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residential collection systems

VOLUME 1 REPORT SUMMARY

a current report
on solid waste management

RESIDENTIAL COLLECTION SYSTEMS

VOLUME I

REPORT SUMMARY

This final report (SW-97c.1) describes work performed for the Federal solid waste management programs under contract No. 68-03-0097 to ACT SYSTEMS, INC. *and is reproduced as received from the contractor*

U.S. ENVIRONMENTAL PROTECTION AGENCY

1974

FOREWORD

In the spring of 1972, the Office of Solid Waste Management Programs engaged ACT Systems, Incorporated to conduct an extensive evaluation of 11 specifically defined residential collection systems. At that time, there was a dearth of good information on residential collection system productivity and costs and how various system parameters affect these items. The results of this study effort would enable the evaluation of residential collection systems and the design of more efficient and improved systems, nationwide.

The 11 systems were defined to determine, insofar as possible, the significance of specific system parameters on productivity, efficiency, and costs for residential collection. These parameters included point of collection, frequency of collection, crew size, equipment type, collection methodology, incentive system, and type of storage container. The impact of the amount of waste generated was also examined. The systems selected were designed to obtain as much interrelated information as possible from a relatively small study sample.

Four crews in each of the 11 systems were studied for a period of one year. The data gathering efforts included four quarterly time and motion studies for the curb and alley systems, four quarterly surveys for the backyard systems and daily operational information gathered each working day for each system. The daily information for each system was processed by a specially designed computerized Data Acquisition and Analysis Program (DAAP). The data was gathered between August 1972 and January 1974.

It is hoped that the information contained in this report will make a significant contribution to the understanding of residential collection system operations and to the improvement of collection system productivity. The EPA project officers on this contract were Dennis A. Schur, Donna Krabbe, and Kenneth A. Shuster.

--Arsen J. Darnay
Deputy Assistant Administrator
for Solid Waste Management

PREFACE

Volume I of this report contains an overall summary of each of the systems studied and the significant performance factors that resulted from the study. A summary of the major conclusions that resulted from the study efforts is provided.

Volume II of this report contains the details of the study effort and the analysis of data, and is being published by EPA through the National Technical Information Service. The basic data that were used in making the analysis are included in this volume.

Volume III of this report is not being published, although some copies are on file in OSWMP headquarters in Washington, D. C., and contains the broad background information and data that was generated by the study effort.

A brief article on this study by the project officer, Kenneth A. Shuster, has been accepted for publication by the Solid Wastes Management/Refuse Removal Journal.

ACKNOWLEDGEMENT

This study effort would not have been possible without the willing cooperation and assistance from all the agencies and individuals that were associated with the program. In the conduct of the studies special recognition is due to the following individuals. Each of these individuals was keenly interested in the work being done and provided every possible assistance to facilitate the data gathering efforts.

Mr. E. Vern Bringhurst, Superintendent of Sanitation, Salt Lake County Highway Department, Utah

Mr. Earl Elton, Director of Public Works, Covina, California

Mr. William McSpadden, Director, Sanitation Department, Phoenix, Arizona

Mr. David Opsahl, General Manager, Browning Ferris Industries of Rockford, Rockford, Illinois

Mr. G.F. Greenwood, Technical Assistant to the Director Of Public Works, Flint, Michigan

Mr. Francis Soike, Assistant Director, Sanitation Division, Operations Department, Tucson, Arizona

Mr. Joseph Maher, Chief of Sanitation, Warwick, Rhode Island

Mr. Terry Danuser, Superintendent, Streets Divsion, Oak Park, Illinois

Mr. Clarence Patterson, Superintendent, Solid Waste Division, Metropolitan Dade County, Florida

Mr. Robert Lawrence, Refuse Supervisor, San Leandro, California

Mr. Fred Larson, Commissioner of Public Works, Racine, Wisconsin.

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SUMMARY OF CONCLUSIONS

This study effort was designed to determine productivity and efficiency measures for 11 specifically defined systems. The systems were defined in terms of type of equipment, crew size, frequency of collection, point of collection, collection methodology, and incentive system. Bags and cans were prescribed as the storage containers for all systems. The analysis was made in terms of these factors and is contained in Volume II of this report. In addition, an analysis was made of the productivity, efficiency, and collection costs of these systems. For the purposes of this report, production is defined as the total output of the collection effort in terms of homes served per day, and total weight collected. Productivity is the production or output of an organizational element related to the resources used to obtain that production. Cost efficiency is productivity related to the costs associated with obtaining the productivity. The following is a summary of the conclusions that resulted from this study effort.

Conclusions Regarding Equipment

There was a strong tendency to underutilize the equipment from a compaction standpoint. Only one system out of eleven was routinely achieving a reasonable minimum "full" load weight for the equipment being used. The majority of the systems were underutilizing the equipment in terms of the weight achieved for "full" loads.

Only two systems out of eleven averaged only one load per day, and both of these underutilized their equipment capacities. All other systems averaged more than one load per day.

In only two systems were the subsequent loads equal to or greater than the first or "full" loads. In both of these systems, the capacity was underutilized for the first and subsequent loads. In all cases, the weight of the subsequent loads was significantly less than the minimum weight expected for "full" loads. This indicates the equipment was underutilized for subsequent loads. This procedure results in relatively more time being spent in transporting and relatively less time being spent in collecting than there should be in a system in which the vehicle characteristics are matched with the route and crew characteristics.

Conclusions Regarding Crew Size

The productivity per crewman in terms of homes served and tons collected per collection hour is greatest with the one-man crews. On the average, the productivity of one two-man crew is less than the productivity of two one-man crews. Likewise, the productivity of one three-man crew is less than the productivity of three one-man crews.

The percentage of on-route productive collection time for one-man crews is significantly greater than the percentage of productive time for two- and three-man crews. For one-man crews, the on-route productive time is about 97 percent. For the two- and three-man crews, the on-route productive time is approximately 70 percent. There is no significant difference in the percentage of productive time between the two- and three-man crews.

In going to the route and in transporting the collected waste, only the driver is productive. All other crewmen, whether they ride with the driver or not, are non-productive in these operational phases. With these phases consuming approximately 30 percent of the work day, then one-half and two-thirds of the man-hours of this effort are wasted for two- and three-man crews, respectively.

Conclusions Regarding Frequency of Collection

Increasing the frequency of collection from once a week to twice a week required approximately 50 percent more crews and equipment than the once-a-week systems. The average number of homes served per week for the twice-a-week collection systems was approximately two-thirds the number for once-a-week collection systems. Conversely, to decrease the frequency of collection from twice a week to once a week requires approximately 33 percent fewer crews and equipment than the twice-a-week systems.

In terms of productivity factors, the twice-a-week collection systems served approximately 50 percent more homes per collection hour than the once-a-week collection systems. The weight collected per collection hour, however, was only 80 percent of the weight collected per collection hour by the once-a-week collection systems.

Conclusions Regarding Storage Point Locations

The productivity of a backyard system in terms of homes served per collection hour and tons collected per collection hour, is approximately one-half the productivity of a corresponding curb and alley system.

Conclusions Regarding Incentive Systems

Collection systems operating under the task incentive system tend to work a smaller percentage of the normal work week than the standard day systems.

The work effort of standard day collection systems has a tendency to expand into overtime operations.

The collection production and productivity of the task incentive systems tend to be greater than the collection production and productivity of standard day systems.

Conclusions Regarding Storage Containers

The percentage of one-way items (bags and miscellaneous items) does have a significant effect on the system productivity. An increase in the percentage of one-way items reduces the time required to service a home, and conversely, increases the number of homes served per collection hour.

The weight per home per collection also affects the system productivity, and this effect is greater and opposite in direction to the effect of one-way items. An increase in weight per home increases the time required to service a home and decreases the number of homes served per collection hour.

Conclusions Regarding Productivity and Efficiency

Curbside is more productive and cost efficient than backyard service.

For the curb and alley systems:

Systems that have a collection frequency of twice a week tend to serve more homes per collection hour, but collect fewer tons per collection hour, than their once-a-week counterparts.

The larger crew sizes have a tendency to collect more tons per collection hour.

When productivity and cost efficiency are considered on a per crewman basis, there is a strong tendency for the smaller crew sizes to have the greatest productivity and best cost efficiency.

For backyard systems:

The system which uses the task incentive system has a greater productivity than the system that uses the standard day system.

There is no clear pattern between the backyard systems regarding collection cost efficiency.

Conclusions Regarding System Costs

Regardless of the kind of equipment that was being used, the initial cost of the equipment, and the number of days per week the equipment was being used, the daily equipment costs were of the same general magnitude for all systems, except that the equipment costs for System 6 with the detachable container equipment and mother truck combination were significantly greater than the equipment costs for the other systems.

The daily personnel costs were related directly to the crew size.

For every system studied, using the study standardized cost data, the daily personnel costs were significantly more than the daily equipment costs. The manpower to equipment ratios averaged 1.4 for one-man crews, 3.0 for two-man crews, and 4.5 for three-man crews.

The incremental effect of an increase in equipment costs of $1,000 was small in comparison with an effective increase in labor costs per crewman of $0.50 per hour.

Since daily personnel costs were significantly more than the daily equipment costs, cost reduction programs should look first in the area of personnel costs. Personnel costs can be lowered by improving personnel productivity, by reducing the numbers of personnel or both. There was a strong tendency for personnel productivity to increase as crew size decreases.

Since incremental cost effects of an increase in equipment cost of $1,000 were small in comparison with an increase in the effective labor rate of $0.50 per hour, compromising equipment performance for the sake of a lower equipment cost appears to be counter productive.

Use of the Study Information

One of the primary purposes of this study effort was to accumulate a base of reliable and factual performance data that could be used by solid waste collection managers to evaluate their performance, and also to evaluate other reasonable alternatives. Accordingly, in reviewing the information of this report, the local manager should ask the two following questions.

"How efficient is my system compared with the systems of the study?"

"What will happen to my productivity and efficiency if I change to a different system?"

The information of SECTION II and SECTION III provides the tools for the manager to answer these questions. The primary emphasis of this study effort was to concentrate on those factors that have the greatest influence on productivity and efficiency. These are the same factors for which general conclusions have been made and presented in the preceding pages. More specific information for each of these factors is included in Table 2 and in the discussion of the factors in SECTION II. All of SECTION III, beginning on Page 75, is devoted to evaluation and prediction procedures.

Ranking of Factors which Affect Productivity and Cost-Efficiency

All of the factors considered in this study have some influence on system productivity and cost-efficiency. All factors are interrelated to some degree. As such, it is impossible to isolate completely the independent effects of the factors that were considered. However, an attempt has been made to rank the effect of the various factors on system productivity and cost-efficiency and to provide the relative magnitude of the effect of the factors. This ranking was done by grouping the data according to the factors being analyzed and then combining, for productivity, homes per crewman and tons per crewman per on-route hour, and for cost-effectiveness, on-route cost per home per week and on-route cost per ton. The results of this analysis are provided in the table below. It must be emphasized that the relationships indicated are for the results of this study and may not agree with the conditions of a specific system. Differences in such factors as distance from street to storage, fences and gates, traffic, parked cars, storage devices used, and crew methodology (including routing) can significantly alter the relative magnitude of effect, and may even alter the order ranking for a specific system. The information in the table, however, gives managers an indication of the relative effects of system factors for the systems studied as a starting point for specific system change considerations (i.e. what change(s) should I, as a manager, consider first if I want to improve productivity and decrease costs?).

FOR ALL SYSTEMS

FACTOR	ORDER FOR PRODUCTIVITY	RELATIVE MAGNITUDE OF EFFECT	ORDER FOR COST EFFICIENCY	RELATIVE MAGNITUDE OF EFFECT
Point of Collection	1	58	1	52
Crew Size (Per Crewman)*	2	38	3	9
Frequency of Collection	3	36	2	28
Incentive System	4	26	4	1
Percent One-Way Items (Per percent)**	5	1	4	1

* To obtain the effect of a decrease of 2 crewmen, multiply the listed effect by 2. Only 1-3 man crew sizes can be used since these were the only ones studied.

** To obtain the effect of more than one percent change, multiply the listed effect by the percent change. Due to the limited sample and non-linearity of this function, a maximum of ±20 percent should be used.

For each of these factors, the direction to improve productivity and costs is, from less to better: point of collection (backyard to curbside), crew size (larger to smaller, but depends on point of collection, amount of waste, and distance between stops), frequency of collection (twice to once-a-week), incentive system (standard 8-hr day to task system), and percent one-way items (less to more, the impact is significantly greater with curbside collection than backyard).

SECTION I

BACKGROUND INFORMATION

Definition of the 11 Collection Systems

The collection systems selected for the study were characterized by differences in type of equipment, crew size, frequency of collection, point of storage, collection methodology and incentive system. Storage containers of bags and cans were prescribed for all systems. The eleven systems selected were defined as indicated in Table 1. These systems were chosen to determine the relative significance of the variables listed, and to assure the study results would have the broadest possible application.

Definition of a Solid Waste Collection Route

For the purpose of the collection system studies, a residential solid waste collection route was defined as the total activities of a collection vehicle and its crew for a period of one week. On a daily basis, the activities begin with the departure of the vehicle and its crew from the motor pool in the morning, and terminates with the arrival back at the motor pool at the end of the day. The daily activities, therefore, encompass the specific operations of going to the area in which collections will be made, collecting the solid waste from residences, transporting the collected waste to a disposal point, and returning to the route and disposal point, as required, and finally returning to the motor pool. Special collections of items not normally handled by the collection vehicle such as heavy logs, tree trunks or "white goods" are excluded in this definition of a collection route.

TABLE 1

DEFINITION OF COLLECTION SYSTEMS STUDIED

Collection System Number	Type of Equipment	Crew Size	Frequency of Collection	Point of Storage	Collection Methodology	Incentive System	Type of Storage Container
1	Side Loader	1	1/week	Curb-Alley	1 Side of St.	Task System	Bags & Cans
2	Side Loader	1	1/week	Curb-Alley	1 Side of St.	8-hr. day	Bags & Cans
3	Side Loader	1	2/week	Curb-Alley	1 Side of St.	Task System	Bags & Cans
4	Rear Loader	2	1/week	Curb-Alley	1 Side of St.	Task System	Bags & Cans
5	Rear Loader	2	1/week	Curb-Alley	1 Side of St.	8-hr. day	Bags & Cans
6	Side Loader w/detachable container	2	2/week	Curb-Alley	1 Side of St.	Task System	Bags & Cans
7	Rear Loader	3	1/week	Curb-Alley	Both Sides	Task System	Bags & Cans
8	Rear Loader	3	1/week	Curb-Alley	Both Sides	8-hr. day	Bags & Cans
9	Rear Loader	3	2/week	Curb-Alley	Both Sides	Task System	Bags & Cans
10	Rear Loader	2	1/week	Backyard	Tote-barrel	Task System	Bags & Cans
11	Rear Loader	2	1/week	Backyard	Tote-barrel	8-hr. day	Bags & Cans

In this report, reference to total hours worked does not include time required at the motor pool at the beginning and at the end of the day to check in and out, to check equipment or to conduct other authorized matters. All reference to crew size includes the driver and collectors.

