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ANALYSIS OF SOURCE SEPARATE COLLECTION OF RECYCLABLE SOLID WASTE-COLLECTION CENTER STUDIES

SCS ENGINEERS, INCORPORATED

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This report summarizes a study that assesses the technical and economic feasibility of operating collection centers for the recovery of recyclable materials. Thirteen recycling centers were studied and detailed case studies of each system were summarized. Three basic types of centers were identified and analyzed: volunteer centers, commercial centers, and municipal centers. In addition, a study of twenty households was performed to quantify the time, cost, and storage impact on families which participate in recycling. This report should be helpful to city officials and volunteer groups interested in developing recycling centers.

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ANALYSIS OF SOURCE SEPARATE COLLECTION

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COLLECTION CENTER STUDIES

Final Report

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I

SUMMARY AND MAJOR CONCLUSIONS

Household Separation

Householder cooperation is necessary for source separation of solid wastes. In order to quantify householder requirements, 20 volunteer households participated in special studies during a two month period. Although the sampling of households was too small to be deemed representative of any specific municipality or region, the primary conclusion drawn with respect to householder efforts is of significance:

- Requirements for householder source separation efforts consume minimal amounts of time and are not costly.

Collection Center Patronage

Regular collection center patrons are drawn from relatively short distances and are primarily from middle to upper-middle class neighborhoods.

Collection Center Performance and Costs

Collection centers generally fall into one of three operational types: citizen, commercial or public (i.e., operated by a municipality). Regardless of type, each center has three elementary requirements: labor, land, and equipment. Voluntary labor was prevalent at citizen centers while virtually all labor was paid for by commercial and public centers. Collection centers were generally located on donated land with size and location of secondary consideration. Expensive and extensive equipment was used at public centers while citizen and commercial centers used donated/salvaged equipment. Although the collection centers studied had individual idiosyncracies, the following major conclusions were drawn:

- Collection center operations in the case study communities generally had no identifiable impact on normal solid waste collection and disposal costs.

- Public collection centers were generally the least efficient and most costly operations included in the case studies.

- The most efficient collection centers 1) relied on voluntary material processing by householders, 2) provided minimal patron assistance, 3) stored collected materials in large roll-off bins, 4) transported materials by a private hauler or secondary materials dealer.

- Newspaper and glass were the most cost-effective materials to handle, providing the greatest revenues for the related costs. Aluminum was a minor consideration at most centers, and other metals were nearly always collected and processed at an economic loss in the overall collection center operation.

II

INTRODUCTION

Collection centers, or "recycling centers" emerged at the grassroots level circa Earth Day 1970. From a few centers established by several environmentally concerned groups at the beginning of the decade, an estimated several thousand citizen, municipal and commercial collection centers now exist, and many thousands of people participate in center associated recycling activities. As such, collection centers are facilitating movement of recyclable materials from the home to secondary materials dealers for reuse.

The U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Resource Recovery Division, (EPA) contracted with SCS Engineers (SCS) to obtain information on the performance and costs of operating these resource recovery programs.

This report presents results of 13 collection center case studies performed throughout the nation. In addition to obtaining information on the performance and costs of operating the centers, information was also sought to determine the time requirements for householders to separate, prepare, and deliver recyclable waste materials to the centers.

III

HOUSEHOLD SEPARATION OF RECYCLABLE MATERIALS

The activities associated with a collection center are depicted in Figure 1. Characteristically, collection centers rely on significant amounts of voluntary householder effort to separate, prepare, deliver, and deposit recyclable waste materials. Once at a collection center, the materials are processed and/or stored for eventual transport to secondary materials dealers.

Householder cooperation is necessary for source separation of solid wastes. Necessary householder activities are depicted in Figure 2, and are determined by material separation and preparation requirements of the collection center. For example, glass containers often must be cleaned, the metal rings removed, and sorted by color; newspapers often must be bundled or bagged; and metal containers may be accepted only if cleaned and crushed, the labels removed, and sorted by type of metal. Regardless of preparation requirements, all separated materials require interim storage at the home prior to delivery to the collection center.

In order to quantify these household activities, twenty SCS and EPA volunteer households participated in special studies.* General demographic information relevant to the participating households is summarized below:

- The median gross annual household income was about $20,000.
- Twelve participants resided in single family-detached houses, 5 in apartments, and 3 in condominiums/townhouses.
- The number of persons per household averaged 3.4.
- The household survey period ranged from 4 to 10 weeks and averaged 7 weeks.

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*It should be noted that the findings presented in this section are derived from too small of a sample to be deemed representative of any specific municipality or region. Rather, the findings are presented for general interest and to express relative efforts and costs heretofore unquantified.

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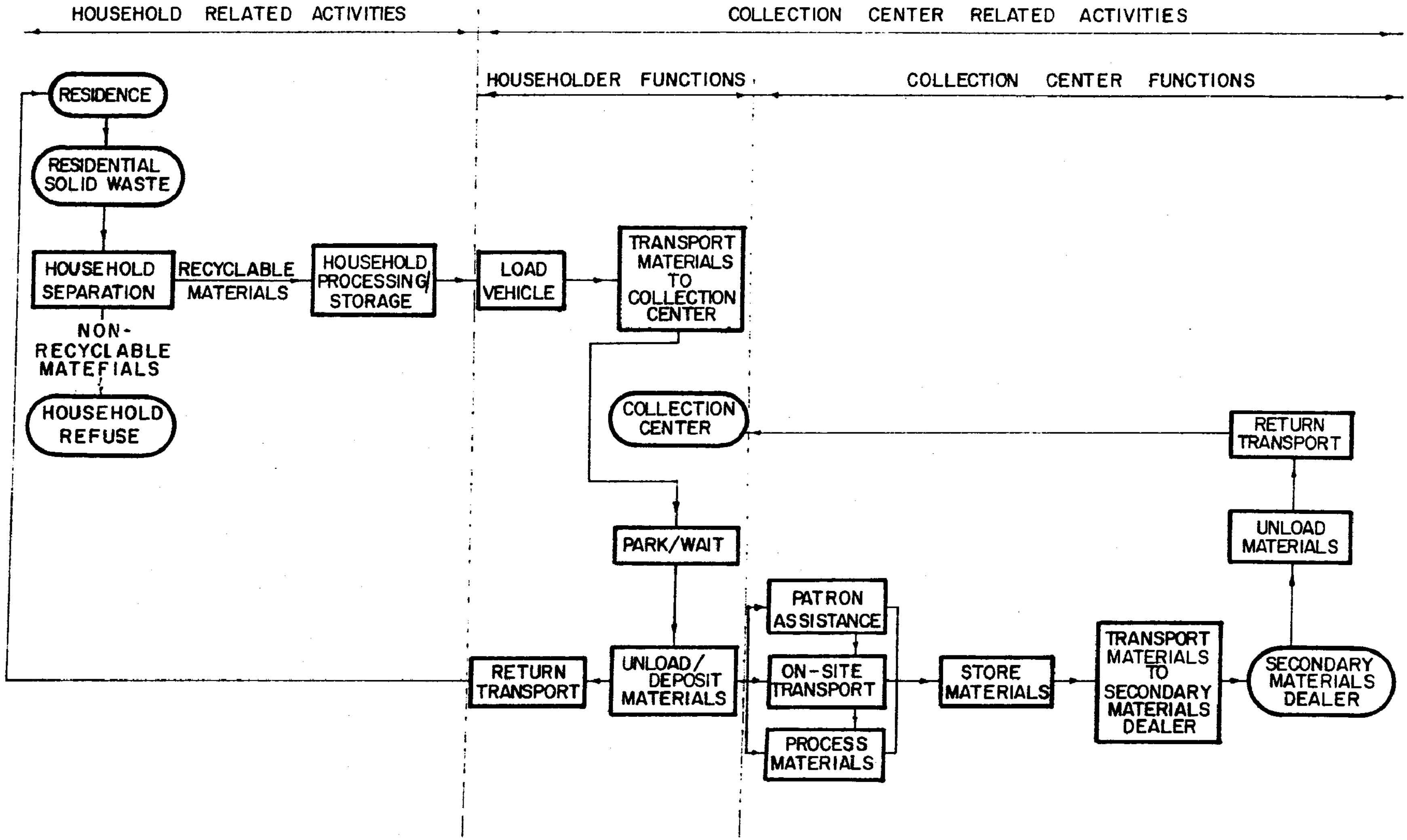

Figure 2. Collection center activities.

