stone	882.00	0.0454	0.0139
Weighmaster-watchman salary	4,100.00	0.2109	0.0645
Land interest	1,181.88	0.0610	0.0186
Fence cost	737.18	0.0379	0.0116
Scale cost	1,034.00	0.0532	0.0163
Utilities	112.00	0.0058	0.0018
Liability insurance	492.45	0.0254	0.0077
Total	36,930.81	1.9009	0.5813
Oak Ridge			
Collection-disposal contract	214,609.00	9.5296	3.7252
Land interest	360.00	0.0160	0.0062
Land improvements	124.20	0.0055	0.0022
Scale expenses	1,034.00	0.0459	0.0179
Fence expenses	1,082.54	0.0481	0.0188

Table 53 (continued)

Municipality and Cost Item	Total Purchase Cost	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Landfill insurance	2,500.00	0.1110	0.0434
Utilities	50.00	0.0022	0.0009
Watchman salary	4,400.00	0.1954	0.0764
Total	224,159.74	9.9537	3.8910
Blount County ^c			
Scraper depreciation	2,578.56	0.1132	0.0393
Scraper interest	1,418.21	0.0623	0.0216
Scraper maintenance	2,062.85	0.0906	0.0314
Scraper fuel	313.96	0.0138	0.0048
Scraper lub oils	87.48	0.0038	0.0013
Tire depreciation	969.85	0.0426	0.0149
Tire interest	110.56	0.0049	0.0017
Tire maintenance	145.48	0.0063	0.0022
Labor	919.10	0.0404	0.0140
Compactor depreciation	4,871.49	0.2139	0.0743
Compactor interest	1,482.56	0.0651	0.0226
Compactor maintenance	3,410.04	0.1497	0.0520
Compactor fuel	1,721.96	0.0756	0.0263
Compactor lub oils	421.20	0.0185	0.0064
Labor	7,878.00	0.3459	0.1201
Roadway crushed stone	882.00	0.0387	0.0134
Weighmaster-watchman salary	4,100.00	0.1800	0.0625
Land interest	1,181.88	0.0519	0.0180
Fence cost	737.18	0.0324	0.0112
Scale cost	1,034.00	0.0454	0.0158
Utilities	112.00	0.0049	0.0017
Liability insurance	492.45	0.0216	0.0075
Total	36,930.81	1.6215	0.5630
Maryville ^d			
Scraper depreciation	2,578.56	0.1226	0.0368
Scraper interest	1,418.21	0.0674	0.0203
Scraper maintenance	2,062.85	0.0981	0.0295
Scraper fuel	313.96	0.0149	0.0045
Scraper lub oils	87.48	0.0042	0.0012
Tire depreciation	969.85	0.0461	0.0139
Tire interest	110.56	0.0053	0.0016
Tire maintenance	145.48	0.0069	0.0021
Labor	919.10	0.0437	0.0131
Compactor depreciation	4,871.49	0.2317	0.0696

Table 53 (continued)

Municipality and Cost Item	Total Pur- chase Cost	Cost Per Ton	Cost Per Cubic Yard
	-----Dollars-----		
Compactor interest	1,482.56	0.0705	0.0212
Compactor maintenance	3,410.04	0.1622	0.0487
Compactor fuel	1,721.96	0.0819	0.0246
Compactor lub oils	421.20	0.0200	0.0060
Labor	7,878.00	0.3747	0.1125
Roadway crushed stone	882.00	0.0419	0.0126
Weighmaster-watchman salary	4,100.00	0.1950	0.0586
Land interest	1,181.88	0.0562	0.0189
Fence cost	737.18	0.0351	0.0105
Scale cost	1,034.00	0.0492	0.0148
Utilities	112.00	0.0053	0.0016
Liability insurance	492.45	0.0234	0.0070
Total	36,930.81	1.7563	0.5276

^aOak Ridge disposal computations include both disposal and collection costs because the contract let is for both services and separation of services is not possible.

^bAlcoa unit costs are computed from 30 percent total costs given in first cost column.

^cBlount County unit costs are computed from 40 percent of total costs given in first cost column.