General Method of Evaluating Solid Waste Collection Systems

For this study, the most productive collection systems which met the requirements of Table 1 were sought. After a system was selected, the four most productive routes were studied for one year. The results of the four routes were averaged and used for analytical purposes.

Two independent approaches were used to evaluate the systems. One method used information which was obtained from the collection routes on a daily basis for one year. These data were processed by a specially designed computer program, the data acquisition and analysis program (DAAP). Standardized costs were used with the DAAP and are provided in Appendix 1. A summary report for the 12 months of study is provided in Appendix 2. The second approach was based on data obtained from time motion studies or backyard surveys which were conducted on a quarterly basis.

Brief System Descriptions

General. All routes studied for each system were defined as indicated in Table 1.

System 1, Salt Lake County, Utah. The right and left hand drive side loading collection vehicle of Figure 1 was used. All vehicles were 25 cubic yards in capacity. Commercial bulky construction or bulky garden wastes were not collected. The crews averaged almost 30 hours per week working compared with a planned work week of 40 hours.

COLLECTION VEHICLES

Figure 1
Side Loading
Collection
Vehicle

Figure 2
A Typical
Rear Loader

Figure 3
Side Loading
Collection Vehicle
with Detachable
Eight Cubic Yard
Container

An average of 410 homes was serviced per day per crew with an average weight per home per collection of 46.2 pounds. Each crew averaged 1.8 loads per day. The average weight collected per crew per day was 9.4 tons. The storage containers consisted of 34 percent bags, 52 percent cans, and 14 percent miscellaneous items.

System 2, Covina, California. The right and left hand drive collection vehicle of Figure 1 was used. All vehicles were 25 cubic yards in capacity. There was no mixing of residential and commercial waste. The crews averaged almost 34 hours per week on collection related activities compared with a planned work week of 40 hours. An average of 254 homes was serviced per day per crew with an average weight per home per collection of 71.0 pounds. Each crew averaged 1.6 loads per day. The average weight collected per crew per day was 9.0 tons. The storage containers consisted of 26 percent bags, 53 percent cans, and 21 percent miscellaneous items.

System 3, Phoenix, Arizona. The right and left hand drive collection vehicle of Figure 1 was used. All vehicles were 33 cubic yards in capacity. There was some mixing of light commercial waste with residential waste on all residential routes. The crews averaged almost 32 hours per week working compared with a planned work week of 40 hours. The City of Phoenix collected on a frequency of twice a week. The collection days were Monday - Thursday, Tuesday - Friday and Wednesday - Saturday. A personnel rotating system was used so that the planned work week for the crews was only 40 hours. Considering the six days of collection, each route averaged slightly more than 38 hours per week compared with a planned period of 48 hours. An average of 410 homes was serviced per day per crew with an average weight per home per collection of 28.2 pounds. Each crew averaged 1.0 loads per day. The average weight collected per crew per day was 5.7

tons. The storage containers consisted of 29 percent bags, 53 percent cans, and 18 percent miscellaneous items.

System 4, Rockford, Illinois. The residential collections in the City of Rockford were performed by a private contractor to the City of Rockford. The company used the rear loading collection vehicle of Figure 2. All vehicles were 20 cubic yards in capacity. There was no mixing of residential and commercial waste.

For this study effort, only operational data were provided. By agreement between the OSWMP and the Corporate Office of the contractor, financial information pertaining to the collection activities would not be provided. No financial information was obtained during the study effort.

The crews worked an average of almost 36 hours per week working compared with a planned work week of 40 hours. An average of 512 homes was serviced per day per crew with an average weight per home per collection of 49.3 pounds. Each crew averaged 2.4 loads per day. The average weight collected per crew per day was 12.6 tons. The storage containers consisted of 56 percent bags, 28 percent cans and 16 percent miscellaneous items.

System 5, Flint, Michigan. The rear loading collection vehicle of Figure 2 was used. Vehicles were 20 and 25 cubic yards in capacity. There was no mixing of residential and commercial waste.

There was no distinction between the driver and collector, and they alternated between driving and collecting. The crews averaged slightly more than 35 hours per week on collection related activities compared with a planned work week of 40 hours. An average of 575 homes was serviced per day per crew with an average weight per home per collection of 50.5 pounds. Each crew averaged 1.9 loads per day. The average weight collected per crew per day was 14.5 tons.

The storage containers consisted of 85 percent bags, 6 percent cans and 9 percent miscellaneous items.

System 6, Tucson, Arizona. The right and left hand drive collection vehicle of Figure 3 was used. This vehicle used a detachable container of eight cubic yards. The full containers were serviced by a front loading auxiliary vehicle (mother truck) of 32 cubic yards capacity. There was some mixing of light commercial waste with the residential waste on all of the residential routes.

The four routes studies operated in a specifically designated geographical area and were supported by one mother truck.

For the purposes of this study, all of the waste from the four routes was kept separate from other wastes and was weighed separately. This was not the normal procedure in the City.

The crew consisted of two men with no distinction between the driver and collector. Both crewmen drove and collected. The crews averaged slightly more than 23 hours per week compared with a planned work week of 32 hours on residential collections. The frequency of collection in Tucson was twice a week. The collection days were Monday-Thursday and Tuesday-Friday. Wednesday was used for special non-residential collections or for maintenance operations.

An average of 574 homes was serviced per day per crew with an average weight per home per collection of 24.4 pounds. Two of the four routes had a large percentage of mobile homes on them. Each crew averaged 4.4 loads per day. The average weight collected per crew per day was 7.0 tons. The storage containers consisted of 19 percent bags, 61 percent cans, and 20 percent miscellaneous items. Subsequent to the completion of the study, the sanitation administrator reported that changes were made to add approximately 200 homes per day to the routes. With this change, the crews averaged approximately 28 hours per week compared with a planned 32 hours.

System 7, Warwick, Rhode Island. The rear loading vehicle of Figure 2 was used. Vehicles were 16 and 20 cubic yards in capacity. There was no mixing of residential and commercial waste.

The crew averaged 26 hours per week working compared with a planned work week of 40 hours. An average of 407 homes was serviced per day per crew with an average weight per home per collection of 62.2 pounds. One route had a high percentage of estate type residences on it with greater distances between stops than the typical suburban areas. Each crew averaged 2.2 loads per day. The average weight collected per crew per day was 12.7 tons. The storage containers consisted of 56 percent bags, 28 percent cans and 16 percent miscellaneous items.

System 8, Oak Park, Illinois. The rear loading vehicle of Figure 2 was used. Vehicles were 17, 18, 20 and 25 cubic yards in capacity. There was no mixing of residential and commercial waste.

Approximately 98 percent of the refuse was collected from alleys The crews averaged slightly more than 39 hours per week on collection related activities compared with a planned work week of 40 hours. Crews collected along the route as far as possible within the normal eight-hour day, then continued from the stopping place on the following day. An average of 306 homes was serviced per day per crew with an average weight per home per collection of 64.9 pounds. Each crew averaged 1.6 loads per day. The average weight collected per crew per day was 9.7 tons. The storage containers consisted of 25 percent bags, 47 percent cans and 28 percent miscellaneous items.

System 9, Metropolitan Dade County, Florida. The rear loading vehicle of Figure 2 was used. Vehicles were 20 and 25 cubic yards in capacity. There was some mixing of light commercial waste with the residential waste on all of the routes.

The crews averaged slightly more than 25 hours per week working compared with a planned work week of 40 hours. Metro-Dade County collected on a frequency of twice a week. The collection days were Monday-Thursday and Tuesday-Friday. No collections were made on Wednesday. The normal collection day was considered to be 10 hours. An average of 854 homes was serviced per day per crew with an average weight per home per collection of 33.1 pounds. Each crew averaged 2.3 loads per day. The average weight collected per crew per day was 14.1 tons. The storage containers consisted of 46 percent bags, 41 percent cans and 13 percent miscellaneous items.

System 10, San Leandro, California. The rear loading vehicle of Figure 2 was used. Vehicles were 20 cubic yards in capacity. There was some mixing of light commercial waste with the residential waste on all of the routes.

This was a backyard system. The crew size was two men. There was no distinction between the driver and collector, and they alternated the driving. The crews averaged slightly more than 31 hours per week working compared with a planned work week of 40 hours. An average of 364 homes was serviced per day per crew with an average weight per home per collection of 33.9 pounds. Each crew averaged one load per day. The average weight collected per crew per day was 6.2 tons. The storage containers consisted of 2 percent bags, 96 percent cans and 2 percent miscellaneous items.

System 11, Racine, Wisconsin. The rear loading vehicle of Figure 2 was used. Vehicles were 13, 16 and 20 cubic yards in capacity. There was some mixing of light commercial waste with the residential waste on all of the routes.

While this was considered a backyard system, approximately one-third of the collections were made from the curb or alleys. The crew size was two men. There was no distinction between the driver and collector, and they alternated the driving. The crews averaged almost 35 hours per week on collection related activities compared with a planned work week of 40 hours. An average of 243 homes was serviced per day per crew with an average weight per home per collection of 51.1 pounds. Each crew averaged 1.9 loads per day. The average weight collected per crew per day was 6.2 tons. The storage containers consisted of 33 percent bags, 55 percent cans, and 12 percent miscellaneous items.

How Representative Are the Systems Chosen

There is great variability in the conduct of residential collection operations across the country. This variability takes many forms. There may be public and private collection operations. Within the collecting organization there may be differences in the operating parameters such as the kind of collecting equipment that is used, the size of the crew, the frequency of collection, the residential collection point, the collection methodology, the incentive system and the kind of storage containers that are used. There are additional factors that have an impact on the collection operation. These may include the climate of the geographical area, the affluence of the area, the amount and type of waste generated, the housing densities, the types of structures (single or multi-family), the distance to the disposal site and any queuing that might exist at the disposal site, the local ordinances or rules and regulations, the personnel administration policies, pay scales, and fringe benefits. This is not an all inclusive list, but does indicate most of the factors that can influence a residential collection operation.

In conceiving this study, the OSWMP desired to obtain reliable information on those facets of a collection operation that appeared to have the greatest impact on the productivity and efficiency of various systems. In addition, it was desired to obtain quantified measures of productivity and efficiency from the best operating systems that could be reasonably found. Accordingly, the factors included in Table 1 were used.

For the purposes of the study, it was desired to study the most productive and most efficient systems that could be found and that met the prescribed definitions. It was hoped that the systems would also provide a reasonable geographical distribution to make the result more generally applicable.

The systems described in the preceding section resulted from the systems search. The system that was chosen for study was considered to be the most productive and efficient of the systems that were known at the time of selection.

That there may be more productive systems than the systems used in this study does not invalidate the study results or conclusions. It is felt that the results of this study are representative and provide reasonable productivity and efficiency goals for comparison purposes. These results will also provide solid waste managers with a valid estimate of what can be expected if a change in system operation is contemplated.

SECTION II

ANALYSIS OF STUDY DATA

Selected Items From the DAAP and Time Motion Reports

To simplify the presentation and understanding of the study data, items of key interest have been extracted from the DAAP and time motion reports and are provided in this section and in Appendices 3-5. More complete data are provided in Volumes II and III.

The yearly averages of selected parameters by system are provided in Appendix 3.

The monthly generation rates in pounds per home per week by system are provided in Appendix 4.

The collection rates in tons per crew per day by system on a monthly basis are provided in Appendix 5.

Collection System Productivity and Cost Efficiency

There is considerable confusion regarding the terms production, productivity, and efficiency. The following concepts will apply for the purposes of this report.

Production, as it pertains to residential solid waste collection activities, is the total output of a work effort in terms of homes served per day and total weight collected. The concept of production applies to every organizational element from the individual route up to and including the highest level (city or company). Production in a residential collection operation can be increased by adding more resources. A manager can increase the number of homes served per day and the number of tons collected by increasing the size of his crews or by adding more crews or by a combination of these methods. Both procedures are followed extensively in practice.

Productivity is the production or output of an organizational element related to the resources used to obtain that production. Thus, if two organizational elements have the same production with the same input of resources, the productivity will be equal for both elements. However, if greater production is achieved with the same input of resources, or if a constant level of output is achieved with a smaller input of resources, the productivity will be increased. Thus, a manager can also increase production by increasing productivity.

For this report, the basic productivity measures will be homes served per crewman per collection hour and tons collected per crewman per collection hour. That is, output is related to manpower input. For information purposes, the less meaningful productivity measures of homes served per crew per collection hour and tons collected per crew per collection hour are also presented.

Another productivity concept that is included in this report is marginal productivity. In this concept the incremental effect of adding a crewman is determined. An additional crewman may increase or decrease the productivities of the other crewmen. If the additional crewman is able to produce more than the other crewmen, and if he helps the other crewmen to produce more, then adding the additional crewman is beneficial. If the additional crewman produces less than the other crewmen, and as a result the entire crew produces less on a per crewman basis, then adding the additional crewman is detrimental. The marginal productivities will also be measured in terms of homes served per collection hour and tons collected per collection hour.

Most of the discussion of productivity has been limited to activities in terms of collection hours (time on route) in order to separate out transport activities to permit on-route productivity comparisons. Because of the individual circumstances surrounding the systems in this study, there were different round trip transport distances and times, different dump times and a different number of loads per day. On a daily basis, these differences would have a significant impact on productivity. By considering productivity on a collection hour (on-route) basis, the differences are eliminated and true productivity comparisons can be made.

While it is possible to design a single index to indicate the level of productivity for various residential collection systems, this approach was not considered for this report. No single item, by itself, will permit a valid comparison of system productivities. Instead, it is necessary to look at each factor separately in order to compare system operations.

In place of a single index the productivity factors for the various systems are related to the same factors for System 1. See Table 1 for a definition of System 1. In this study, System 1 is considered to be the basic system because it is the simplest in concept. System 1 is also the most productive in terms of output to input. These indices are presented later in this report. In all cases, the index is the performance value of a compared system divided by the performance value for System 1.

For comparative purposes, the most meaningful system performance measure is the collection cost efficiency index. As used in this report, this index associates the concept of productivity with collection cost. Cost efficiency may be examined on an on-route or total day basis.

The organization that achieves a given level of productivity at least cost has the greatest collection cost efficiency. For example, if two crews have exactly the same performance parameters per day in terms of homes served, weight collected, miles traveled and time worked, their productivity would be exactly the same. If one crew was using a new vehicle of 20 cubic yards capacity and the other crew was using one of 25 cubic yards capacity, then the crew that was using the vehicle of 20 cubic yards capacity would have the greater cost efficiency. The reason for this is that the 25 cubic yard vehicle would cost more, and this additional cost would be reflected as an additional incremental cost for each parameter being considered. The system that has a collection cost per home of $0.13 per week is more efficient than systems with a collection cost per home per week greater than $0.13.