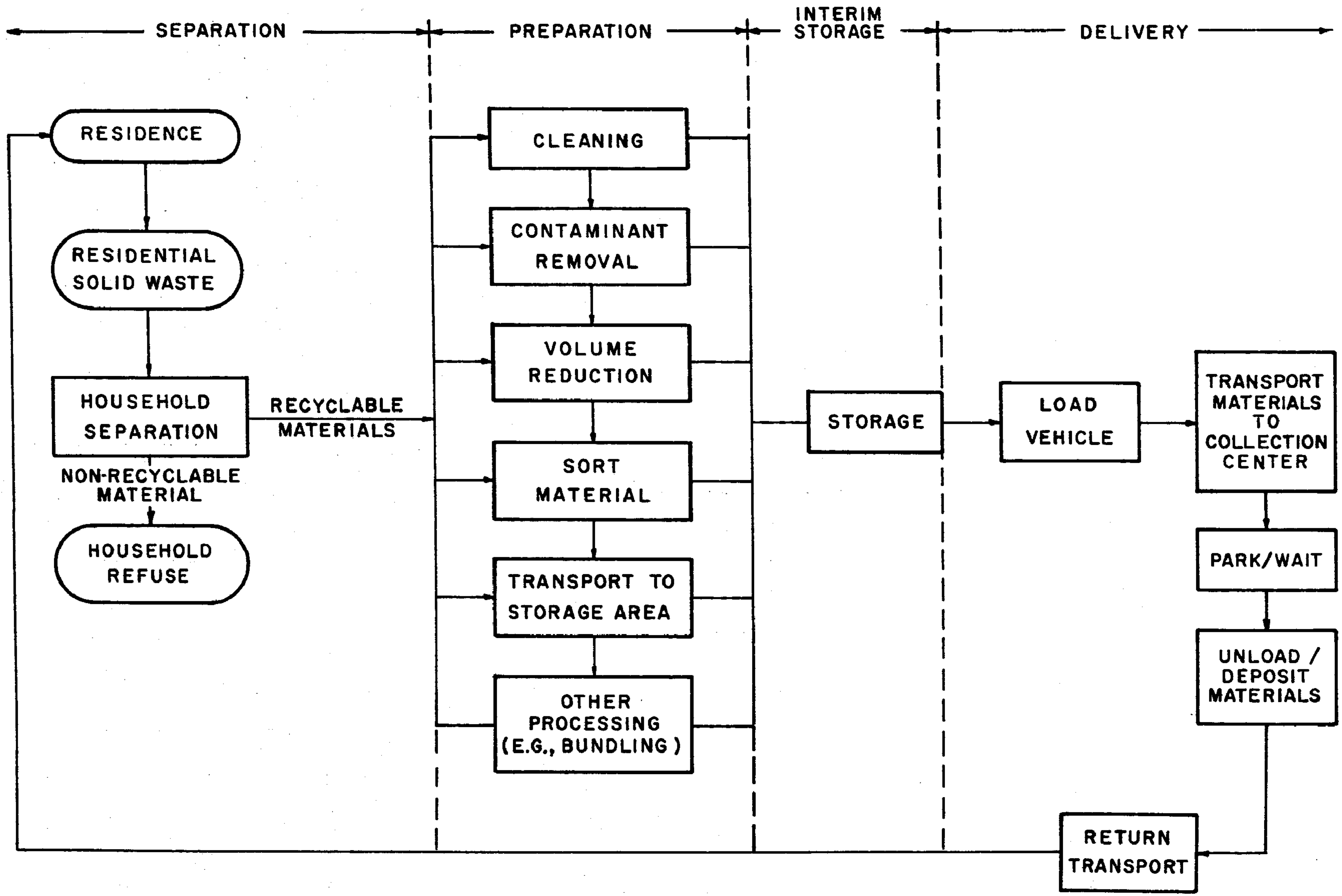

Figure 3. Householder functions associated with providing recyclable materials to a collection center.

Each household used prepared forms to record daily solid waste generation data relevant to five recyclable waste material categories:

- Glass (by color);
- Tin/bi-metal;
- Aluminum;
- Newspaper; and
- All other solid waste (excluding yard trimmings).

The data forms were also used to record time requirements per material associated with the activities shown in Figure 2. Other data collected included storage requirements and supplies or resources used (e.g., twine for bundling and water for cleaning).

Material Generation

Table 1 presents the average quantities of recyclable and non-recyclable materials generated per person per day, and per household per week. The definition for recyclable materials was based on an initial screening of over 60 recycling operations (separate collection programs and collection centers) and limited to those materials most commonly accepted (i.e., glass, tin/bi-metal, aluminum, and newspaper). Thus, excluding yard trimmings, non-recyclable materials were defined as all other residential solid waste. Potentially recyclable items such as corrugated cardboard, textiles, and possibly food wastes are admittedly penalized under this definition.

Tabular results show that nearly equivalent quantities of recyclable and non-recyclable materials were generated during the survey period.

Adding the daily per capita generation rates for recyclable materials (0.78 lbs) and non-recyclable materials (0.83 lbs) equates to a total of about 1.6 lbs for the participating households. This sum was significantly less than published national figures of 2.5 lbs per person per day, and a Los Angeles figure of 2.1 lbs per person per day (half of the household studies were conducted in the Los Angeles area). As previously defined, however, waste quantities excluded yard trimmings. In Los Angeles, yard trimmings comprise about 33 percent (by weight) of the total residential solid waste collected and disposed.[1]

Nationally, the American Public Works Association estimates that average municipal refuse contains 12 percent (by weight) of yard type waste.[2] The percentage expressed in terms of only the residential portion of municipal refuse

TABLE 1

QUANTITIES OF RECYCLABLE AND NON-RECYCLABLE MATERIALS*

	Recyclable Materials (lbs)					Non-Recyl. Materials (lbs)	Total (lbs)
	Glass	Tin/bi-metal	Alum.	News-paper	Total		
lbs/cap/day	0.19	0.07	0.01	0.51	0.78	0.83	1.61
lbs/house-hold/wk	4.5	1.7	0.3	12.2	18.7	19.8	38.5

*Excludes yard trimmings.

would likely be higher. Thus, the overall generation rate recorded during the household study appears appropriate when all factors are considered.

Thus, the separated material weight represented about one-third of the solid waste emitted from each household.

Material Preparation

Weekly time requirements per household for the activities associated with preparing recyclable materials are summarized in Table 2. The total of 15.9 minutes per week to prepare all the materials averaged to about 2 minutes per day.

Table 3 presents a comparison of the preparation time requirements in terms of material quantity. Newspaper required the minimum amount of preparation time per unit weight of material and was thus, the most efficient material for the householder to separate. In essence, bundling was the only significant time requirement. Bundling was normally accomplished in one of two ways: tying string or twine around newspapers, or stuffing newspapers in grocery bags.

Glass was the second most efficient material to separate. Cleaning and contaminant removal were the major time contributors. The least efficient materials to separate were metallic. Aluminum containers were low generation items although preparation time was proportionately high due to cleaning, contaminant removal, and volume reduction

TABLE 2

SUMMARY OF HOUSEHOLD TIME REQUIREMENTS FOR MATERIAL PREPARATION

	Average Preparation Time (Min/Wk)				
Material Preparation Operation	Glass	Tin/Bi-Metal	Aluminum	Newspaper	Total
. Clean*	2.4	2.3	0.7	N.A.	5.4
. Contaminant removal	0.6	1.1	0.1	0.1	1.9
. Volume reduction	0.0	2.2	0.2	N.A.	2.4
. Bundle	N.A.	N.A.	N.A.	2.3	2.3
. Transport (in home)	1.6	1.4	0.3	0.6	3.9
Total	4.6	7.0	1.3	3.0	15.9

N.A. = Not Applicable

*Includes time for material sorting

TABLE 3

HOUSEHOLDER SEPARATION TIME REQUIREMENTS VERSUS QUANTITY OF RECYCLABLE MATERIAL GENERATED

Material	Householder preparation time (% of total time)	Quantity separated (% of total weight)	Time to weight ratio
Glass	29	24	1.2
Tin/bi-metal	43	9	4.8
Aluminum	9	1	9.0
Newspaper	19	66	0.3

activities being performed prior to storage. Tin/bi-metal material preparation time requirements were highest because of time required to flatten containers. While aluminum containers were readily crushed, flattening tin/bi-metal containers necessitated removal of the can bottom.

Viewed in terms of material value, Table 4 shows that preparation of newspaper and aluminum had the greatest worth in terms of monetary return on invested householder preparation efforts - eight cents per min of preparation. Glass preparation had half of the newspaper/aluminum worth, while tin/bi-metal had the lowest worth ratio - less than a penny per min of householder effort. Thus, in terms of efficiency and worth, newspaper appears to be the optimum material in terms of householder source separation requirements.

TABLE 4

HOUSEHOLDER PREPARATION TIME VERSUS RECYCLABLE MATERIAL VALUE

Material	Material value* ($/ton)	Householder preparation effort (min/ton)	Monetary return on householder effort ($/min of effort)
Glass	20	500	0.04
Tin/bi-metal	15	2,000	0.01
Aluminum	200	2,600	0.08
Newspaper	8	100	0.08

*Based on typical revenue received by the case study collection centers (April 1973 values).

Material Preparation Costs. Material preparation costs were defined as the incremental costs incurred by a householder for supplies or resources used while separating and preparing recyclable materials. Included in this definition would be water used for cleaning, energy used if metal container volume reduction was accomplished with the aid of an electric can opener, and twine used when bundling newspapers. Implied costs of householder time were excluded.

Participants in the household study did not use soap for cleaning separated containers unless the soap was contained in used dishwater. Similarly, mechanical dishwashers were not used for cleaning containers. Thus, no incremental costs were assigned for soap or dishwasher use.

Incurred material preparation costs are presented in Table 5. The preparation cost per ton varied by material and ranged from zero when no preparation activities were performed to a high of about $2.30 per ton for cleaning and flattening aluminum containers. Expressed as a household cost per month, about $0.02 per month would be expended if all material were prepared for separate collection. A detailed derivation of the incurred costs is provided in Appendix A.

Comparing Tables 3 and 5 presents an interesting inverse relationship. While newspapers were the most efficient material to separate, they were also the most costly to prepare. At about one penny per month, however, the cost of preparation should not deter household participation.

Material Storage

The floor area used to store separated materials during the household study was defined as the amount of floor space consumed by containers used to store materials or to stack newspapers. Consequently, the storage area requirement was a function of separated material generation rates and the accumulation time between material transport to a collection center. The type of material and the amount of volume reduction practiced were also factors in storage area requirements. Newspapers, for example, when bundled and stacked, do not require any additional floor space for a one-week versus a one-month accumulation period. Glass accumulations, however, usually required additional floor space for storage as the accumulation period lengthens because it is potentially hazardous to practice glass volume reduction in the home. Tin/bi-metal and aluminum materials storage space requirements were dependent on the amount of volume reduction practiced.

TABLE 5

RECYCLABLE MATERIAL PREPARATION COSTS

Material	Range in Material Preparation Cost ($/ton)	Average Material Generation Rate* (lbs/mo)	Time Required to Accumulate One Ton of Material Per Household[+] (mo)	Range in Material Preparation Cost ($/household/mo)
Glass	0 to 0.53	19.3	104	0 to 0.005
Tin/bi-metal	0 to 1.45	7.2	278	0 to 0.005
Aluminum	0 to 2.33	1.3	1,538	0 to 0.002
Newspaper	0 to 0.43	52.8	38	0 to 0.011

*Based on generation rates determined from household study.
+Rounded to nearest month.

Based on household study data, Table 6 presents the average floor space required for storage of each type of separated material. The household accumulation period averaged one month. Data were not amenable to further breakdown.

TABLE 6

RECYCLABLE MATERIAL STORAGE SPACE REQUIREMENTS (One Month Accumulation Period)

Glass	Tin/Bi-Metal		Aluminum		Newspaper
(sq ft)	Volume reduction (sq ft)	No volume reduction (sq ft)	Volume reduction (sq ft)	No volume reduction (sq ft)	Stacked (sq ft)
2.2	1.6	2.8	1.8	1.9	3.3

Incurred Material Storage Costs. Based on the household study and information obtained during the nationwide case studies, storage containers used by householders for separated materials were generally of a makeshift nature (e.g., cardboard boxes or grocery bags). Similarly, existing space was used for storage of recyclable materials. Thus, for all practical purposes, there were no incremental costs incurred by householders for storage of separated materials.

Material Delivery

Household activities involved in delivering separated materials to a collection center include loading materials into a vehicle, transporting materials to a collection center, parking and/or waiting time at the center, unloading and depositing materials, and return transport to the household. With the exception of transport times, each activity was a wholly incremental requirement. The transport requirement may be partially or wholly attributable. For example, if delivery of separated materials was performed in conjunction with shopping or taking children to school, only the "out-of-the-way" time was assigned. If the trip was made specifically for the purpose of delivering separated materials, the entire time was assigned.