^dMaryville unit costs are computed from 30 percent of total costs given in first cost column.

Table 54. Annual Allocated Total and Unit Cost^a of Solid Waste Disposal at Alcoa Landfill for Maryville, Alcoa, and Blount County, 1970

Municipality	Total Cost ^b	Cost Per Ton	Cost Per Cubic Yard
-----Dollars-----			
Maryville	11,079.24	1.7563	0.5276
Alcoa	11,079.24	1.9009	0.5813
Blount County	<u>14,772.32</u>	1.6215	0.5630
Total ^c	36,930.81		

^aCost allocated at the rate of 30 percent, 30 percent, and 40 percent for Maryville, Alcoa, and Blount County, respectively, by joint agreement among the municipalities.

^bTotal cost computed from model landfill operation synthesized for Alcoa.

^cTotal does not add to \$36,930.81 because of rounding errors.

Computations of an exploratory sample to estimate the population standard deviation for the purpose of computing a random sample size, 1970:

$$n = 10; \quad 237^a$$

$$410$$

$$408$$

$$370$$

$$273$$

$$313$$

$$351$$

$$215$$

$$231$$

$$301$$

$$\Sigma x = 3109$$

$$\Sigma x^2 = 1,013,519$$

$$\bar{x} = 311$$

$$\hat{\sigma}_x^2 = \frac{n \Sigma x^2 - (\Sigma x)^2}{n(n-1)}$$

$$= \frac{(10)(1,013,519) - (3109)^2}{10(10 - 1)}$$

$$= 5214.5$$

$$\hat{\sigma}_x = 72.2 \text{ pound per CY}$$

$$n = \left(\frac{(Z)(\sigma_x)}{L} \right)^2$$

$$= \left(\frac{(1.96)(72.2)}{10} \right)^2$$

$$= 200$$

where Z is confidence level, σ_x is the estimated standard deviation, and L is the allowable error in pounds.

^aUnits in pounds per CY (cubic yards).

Determination of sample size for strata of solid waste population for the purpose of random sampling packer garbage trucks, 1970.

$$\text{Use: } n_h = \left(\frac{N_h \sigma_h^2}{N_h \sigma_h^2} \right)^n$$

where n_h is the sample size of the h^{th} stratum, N_h is the population in the h^{th} stratum; σ_h^2 is the variance in the h^{th} stratum, and n is the total sample size required.

Four strata:

Knoxville: ^a	200	$\left(\frac{355}{551} \right)$	= 129
Blount County:	200	$\left(\frac{90}{551} \right)$	= 33
Knox County:	200	$\left(\frac{40}{551} \right)$	= 15
Oak Ridge:	200	$\left(\frac{66}{551} \right)$	= 24
Total: ^b			201

^aThe value 200 is the n size computed in Table 52, page 178.

^bTotal exceeds 200 due to rounding.

Computations for estimating costs to contract trench digging for Alcoa landfill, 1970 prices.

Rectangular trench size volume: $559.99' \times 50' \times 18' \div 27 =$

18.666.33 CY

+ 1,039.13^a CY volume in ends

19,705.46 CY

$\times \$0.50$ per CY excavation rate^b

\$9,852.73 per trench

$\times 6$ trenches required per year

\$19,705.46 total trench excavation cost per year

Trench interest:

$$\begin{array}{rcl} \frac{\$9,852.73}{2} \times 0.06 & = & \$295.58 \text{ per trench per year} \\ & & \times 2 \text{ trenches per year} \\ & & \hline & & \$591.16 \text{ annual interest cost.} \end{array}$$

^aVolume in the triangular shaped ends, see Figure 4, page 99.

^bEstimated cost per cubic yard for excavation services with moderate haul required, prices quoted by two local excavators.

Calculations for determining the number of hours per annum the scraper operates at Alcoa landfill, 1970.

260 days per five work day week

34.1 percent precipitation factor

88.66 days lost due to precipitation

That is, 171.34 days are without precipitation.