Before presenting the productivity and cost efficiency results of the systems in this study, it is necessary to discuss the multi-variable nature of solid waste collection and the compariability of systems. There are many community and system variables that impact on productivity and cost efficiency. These variables are so interrelated and dependent upon each other that it is extremely difficult to identify the full impact of any single variable. When comparing systems, it is necessary to hold constant as many variables as possible while considering other variables. Variables easily held constant in comparing systems include: point of collection, frequency of collection, crew size, incentive system and vehicle size and type. Other variables are difficult, if not impossible, to hold constant. They include amount of waste, type and number of storage devices, housing density, collection methodology, traffic, and street to storage distance. Because the nature and effect of a variable may, at times, be impossible to identify and define, even experienced analysts may have difficulty in deciding which of two systems is better. It is also possible to overlook an important variable and make an invalid conclusion. With these cautioning remarks in mind, the next portions of the report present an analysis of the data that were obtained during the study. In making the analysis the objective is to highlight the significant impact of the variable being considered. The values reported are those that resulted from this study effort. The magnitude of the relationship may not be the same in another system comparison; however, the relationships that are developed should apply generally. For example, the results clearly show that curbside is more productive and cost efficient than backyard service, but for any given system, other factors may make this difference more or less than that reported from the study.

Presentation of System Productivity and Efficiency Measures

The most significant descriptive and performance parameters that relate to productivity and cost efficiency are summarized for each system in Table 2. This information was extracted from the DAAP and time motion reports.

The table is divided into several sections. At the top of the table is a description of each system. The data are grouped by curb/alley systems and backyard systems, then by frequency of collection and by crew size.

The second section shows percent of total crew time spent on various activities. Data in this section are derived from the DAAP and the time motion reports.

TABLE 2

SYSTEMS PRODUCTIVITY AND EFFICIENCY MEASURES

SYSTEM DEFINITION

CHARACTERISTICS	CURB-ALLEY SYSTEMS									BACKYARD SYSTEMS	
System Number	1	2	4	5	7	8	3	6	9	10	11
Collections/Week	1	1	1	1	1	1	2	2	2	1	1
Crew Size	1	1	2	2	3	3	1	2	3	2	2
Incentive System	Task	Std dy	Task	Std dy	Task	Std dy	Task	Task	Task	Task	Std dy
Collection Pattern	1 side	1 side	1 side	1 side	Both sides	Both sides	1 side	1 side	Both sides	Tote barrel	Tote barrel
Vehicle Size (Cu Yds) & Type	25 SL	25 SL	20 RL	25 RL	20 RL	25 RL	33 SL	8-DC	20 RL	20 RL	13 RL
ACTIVITY	**PERCENT OF TOTAL CREW TIME SPENT ON ACTIVITY**										
To Route And Transport	34.8	32.2	31.5	30.2	24.2	35.4	22.6	27.2	30.0	18.3	20.6
ON ROUTE: Driving*	17.9	13.5	8.9	12.2	5.8	3.1	24.7	10.0	7.2	----	----
ON ROUTE: Riding* Walking	0.0	0.0	7.8	11.6	11.8	5.8	0.2	18.1	14.5	----	----
ON ROUTE: Collecting	45.8	51.5	30.6	19.5	35.7	38.2	50.1	27.8	29.3	81.7	79.4
ON ROUTE: Waiting**#	0.8	1.8	20.8	26.4	22.2	17.3	1.1	6.5	18.5	----	----
ON ROUTE: Other**	0.7	1.0	0.4	0.2	0.3	0.4	1.3	10.4	0.5	----	----
TOTAL TIME UTILIZATION (PERCENT)											
Crew Productive Time	98.5	97.2	63.0	58.3	61.3	58.7	97.6	69.5	61.0	----	----
Crew Non-Productive Time	1.5	2.8	37.0	41.7	38.7	41.3	2.4	30.5	39.0	----	----
Total	100	100	100	100	100	100	100	100	100	----	----
ROUTE CHARACTERISTICS (DAILY AVERAGES)											
Pounds/Home/Collection	46.2	71.0	49.3	50.5	62.2	64.9	28.2	24.4	33.1	33.9	51.1
Percent Bags/Number Per Home Per Collection	34/1.5	26/1.3	56/2.6	85/4.6	56/3.6	25/1.5	29/0.9	19/0.5	46/1.2	2/0.0	33/1.4
Percent Cans/Number Per Home Per Collection	52/2.3	53/2.7	28/1.3	6/0.4	28/1.5	47/2.7	53/1.6	61/1.5	41/1.1	96/1.2	55/2.4
Percent Misc/Number Per Home Per Collection	14/0.7	21/1.1	16/0.7	9/0.5	16/1.0	28/1.7	18/0.5	20/0.5	13/0.4	2/0.0	12/0.5
On Route Miles/Day	10.5	6.1	10.1	13.1	10.5	4.5	13.7	20.5	10.4	6.9	6.6
Transport Miles/Day	46.1	18.8	32.6	29.9	14.3	34.4	22.2	12.0	33.4	6.0	17.6
On Route Hours/Day	3.83	4.56	4.82	4.67	3.91	4.88	4.88	4.14	4.38	5.06	5.47
Transport Hours/Day	1.71	2.01	1.92	1.75	1.05	2.50	1.07	1.38	1.55	0.98	1.25
Hours Worked/Day	5.87	6.71	7.02	6.69	5.16	7.57	6.32	5.69	6.26	6.19	6.89
Loads/Day	1.8	1.6	2.4	1.9	2.2	1.6	1.0	4.4	2.3	1.0	1.9
Services/Day	410	254	512	575	407	306	410	574	854	364	243
Tons/Day	9.44	9.00	12.62	14.49	12.65	9.72	5.73	6.96	14.10	6.18	6.18
ON-ROUTE PRODUCTIVITY											
Services/Crew/On Route Hour	107.3	55.7	107.0	123.3	104.5	62.7	84.2	138.4	200.5	72.1	44.4
Tons/Crew/On Route Hour	2.5	2.0	2.6	3.1	3.3	2.0	1.2	1.7	3.3	1.2	1.1
Services/Crewman/On Route Hour	107.3	55.7	53.4	57.7	34.9	20.9	84.2	66.6	66.5	35.3	22.1
Tons/Crewman/On Route Hour	2.5	2.0	1.3	1.5	1.1	0.7	1.2	0.8	1.1	0.6	0.6
COST EFFICIENCY											
On Route Cost/Home/Week	0.13	0.20	0.16	0.15	0.30	0.36	0.29	0.37	0.34	0.27	0.37
Total Cost/Home/Week	0.19	0.30	0.23	0.22	0.39	0.55	0.37	0.51	0.48	0.32	0.47
On Route Cost/Home/Year	6.76	10.40	8.32	7.80	15.60	18.72	15.08	19.24	17.68	14.04	19.24
Total Cost/Home/Year	9.88	15.60	11.96	11.44	20.28	28.60	19.24	26.52	24.96	16.64	24.44
On Route Cost/Ton	5.42	5.75	6.54	6.09	9.71	11.07	10.42	15.40	10.26	15.74	14.62
Total Cost/Ton	8.29	8.46	9.53	8.72	12.82	17.13	13.48	21.15	14.67	19.26	18.41
Indices of On Route Cost Per Home*	1.00	0.65	0.81	0.87	0.43	0.36	0.45	0.35	0.38	0.48	0.35
Indices of On Route Cost/Ton*	1.00	0.94	0.83	0.89	0.56	0.49	0.52	0.35	0.53	0.34	0.37

* Driving Riding For 1-Man Systems
**Non-productive Time
\# Waiting includes compaction delays

*Indices based on corresponding costs for System 1.

The third section summarizes the productive and non-productive crew times for each of the systems studied. In the collection phase of operations, the waiting and other time are considered non-productive. In going to the route and the transport phases of the operation, only the driver is considered to be productive.

The fourth section summarizes the route characteristics for each system to enable direct comparisons to be made among systems.

In the fifth section, productivity factors as they relate to the performance of the crew and the performance of a crewman are provided. The productivity factors are in terms of services per collection hour and tons per collection hour.

The last section provides the cost efficiencies associated with the various systems. Cost information based on the on-route phase of operations and also on the total operations is provided. The last two lines of this section provide indices of on-route cost per home and on-route cost per ton.

Table 3 provides additional productivity and efficiency indices. In each case the performance of System 1 is used as the basis for determining the index. Since all systems are compared with System 1, they may also be compared with each other.

The bar graphs of Figures 4 through 9 show graphically the relationship among the systems for homes served per crew and per crewman per collection hour, the tons collected per crew and per crewman per collection hour, and the collection cost per home per week and per ton collected.

Detailed Analysis of Systems Under Study

In this section, data are grouped to facilitate an analysis of the information gathered in the study effort. An analysis will

TABLE 3

PRODUCTIVITY AND EFFICIENCY INDICES

			PRODUCTIVITY INDEX								COLLECTION COST EFFICIENCY INDEX			
SYSTEM NUMBER	POUNDS PER SERVICE PER DAY	TOTAL SERVICES PER DAY	SERVICES PER CREW MAN PER COLL. HR.	INDEX	SERVICES PER CREW PER COLL. HR.	INDEX	TONS PER CREW MAN PER COLL. HR.	INDEX	TONS PER CREW PER COLL. HR.	INDEX	COST PER SERVICE PER WEEK	INDEX	COST PER TON	INDEX
1	46.2	410	107.3	1.00	107.3	1.00	2.5	1.00	2.5	1.00	.13	1.00	5.42	1.00
2	71.0	254	55.7	.52	55.7	.52	2.0	.80	2.0	.80	.20	.65	5.75	.94
3	28.2	410	84.2	.78	84.2	.78	1.2	.48	1.2	.48	.29	.45	10.42	.52
4	49.3	512	53.4	.50	107.0	1.00	1.3	.52	2.6	1.04	.16	.81	6.54	.83
5	50.5	575	57.7	.54	123.3	1.15	1.5	.60	3.1	1.24	.15	.87	6.09	.89
6	24.4	574	66.6	.62	138.4	1.29	.8	.32	1.7	.68	.37	.35	15.40	.35
7	62.2	407	34.9	.33	104.5	.97	1.1	.44	3.3	1.32	.30	.43	9.71	.56
8	64.9	306	20.9	.19	62.7	.58	.7	.28	2.0	.80	.36	.36	11.07	.49
9	33.1	854	66.5	.62	200.5	1.87	1.1	.44	3.3	1.32	.34	.38	10.26	.53
10	33.9	364	35.3	.33	72.1	.67	.6	.24	1.2	.48	.27	.48	15.74	.34
11	51.1	243	22.1	.21	44.4	.41	.6	.24	1.1	.44	.37	.35	14.62	.37