Based on this consideration, Table 7 presents the average incremental time requirements to deliver separated materials to a collection center as determined by the household study. The frequency of delivery averaged about once per month during the study.

TABLE 7

TIME REQUIREMENTS TO DELIVER RECYCLABLE MATERIALS TO A COLLECTION CENTER

Material delivery function	Time requirements (min/mo)				
	Glass	Tin/ bi-metal	Aluminum	News-paper	Total
Load vehicle	1.3	0.9	0.6	1.5	4.3
Transport to center	-	-	-	-	2.9*
Park/wait	-	-	-	-	0.4*
Unload/deposit	1.1	0.7	0.5	1.2	3.5
Return transport	-	-	-	-	2.9
Total time required	-	-	-	-	14.0

*Total not identified by material type.

<u>Incurred Material Delivery Costs</u>. Material delivery costs were defined as encompassing only the incremental vehicle operating costs incurred by a householder for the out-of-the-way distance while driving to and from a collection center. As determined by the household study, out-of-the-way mileage averaged about four miles per round trip. Assuming fuel to be the major incurred cost attributable to material delivery and that a typical vehicle used for delivery gets 15 miles per gallon, incurred material delivery costs were estimated to be about $0.16 per trip based on fuel costs of $0.60 per gallon. In that materials were transported at the rate of once per month, incurred delivery costs equate to an average of about $3.70 per ton based on the average monthly generation rate of 80 lbs.

IV

COLLECTION CENTER PATRONAGE

Case study collection center personnel sporadically maintained information to categorize or describe patrons of their respective centers.

Participation

Participation estimates were available from 7 of the 13 case study locations and are summarized in Table 8. Where ranges are shown, the low estimate represents the regular patrons and the high estimate represents the regulars plus sporadic patrons. Overall, participation at the seven centers listed was estimated at about 15 percent of the tributary community.

TABLE 8

COLLECTION CENTER PARTICIPATION RATES

Center location	Estimated participation (%)
Corvallis, Ore.	1-5
No. Hempstead, N.Y.	25-30
Palo Alto, Calif.	15
Palos Verdes, Calif.	12
St. Petersburg, Fla.	20
San Clemente, Calif.	10-25
Scottsdale, Ariz.	10-15
Average	15

In general, the majority of patrons were stated as being from middle to upper-middle class neighborhoods. This generality corresponds to socio-demographic research performed at the University of Wisconsin with respect to categorizing users and non-users of the Madison, Wisconsin, collection center.[3] The results are of significance and should be considered when assessing the feasibility of establishing a collection center. The study concluded that the major differences between users and non-users were:

- The majority of the non-users had gross annual incomes of under $10,000 while the majority of the users earned over $14,000.

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- Occupation of the family head was strongly related to collection center use. Thirty-nine percent of the user family heads were professionals (i.e, lawyer, medical doctor, professor, engineer, etc.) as compared to 10 percent for the non-user families.

- Education of the family head and wives revealed the strongest relationship of user criteria examined. Seventy-three percent of the family heads and 59 percent of the wives in user homes had four or more years of college. Comparatively, 34 percent of the non-user family heads and 22 percent of the wives had four or more years of college. Further, 41 percent of the non-user family heads had four years of high school or less as compared to 13 percent of the user family heads.

Two other points highlighted in the Madison study were also of interest: there was no relationship found between the number of children under 18 and use of the collection center. Nor was age of the family head found to be a factor. The study had hypothesized that collection center users would have more children and be younger. Neither hypothesis was supported by the study data.

Material Delivery Characteristics

Limited data were available from nine case study collection centers describing patronage characteristics such as distance traveled to a collection center, average travel time, amount of material delivered per trip, and value of material delivered. These data are presented in Table 9. As shown, the average collection center patron drove approximately 3 miles one-way to the center, taking from two to twelve minutes to get there. The material delivered weighed an average of 67 lbs and had an estimated value of slightly more than 50 cents based on April, 1973 conditions. Although not shown, materials were said to have been delivered about once per month by the average patron. These values compared quite closely with those from the SCS/EPA household study which are summarized at the bottom of Table 9.

A breakdown of the average material composition as delivered to five centers keeping such data is summarized in Table 10. As shown, glass and newspaper comprised about 90 percent of the recyclable deliveries by weight. These values correlate closely with the quantities generated during the household study - the only significant difference being the quantity of newspaper generated in the areas where the household studies were conducted (The Los Angeles Times and The Washington Post).

TABLE 9

SUMMARY DATA ON COLLECTION
CENTER MATERIAL DELIVERIES

Location	One-way distance traveled (mi.)	Travel time (min.)*	Materials delivered: Quantity (lbs)	Materials delivered: Estimated value ($)#
Berkeley, Calif.	3	10	79	0.60
Corvallis, Ore.	6	12	NA	NA
Modesto, Calif.	2	4	34	0.25
No. Hempstead, N.Y.	1	2	NA	NA
Palo Alto, Calif.	3	6	51	0.47
Palos Verdes, Calif.	4	8	116	0.75
St. Petersburg, Fla.	1	2	NA	NA
San Clemente, Calif.	4	8	56	0.65
Washington, D.C.	3	6	NA	NA
Average (all centers)	3	6	67	0.54
Household study	2	5	80	0.50

*Estimated using 30 mph average speed, except Berkeley.
#Based on March 1973 revenue rates.
NA: No estimate available.

TABLE 10

AVERAGE COMPOSITION OF
MATERIALS DELIVERED

Material	Average quantity delivered (lbs/patron trip)*	
	Case studies#	Household study
Glass	24	19
Metal	7	7
Aluminum	1	1
Newspaper	34	53
Other+	1	0
Total	67	80

*Frequency of delivery was once per month in both instances.
#Data from five centers only.
+Generally consisted of corrugated cardboard and/or magazines.

V

COLLECTION CENTER PERFORMANCE AND COSTS

The thirteen collection centers visited during the study are summarized in Table 11 with respect to location, type of operation, and type and quantities of materials accepted. As shown, six of the case study sites were operated by citizen groups, one was a commercial operation, and six public centers were operated by municipalities.

Material Acceptance/Preparation

Newspaper was accepted at 10 of the 13 centers visited. Bundling was required at seven locations while two locations provided the patron with the option to bundle or bag the material. One center accepted loose newspaper.

Four centers accepted flattened corrugated cardboard containers without waxed surfaces. Three accepted magazines kept separate from other paper types while two accepted mixed paper bundled separate from newspaper.

Every location except Scottsdale accepted glass. This location experienced injury problems with broken glass and the nearest market for glass was several hundred miles distant. Nine centers required that the glass be cleaned and sorted by color. Only one center required removal of paper labels.

Metal containers of one type or another were accepted at every center. Eight locations required sorting by type (i.e., tin/bi-metal and aluminum) while seven required the containers to be flattened prior to delivery. Removal of labels was required at three locations to aid detinning processors.

Only the Los Angeles center accepted plastic containers.

Collection Center Activities

The functions associated with a collection center once materials are delivered are diagrammed in Figure 3. Patrons are often assisted upon center arrival unless the center is unmanned - or functions as a satellite drop-off station.*

*Satellite systems accept materials at several locations throughout the community. Materials deposited are collected and transported to a large central facility for storage/processing and subsequent transport to secondary material dealers.

TABLE 11

COLLECTION CENTER CASE STUDY PROFILE

Center location/ type	Materials collected (tons/mo)					
	News-paper	Corru-gated	Glass	Tin/ bi-metal	Alum-inum	Total
Citizen						
Berkeley, Calif.	88	*	99	22	2	211
Corvallis, Ore.	-	2	9	4	neg.	15
Modesto, Calif.	15	2	34	5	1	57
Palos Verdes, Calif.	69	*	24	3	1	97
Scottsdale, Ariz.	55	-	-	3	1	59
Washington, D.C.	34	-	27	-	neg.	61
Average citizen	52	2	39	7	1	83
Commercial						
San Clemente, Calif.	42	-	4	-	neg.	46
Public						
Briarcliff Manor, N.Y.	-	-	20	2	-	22
Los Angeles, Calif.	-	-	24	5	1	30
No. Hempstead, N.Y.	40	-	41	13	neg.	94
Palo Alto, Calif.	107	11	83	20	3	224
St. Petersburg, Fla.	109	-	38	6	1	154
Seattle, Wash.	52	-	41	68	-	161
Average public	77	11	41	19	1	114
Average center	61	5	37	14	1	95

*Corrugated total not separable from newspaper. neg. = negligible

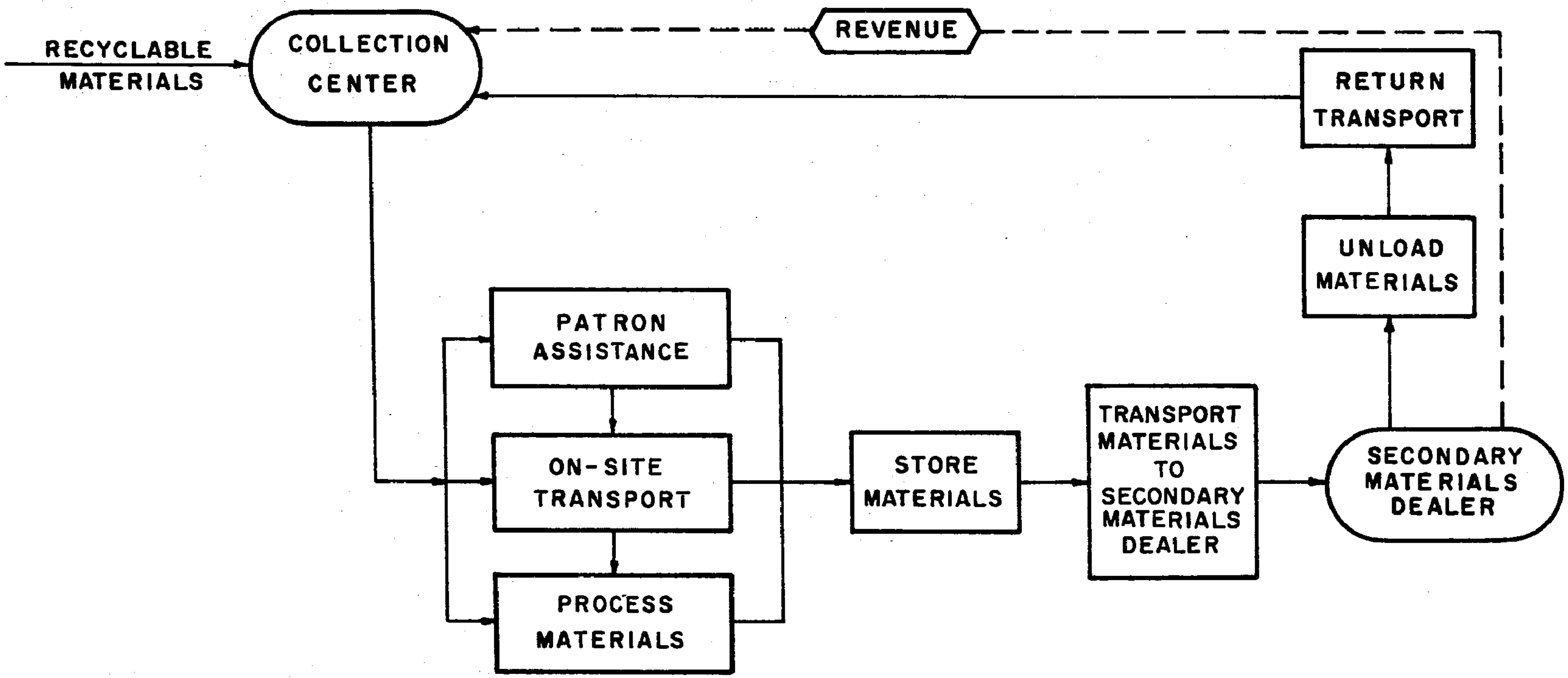

Figure 3. Collection center functions and revenue flow.