171.34 days available without precipitation

-38.52 days required to dig 2 trenches

132.82 work days in which the scraper is used to provide cover material

+52 Saturdays

184.82 x 0.5 hours of machine time =

92.41 machine hours providing cover material per year

38.52 days excavating trenches per annum

x 6 hours per day operating efficiency^a

231.12 operating hours during excavation

+92.41 operating hours providing cover

323.53 total operating hours per year

^aDrevdahl, p. 3-32.



APPENDIX C

Table 55. Units Sold and Percentage of Paper, Glass, and Plastic Containers by Container Size, Federal Milk Order No. 101, Knoxville, Tennessee, November 1970

Container Size	Quantity	Paper	Glass	Plastic
-----Percent-----				
Dispenser	45,943 ^a	b	43.5 ^c	56.5
Gallons	1,024,447	78.8	14.13 ^d	7.06 ^d
Half Gallons	1,003,972	85.3	14.7	b
Quarts	440,232	87.7	12.3	b
Pints	762,096	100.0	b	b
Third Quarts	118,783	100.0	b	b
Half Pints	3,768,465 ^e	100.0	b	b

^aThe dispenser containers consist of 18,377 six gallon units and 27,566 five gallon units.

^bNot applicable.

^cMetal cans.

^dFederal Order data did not separate glass and plastic because less than three handlers packaged plastic. The researcher interviewed Robert Bignamey and John North, Production Managers of Wolfe Dairy and Pet Dairy, respectively, Knoxville, Tennessee, February 9, 1971.

^eDuring three summer months quantity of half pints sold averages 70 percent of November 1970 sales.

Table 56. Weighted Average Cost Per Unit Weight and Volume of Solid Waste Collected and Disposed in Knoxville Area Research Project, 1970 Prices

Municipality	-----Dollars-----		Population ^a	-----Dollars-----	
	Cost Per Ton	Cost Per CY		Weighted ^b Average Cost Per Ton	Weighted ^c Average Cost Per CY
Knoxville	9.9944	3.5890	174,587	7.1400	2.5640
Knox County	26.1933	8.1027	9,840	1.0556	0.3265
Maryville	22.7080	6.8196	13,808	1.2830	0.3853
Alcoa	24.7279	6.4470	7,739	0.7839	0.2044
Blount County	24.1558	7.4984	10,103	0.9976	0.3097
Oak Ridge	10.4879	4.0998	28,319	1.2155	0.4752
Total			244,396	12.4756	4.2651

^aPopulation includes only those persons having municipal or contract refuse collection and disposal.

^bThe following is an example of the computation procedure:

$$\text{Knoxville} \left[\frac{174,587}{244,396} \right] \times 9.9944 = 7.1400$$

This procedure was done for each municipality and the results were totaled.

^cSee footnote b above for procedure.

Table 57. Summary of Weights and Volumes of Solid Waste Created in Research Area by Discarded Milk Containers by Container Size and Type, 1970

Package Item	Paper		Glass ^a		Disposable Plastic		Returnable Plastic ^b	
	Tons	CY	Tons	CY	Tons	CY	Tons	CY
Gallon	707.91	1,018.14	222.50	109.88	536.70	673.88	11.33	14.23
Half gallon	383.08	519.35	139.55	68.80	292.15	366.64	7.31	9.17
Quart	81.74	121.59	33.94	16.76	81.74	121.59	33.94	16.76
Pint	86.41	125.08	45.13	22.29	86.41	125.08	45.13	22.29
10 ounce	11.62	16.27	^c	^c	11.62	16.27	^c	^c
Half pint	287.65	430.09	154.64	76.37	287.65	430.09	154.64	76.37
Bulk	167.05	746.17	23.88	31.90	167.05	746.17	23.88	31.90
Caps	^c	^c	76.72	35.14	23.02	10.54	76.72	35.14
Total	1,725.46	2,976.69	696.36	361.14	1,486.34	2,490.26	352.95	205.86

^aGlass weights and volumes computations based on bottle life of 38 trips.

^bReturnable plastic weights and volumes computations based on bottle life of 100 trips.

^cNot applicable.

VITA

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