FIGURE 4
Homes Served Per Crew Per
Collection Hour

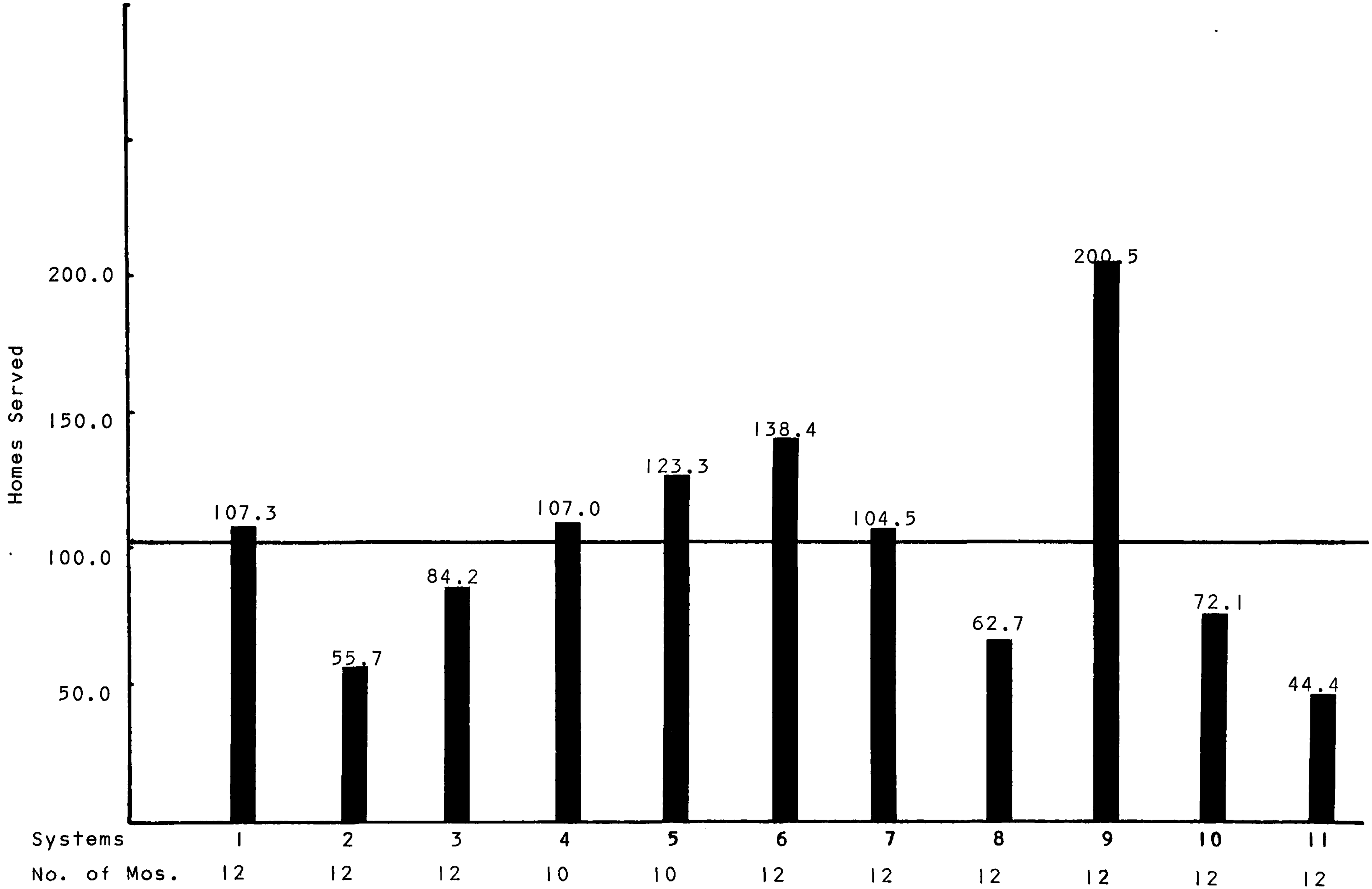


FIGURE 5
Homes Served Per Crewman
Per Collection Hour

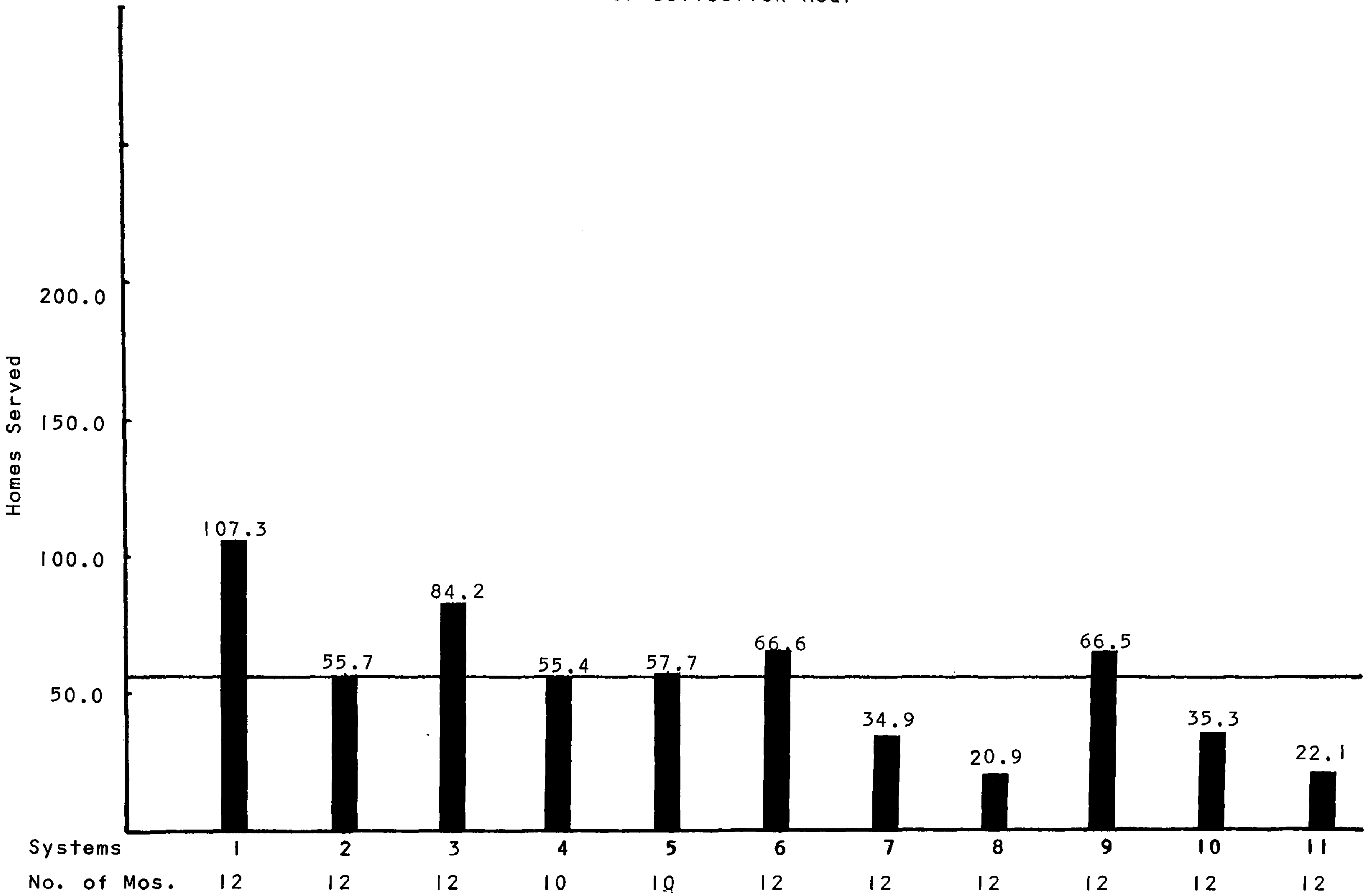


FIGURE 6.
Weight Handled Per Crew
Per Collection Hour

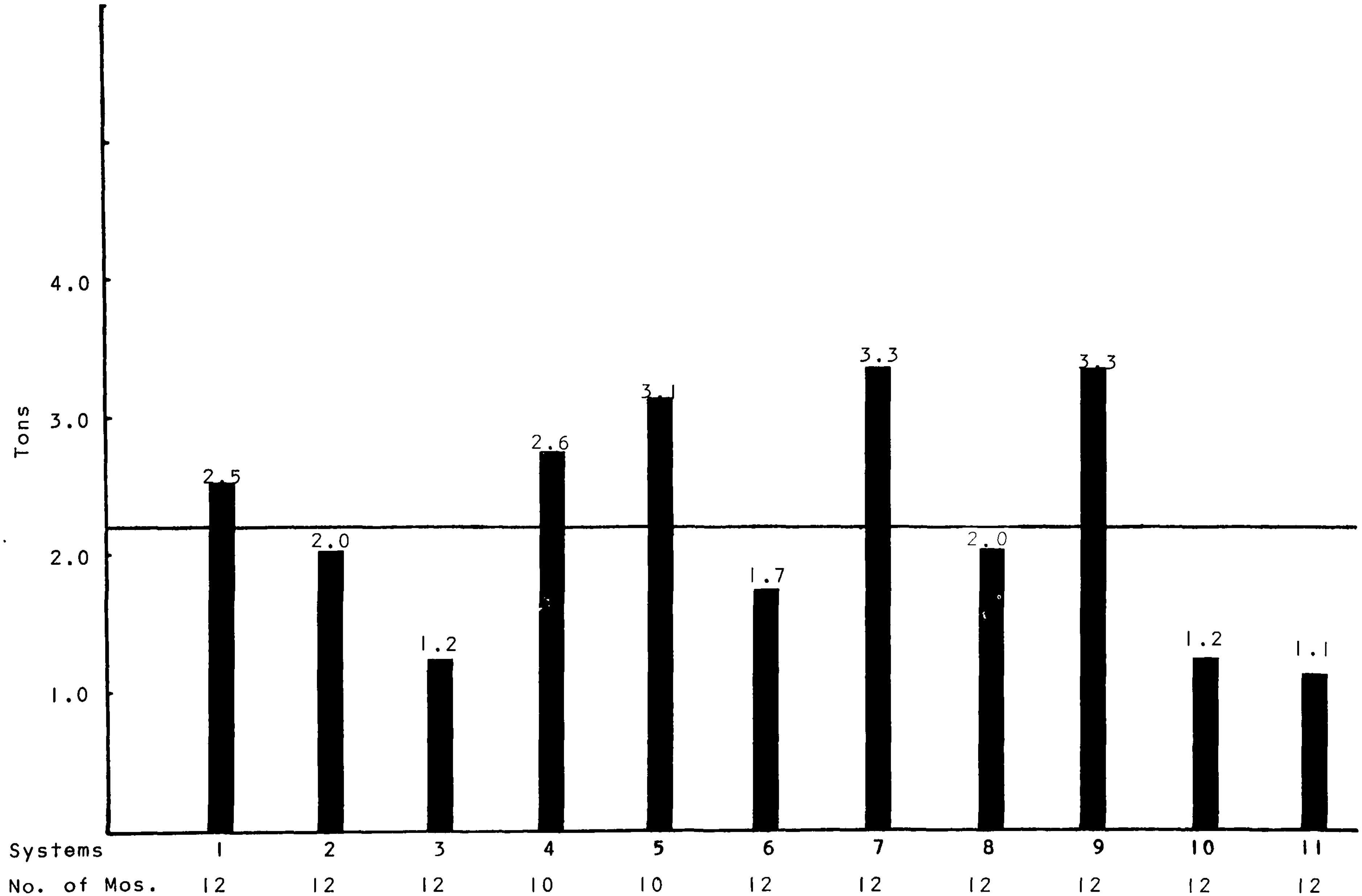


FIGURE 7
Weight Handled Per Crewman
Per Collection Hour

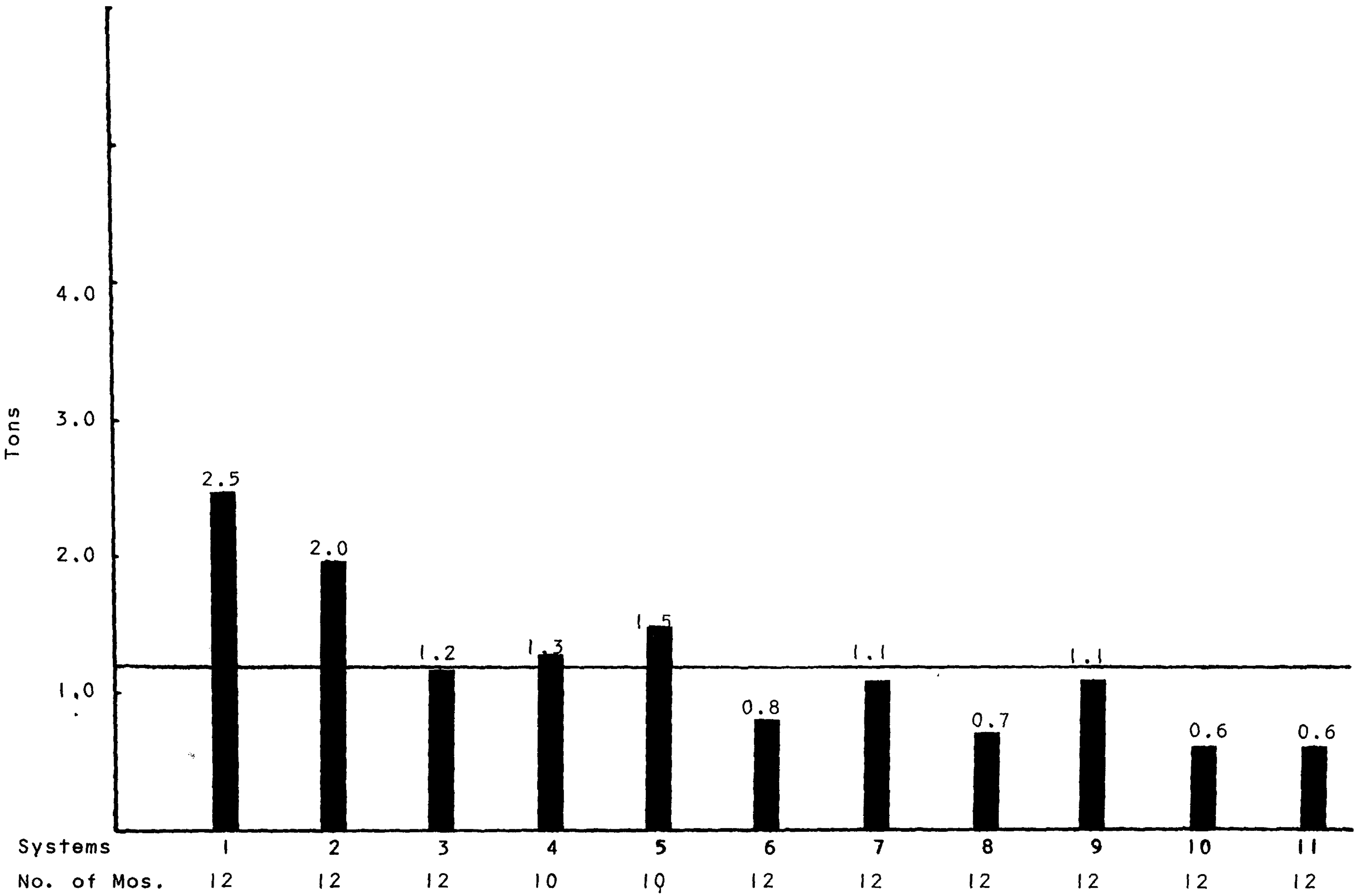


FIGURE 8
Collection Cost Per Home Served Per Week

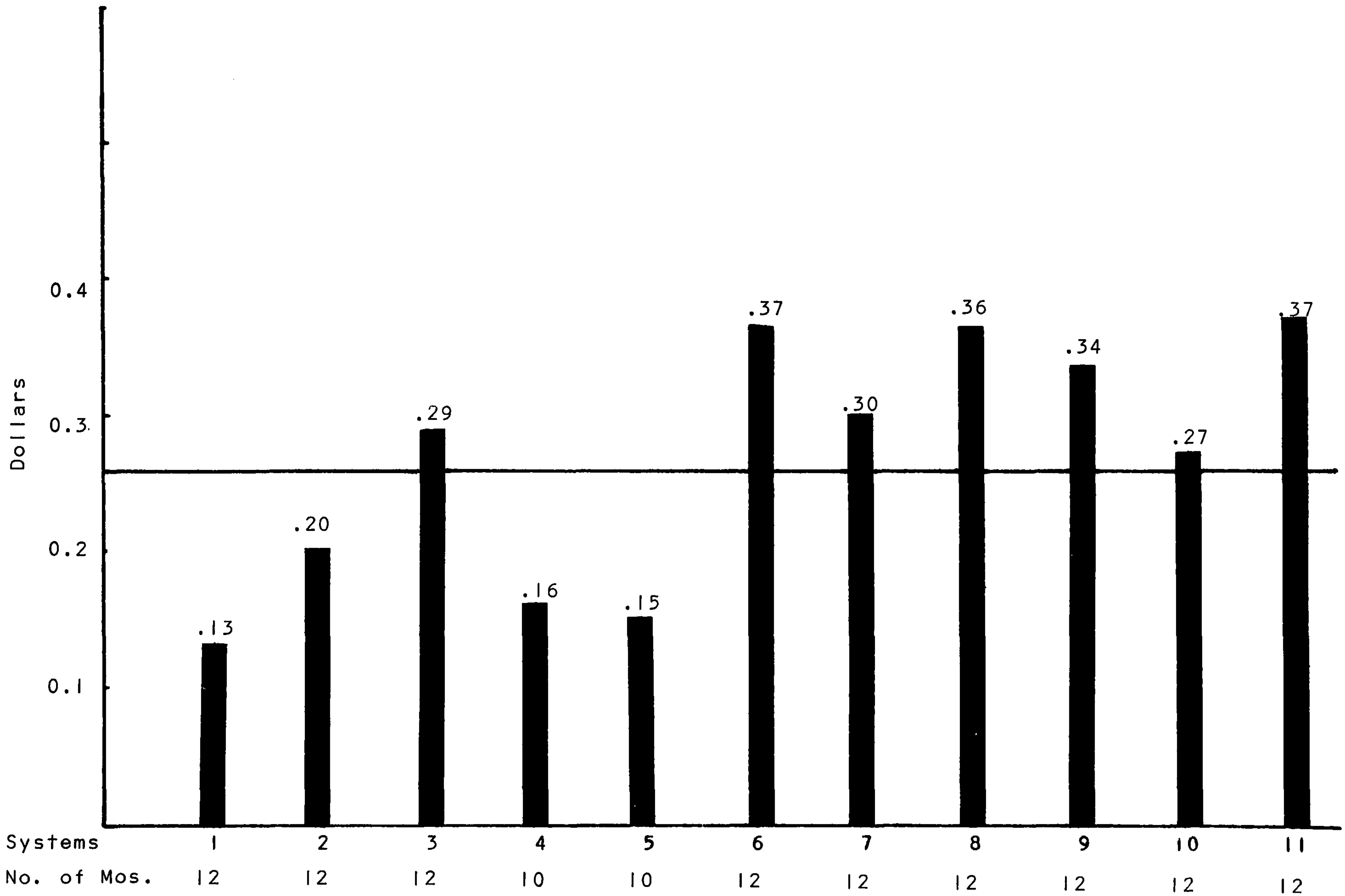
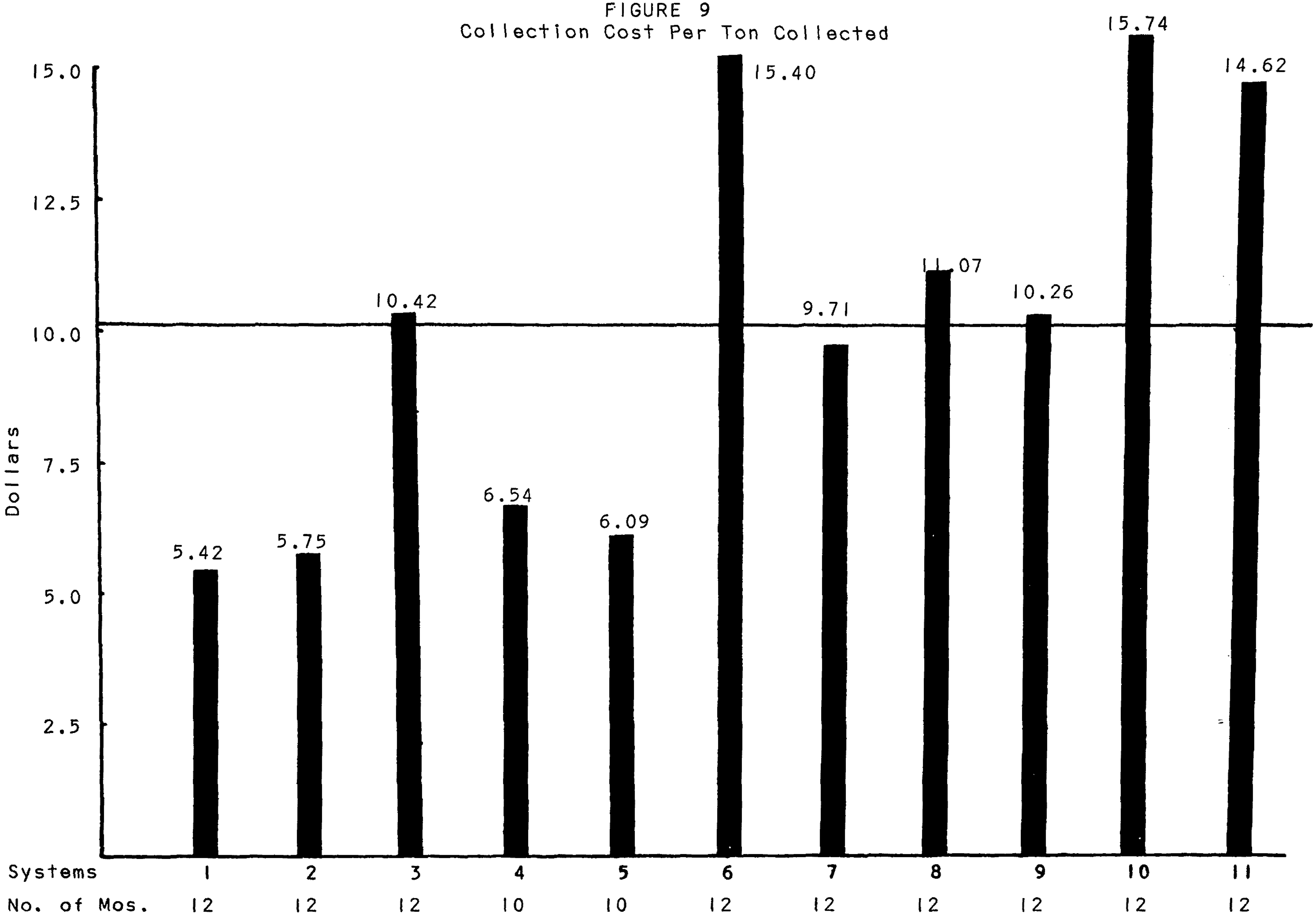


FIGURE 9
Collection Cost Per Ton Collected



be made of the individual parameters of Table 1, then an overall analysis of system productivity, efficiency, and costs will be made. All of the parameters under consideration are interrelated to some degree. It is impossible to isolate completely the independent effects of each factor being considered. General trends and significant conclusions, however, can be made from the analysis.

Performance Analysis by Type of Equipment

General. Systems 1, 2, and 3 used the side loading equipment (Figure 1). The vehicle may be loaded and driven from either side. The collection vehicle was designed to be operated by a one-man crew. The packer is designed to achieve densities in the range of 500 to 550 pounds per cubic yard. The packer can be operated by the main vehicle engine or by an auxiliary engine. The vehicle is available in four sizes: 25, 29, 33, and 37 cubic yards.

System 6 used the side loading vehicle of Figure 3. This vehicle used a detachable container of eight cubic yards. The full containers were emptied by a front loading mother truck. The collection vehicle may be loaded and driven from either side, and was designed to be operated by a one- or two-man crew. The vehicle is designed to achieve densities in the range of 500 to 600 pounds per cubic yard.

All other systems used the conventional rear loading equipment of Figure 2. The vehicle was designed to be operated with a crew of two or more. The rear loading equipment may be either medium duty or heavy duty from a compaction standpoint. The medium duty equipment is designed to achieve densities in the range of 700 to 750 pounds per cubic yard. The heavy duty equipment is designed to achieve densities in the range of 900 to 1,000 pounds per cubic yard. Rear loading equipment is available in many sizes, ranging generally from 10 to 25 cubic yards.

A summary of the significant equipment performance data obtained during the study is provided by Table 4. For the purposes of this study, the first loads were assumed to be "full" loads in terms of the operating performance of each system. Figure 10 shows graphically the relationship between the weight of the first loads and the weight of the other loads.

The information of Table 4 shows the difference between the equipment performance being achieved in actual practice and the minimum performance that can reasonably be expected from the equipment. While there were differences in the age of the equipment being used in this study, all of the equipment was sufficiently new to be able to achieve the minimum compaction densities established in the table.

Discussion. Many factors influence the selection of collection equipment. Some of these factors include the size of the crew, the number of homes to be served, the waste generation rates, the type of waste being collected, the time spent in collecting waste, the distance to the disposal point and relative costs of the equipment.

In considering compaction collection vehicles, the user has the choice of front loading, side loading, or rear loading equipment. The user can also select light duty, medium duty, or heavy duty compacting equipment. Within each of these categories, a wide range of sizes is available.

In selecting his equipment, the user should match the equipment specifications (size, type, and compacting performance) with the

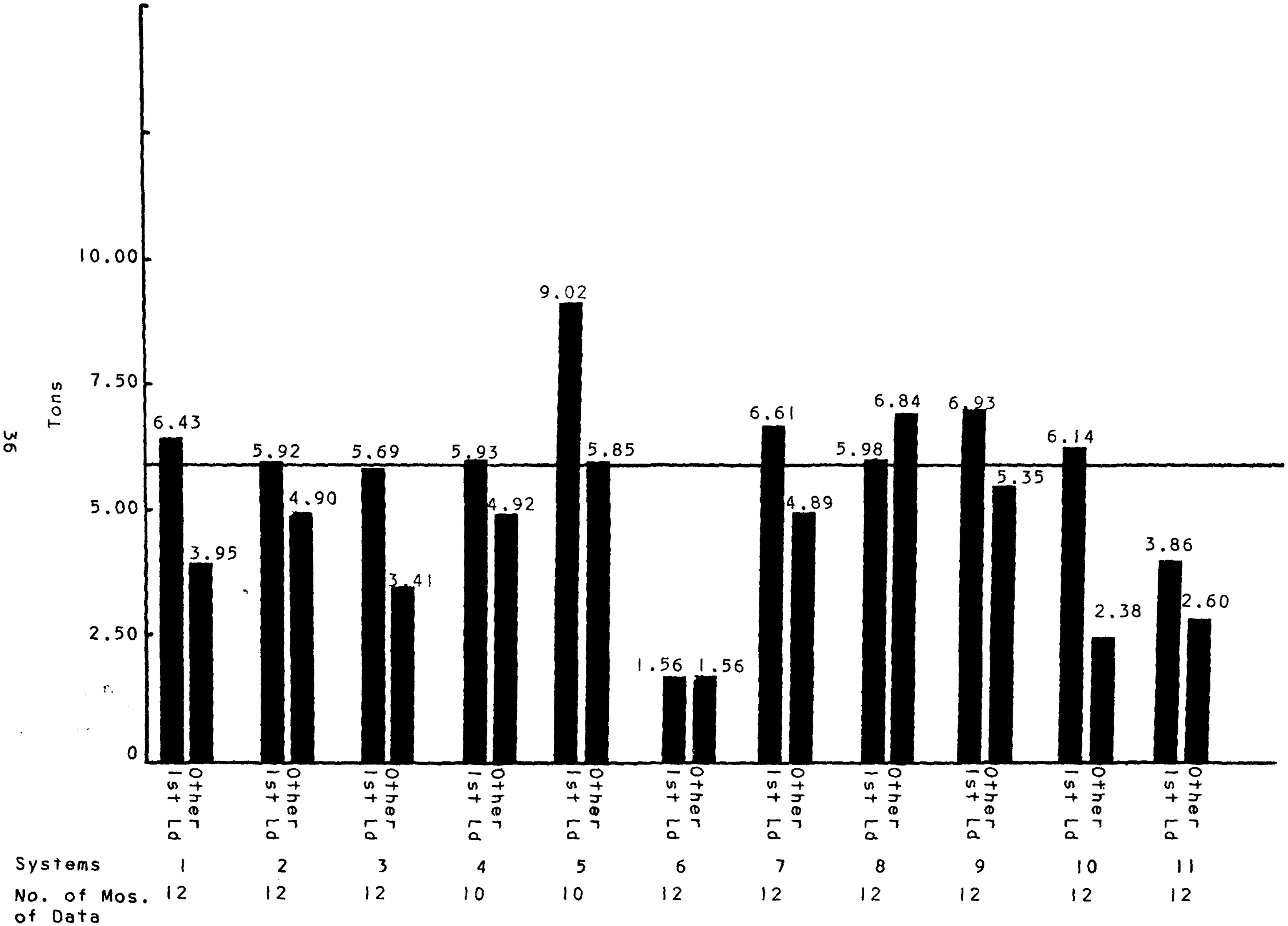
TABLE 4
EQUIPMENT PERFORMANCE DATA

STUDY RESULTS									EXPECTED RESULTS		
SYSTEM NUMBER	TYPE EQUIPMENT	AVERAGE SIZE (CU YD)	AVERAGE LOADS PER DAY	AVERAGE WEIGHT PER DAY (TONS)	AVERAGE WEIGHT FIRST LOAD (TONS)	AVERAGE WEIGHT ALL OTHERS (TONS)	RATIO ALL OTHERS TO FIRST LOAD	WEIGHT PER CUBIC YARD FIRST LOAD (POUNDS)	MINIMUM[1] EXPECTED WEIGHT PER CUBIC YARD (POUNDS)	MINIMUM[2] EXPECTED WEIGHT PER LOAD (TONS)	RATIO[3] FIRST LOAD TO MINIMUM EXPECTED WEIGHT PER LOAD
1	SL	25.0	1.8	9.44	6.43	3.95	0.61	515	500	6.25	1.03