Delivered materials are transported to appropriate containers at a fixed center or transported to a central location when a network of satellite centers is operated. The materials are then processed and stored until accumulations warrant transport to a secondary materials dealer.

Collection Center Elements and Costs

Regardless of differences in mode of operation (e.g., single site versus a satellite system) collection centers have three common elements: labor, land, and equipment. The following sections discuss these elements as they pertain to the 13 case study centers.

Labor. Labor activities at a collection center generally fall into one of four basic categories:

- Patron assistance - helping to unload patron vehicles, directing patrons to appropriate unloading locations, and answering questions regarding material preparation requirements.
- Material processing - sorting improperly deposited materials and/or reducing the volume of delivered materials.
- Transportation - gathering materials within the collection center complex and transporting the materials to a central location (satellite operations) and/or to a secondary materials dealer.
- Administration - supervisory and/or clerical activities.

Labor Required. Table 12 summarizes monthly labor distribution at each collection center by labor activity regardless of whether labor was voluntary or paid. Productivity (person-hours per ton) is also tabulated by activity. A material by material breakdown of labor distribution and productivity is included in Appendix B for interested parties.

Distribution of labor summarized in Table 12 characterizes the type of service offered at each center. Assistance when delivering recyclable materials to a center was offered to patrons at five locations. The level of assistance generally was less the 2 person-hours per ton of material delivered although the Los Angeles network of collection centers provided patron assistance at the rate of about 14 person-hours per ton using labor funded via the Federal Emergency Employment Act.

TABLE 12

SUMMARY OF COLLECTION CENTER LABOR REQUIREMENTS

Center location/ type	Material collected (tons/mo)	Labor Activities (person-hrs): Patron Assistance		Material processing		On-site transport*		Transport to dealer		Administration		Total labor	
		per mo	per ton	per mo	per ton	per mo	per ton	per mo	per ton	per mo	per ton	per mo	per ton
Citizen													
Berkeley, Calif.	211	26	0.1	1,031	4.9	0	-	387	1.8	244	1.2	1,688	8.0
Corvallis, Ore.	15	0	-	210	14.0	0	-	67	4.4	84	5.6	361	24.0
Modesto, Calif.	57	0	-	66	1.2	372	6.5	20	0.4	65	1.1	523	9.2
Palos Verdes, Calif.	97	134	1.4	0	-	0	-	0	-	22	0.2	156	1.6
Scottsdale, Ariz.	59	0	-	0	-	18	0.3	0	-	33	0.6	51	0.9
Washington, D.C.	61	0	-	32	0.5	0	-	0	-	43	0.7	75	1.2
Average Citizen	83											475	7.5
Commercial													
San Clemente, Calif.	46	0	-	145	3.1	0	-	20	0.5	4	0.1	169	3.7
Public													
Briarcliff Manor, N.Y.	22	0	-	24	1.1	0	-	9	0.4	2	0.1	35	1.6
Los Angeles, Calif.	30	417	13.9	0	-	0	-	345	11.5	150	5.0	912	30.4
No. Hempstead, N.Y.	94	30	0.3	412	4.4	264	2.8	182	2.0	218	2.3	1,106	11.8
Palo Alto, Calif.	224	75	0.3	493	2.2	0	-	60	0.3	7	-	635	2.8
St. Petersburg, Fla.	154	0	-	150	1.0	1,064	6.9	19	0.1	14	0.1	1,247	8.1
Seattle, Wash.	161	0	-	0	-	0	-	87	0.5	3	-	90	0.5
Average Public	114											671	9.2
Average Center	95											542	8.0

*Transporting materials from satellite locations to a central location.

Material processing was generally performed at a rate of less than five person-hours per ton. Processing, when performed, varied from center to center but encompassed such activities as baling newspaper (Berkeley and San Clemente), glass crushing to increase transport density (most centers), and metal can crushing (most centers). An inordinately large processing factor occurred in Corvallis primarily due to scale problems (i.e., a large number of hours spent on small quantities of materials). Conversely, the Palos Verdes, Scottsdale, Los Angeles and Seattle centers performed no material processing.

The on-site transportation activity was limited to satellite center operations -- i.e., transporting deposited materials from a network of drop-off stations to a central location. Two citizen centers (Modesto and Scottsdale) and two public centers (North Hempstead and St. Petersburg) operated satellite systems. (Los Angeles maintained a network of six centers, each of which functioned independently.) The Scottsdale program, however was atypical. In Scottsdale, container trains were used for residential collection in portions of the city; spare containers were placed in four locations to receive tin/bi-metal and aluminum containers. (Glass was not collected and newspaper bins were provided by a paper stock dealer.) When full, the containers were integrated with residential collection activities and hauled to the city yard, thus minimizing time requirements.

The labor required to perform the "on-site transport" function at the Modesto, North Hempstead, and St. Petersburg centers ranged from about 200 to 1,000 person-hours per month with associated productivity factors ranging from 6 to 9 person-hours per ton of material transported to a central site. Another measure of productivity is tabulated below in terms of person-hours per satellite station:

Center location	Inter-center transport labor (pers-hrs/mo)	Number satellite stations	Labor per satellite station (pers-hrs/station)
Modesto, Calif.	372	6	62
No. Hempstead, N.Y.	264	9	33
St. Petersburg, Fla.	1,064	68	16

Although factors such as quantities generated and distance from the central site must be considered, labor per satellite station decreased with the number of stations. Apparently economies of scale were achieved. For example, roughly half of the St. Petersburg satellite stations were located at apartment houses and received newspaper only. The apartment house collections were sufficient such that a route was designed to minimize distances traveled and collection labor required. Collection of materials from multimaterial satellite stations in St. Petersburg also benefited from economies of scale.

Several collection centers reached agreement with secondary materials dealers and/or private haulers for transportation of some or all collected materials to market. Under the agreements, large material storage bins were provided by the hauler in conjunction with transport services. In exchange for this service, centers often received defrayed revenue. This approach reduced the amount of labor expended by center personnel. In terms of labor productivity associated with center-provided transport, only Berkeley, Corvallis, and Los Angeles spent over one person-hour per ton. Each of these centers provided their own transportation of materials to market.

Administrative and clerical labor was less than 3 person-hours per day at 10 of the 13 centers visited. Berkeley, Los Angeles, and North Hempstead spent the equivalent of one person-day or more per week performing administrative functions.

As summarized in Table 12, labor at citizen centers was generally more productive than at public collection centers (5.7 versus 6.6 person-hours per ton, respectively). The citizen group is heavily weighted by the Berkeley program which was inordinantly labor intensive in relation to the other citizen collection centers studied. Without Berkeley, the citizen center productivity ratio reduces to 3.3 person-hours per ton of material collected, which is virtually equivalent to the commercial center in San Clemente which was, more or less, operated as a citizen center.

Labor Costs. Labor costs generally varied in relation to the center type. As summarized in Table 13, citizen centers received more volunteer labor than did commercial or public centers. The citizen centers, which were heavily influenced by the large Berkeley program, paid for three of every four hours at an average wage of $2 per hour. Excluding the Berkeley program, about half of the hours were paid and half volunteered. In relation to the quantities

TABLE 13

SUMMARY OF COLLECTION CENTER LABOR COSTS

Center location/ type	Total labor (pers-hr/ mo)	Paid labor (pers-hr/ mo)	Percent paid labor	Paid labor cost ($/mo)*	Materials collected (tons/mo)	Paid labor ($/ton)#
Citizen						
Berkeley, Calif.	1,688	1,688	100	3,400	211	16
Corvallis, Ore.	361	168	46	320	15	21
Modesto, Calif.	523	200	38	400	57	7
Palos Verdes, Calif.	156	43	28	100	97	1
Scottsdale, Ariz.	51	18	35	40	59	1
Washington, D.C.	75	43	57	90	61	1
Average citizen	475	360	76	725	83	9
Commercial						
San Clemente, Calif.	169	169	100	330	46	7
Public						
Briarcliff Manor, N.Y.	35	33	94	130	22	6
Los Angeles, Calif.	912	912	100	4,400	30	147
No. Hempstead, N.Y.	1,106	971	88	4,970	94	53
Palo Alto, Calif.	635	630	99	2,090	224	9
St. Petersburg, Fla.	1,247	1,247	100	2,600	154	17
Seattle, Wash.	90	87	97	600	161	4
Average public	671	647	96	2,460	114	39
Average center	542	478	88	1,500	95	22

*Rounded to nearest $10.00
#Rounded to nearest $1.00

of material accepted, the citizen centers paid for labor at a rate of $9 per ton. Without the Berkeley program, paid labor averaged $3 per ton.

The commercial center at San Clemente also paid wages of $2 per hr which resulted in paid labor averaging about $6 per ton. With the exception of Scottsdale, all labor costs incurred by citizen and commercial centers were incremental -- i.e., directly attributable to center operations. Revenue from the sale of materials paid for labor in Berkeley, Palos Verdes, and San Clemente and partially in Modesto. Grants or federal work-study programs paid for labor in Corvallis, Modesto, and Washington, D.C. In Scottsdale, city employees performed administrative and labor functions in support of the citizen center.