2	SL	25.0	1.6	9.00	5.93	4.90	0.83	474	500	6.25	0.95
3	SL	33.0	1.0	5.73	5.69	3.41	0.60	345	500	8.25	0.69
4	RL	20.0	2.4	12.62	5.92	4.92	0.83	593	700	7.00	0.85
5	RL	24.2	1.9	14.49	9.02	5.85	0.65	744	900	10.89	0.83
6	DC	8.0	4.4	6.96	1.56	1.58	1.00	390	500	2.00	0.78
7	RL	20.0	2.2	12.65	6.61	4.89	0.74	662	700	7.00	0.94
8	RL	23.0	1.6	9.72	5.98	6.84	1.14	525	700	8.05	0.74
9	RL	20.0	2.3	14.10	6.93	5.35	0.77	693	700	7.00	0.99
10	RL	20.0	1.0	6.18	6.14	2.38	0.39	614	700	7.00	0.88
11	RL	15.0	1.9	6.18	3.86	2.60	0.67	522	700	5.25	0.74

NOTES:

1. Assumed densities based on expected performance by manufacturers of equipment.
   Normal densities for the side loading vehicle should range from 500 to 550 pounds per cubic yard.
   Normal densities for medium duty rear loading packing equipment should range from 700 to 750 pounds per cubic yard.
   Normal densities for the detachable container should range from 500 to 600 pounds per cubic yard.
   Normal densities for heavy duty rear loading packing equipment should range from 900 to 1,000 pounds per cubic yard.
2. Expected minimum load based on the minimum densities of Note 1 and average size (cubic yards) of the system vehicles.
3. Ratio of the system first load weight which is assumed to be a "full" load, and the minimum expected weight per load.

Figure 10
Average Weight Per Load
(1st load, others)



characteristics of his operation (crew size, weight to be collected, collection time and distance to the disposal point) such that full loads are collected, insofar as possible, and the number of loads is minimized. Full loads in this context means achieving the minimum compaction density for the class of equipment being used or considered. Collecting full loads minimizes the proportion of time being spent in the collection phase of the operation by minimizing the transport time and number of loads and provides maximum cost effectiveness in the utilization of the collection equipment.

The decision to select a specific kind and size of collection equipment should not be taken lightly by the solid waste collection manager. The most important reasons are that equipment impacts on labor productivity, and the equipment selected represents a considerable capital investment that will be used for several years. During the period of use, there is little that can be done to change a bad decision because in most cases the equipment is used until it is worn out. This period is generally from five to ten years. Since most packers tend to be competitive in cost, price should not be a primary consideration in selecting equipment.

Two general methods can be used to determine the size of vehicle that is required for the collection operations. The best method is to match the equipment specifications with the expected operational performance. In this case, the kind and size of vehicle is determined from a rational analysis of the factors that effect the collection activities. The significant factors would include crew size, the annual generation rates, the time available for collecting, and the performance standards expected from the crews. With this information, the trade-offs between the kinds of vehicles and then sizes can be analyzed to provide the most cost-effective solution for the operation.

An alternate method is deciding on a general purpose vehicle, such as medium duty packer of 20 cubic yards, and then designing the route around this vehicle. This is the method that is probably used most often; however, with this method there tends to be a significant imbalance between the capabilities of the vehicle and the characteristics of the route and capability of the crews. This leads to the underutilization of vehicles that is indicated in Table 4.

The difference between the minimum compaction density and maximum compaction density constitutes a reserve that can be used to handle peak generation rates or to permit growth in the route structure. This reserve is of the nature of 50 pounds per cubic yard for the light and medium duty equipment and 100 pounds per cubic yard for heavy duty equipment.

In only one system the weight of the subsequent loads exceeded the weight of the first load. This condition indicates the time at which collection ends for the first load is being dictated by considerations other than having a full load. Even though the subsequent loads were heavier than the first loads, they were still significantly less (0.85) than the minimum expected weight for a full load.