At public centers, virtually all labor was paid for at an average wage of about $4 per hr which equated to about $24 per ton of material accepted. Labor used at Briarcliff Manor and half of the labor at the North Hempstead center was derived from existing sources and, therefore, not incremental to collection center operations. All other paid labor listed in Table 13 was incremental to the respective programs and paid by city funds or via the federal Emergency Employment Act (all of Los Angeles and half of North Hempstead).

Table 14 delineates paid labor on the basis of material type accepted by each center. Labor costs associated with newspaper were the least on a cost per ton basis. The range of costs from less than $1 per ton to $23 per ton has a rational explanation. Each of the four programs with costs of less than $1 per ton utilized roll-off bins provided by paperstock dealers for patron deposit of newspaper. Thus, aside from negligible patron assistance, there were virtually no costs associated with newspaper handling or transportation. The San Clemente and Berkeley programs, at $6 and $8 per ton, respectively, employed the use of balers to facilitate handling and to increase revenue. The two centers with the highest newspaper handling costs -- St. Petersburg ($10 per ton) and North Hempstead ($23 per ton) operated satellite collection centers which necessitated collection of newspaper and transport to a central location.

Labor associated with glass had similar rationale. In order to reduce transportation frequency, glass was normally crushed (manually or mechanically). Briarcliff Manor and Palos Verdes circumvented this labor intensive requirement by placing large storage bins at the base of an incline with a metal chute running up to ground level. Volume reduction was achieved by the breakage that occurred upon impact with

TABLE 14

PAID LABOR COSTS BY MATERIAL

Center location/ type	Paid labor costs ($/ton)					
	News- paper	Corru- gated	Glass	Tin/ bi-metal	Alum- inum	Total*
<u>Citizen</u>						
Berkeley, Calif.	8	#	13	49	159	16
Corvallis, Ore.	-	24	18	19	+	21
Modesto, Calif.	2	4	6	22	61	7
Palos Verdes, Calif.	<1	#	1	7	22	1
Scottsdale, Ariz.	<1	-	-	8	12	1
Washington, D.C.	<1	-	3	-	+	1
<u>Commercial</u>						
San Clemente, Calif.	6	-	14	-	+	7
<u>Public</u>						
Briarcliff Manor, N.Y.	-	-	2	46	**	6
Los Angeles, Calif.	-	-	92	245	950	147
No. Hempstead, N.Y.	23	-	27	39	1,112	53
Palo Alto, Calif.	<1	3	5	71	68	9
St. Petersburg, Fla.	10	-	23	54	325	17
Seattle, Wash.	4	-	4	4	**	4

*Weighted average over all materials
#Included with newspaper
+Negligible quantities
**Mixed with tin/bi-metal

the bin and/or contents. Consequently labor costs were $2 per ton or less. Seattle and Palo Alto opted not to crush glass and had labor costs of $5 per ton or less. Transportation to and from satellite centers accounted for the $23 to $27 per ton labor costs associated with centers at North Hempstead and St. Petersburg. In Los Angeles materials were independently transported to market from each of the six centers. As a result, labor costs associated with glass were inordinantly high at $92 per ton.

Due primarily to economies of scale, tin/bi-metal labor costs were high. Volume reduction of these metallic materials required about the same amount of time as glass although the weight of tin/bi-metal was about one-third that of glass at the average center (14 tons per mo versus 37 tons per mo). Seattle, Palo Alto and Scottsdale opted to accept cans in the condition delivered by patrons, and had the lowest labor cost ratios (ranging from $4 to $8 per ton). Aside from the Los Angeles program which had labor costs averaging $245 per ton for the reasons previously stated, costs associated with tin/bi-metal ranged from about $20 to $70 per ton.

Economies of scale also influenced labor costs associated with aluminum. Scottsdale and Palos Verdes, respectively at $12 and $22 per ton, had the lowest cost ratios. Again each of these locations accepted aluminum as delivered and performed no further volume reduction. Volume reduction of aluminum was not practiced at the Los Angeles or North Hempstead centers although labor for transporting the small quantities was $950 and $1,100 per ton, respectively.

In general, the labor cost ratios were lower at the citizen operated centers. The two public centers with the highest cost ratios (Los Angeles and North Hempstead) were both heavily staffed with labor funded via the federal Emergency Employment Act. Although the out-of-pocket costs to these two municipalities was low, the inordinate use of labor was apparent.

Regardless of center type, the least labor costs were exhibited by centers which minimized processing and/or had private haulers provide storage bins and transportation services.

<u>Land</u>. Land used for collection center operations was located adjacent to landfills and at municipal sanitation yards, schools, city parks, auto garages, and shopping centers. The amount of land used and the space under roof at each case study location is summarized in Table 15. The amount of land used ranged from 400 to 40,000 sq ft with an

TABLE 15

SUMMARY OF COLLECTION CENTER FACILITIES

Center location/ type	Open space (sq ft)		Space under roof (sq ft)	
	Donated	Paid for	Donated	Paid for
Citizen				
Berkeley, Calif.	20,000			
Corvallis, Ore.	1,900			1,500 ($120/mo)
Modesto, Calif.	11,800			8,000 ($320/mo)
Palos Verdes, Calif.	40,000			
Scottsdale, Ariz.	10,000			
Washington, D.C.	800			
Average citizen	14,080			4,750
Commercial				
San Clemente, Calif.		4,400		1,000 ($50/mo)
Public				
Briarcliff Manor, N.Y.	400		250	
Los Angeles, Calif.	6,000			
No. Hempstead, N.Y.	21,600		1,100	
Palo Alto, Calif.	14,600		400	
St. Petersburg, Fla.	7,000		2,100	
Seattle, Wash.	1,500			
Average public	8,520		960	
Average center*	10,770		2,050	

*Average for both donated and paid for facilities.

overall average of about one-quarter of an acre. The wide variance was virtually unrelated to any specific parameters. Rather, with the exception of the commercial operation in San Clemente, collection centers were located where donated land was made available. Consequently, property size was of secondary importance.

Open areas were used by most centers. However, seven centers had small buildings for office space and/or warehouses for materials storage. Again, donated facilities were predominant. Aside from the commercial operation, only Modesto paid rent for "under roof" space. The Corvallis expenditures were limited to initial construction costs for a processing/storage facility.

Equipment. Collection centers utilized a variety of equipment for storage, processing and transportation.* All centers necessarily required the use of storage containers, while processing equipment requirements varied with the operations performed at the centers. Some of the centers owned or rented their own transportation equipment while others paid outside agencies to haul separated materials to secondary dealers.

Storage Equipment. On-site storage for materials was normally provided by makeshift containers such as 55 gal drums and wooden boxes and/or storage bins with capacities ranging from 1 to 40 cu yd. In general citizen collection centers were able to obtain storage equipment without capital expenditures while storage equipment purchase or rental was prevalent among the public centers.

Specific storage equipment used by the 13 case study centers varied so greatly that efforts to arrive at a "typical center" were discouraged. On a material by material basis, however, newspaper (and cardboard where accepted) was generally stored in large capacity roll-off bins (15 to 40 cu yd capacity) provided by secondary materials dealers while glass and metals were stored in donated 55 gal drums at about half of the accepting centers and in bins at the other half.

Processing Equipment. Donated or constructed (i.e., "homemade") processing equipment was used at all citizen centers performing material processing. Conversely, public centers generally purchased or rented processing equipment.

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*Appendix C lists all storage, processing, and transportation equipment used at each case study site.

Glass crushers were the most frequently used processing equipment. Glass crushing was performed to increase storage density and to minimize transportation requirements. As previously noted the Palos Verdes and Briarcliff Manor centers circumvented the need for crushing equipment by placing storage bins at the base of an incline with a metal chute running up to ground level. Volume reduction of glass was thus achieved by the breakage that occurs upon impact with the bin and/or contents.

Can crushers were used in Corvallis, North Hempstead, and St. Petersburg. At all other centers, patrons were either requested to flatten the cans prior to delivery, or compactor trucks were used to make collections (Los Angeles and Seattle), thus achieving some degree of volume reduction. At Briarcliff Manor, cans were dumped at the city yard and crushed by the city highway roller. Center patrons were not requested to separate metallic containers at North Hempstead and St. Petersburg. These two centers purchased magnetic separators to increase the revenue received.

A donated shredder was used in Modesto to increase the revenue received for aluminum. Donated paper balers were used in Berkeley and San Clemente for the same rationale.

Typical processing equipment costs are summarized in Table 16 based on the costs reported by the case study locations.

TABLE 16

TYPICAL PROCESSING EQUIPMENT COSTS

Equipment	Capital investment ($)	Operating and maintenance costs ($)	
		Annual	Monthly
Glass crusher	3,000	300	25
Can crusher	900-4,000	360-650	30-50
Magnetic separator	3,000	200	20
Paper baler	2,000-5,000	100-200	10-20
Can shredder	3,000	600	50

Transportation Equipment. Collection centers employed two basic modes for transporting recyclable materials to market. Transportation was provided either by using transport equipment and personnel of the collection center itself, or of a private hauler or secondary materials dealer.

Citizen centers generally used donated pick-up and/or stake trucks to transport glass and metal while transport of paper products was accomplished by secondary materials dealers using tilt-frame trucks. City-owned tilt-frame and compactor trucks were the primary transportation equipment for public centers.

As evidenced in Table 17, equipment costs for transportation provided by the collection center were higher than those provided by a private hauler for materials with the greatest generation rate (i.e., newspaper and glass). This occurred primarily because centers providing their own transportation for large quantities tended to utilize less efficient and smaller vehicles and containers for hauling. Therefore, additional trips were made taking more time and increasing mileage greatly. Conversely, the smaller vehicles were more suitable for transporting tin/bi-metal and aluminum.

TABLE 17

AVERAGE EQUIPMENT COSTS FOR TRANSPORTATION OF MATERIALS TO MARKET

Transportation mode	Material: Equipment cost ($/ton)			
	Glass	Tin/ bi-metal	Aluminum	Newspaper
Collection center	16	6	33	6
Private hauler	6	8	31	4

Table 18 summarizes initial equipment purchase, operating and maintenance, and rental costs reported by each center. Start-up costs (i.e., initial equipment costs) varied from nothing at four centers to almost $40,000 at St. Petersburg. Purchasing equipment was the last avenue explored by citizen centers who minimized start-up costs by using donated and salvaged equipment. As a result all citizen centers had start-up costs of under $1,000. Public centers were generally at the opposite end of the initial cost spectrum. Expensive processing equipment and/or trucks were purchased at three of the public centers visited. The other three public centers were able to use existing city-owned equipment to minimize start-up costs.