Conclusions. The following conclusions resulted from a consideration of the equipment used in the study.

There is a strong tendency to underutilize the equipment from a compaction standpoint. Only one system out of eleven routinely achieved a reasonable minimum first load weight for "full" loads for the equipment being used.

Two systems out of eleven averaged only one load per day, and both of these underutilized their equipment capacities. All other systems averaged more than one load per day.

In two systems the subsequent loads were equal to or greater than the first or "full" loads. In all cases, the weight of the subsequent loads was significantly less than the minimum weight expected for "full" loads. This indicates the equipment was underutilized for subsequent loads. This procedure results in relatively more time being spent in transporting and relatively less time being spent in collecting than there should be in a system in which the vehicle characteristics are matched with the route and crew characteristics.

Performance Analysis by Crew Size

General. In this analysis only the curb and alley systems were considered. Both backyard systems used a crew of two men. The curb and alley systems used crew sizes of one, two, and three men. While there were significant differences in the operation of the nine curb and alley systems, the analytical approach provides a general indication of what can be expected from crews of various sizes. Data were examined from the standpoint of the whole crew and also from the standpoint of the individual crewman.

A summary of the significant crew and crewman performance data for curb and alley systems is provided by Table 5. This table shows the productivity of the various systems in terms of homes served and tons collected.

A summary of crew productive time for curb and alley systems is provided by Table 6.

The marginal productivity of the crews and individual crewmen for curb and alley systems is provided by Table 7. In the first

TABLE 5

CREW PERFORMANCE DATA (CURB AND ALLEY SYSTEMS)

CREW DATA						CREWMAN DATA			
SYSTEM NUMBER	CREW SIZE	HOMES SERVED PER CREW PER DAY	HOMES SERVED PER CREW PER COLLECTION HOUR*	TONS COLLECTED PER CREW PER DAY	TONS COLLECTED PER CREW PER COLLECTION HOUR	HOMES SERVED PER CREWMAN PER COLLECTION HOUR	INDEX	TONS COLLECTED PER CREWMAN PER COLLECTION HOUR	INDEX
SYSTEMS COLLECTING ONCE WEEKLY									
1	1	410	107.3	9.44	2.5	107.3	1.00	2.5	1.00
2	1	254	55.7	9.00	2.0	55.7	0.52	2.0	0.80
4	2	512	107.0	12.62	2.6	53.4	0.50	1.3	0.52
5	2	575	123.3	14.49	3.1	57.7	0.54	1.5	0.60
7	3	407	104.5	12.65	3.3	34.9	0.33	1.1	0.44
8	3	306	62.7	9.72	2.0	20.9	0.19	0.7	0.28
SYSTEMS COLLECTING TWICE WEEKLY									
3	1	410	84.2	5.73	1.2	84.2	0.78	1.2	0.48
6	2	574	138.4	6.96	1.7	66.6	0.62	0.8	0.32
9	3	854	200.5	14.10	3.3	66.5	0.62	1.1	0.44

*Collection hour = on-route time

TABLE 6

CREW PRODUCTIVE TIME (CURB AND ALLEY SYSTEMS)

System Number	Crew Size	ON-ROUTE ACTIVITIES				TOTAL ACTIVITIES		
		Relative Time On Route	Relative Productive Time	Percent Productive Time	Percent Non-Productive Time	Relative Total Time	Percent Productive Time	Percent Non-Productive Time
1	1	65.2	63.7	97.6	2.4	100.0	98.5	1.5
2	1	67.8	65.0	95.8	4.2	100.0	97.2	2.8
3	1	77.4	75.0	96.8	3.2	100.0	97.6	2.4
4	2	68.5	47.3	69.0	31.0	100.0	63.0	37.0
5	2	69.8	43.2	61.8	38.2	100.0	58.3	41.7
6	2	72.8	55.9	76.7	23.3	100.0	69.5	30.5
7	3	75.8	53.3	70.3	29.7	100.0	61.3	38.7
8	3	64.6	46.9	72.6	27.4	100.0	58.7	41.3
9	3	70.0	51.0	72.8	27.2	100.0	61.0	39.0

TABLE 7

MARGINAL PRODUCTIVITY (CURB AND ALLEY SYSTEMS)

CREW SIZE	HOMES PER CREW PER HOUR	MARGINAL INCREASE IN PRODUCTIVITY HOMES PER CREW PER HOUR	TONS PER CREW PER HOUR	MARGINAL INCREASE IN PRODUCTIVITY TONS PER CREW PER HOUR	HOMES PER CREWMAN PER HOUR	MARGINAL DECREASE IN PRODUCTIVITY HOMES PER CREWMAN PER HOUR	TONS PER CREWMAN PER HOUR	MARGINAL DECREASE IN PRODUCTIVITY TONS PER CREWMAN PER HOUR
				AVERAGE OF ALL SYSTEMS				
1 man	82.4	-----	1.9	---	82.4	----	1.9	---
2 man	122.9	40.5	2.5	0.6	59.9	22.5	1.2	0.7
3 man	122.6	(0.3)	2.9	0.4	40.8	19.1	1.0	0.2
				AVERAGE OF ALL SYSTEMS COLLECTING ONLY ONCE A WEEK				
1 man	81.5	------	2.3	-----	81.5	----	2.3	---
2 man	115.2	33.7	2.9	0.6	56.6	24.9	1.4	0.9
3 man	83.6	(31.6)	2.7	(0.2)	27.9	28.7	0.9	0.5
				AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK				
1 man	84.2	----	1.2	---	84.2	----	1.2	-----
2 man	138.4	54.2	1.7	0.5	66.6	17.6	0.8	0.4
3 man	200.5	62.1	3.3	1.6	66.5	0.1	1.1	(0.3)
				MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS				
1 man	107.3	----	2.5	---	107.3	----	2.5	---
2 man	138.4	31.1	3.1	0.6	66.6	40.7	1.5	1.0
3 man	200.5	62.1	3.3	0.2	66.5	0.1	1.1	0.4

section of the table, system averages by size of crew are indicated. Each number for each crew size represents eight once-a-week and four twice-a-week crews. In the second portion, information for those systems that collect once weekly was averaged by size of crew. In the third section, information for those systems that collect twice weekly is provided. In the last section, the best single parameter for each crew size was used, regardless of the frequency of collection.

Ranges of crew and crewman productivity are provided by Table 8.

Discussion. Many factors influence the productivity of the collection crews and crewmen. Some of these factors include the point of collection, frequency of collection, routing, housing density, traffic and parked cars, collection methodology, width of the street, type of equipment being used, the expected work effort in the normal work day, the waste generation rates, the type of waste being collected, the nature of the storage container, general climate conditions, the kind of incentive system and the motivational aspects of the collection organization to include the relative pay scales. No attempt was made during this study to isolate the effect of the individual factors that influence the crew productivity.

While there is considerable knowledge on the motivational aspects of many kinds of workers, there is very little information in the literature concerning the solid waste collector. this study shows that the one-man crew is significantly more productive than his counterpart in multi-man crews. One can speculate, based on motivational studies that have been conducted with other workers, that this is related to the degree of control the one-man crew exercises over his task. He has control over his time

TABLE 8

RANGES OF CREW AND CREWMAN PRODUCTIVITY (CURB AND ALLEY SYSTEMS)

SYSTEM NUMBER	CREW PRODUCTIVITY				CREWMAN PRODUCTIVITY			
	HOMES PER COLLECTION HOUR*		TONS PER COLLECTION HOUR*		HOMES PER COLLECTION HOUR*		TONS PER COLLECTION HOUR	
	RANGE	AVERAGE	RANGE	AVERAGE	RANGE	AVERAGE	RANGE	AVERAGE
1	92-124	107	1.9-3.2	2.5	92-124	107	1.9-3.2	2.5
2	50-68	55	1.7-2.3	2.0	50-68	55	1.7-2.3	2.0
3	77-92	84	1.1-1.3	1.2	77-92	84	1.1-1.3	1.2
4	94-135	107	2.1-3.1	2.6	47-67	53	1.1-1.6	1.3
5	110-165	123	2.7-3.8	3.1	45-78	57	1.2-1.9	1.5
6	130-159	138	1.5-1.9	1.7	62-79	66	0.8-1.0	0.8
7	87-125	104	3.0-4.0	3.3	29-41	34	1.0-1.3	1.1
8	58-66	62	1.5-2.3	2.0	19-22	20	0.5-0.7	0.7
9	179-226	200	3.1-3.5	3.3	58-74	66	1.0-1.2	1.1

* Collection = On-Route

and physical movement. He establishes the pace at which he chooses to work. He is not dependent upon the activities of other crew members. He also has complete control over his technical environment. He is generally freer from close direct supervision. These control aspects may give the one-man crews greater job satisfaction, and hence, result in greater productivity. In addition, the one-man crews generally receive more pay than members of larger crew sizes. This situation also probably contributes to the greater productivity of one-man crews.

The time motion data indicate that the one-man crews spend a significantly greater proportion of the on-route time in productive activities in comparison with the two- and three-man crews. The average on-route percentage of productive time for the one-man crews was 96.7 percent. The non-productive time was about equally divided between waiting and other time. The two- and three-man crews show a significant decrease in the proportion of productive time on-route. This percentage averaged 69.2 for the two-man crews and 71.9 for the three-man crews. The non-productive time with the two- and three-man crews was associated primarily with waiting. In these cases, one crew member is waiting on another crew member or the crew members are waiting on the compaction cycle.

The study addressed only the productive and non-productive times associated with the collection or on-route phase of the operations. For the two- and three-man crews there was also a significant amount of non-productive time associated with the going to the route and transport phases of the operation. This non-productiv effort is included under the total activities columns of Table 5. These columns indicate that the percentage of productive time for the total activities of the day averaged 63.6 for the two-man crews and 60.3 for the three-man crews. These figures include the non-productive time associated with going to the route and transporting waste. Table 2 indicates that approximately 30 percent of the time for the curb and alley systems is spent in going to the route and in transporting waste. The one-man crews are completely effective in these phases. With the two-man crews, one man is non-productive. Therefore, one-half of the man-hours spent in these phases is non-productive. For the three-man crew, two men are non-productive, and two-thirds of the man-hours spent in these phases is wasted effort.

Table 7 indicates there is a considerable range in the productivity factors for each system, both in terms of the crew performance and the crewman performance. Much of this variability is undoubtedly associated with the crew members pacing themselves to get the work done in a reasonable time. A review of the monthly DAAP data indicates that in periods of high generation, the rate at which the weight is collected increases. Likewise, in periods of low generation, the rate at which homes are served increases.

Conclusions. The following conclusions resulted from a consideration of the crew sizes that were studied.

The productivity per crewman in terms of homes served and tons collected per collection hour is greatest with the one-man crews. On the average, the productivity of one two-man crew is less than the productivity of two one-man crews. Likewise, the productivity of one three-man crew is less than the productivity of three one-man crews.

The percentage of on route productive collection time for one-man crews is significantly greater than the percentage of productive time for two- and three-man crews. For one-man crews, the on-route productive time is approximately 70 percent. There is no significant difference in the percentage of productive time between the two- and three-man crews.

In going to the route and in transporting the collected waste only the driver is productive. All other crewmen, whether they ride with the driver or not, are non-productive in these operational phases. With this transport phase consuming approximately 30 percent of the work day, then one-half and two-thirds of the man-hours of this effort are wasted for two- and three-man crews, respectively.

Performance Analysis by Frequency of Collection

General. In this analysis only the curb and alley systems were considered. Both backyard systems collected on a frequency of once a week. Six of the curb and alley systems collected once a week and three of the systems collected twice a week. Of the six curb and alley systems that collected once a week, two systems utilized a crew of one man, two utilized a crew of two men, and two utilized a crew of three men. The three systems that collected twice a week consisted of one system with each crew size. A summary of the significant performance data by frequency of collection is provided by Table 9.

Discussion. The collection frequency adopted by a governmental agency may be dictated by several factors. Probably the most important factor is associated with the amount of waste compared to storage space available. Also important are the general climates and health conditions in the area, and the level of service desired by the citizens and for which they are willing to pay. Collection

TABLE 9

FREQUENCY OF COLLECTION DATA

SYSTEM NUMBER	POUNDS PER HOME PER COLLECTION	POUNDS PER HOME PER WEEK	HOMES SERVED PER WEEK	HOMES SERVED PER COLLECTION HOUR	COLLECTION COST PER HOME PER COLLECTION	COLLECTION COST PER HOME PER WEEK	TONS COLLECTED PER COLLECTION HOUR	COLLECTION COST PER TON
COLLECTION ONCE A WEEK								
1	46.2	46.2	2,052	107.3	0.13	0.13	2.5	5.42
2	71.0	71.0	1,268	55.7	0.20	0.20	2.0	5.75
4	49.3	49.3	2,561	107.0	0.16	0.16	2.6	6.54
5	50.5	50.5	2,876	123.3	0.15	0.15	3.1	6.09
7	62.2	62.2	2,034	104.5	0.30	0.30	3.3	9.71
8	64.9	64.9	1,531	62.7	0.36	0.36	2.0	11.07
Averages	57.4	57.4	2,053	93.4	0.22	0.22	2.6	7.43
COLLECTION TWICE A WEEK								
3	28.2	56.3	1,231	84.2	0.15	0.29	1.2	10.42
6	24.4	48.8	1,147	138.4	0.19	0.37	1.7	15.40
9	33.1	66.1	1,707	200.5	0.17	0.34	3.3	10.26
Averages	28.6	57.1	1,361	141.0	0.17	0.33	2.1	12.02

twice a week is a higher level of service than collection once a week. In comparison with service once a week, collection twice a week requires additional resources in terms of crews and equipment.

Twice-a-week collection has a greater impact on the number of homes served per collection hour than on the tons collected per collection hour when compared with the same productivity factors for the once-a-week collection. This is undoubtedly related to the lesser weight collected per home each collection day and a correspondingly smaller number of containers present at each home.

Conclusions. The following conclusions resulted from a consideration of the frequencies of collection that were studied.

Increasing the frequency of collection from once a week to twice a week required approximately 50 percent more crews and equipment than the once-a-week systems. The average number of homes served per week for the twice-a-week collection systems was approximately two-thirds the number for once-a-week collection systems. Conversely, to decrease the frequency of collection from twice a week to once a week requires approximately 33 percent fewer crews and equipment than the twice-a-week systems.

In terms of productivity factors, the twice-a-week collection systems served approximately 50 percent more homes per collection hour than the once-a-week collection systems. The weight collected per collection hour, however, was only 80 percent of the weight collected per collection hour by the once-a-week collection systems.

Performance Analysis by Storage Point

General. Two storage point locations were prescribed for the study effort. These were curb and alley and backyard. No distinction was made between the curb and alley for study purposes. Of the systems studied, only System 8 was basically an alley system. Systems 10 and 11 were backyard systems. All other systems were curb and alley systems with collection being made predominantly from the curb.

For the purposes of this analysis, only the two-man crews were considered. A summary of the significant performance data considered by storage point is provided by Table 10.

Discussion. Backyard collection is a higher level of service than curb and alley collection. This kind of service causes the least impact on the physical requirements of the citizens regarding the removal of solid waste. This level of service is also the most expensive as additional personnel and equipment resources are required in comparison with curb and alley systems for the same number of homes served per week.

Conclusions. The following conclusion resulted from a consideration of the storage point locations that were studied.

The productivity of a backyard system, in terms of homes served per collection hour and tons collected per collection hour, is approximately one-half the productivity of a corresponding curb and alley system.

Collection Methodology

Three collection methodologies were prescribed for the study effort depending on crew size and point of collection. They were: collection from one side of the street at a time for curbside collection, one and two-man crews (Systems 1-6); collection from both sides of the street at a time for curbside collection, three-man crews (Systems 7-9); and use of the tote-barrel for backyard collection (Systems 10 and 11).

TABLE 10

STORAGE POINT DATA

SYSTEM NUMBER	COLLECTION FREQUENCY	WEIGHT PER HOME PER COLLECTION (POUNDS)	COLLECTION TIME PER HOME PER COLLECTION (MIN)	SERVICES PER CREW PER COLLECTION HOUR	WEIGHT COLLECTED PER CREW PER COLLECTION HOUR
CURB AND ALLEY SYSTEMS - 2 MAN CREW					
4	1	49.3	0.56	107.0	2.6
5	1	50.5	0.49	123.3	3.1
6	2	24.4	0.44	138.4	1.7
BACKYARD SYSTEMS - 2 MAN CREW					
10	1	33.9	0.83	72.1	1.2
11	1	51.1	1.36	44.4	1.1

Both backyard systems used two-man crews. In each case, both the driver and collector drove and collected. Both sides of the street were collected at the same time.

These methodologies were selected because they had been shown to be very productive and efficient in previous EPA studies. For curbside collection, it is generally impractical to collect from both sides of the street with one- and two-man crews.

With the three-man systems, there is a practical choice between collecting from one side and collecting from both sides of the street at a time. Factors which influence this decision are the width of street, traffic flow, parked cars, and housing density. With wide streets, heavy traffic and high density housing, it is generally safer and best to collect from one side of the street at a time to avoid traffic and street crossing delays. However, with narrow streets and little traffic, there is greater potential for waiting delays on the part of the crewmen in collecting only one side at a time.

Performance Analysis by Incentive System

General. Two incentive systems were investigated in the study effort. They were the task incentive system and the standard day system.

The task incentive system was used by seven of the eleven systems in the study.

The task incentive system is one in which a work effort is prescribed for the crew. When this work effort is completed, to the satisfaction of the appropriate supervisor, the crew is dismissed (unless another crew is unable to cover its route because of absenteeism or equipment failure). With the task incentive system compensation is not generally paid to the crew for overtime work unless the reason for overtime was clearly not the fault of the crew. For the purposes of this study, overtime was not considered for the systems which operated under the task incentive system.

The standard day system is one in which a work effort is usually prescribed for the crew, but regardless of how early the task is completed, the crew is required to work the full standard day. The standard day for the four systems in this study was eight hours. Thus, the crews were obligated to perform additional work if they completed the collection effort in less than the standard day. In addition, compensation at the rate of 1.5 times the regular pay was made for all overtime worked in this study.

In the scheme of systems studies in this effort, there was one task incentive system and one standard day system for each crew size in the curb and alley once-a-week systems. One of the backyard systems used the task incentive system and the other used the standard day system. A summary of the significant incentive system performance data for the different collection systems is provided by Tables 11 and 12.

Discussion. An exact proportion of systems that use the Task Incentive system in comparison with the standard day system is not available. It is generally believed that somewhat more than one-half of the systems are operating under the task incentive system.

The application of the standard day system takes many forms in actual practice. This ranges from a fully productive application such as is indicated by System 5 to a deliberate expansion of the work effort to consume the entire work day or to a diversion of personnel to other efforts after the collection activities have been completed.

TABLE 11

INCENTIVE SYSTEM PERFORMANCE DATA - COMPARISONS BY INCENTIVE SYSTEMS

SYSTEM NUMBER	INCENTIVE SYSTEM	PLANNED WORK WEEK (HOURS)	HOURS WORKED PER WEEK	PERCENT OF WEEK WORKED	TOTAL ANNUAL OVERTIME COST PER CREW	DAAP COLLECTION TIME PER HOME (MIN)	TIME MOTION PRODUCTIVE TIME PER HOME (MIN)	DAAP TIME PER HOME TO TIME MOTION PRODUCTIVE TIME PER HOME
			CURB AND ALLEY - COLLECTION ONCE WEEKLY - 1 MAN CREW					
1	Task	40	29.62	74.1	--------	0.56	0.58	0.97
2	Standard Day	40	33.74	84.4	107.81	1.08	0.83	1.30
			CURB AND ALLEY - COLLECTION ONCE WEEKLY - 2 MAN CREW					
4	Task	40	35.64	89.1	--------	0.56	0.43	1.30
5	Standard Day	40	35.17	87.9	1,492.12	0.49	0.35	1.40
			CURB AND ALLEY - COLLECTION ONCE WEEKLY - 3 MAN CREW					
7	Task	40	26.03	65.1	--------	0.58	0.53	1.09
8	Standard Day	40	39.22	98.1	2,804.32	0.98	0.72	1.36
			BACKYARD - COLLECTION ONCE WEEKLY - 2 MAN CREW					
10	Task	40	31.32	78.3	--------	0.83	----	----
11	Standard Day	40	34.75	86.9	62.85	1.36	----	----
Averages	Task	40	30.65	76.6	--------	0.63	0.51	1.12
	Standard Day	40	35.72	89.3	1,116.78	0.98	0.63	1.35

TABLE 12

INCENTIVE SYSTEM PERFORMANCE DATA - COMPARISONS BY PRODUCTIVITY MEASURES

SYSTEM NUMBER	INCENTIVE SYSTEM	HOMES SERVED PER DAY	TONS COLLECTED PER DAY	HOMES SERVED PER CREW PER COLLECTION HOUR	TONS COLLECTED PER CREW PER COLLECTION HOUR
		CURB AND ALLEY - COLLECTION ONCE WEEKLY - 1 MAN CREW			
1	Task	410	9.44	107.3	2.5
2	Standard Day	254	9.00	55.7	2.0
		CURB AND ALLEY - COLLECTION ONCE WEEKLY - 2 MAN CREW			
4	Task	512	12.62	107.0	2.6
5	Standard Day	575	14.49	123.3	3.1
		CURB AND ALLEY - COLLECTION ONCE WEEKLY - 3 MAN CREW			
7	Task	407	12.65	104.5	3.3
8	Standard Day	306	9.72	62.7	2.0
		BACKYARD - COLLECTION ONCE WEEKLY - 2 MAN CREW			
10	Task	364	6.18	72.1	1.2
11	Standard Day	243	6.18	44.4	1.1
Averages	Task	423	10.22	97.7	2.4
	Standard Day	344	9.85	71.5	2.0

It is generally acknowledged that the task incentive system is more productive in practice than the standard day system. Indeed, the results of this study indicate this in three direct comparisons of systems out of four. When the results of all of the task incentive systems are averaged and compared with the standard day systems, this is clearly the case in this study.

The task incentive system, however, is a good system only if the work effort which is expected to be accomplished in a normal work day bears some reasonable relationship to what should be accomplished in the normal work day. The data of Table 11 indicates that the portion of the normal work week that was spent on collection activities (to route, collection, and transport) for the task incentive systems ranged from a low of 65.1 percent to a high of 89.1 percent. The average of these systems was approximately 76.6 percent. Each individual manager will have to appraise his own situation and decide what objective figure would be right for his organization. In most of the task incentive systems studied in this effort, an additional planned one-half hour per day would have resulted in better utilization of the equipment and greater cost effectiveness in the operation, even if a fair percentage of the savings were returned to the crews in the form of higher wages.

In considering the productivity of the standard day systems, there is a tendency for the task to expand to fill the day, and if not controlled, to go into overtime. Even with System 5, which was the one standard day system that out-performed the task incentive system, the DAAP collection time per home (actual time) was 1.40 times the time motion productive time (actual time minus non-productive time) per home. This was the highest ratio among the standard day systems. Consequently, other factors must account for the high productivity of System 5. The high percentage of bags and one-way items undoubtedly has a favorable influence on this performance. The significance of the percentage of one-way items will be discussed in the next section.

In the case of systems using a one-man crew, it would appear that the standard day system would be counter productive. If the higher productivity that is indicated by the one-man systems can be explained by current motivational concepts, then productivity must be associated with the high degree of control the crewman has over his work. In this context, it makes little sense to give the crewman this control so he can establish his work pace and, at the same time, require him to work a full standard day. The task incentive system should be used with all operations involving a crew of one man.

In general, it appears that the majority of the task incentive systems have a higher level of collection production and productivity than the standard day systems. This is true in an absolute sense, but, more importantly, the task incentive systems appear to be doing the work more efficiently. Stating this differently, the task incentive systems tend to do more work and do it more efficiently than the standard day systems.

Conclusions. The following conclusions resulted from a consideration of the incentive system data that were studies.

Collection systems operating under the task incentive system tend to work a smaller percentage of the normal work week than the standard day systems.

The work effort of standard day collection systems has a tendency to expand into overtime operations.

The collection production and productivity of the task incentive systems tend to be greater than the collection production and productivity of standard day systems.

Performance Analysis by Type of Storage Container

General. Bags and cans were prescribed as the storage containers for all of the systems that were studied. The relative quantities of bags, cans and miscellaneous items were determined from the time motion studies and backyard survey.

Miscellaneous items are considered to be one-way items from a collection standpoint and are considered in the same category as bags. Miscellaneous items include things such as cardboard boxes of waste, bundles of paper, and bundles of small twigs and branches. One-way items need to be handled only once on the part of the collectors, and hence, should have a tendency to improve the productivity of the crews. On the other hand, poorly contained waste tends to slow the crews down.

A summary of the significant data pertaining to storage containers is provided by Table 13.

Discussion. System 10 averaged only 1.2 containers per service. This was the smallest average among the systems. In addition, 96 percent of the containers were cans. This was also the highest percentage of cans. System 10 required all items to be placed in cans and charged for service on the basis of the number of cans served. These requirements tended to limit the number of bags and miscellaneous items that were used in service. They also tended to limit the number of cans that residents used as storage containers.

System 7 averaged 6.1 containers per service. This was the

TABLE 13

STORAGE CONTAINER DATA

SYSTEM NUMBER	AVERAGE NUMBER OF CONTAINERS PER COLLECTION	AVERAGE NUMBER (AND PERCENT) OF STORAGE CONTAINERS			PERCENT		HOMES SERVED PER COLLECTION HOUR	DAAP COLLECTION TIME PER HOME (MIN)
		BAGS	CANS	MISC	ONE WAY ITEMS	TWO WAY ITEMS		
			CURB AND ALLEY SYSTEMS - BAGS AND CANS					
1	4.5	1.5 (34.0)	2.3 (52.0)	0.7 (14.0)	48.0	52.0	107.3	0.56
2	5.1	1.3 (26.0)	2.7 (53.0)	1.1 (21.0)	47.0	53.0	55.7	1.08
3	3.0	0.9 (29.0)	1.6 (53.0)	0.5 (18.0)	47.0	53.0	84.2	0.72
4	4.6	2.6 (56.0)	1.3 (28.0)	0.7 (16.0)	72.0	28.0	107.0	0.56
5	5.5	4.6 (85.0)	0.4 (6.0)	0.5 (9.0)	94.0	6.0	123.3	0.49
6	2.5	0.5 (19.0)	1.5 (61.0)	0.5 (20.0)	39.0	61.0	138.4	0.44
7	6.1	3.6 (56.0)	1.5 (28.0)	1.0 (16.0)	72.0	28.0	104.5	0.58
8	5.9	1.5 (25.0)	2.7 (47.0)	1.7 (28.0)	53.0	47.0	62.7	0.98
9	2.7	1.2 (46.0)	1.1 (41.0)	0.4 (13.0)	59.0	41.0	200.5	0.31
			BACKYARD SYSTEMS - TOTE-BARREL					
10	1.2	0.0 (2.0)	1.2 (96.0)	0.0 (2.0)	4.0	96.0	72.1	0.83
11	4.3	1.4 (33.0)	2.4 (55.0)	0.5 (12.0)	45.0	55.0	44.4	1.36

largest average among the systems. A little over one-half of the containers were bags, but 72 percent of the containers were one-way items. This was the second highest percentage of one-way items.

System 5 had the highest percent of one-way items. Ninety-four percent of the items were one-way items, and 85 percent of the items were bags. The ordinance under which System 5 operated tended to generate a high percentage of bags even though these were provided by the residents. Cans were limited to 15 gallons capacity. Bags were limited to 30 gallons capacity. Although there was no limit on the number of items that could be placed on the curb, these requirements tended to limit the number of cans to a large degree.

Intuitively, it appears that the percentage of one-way items and the weight per home per collection would have an important influence on the productivity of collection systems, especially for the curb and alley systems. To investigate this possibility, selected data were subjected to regression analysis. The resulting equation was $Y = 0.489 - 0.008X_1 + 0.013X_2$

where Y = collection minutes per home

X_1 = percent one-way items

X_2 = pounds per home per collection

This equation does indicate that the percent one-way items (X_1) does have a beneficial effect on crew productivity and tends to decrease the collection minutes per home (Y). The pounds per home per collection (X_2) has an adverse effect on productivity and tends to increase the time required to service a home. These conditions are in agreement with what we would expect in the field. The actual effect of a change in percentage of one-way items and pounds per home per collection depends on the magnitudes of these variables.

For a 10 percent change in the average values of X_1 (59.0 percent) and X_2 (47.8 pounds) the equation indicates that the pounds per home per collection has about 1.3 times the effect of percent one-way items and is in the opposite direction.

Conclusions. The following conclusions resulted from a consideration of the type of storage containers.

The percentage of one-way items (bags and miscellaneous items) does have a significant effect on the system productivity. An increase in the percentage of one-way items reduces the time required to service a home, and conversely, increases the number of homes served per collection hour. A decrease in the percentage of one-way items increases the time required to service a home, and conversely, reduces the number of homes served per collection hour.

The weight per home per collection also effects the system productivity, and this effect is greater and opposite in direction to the effect of one-way items. An increase in weight per home increases the time required to service a home and decreases the number of homes served per collection hour. Conversely, a decrease in weight per home per collection reduces the time required to service a home and increases the number of homes served per collection hour.

Performance Analysis by Productivity and Efficiency

General. For the purpose of this analysis, productivity will be considered in terms of homes served per collection hour and tons collected per collection hour. Productivity will be considered from the standpoint of the crew and the individual crewman. The productivity of each system will be compared with System 1.

Efficiency for the purpose of this analysis will be considered in terms of the cost per service per week and the cost per ton. The efficiency of each system will be compared with System 1.

Productivity and efficiency indices were provided in Table 3.