Equipment operating costs, including depreciation and rental costs where applicable, averaged $270 per mo at citizen

TABLE 18

ESTIMATED COLLECTION CENTER EQUIPMENT COSTS

Center location/ type	Materials collected (tons/mo)	Equipment costs				
		Initial ($)	O & M ($/mo)	Rental ($/mo)	Total operating ($/mo)	Monthly cost ($/ton)
Citizen						
Berkeley, Calif.	211	Cost data not available			—	—
Corvallis, Ore.	15	980	250	-	250	17
Modesto, Calif.	57	700	240	60	300	5
Palos Verdes, Calif.	97	0	0	520	520	5
Scottsdale, Ariz.	59	0	-	30	30	1
Washington, D.C.	61	0	-	250	250	4
Average citizen*	58	210			270	6
Commercial						
San Clemente, Calif.	46	1,000	160	-	160	3
Public						
Briarcliff Manor, N.Y.	22	300	510	-	510	23
Los Angeles, Calif.	30	0	1,220	-	1,220	41
No. Hempstead, N.Y.	94	19,400	1,200	-	1,200	13
Palo Alto, Calif.	224	900	-	1,050	1,050	5
St. Petersburg, Fla.	154	39,500	530	-	530	3
Seattle, Wash.	161	33,000	590	-	590	4
Average public	114	15,520			850	15
Average center*	85	7,920			550	10

*Does not include Berkeley program due to lack of data.

centers versus an $850 per mo average at public centers. The commercial center had an operating cost of $160 per mo. The citizen-public discrepancy was again due to the more extensive and expensive equipment used at public centers. In terms of materials collected the relationship was still evident with equipment costs averaging $5 per ton at citizen centers versus $8 per ton at public centers. Regardless of the discrepancies, however, economies of scale were evident. With the exception of San Clemente, centers collecting under 50 tons per month had monthly equipment costs ranging from $17 to $41 per ton. Exclusive of North Hempstead, centers collecting over 50 tons per month had a corresponding range of $1 to $5 per month.

Total Costs. A summary of labor, land and equipment costs is presented in Table 19. Citizen centers and the commercial center generally had less costs than did the public centers although the economies of scale discussed earlier were evident.

Revenue and Disposal Savings

Revenue from collected materials and savings from materials diverted from ultimate disposal should be credited to collection center costs to determine the effective savings and/or costs. As discussed below, quantities diverted from the residential solid waste stream were insufficient to have any quantifiable impact on refuse collection operations.

Revenue. Revenue received from sale of collected materials is summarized in Table 20 for each case study location. The differences in newspaper revenue received between citizen ($5 per ton average) and public centers ($9 per ton average) are believed to be due more to local market conditions than discrepancies between center types. For example, lack of proximity to a market was the primary reason for Scottsdale receiving only $3 per ton for newspaper. The local paper dealer paid this low sum because of high transportation costs to the consumer located in Oklahoma. At the opposite end of the newspaper revenue spectrum was San Clemente which received $18 per ton for the baled material.

Glass revenues fluctuated very little. In general, glass revenue to citizen centers was $20 per ton while public centers generally received $15 per ton. Mixed glass such as marketed by Palos Verdes and North Hempstead received lower revenue. Only in Modesto did glass revenue exceed $20 per ton. A large winery and bottling operation located in Modesto contracted with the center to purchase all glass collected without color separation, provide transportation, and pay $25 per ton.

TABLE 19

SUMMARY OF COLLECTION CENTER COSTS

Center location/ type	Materials collected (tons/mo)	Cost elements ($/mo)				Cost ratio ($/ton)
		Labor	Land	Equipment	Total	
Citizen						
Berkeley, Calif.	211	3,400	0	N.A.	3,400#	16#
Corvallis, Ore.	15	320	120	250	690	46
Modesto, Calif.	57	400	320	300	1,020	18
Palos Verdes, Calif.	97	100	0	520	620	11
Scottsdale, Ariz.	59	40	0	30	70	1
Washington, D.C.	61	90	0	250	340	6
Average citizen+	58	190	90	270	550	16
Commercial						
San Clemente, Calif.	46	330	50	160	540	12
Public						
Briarcliff Manor, N.Y.	22	130	0	510	640	29
Los Angeles, Calif.	30	4,400	0	1,220	5,620	187
No. Hempstead, N.Y.	94	4,970	0	1,200	6,170	66
Palo Alto, Calif.	224	2,090	0	1,050	3,140	14
St. Petersburg, Fla.	154	2,600	0	530	3,130	20
Seattle, Wash.	161	600	0	590	1,190	7
Average public	114	2,460	0	850	3,310	54
Average center+	85	1,340	40	550	1,930	35

+Berkeley not included due to lack of all applicable data.
#Based on labor costs only.

TABLE 20

REVENUE RECEIVED BY COLLECTION CENTERS

Center location/ type	Material revenue ($ per ton)					
	News- paper	Corru- gated	Glass	Tin/ bi-metal	Alum- inum	Weighted average+ ($ per ton)
Citizen						
Berkeley, Calif.	4	-	20	20/10*	200	14.70
Corvallis, Ore.	-	8	20	10	200	17.50
Modesto, Calif.	5	0#	25	20	240	22.50
Palos Verdes, Calif.	9	-	13	17	200	12.10
Scottsdale, Ariz.	3	-	-	20	200	4.80
Washington, D.C.	6	-	20	-	-	12.40
Average citizen	5	8	20	15	208	14.00
Commercial						
San Clemente, Calif.	18	-	20	-	200	18.00
Public						
Briarcliff Manor, N.Y.	-	-	20	12	200	19.50
Los Angeles, Calif.	-	-	15	10	200	16.60
No. Hempstead, N.Y.	10	-	5	20	200	9.40
Palo Alto, Calif.	10	17	15	18/10*	200	15.50
St. Petersburg, Fla.	7	-	13	12	200	10.20
Seattle, Wash.	14	-	15	10	-	12.40
Average public	10	17	14	13	200	14.00
Average center	9	12	17	14	204	14.00

*Tin revenue/bi-metal revenue.
#No revenue in exchange for bin usage.
+Weighted by material collected at each center.

Revenue for tin/bi-metal ranged from $10 to $20 per ton and again were subject to local conditions.

With the exception of Modesto, all centers received $200 per ton for aluminum. Modesto shredded aluminum and received $240 per ton.

Weighted by the quantities of material collected, both citizen and public collection centers had overall average revenues of $14 per ton. The extremes, relevant to previous market discussions, were $5 per ton at Scottsdale to $22 per ton at Modesto.

Disposal Savings. Table 21 estimates the impact of collection center quantities on overall residential solid waste management. The average center diverted about 2 percent of the total residential solid waste generated within the surrounding community. Briarcliff Manor (8 percent) and San Clemente (7 percent) were the most successful programs in terms of diversion percentage. Both were communities of less than 20,000 population. Also quite successful was the Berkeley program (6 percent) which was located in a highly environmentally conscious community of over 100,000 residents. In general, however, the rate of diversion decreased with a rise in population.

In none of the collection center communities were refuse collection operations modified to account for diverted quantities of waste. Briarcliff Manor, however, initiated a municipal collection system with respect to the collection center and a separate newspaper collection program. Also, the Berkeley center receives annual monetary and service support amounting to $65,000 from the city refuse collection division in recognition of the center effectiveness in reducing disposable wastes.

Disposal savings, as developed in Appendix D, were estimated in terms of first-and-second party ownership. First party ownership represents the case where the center is located in a municipality which owns the disposal site. Thus, only a portion of disposal costs attributable to reduced operating expenses are applicable to diverted materials. Second party ownership represents the situation where the center is located in a municipality which pays a second party for disposal. Thus, each ton diverted represents a unit cost savings. The disposal savings are summarized in Table 22.

Effective Costs. Table 22 presents the effective collection center costs and/or savings by deducting revenue and

TABLE 21

REFUSE QUANTITIES DIVERTED BY COLLECTION CENTERS

Center location/ type	Population (1,000)	Total materials collected (tons/mo)	Total residential refuse (tons/mo)	Percent diverted
Citizen				
Berkeley, Calif.	117	211	3,550	5.9
Corvallis, Ore.	37	15	1,410	1.0
Modesto, Calif.	100	57	3,800	1.5
Palos Verdes, Calif.	65	97	3,470	2.8
Scottsdale, Ariz.	85	59	3,230	1.8
Washington, D.C.	760	61	83,330	0.1
Average citizen		83		2.2
Commercial				
San Clemente, Calif.	18	46	680	6.8
Public				
Briarcliff Manor, N.Y.	8	22	280	8.0
Los Angeles, Calif.	2,840	30	105,400	negligible
No. Hempstead, N.Y.	236	94	12,500	0.8
Palo Alto, Calif.	57	224	8,330	2.7
St. Petersburg, Fla.	235	154	25,000	0.6
Seattle, Wash.	515	161	19,580	0.8
Average public		114		2.2
Average center		95		2.5

diverted disposal savings from the estimated operating costs.

Collectively, the citizen operated centers broke even although most were operating at profits ranging from $3 to $8/ton due primarily to donated labor and/or minimal material processing and transportation. It should also be noted that the centers would have been "profitable" even without diverted disposal credit.

Similarly, the commercial center operated at a profit of $7/ton.

Only two public centers operated profitably. Both Palo Alto and Seattle performed very little material processing. In fact, the Seattle program provided no services except for transporting materials to market. Los Angeles and North Hempstead, each supplemented with labor from federal programs, again exemplifying the impact of excessive labor on costs. Due primarily to these two programs, the average public center operated at a loss of $34 per ton after diverted disposal savings were credited.

TABLE 22

EFFECTIVE COLLECTION CENTER COSTS/SAVINGS

Center location/ type	Collection center operating costs ($/ton)	Revenue from materials collected ($/ton)	Diverted disposal savings ($/ton)	Effective cost (savings) ($/ton)
Citizen				
Berkeley, Calif.	N.A.	15	0*	N.A.
Corvallis, Ore.	46	18	8	20
Modesto, Calif.	18	22	1	(5)
Palos Verdes, Calif.	11	12	2	(3)
Scottsdale, Ariz.	1	5	1	(5)
Washington, D.C.	6	12	2	(8)
Average citizen	16	14	2	0
Commercial				
San Clemente, Calif.	12	18	1	(7)
Public				
Briarcliff Manor, N.Y.	29	20	8	1
Los Angeles, Calif.	187	17	1	169
No. Hempstead, N.Y.	66	9	7	50
Palo Alto, Calif.	14	16	1	(3)
St. Petersburg, Fla.	20	10	2	8
Seattle, Wash.	7	12	1	(6)
Average public	54	14	3	34
Average center	35	14	3	16

N.A. - Not available due to lack of all applicable data.

*No charge made under operator/city agreement.

VI

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VII

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IX

APPENDICES

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APPENDIX A

INCURRED MATERIAL PREPARATION COSTS

Material preparation costs incurred by a householder may include costs for water used when rinsing or cleaning materials, energy used if metal container volume reduction requirements are accomplished with the aid of an electric can opener, and the amount of time used when bundling newspaper. Data to estimate the incurred costs were obtained during the voluntary household study conducted in conjunction with the primary study. This Appendix delineates the amount of supplies and resources used and estimates the householder costs incurred for each of three material preparation activities: cleaning, volume reduction, and bundling.

Cleaning

The average time spent cleaning separated containers totaled 5.4 person-minutes per week. On a material by material basis the average weekly cleaning time and material amounts cleaned were as follows:

Material	Average weekly cleaning time (min.)	Average weekly generation rate (lbs)
Glass	2.4	4.5
Tin/bi-metal	2.3	1.7
Aluminum	0.7	0.3
Total	5.4	6.5

The average rate of water flow used during rinsing and cleaning of containers was computed to be approximately one gallon per minute (gpm). The cost of residential water was estimated to be $0.0005 per gallon based on a survey of water rates in the sixteen largest cities in the United States[4]. (Note: Case studies were conducted in nine of these cities.) Water used during cleaning is dependent on the portion of time that water was actually used for cleaning purposes. For example, if dishwater was used both for container cleaning and for washing dishes, no incremental water cost was assigned for cleaning. Conversely, if tap water was kept running throughout the cleaning exercise, the total quantity of water was attributed to cleaning.

Participants in the household study did not use soap for cleaning separated containers, unless soap was in used dishwater. Similarly, mechanical dishwashers were not used for cleaning containers. Thus, no incremental costs were assigned for soap or for dishwasher use.

Table A-1 converts the time/quantity data above to incurred cleaning costs at the average water cost rate.

Based on average generation rates, Table A-2 presents the number of months required to produce one ton of each material and converts the cleaning cost per ton to a cost per household per month.

Volume Reduction

Aluminum containers can be readily crushed without mechanical assistance. Glass containers are not normally crushed in the household due to the potential hazards of broken glass. Therefore, tin/bi-metal containers were the only separated material to which incurred volume reduction costs were attributed.

Household studies indicated that when volume reduction was performed, an average of 2.2 minutes were spent crushing the 1.7 lbs of tin/bi-metal plated containers generated weekly. As an aid to volume reduction, the normal procedure was to cut the top and bottom from the container and flatten the resulting cylinder. Removing the container top is a utilitarian procedure and was therefore not attributable to material preparation costs. Removing the container bottom for ease of crushing was not, however, and therefore an attributable material preparation cost.

Bottom removal may be accomplished manually with a hand-held can opener or mechanically with an electric can opener. Removing the container bottom consumed about 90 percent of the total crushing time with no significant time differences between the two removal methods. Assuming typical electric can opener has a rating of 160 watts, and electricity costs $0.015 per KWH[4], the weekly cost of electricity was approximately $0.00009 which is equivalent to about $0.10 per ton of tin/bi-metal containers reduced in volume. As previously estimated, 278 months would be required to produce one ton of tin/bi-metal containers. Thus, when volume reduction was accomplished with the aid of an electrical can opener, the incurred household cost was about $0.0004 per month. Conversely there was no incurred cost when manual aids such as a hand-held can opener were used (no hand-held can openers were purchased specifically for volume reduction during the household studies).

TABLE A-1

CLEANING COST CALCULATIONS

Material	Weekly water cost conversion			Material generation	Cleaning cost
	(Gal/Wk)	x ($/Gal)	= ($/Wk)	(lbs/wk)	($/ton)
Glass	2.4	0.0005	0.00120	4.5	0.53
Tin/Bi-metal	2.3	0.0005	0.00115	1.7	1.35
Aluminum	0.7	0.0005	0.00035	0.3	2.33
Total/Average	5.4	0.0005	0.00270	6.5	0.83

TABLE A-2

CLEANING COSTS PER HOUSEHOLD

Material	Cleaning cost ($/ton)	Material generation Rate* (lbs/mo)	Time required to accumulate one ton of material per household+ (mo)	Incurred cost per household ($/mo)
Glass	0.53	19.3	104	0.0051
Tin/Bi-metal	1.35	7.2	278	0.0048
Aluminum	2.33	1.3	1,538	0.0015

*Based on generation rates determined from household study.
+Rounded to nearest whole month.

Bundling

Incurred bundling costs occur only when twine or a similar material is used to bind newspapers. Bundling serves to ease handling and reduces litter problems during collection or delivery. Grocery bags may be used to accomplish this purpose, however; no incremental costs were assigned if this method was used.

About 30 percent of the household participants voluntarily bundled newspaper with twine. About 2.6 ft of twine per week was used to bundle an average of 12.2 lbs of newspaper generated weekly. The cost of twine was estimated to be $0.001 per linear foot equating to a cost of $0.43 per ton. At a rate of 12.2 lbs per week (52.8 lbs per month) approximately 38 months would be required to generate one ton of newspaper. Thus, the incurred household cost per month was $0.011, or about a penny per month if bundling was accomplished with twine.

APPENDIX B

LABOR DISTRIBUTION AND PRODUCTIVITY FOR SELECTED RECYCLABLE MATERIALS

The following tables provide a material by material breakdown of labor distribution and productivity for newspaper, glass, tin/bi-metal, and aluminum.

TABLE B-1

SUMMARY OF COLLECTION CENTER LABOR REQUIREMENTS AND PRODUCTIVITY

Newsprint

Center type/ location	Labor requirement (man-hr/mo.) Material collected (tons/mo)	On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total	Labor productivity (man-hr/ton) On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total
Citizen													
Berkeley, CA	88	5	315	0	0	49	369	0.1	3.6	0	0	0.6	4.2
Corvallis, OR			(NONE ACCEPTED)										
Modesto, CA	15	0	1	19	5	7	32	0	0.1	1.3	0.3	0.5	2.1
Palos Verdes, CA	66	33	0	0	0	5	38	0.5	0	0	0	0.1	0.6
Scottsdale, AR	46	0	30	0	0	12	42	0	0.6	0	0	0.3	0.9
Washington, DC	34	0	0	0	0	14	14	0	0	0	0	0.4	0.4
Commercial													
San Clemente, CA	42	0	114	0	16	3	133	0	2.7	0	0.4	0.1	3.2
Public													
Briarcliff Manor, NY			(NONE ACCEPTED)										
Los Angeles, CA			(NONE ACCEPTED)										
North Hempstead, NY	19	15	108	33	0	46	202	0.8	5.7	1.7	0	2.4	10.6
Palo Alto, CA	101	10	0	0	0	0.5	10.5	0.1	0	0	0	0	0.1
Seattle, WA	52	0	0	0	28	1	29	0	0	0	0.5	0	0.5
St. Petersburg, FL	109	0	0	494	0	4	498	0	0	4.5	0	0	4.6

TABLE B-1 Continued

Aluminum

Center type/ location	Material collected (tons/mo)	Labor requirement (man-hr/mo.) On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total	Labor productivity (man-hr/ton) On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total
Citizen													
Berkeley, CA	2.0	5	66	0	39	49	159	2.5	33.0	0	19.0	24.5	79.0
Corvallis, OR	0.4	0	16	0	2	20	38	0	40.0	0	5.0	50.0	95.0
Modesto, CA	1.1	0	28	29	4	19	80	0	25.5	26.4	3.6	17.3	72.
Palos Verdes, CA	0.7	30	0	0	0	5	35	42.9	0	0	0	7.1	50.0
Scottsdale, AR	0.35	0	8	0	0	12	22	0	22.9	0	0	34.3	57.2
Washington, DC	.02	0	1	0	0	1	2	0	0	50	0	50	100
Commercial													
San Clemente, CA	0.3	0	6	0	1.5	0	9.5	0	20.0	0	5.0	0	25.0
Public													
Briarcliff Manor, NY		(NOT SEPARATED FROM OTHER METALS)											
Los Angeles, CA	0.7	139	0	0	9	50	189	198.6	0	0	12.9	71.4	270.0
North Hempstead, NY	0.2	15	129	51	12	42	249	75.0	645	255	60	210	1245
Palo Alto, CA	2.9	15	43	0	0	0.5	58.5	5.2	14.8	0	0	0.2	20.2
Seattle, WA		(NOT SEPARATED FROM OTHER METALS)											
St. Petersburg, FL	1.2	0	6	131	6	3	146	0	5.0	109.2	5.0	2.5	121.7

TABLE B-1 Continued

Tin & bi-metal

Center type/ location	Labor requirement (man-hr/mo.) Material collected (tons/mo)	On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total	Labor productivity (man-hr/ton) On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total
Citizen													
Berkeley, CA	21.8	11	256	0	174	97	538	0.5	11.7	0	8.0	4.4	24.7
Corvallis, OR	3.7	0	48	0	18	20	86	0	13.0	0	4.9	5.4	23.3
Modesto, CA	5.3	0	10	108	10	18	146	0	1.9	20.4	1.9	3.4	27.5
Palos Verdes, CA	2.5	30	0	0	0	5	35	12.0	0	0	0	2.0	14.0
Scottsdale, AR	2.3	0	0	20	8	12	40	0	0	8.7	3.5	5.2	17.4
Washington, DC			(NONE ACCEPTED)										
Commercial													
San Clemente, CA			(NONE ACCEPTED)										
Public													
Briarcliff Manor, NY	2.0	0	14	0	0	1	17	0	7.0	0	1.0	0.5	8.5
Los Angeles, CA	5.8	139	0	0	66	50	255	24.0	0	0	11.4	8.6	44.0
North Hempstead, NY	2.4	15	150	57	20	42	284	6.2	62.5	23.7	8.3	17.5	118.3
Palo Alto, CA	19.6	25	380	0	0	0.5	405	1.3	19.4	0	0	0	20.7
Seattle, WA	67.8	0	0	0	37	1	38	0	0	0	0.5	0	0.5
St. Petersburg, FL	6.0	0	6	131	6	3	146	0	1.0	21.8	1.0	0.5	24.3

TABLE B-1 Continued

Glass

Center type/ location	Material collected (tons/mo)	Labor requirement (man-hr/mo.) On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total	Labor productivity (man-hr/ton) On-site assist.	On-site proc.	On-site trans./ coll.	Trans. to dealer	Adm.	Total
Citizen													
Berkeley, CA	99	5	394	0	174	49	622	0.1	4.0	0	1.8	0.5	6.3
Corvallis, OR	9	0	122	0	41	20	183	0	13.9	0	4.7	2.3	20.9
Modesto, CA	34	0	25	212	0	19	256	0	0.7	6.2	0	0.5	7.6
Palos Verdes, CA	26	30	0	0	0	5	35	1.2	0	0	0	0.2	1.4
Scottsdale, AR		(NONE ACCEPTED)											
Washington, DC	27	0	111	0	0	28	139	0	4.0	0	0	1.0	5.1
Commercial													
San Clemente, CA	4	0	24	0	4	1	29	0	5.9	0	1.0	0.2	7.1
Public													
Briarcliff Manor, NY	20	0	7	0	0	1	8	0	0.3	0	0	0.1	0.4
Los Angeles, CA	24	139	0	0	270	50	459	5.8	0	0	11.2	2.1	19.1
North Hempstead, NY	17	15	60	123	0	46	244	0.9	3.5	7.2	0	2.7	14.3
Palo Alto, CA	83	25	91	0	0	0.5	116.5	0.3	1.1	0	0	0	1.4
Seattle, WA	41	0	0	0	22	1	23	0	0	0	0.5	0	0.6
St. Petersburg, FL	38	0	130	247	6	3	386	0	3.4	6.5	0.2	0.1	10.2

APPENDIX C

EQUIPMENT USED AT COLLECTION CENTERS

The specific type and size of equipment used for storage, processing, and transportation at each of the case study collection centers is tabulated in Table C-1. Tables C-2 through C-4, respectively characterize how storage, processing, and transportation equipment was acquired by each center (i.e., donated, purchased, rented, etc.).

TABLE C-1

COLLECTION CENTER EQUIPMENT INVENTORY

Location	Center activity		
	Storage	Processing	Transportation
Berkeley, CA	15 cu yd roll-off bins	Fork lift	Flat-bed truck
	Small containers	Mule	Light trailer
		Baler	2-ton dump truck
		Block & tackle	Several pick-up trucks
		Can flatteners	Stake truck
			Compactor truck
			Covered trailers
			Flat-bed truck w/lift gate
			Tilt-frame truck
Corvallis, OR	4x4x7-1/2 wooden boxes	Can crusher	2-2 1/2 ton flat-bed trucks
	300-50 gal drums	Glass crusher	
	30 cu yd roll-off bin	Hand trucks	
		Fork lift	

TABLE C-1 Continued

Location	Center activity		
	Storage	Processing	Transportation
Modesto, CA	35-55 gal drums	Alum. can shredder	22-ft van
	20 cu yd roll-off bin		1/2 ton pick-up truck
	40 cu yd roll-off bin		
Palos Verdes, CA	6-40 cu yd roll-off bins		Tilt-frame truck
Scottsdale, AR	3-40 cu yd roll-off bins		32 cu yd compaction truck
	10-5 cu yd trailer train bodies		Pick-up truck
	2-8 cu yd bins		
San Clemente, CA	12-1 ton news bins	Fork lift (1/2 ton)	1 truck
	50-55 gal drums	Baler (50 ton)	
Seattle, WA	6-25 cu yd roll-off bins		1 tilt-frame truck

TABLE C-1 Continued

Location	Center activity		
	Storage	Processing	Transportation
Briarcliff Manor, NY	3-10 cu yd lugger boxes 3-20 cu yd lugger boxes 2 wooden bins 5-55 gal drums	2-Skip loaders Dump truck Roller Compactor trucks	
Los Angeles, CA	64-3 cu yd bins		2 Compactor trucks
Washington DC	1-20 cu yd roll-off bin 1-10 cu yd dumpster 1-16 ft. Flatbed truck 2-55 gal drums	1 Glass crusher	1 Van
Palo Alto, CA	10-15 cu yd roll-off bins 4-8 cu yd bins	Can crusher Forklift	Tilt frame

TABLE C-1 Continued

Location	Center activity		
	Storage	Processing	Transportation
No. Hempstead, NY	3-12'x12'x6' wood bins	Magnetic Separator	Pick-up truck
			Dump truck
	2-16'x16'x6' wood bins	Can crusher	
		2 Glass crushers	
	1-24'x12'x6' wood bin	Forklift (3 ton)	
	90-55 gal drums	Conveyor system	
	12-1.33 cu yd bins	Skip loader	
St. Petersburg, FL	500-55 gal drums		23 cu yd compactor truck
	21-1 cu yd containers		2 Stake trucks
	180-55 gal drums		

TABLE C-2

STORAGE EQUIPMENT USED AT COLLECTION CENTERS

Center location/ type	Storage equipment							
	Newspaper		Glass		Metal*		Other	
	Make-shift	Bins	Make-shift	Bins	Make-shift	Bins	Make-shift	Bins
<u>Citizen</u>								
Berkeley, Calif.	D		C		D	D	D	
Corvallis, Ore.			D		C			S
Modesto, Calif.		S	D	R	C			S
Palos Verdes, Calif.		S		S		S		S
Scottsdale, Ariz.		R				D		
Washington, D.C.		S		R	D			S
<u>Commercial</u>								
San Clemente, Calif.		P	D		D		D	
<u>Public</u>								
Briarcliff Manor, N.Y.					C	R		
Los Angeles, Calif.				D		D		D
No. Hempstead, N.Y.	C		D		D		C	
Palo Alto, Calif.		S		R		R		S
St. Petersburg, Fla.		P	D		D			
Seattle, Wash.		P		P		P		

*Aluminum, tin, bi-metal

Key:

C - Constructed by center
D - Donated to center
P - Purchased by center
R - Rented by center
S - Provided to center by secondary materials dealer

TABLE C-3

PROCESSING EQUIPMENT USED AT COLLECTION CENTERS

Center location/ type	Processing equipment				
	Paper baler	Can shredder	Can crusher	Magnetic separator	Glass crusher
<u>Citizen</u>					
Berkeley, Calif.	D				
Corvallis, Ore.			C		C
Modesto, Calif.		D			
Washington, D.C.					D
<u>Commercial</u>					
San Clemente, Calif.	D				
<u>Public</u>					
No. Hempstead, N.Y.			P	P	D(2)
Palo Alto, Calif.			R		
St. Petersburg, Fla.				P	P

Key:

C - Constructed by center
D - Donated to center
P - Purchased by center
R - Rented by center

TABLE C-4

TRANSPORTATION EQUIPMENT USED AT COLLECTION CENTERS

Center location/ type	Transportation equipment				
	Pick-up	Flat bed/ stake	Tilt frame	Compactor	Other
Citizen					
Berkeley, Calif.	D	R	R		
Corvallis, Ore.		P/D			
Modesto, Calif.	P				D
Palos Verdes, Calif.			R		
Scottsdale, Ariz..	D			R	
Washington, D.C.		D	R		D
Commercial					
San Clemente, Calif.		D			
Public					
Briarcliff Manor, N.Y.				D	
Los Angeles, Calif.				P	
No. Hempstead, N.Y.	P				P
Palo Alto, Calif.			R		
St. Petersburg, Fla.		P		P	
Seattle, Wash.			P		

Key: D - Donated to center
P - Purchased by center
R - Rented by center

APPENDIX D

DIVERTED DISPOSAL VALUES

Materials diverted by collection center activities have a diverted disposal value. Although not received by a center, the value should be considered when assessing program viability.

Savings in diverted solid waste disposal costs are dependent on whether the municipality in which the center is located operates its own disposal facility or pays a second party for disposal. In a secondary sense, the savings value varies with the cost of the disposal method employed.

In twenty-two separate collection case study locations made in conjunction with this overall study[5], disposal was either by sanitary landfill or incineration. If the municipality pays a second party for disposal, the entire disposal cost per ton can be recovered through separate collection. If the disposal facility is owned and operated by the municipality, however, only a portion of the disposal cost can be saved. None of the case study locations in the latter category had attempted to quantify the portion of cost applicable to diverted disposal. Therefore, diverted disposal savings for landfill and incineration operations were estimated in the manner discussed below.

Sanitary Landfill. Benefits of separate collection on sanitary landfill operations include a decrease in the rate of use of remaining landfill space and a decrease in landfill equipment usage. Based on the case studies, reported sanitary landfill ownership and operating costs ranged from $0.85 to $7.50 per ton with an average of about $2.50 per ton. Land costs were assumed to represent $0.50 of the total cost based on the disposal of 10,000 tons per acre and a net land cost of $5,000 per acre. Thus, diversion of recyclables was assumed to potentially save $0.50 per ton in land costs at the sanitary landfill.

The remaining $2 of the total $2.50 per ton was attributed to operating costs. Assuming a track dozer can spread and compact up to 80 tons of solid waste per hour[6] and that equipment and operator costs average $25 per hour, an additional operating cost savings of about $0.30 per ton can be attributed to wastes diverted by separate collection. Thus, a total diverted disposal cost savings of $0.80 per ton was assigned to a collection center when the municipality within which the center operated, owned and operated its own sanitary landfill while the total disposal cost per ton was assigned in cases where the municipality paid a second party for disposal.

Incineration. The diversion of materials from incineration through collection center activities can be expected to reduce equipment usage and residue disposal requirements. Incineration costs reported for the case study locations ranged from $7.20 to $17.40 per ton with an average of $10.50 per ton. A breakdown of incinerator operating costs was provided for Chicago, Illinois[7] (a case study location). Table D-1 presents an estimated breakdown of incinerator cost elements believed to be affected as a result of refuse tonnage diverted via collection center operation.

Assuming applicability of the tabulated data to the case study locations, estimated savings from diverted materials amounts to 51 percent of the cost for incineration.

TABLE D-1

INCINERATION COST ELEMENTS AS A PERCENTAGE OF TOTAL PLANT OPERATING COSTS

Operating cost element	Percent of total operating cost	Applicable to diverted tonnage
Operating less residue disposal	27	27
Maintenance and repair	22	22
Administration and supervision	8	0
Pension	4	0
Fuel and utilities	2	2
Amortization	20	0
Miscellaneous	17	0
	100	51

In addition, ash residue must be hauled for final landfill disposal. Residue transport costs vary with many factors, but for purposes of this study, savings were assumed to average $0.50 per ton of residue. Disposal costs of residue at the landfill was valued at $0.80 per ton for a municipally owned landfill and the total cost per ton for second-party ownership based on the preceding landfill discussion.

A 95 percent reduction in weight of material was assumed for paper processed through an incinerator. No weight reduction was attributed to glass and metal if processed through an incinerator.

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