Systems are ranked according to their productivity in Table 14.

Systems are ranked according to their collection cost efficiency in Table 15.

Discussion. Productivity and efficiency are interrelated with the factors that have already been considered previously. The total influence of these factors results in a collection rate per hour in terms of homes served and tons collected. From the information that has been presented previously, it appears that the system that has the greatest productivity per crewman and the best balance among all of the factors that influence system performance will have the best cost effectiveness and, hence, the greatest cost efficiency. Of the systems studied, System 1 clearly meets this requirement to a greater extent than any other system and, hence, has the best collection cost efficiency.

Conclusions. The following conclusions resulted from a consideration of the productivity and efficiency factors.

Curbside is more productive and cost efficient than backyard service.

For the curb and alley systems:

Systems that have a collection frequency of twice a week tend to serve more homes per collection hour, but collect fewer tons per collection hour, than their once-a-week counterparts.

When productivity and cost efficiency are considered on a per crewman basis, there is a strong tendency for the smaller crew sizes to have the greatest productivity and best cost efficiency.

TABLE 14

RANKING OF SYSTEMS BY PRODUCTIVITY

SERVICES PER CREWMAN PER HOUR				TONS PER CREWMAN PER HOUR				SERVICES PER CREW PER HOUR				TONS PER CREW PER HOUR			
SYSTEM	CREW SIZE	ACTUAL	INDEX	SYSTEM	CREW SIZE	ACTUAL	INDEX	SYSTEM	CREW SIZE	ACTUAL	INDEX	SYSTEM	CREW SIZE	ACTUAL	INDEX
CURB AND ALLEY SYSTEMS															
1	1	107.3	1.00	1	1	2.5	1.00	9*	3	200.5	1.87	9*	3	3.3	1.32
3*	1	84.2	0.78	2	1	2.0	0.80	6*	2	138.4	1.29	7	3	3.3	1.32
6*	2	66.6	0.62	5	2	1.5	0.60	5	2	123.3	1.15	5	2	3.1	1.24
9*	3	66.5	0.62	4	2	1.3	0.52	1	1	107.3	1.00	4	2	2.6	1.04
5	2	57.7	0.54	3*	1	1.2	0.48	4	2	107.0	1.00	1	1	2.5	1.00
2	1	55.7	0.52	7	3	1.1	0.44	7	3	104.5	0.97	2	1	2.0	0.80
4	2	55.4	0.50	9*	3	1.1	0.44	3*	1	84.2	0.78	8	3	2.0	0.80
7	3	34.9	0.33	6*	2	0.8	0.32	8	3	62.7	0.58	6*	2	1.7	0.68
8	3	20.9	0.19	8	3	0.7	0.28	2	1	55.7	0.52	3*	1	1.2	0.48
BACKYARD SYSTEMS															
10	2	35.3	0.33	10	2	0.6	0.24	10	2	72.1	0.61	10	2	1.2	0.48
11	2	22.1	0.21	11	2	0.6	0.24	11	2	44.4	0.41	11	2	1.1	0.44

*Collection twice weekly.

TABLE 15

RANKING OF SYSTEMS BY COLLECTION COST EFFICIENCY

COLLECTION COST PER SERVICE PER WEEK				COLLECTION COST PER TON PER WEEK			
SYSTEM	CREW SIZE	COST	INDEX	SYSTEM	CREW SIZE	COST	INDEX
CURB AND ALLEY SYSTEMS							
1	1	0.13	1.00	1	1	5.42	1.00
5	2	0.15	0.87	2	1	5.75	0.94
4	2	0.16	0.81	5	2	6.09	0.89
2	1	0.20	0.65	4	2	6.54	0.83
3*	1	0.29	0.45	7	3	9.71	0.56
7	3	0.30	0.43	9*	3	10.26	0.53
9*	3	0.34	0.38	3*	1	10.42	0.52
8	3	0.36	0.36	8	3	11.07	0.49
6*	2	0.37	0.35	6*	2	15.40	0.35
BACKYARD SYSTEMS							
10	2	0.27	0.48	11	2	14.62	0.37
11	2	0.37	0.35	10	2	15.74	0.34

*Collection twice weekly.

For backyard systems:

The system which uses the task incentive system has a greater productivity than the system that uses the standard day incentive system.

There is no clear pattern between the backyard systems regarding collection cost efficiency.

Cost Analysis of Systems Performance

General. The standard cost data of Appendix 1 were used for all systems of the study effort to eliminate the effects of local cost variations and to facilitate a cost analysis of system performance. By using standard costs, any significant cost differences among the systems would then reflect differences in the operational performance of the systems. These differences may be related to the kind of equipment that was used and the cost of that equipment, the crew size, the frequency of collection, the storage point location, collection methodology and the incentive system used for the collection effort. In addition, the differences in cost would be related to the location of the route relative to the motor pool and also the location of the disposal point relative to the route. Since the study effort concentrated on the collection (on-route) phase of the operations, this aspect of the operation will be emphasized in the cost analysis. For this analysis cost data are grouped by systems on the basis of crew size in Table 16.

Discussion. Even with standard costs, there was considerable variation in the cost related factors of the collection system operations; although crew size, frequency of collection, and point of collection explained much of this. Differences in local costs would increase these cost variations. How then does the local

TABLE 16

SYSTEM COST DATA - COMPARISONS BY CREW SIZE

SYSTEM NUMBER	COST TO ROUTE PER DAY	COST TO COLLECT PER DAY	COST TO TRANSPORT PER DAY	EQUIPMENT COST PER DAY	MANPOWER COST PER DAY	TOTAL COST PER DAY	MANPOWER COST TO EQUIPMENT COST	COST PER TON	COST PER HOME PER WEEK	COLLECTION COST PER TON	COLLECTION COST PER HOME PER WEEK	RATIO COLLECTION COST TO TOTAL COST
					CURB AND ALLEY - CREW SIZE - 1 MAN							
1	4.32	51.07	22.77	32.54	45.62	78.16	1.40	8.29	0.19	5.42	0.13	0.65
2	1.60	51.75	22.80	30.70	45.44	76.14	1.49	8.46	0.30	5.75	0.20	0.68
3[a]	4.45	59.66	13.10	31.60	45.62	77.22	1.40	13.48	0.37	10.42	0.29	0.77
					CURB AND ALLEY - CREW SIZE - 2 MAN							
4	4.87	82.23	32.86	30.66	89.30	119.96	2.91	9.54	0.23	6.54	0.16	0.69
5	5.07	88.24	32.98	31.68	94.60	126.28	2.99	8.72	0.22	6.09	0.15	0.70
6[b]	4.34	107.14	35.70	43.69	103.48	147.17	2.37	21.15	0.51	15.40	0.37	0.73
					BACKYARD - CREW SIZE - 2 MAN							
10	2.94	97.23	18.88	28.74	90.31	119.05	3.14	19.27	0.32	15.74	0.27	0.82
11	2.78	90.25	20.63	23.98	89.68	113.66	3.74	18.41	0.47	14.62	0.37	0.79
					CURB AND ALLEY - CREW SIZE - 3 MAN							
7	6.25	122.52	32.80	28.70	132.87	161.57	4.63	12.82	0.39	9.71	0.30	0.76
8	3.93	107.14	54.88	30.18	135.77	165.95	4.50	17.13	0.55	11.07	0.36	0.65
9[b,c]	10.24	143.33	51.23	38.18	166.62	204.79	4.36	14.67	0.48	10.26	0.34	0.70

a. Operates six days per week.

b. Operates four days per week.

c. Normal work day is 10 hours.

collection system manager relate his costs to the systems studied? While it is possible to convert systems study costs to local costs and vice versa, the most practical approach is to consider both the systems study performance and the local performance in terms of the local costs.

The total daily costs for a local operation may be determined by completing the form of Figure 11. The local daily costs can be related to the three phases of collection operations, and also to the cost per home per week, and cost per ton by the formulas provided in Figure 12.

The formulas for cost per home per week and cost per ton provide the local manager with a simple and powerful tool for analyzing his performance in terms of the performance of the systems studied. By using his daily costs per day, and the operational productivity and performance factors of the system or systems under consideration, the manager can make direct cost comparisons with his own performance.

Increasing the effective labor rate by $0.50 per hour increases labor costs approximately $1,000 per man per year. Two tables of data have been prepared to demonstrate the effect which various local labor rates would have on the collection cost per ton, Table 17, and collection cost per home per week, Table 18. These tables can be used to approximate very closely what the collection costs per ton and per home per week would be using local labor rates and assuming the study system performance.

Increasing the capital costs by $1,000 increases the equipment costs by $200 per year with a five-year depreciation schedule.

Table 19 provides the incremental effect on collection cost per home per week and per ton for an increase in equipment costs of

FIGURE 11

PROCEDURE FOR DETERMINING LOCAL
TOTAL PERFORMANCE COSTS PER DAY

Total Costs = Manpower Costs + Equipment Costs

Manpower Costs (Per Day)		
Labor Costs (Wages)	xxxxx	
Fringe Benefits Costs	xxxxx	
Personnel Overhead Costs	xxxxx	
Total Manpower Costs		xxxxx
Equipment Costs (Per Day)		
Depreciation	xxxxx	
Maintenance	xxxxx	
Daily Consumables (gas and oil)	xxxxx	
Other (Insurance, Fees, Etc.)	xxxxx	
Total Equipment Costs		xxxxx
Total Costs (Per Day)		xxxxx

FIGURE 12

PROCEDURE FOR DETERMINING LOCAL PERFORMANCE COSTS FOR COMPARISON WITH SYSTEM STUDIES COST

Cost to Route (Per Day)* =

$$\text{Local Total Cost (Per Day)} \times \frac{\text{Average Time to Route (Per Day)}}{\text{Average Total Time Worked (Per Day)}}$$

Cost to Collect (Per Day)* =

$$\text{Local Total Cost (Per Day)} \times \frac{\text{Average Time to Collect (Per Day)}}{\text{Average Total Time Worked (Per Day)}}$$

Cost to Transport (Per Day)* =

$$\text{Local Total Cost (Per Day)} \times \frac{\text{Average Time to Transport (Per Day)}}{\text{Average Total Time Worked (Per Day)}}$$

Cost Per Home Served (Per Week) =

$$\frac{\text{Local Total Costs (Per Day)} \times \text{Frequency of Collection (Per Week)}}{\text{Average Homes Served (Per Day)}}$$

Cost Per Ton =

$$\frac{\text{Local Total Costs (Per Day)}}{\text{Tons Collected (Per Day)}}$$

Collection Cost Per Home Served (Per Week) =

$$\frac{\text{Local Collection Costs (Per Day)} \times \text{Frequency of Collection (Per Wk)}}{\text{Average Homes Served (Per Day)}}$$

Collection Cost Per Ton =

$$\frac{\text{Local Collection Costs (Per Day)}}{\text{Average Tons Collected (Per Day)}}$$

* Cost by activity is determined on the basis of relative time spent on the activity. Therefore, the average total time worked per day serves as the basis for the activity costs, and not the total paid time. The total paid time is reflected in the total cost per day.

TABLE 17

THE EFFECT OF LABOR COSTS ON COLLECTION COST PER TON

1-Man Crew

System Number	Labor Rates								
	3.50	4.00	4.50	5.00	5.50	5.70*	6.00	6.50	7.00
1	4.19	4.47	4.75	5.02	5.30	5.41	5.58	5.85	6.13
2	4.43	4.73	5.03	5.33	5.63	5.75	5.93	6.23	6.53
3	8.04	8.58	9.12	9.66	10.20	10.41	10.74	11.28	11.81

2-Man Crew

System Number	Labor Rates									
	7.00	8.00	9.00	10.00	11.00	11.15*	12.00	12.70**	13.00	14.00
4	4.72	5.15	5.59	6.03	6.46	6.53	6.90	7.20	7.33	7.81
5	4.39	4.80	5.21	5.62	6.03	6.09	6.44	6.72	6.85	7.26
6	10.54	11.39	12.24	13.09	13.94	14.07	14.80	15.39	15.65	16.49
10	11.29	12.36	13.43	14.50	15.57	15.73	16.64	17.39	17.71	18.78
11	10.31	11.35	12.38	13.42	14.45	14.60	15.48	16.21	16.52	17.55

3-Man Crew

System Number	Labor Rates								
	10.50	12.00	13.50	15.00	16.50	16.60*	18.00	19.50	21.00
7	6.76	7.48	8.20	8.92	9.64	9.69	10.36	11.08	11.80
8	7.71	8.52	9.34	10.15	10.97	11.02	11.78	12.60	13.41
9	7.13	7.87	8.62	9.37	10.12	10.17	10.86	11.61	12.36

* *Study Standard Rate*
** Standard rate for System 6

TABLE 18

THE EFFECT OF LABOR COSTS ON
COLLECTION COST PER HOME PER WEEK

1-Man Crew

System Number	Labor Rates								
	3.50	4.00	4.50	5.00	5.50	5.70*	6.00	6.50	7.00
1	0.10	0.10	0.11	0.12	0.12	0.13	0.13	0.13	0.14
2	0.16	0.17	0.18	0.19	0.20	0.20	0.21	0.22	0.23
3	0.22	0.24	0.25	0.27	0.28	0.29	0.30	0.32	0.33

2-Man Crew

System Number	Labor Rates									
	7.00	8.00	9.00	10.00	11.00	11.15*	12.00	12.70**	13.00	14.00
4	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.18	0.18	0.19
5	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.17	0.17	0.18
6	0.26	0.28	0.30	0.32	0.34	0.34	0.36	0.37	0.38	0.40
10	0.19	0.21	0.23	0.25	0.26	0.27	0.28	0.30	0.30	0.32
11	0.26	0.29	0.31	0.34	0.37	0.37	0.39	0.41	0.42	0.45

3-Man Crew

System Number	Labor Rates								
	10.50	12.00	13.50	15.00	16.50	16.60*	18.00	19.50	21.00
7	0.21	0.23	0.25	0.28	0.30	0.30	0.32	0.34	0.37
8	0.24	0.27	0.30	0.32	0.35	0.35	0.37	0.40	0.43
9	0.24	0.26	0.28	0.31	0.33	0.34	0.36	0.38	0.41

* Study Standard Rate
** Standard Rate for System 6

TABLE 19

THE EFFECT OF CAPITAL COSTS ON COLLECTION RELATED COSTS

An increase of $1,000 in equipment cost has the following incremental effect on collection related costs. These costs are based on a 5 year depreciation period and the number of work days a year in each system.

System Number	Number Workdays/Year	Collection Cost/ Home/Week	Collection Cost/Ton
1	260	.001	.053
2	255	.002	.059
3*	310	.002	.087
4	261	.001	.041
5	261	.001	.035
6*	208	.002	.098
7	260	.001	.046
8	252	.002	.051
9*	207	.002	.047
10	255	.002	.103
11	260	.003	.098

*Collection twice weekly.

$1,000 for the systems studied.

The analysis of crew size indicates that the productivity of crewmen has a strong tendency to increase as the crew size decreases. The greatest productivity per crewman is with the one-man crews. To reduce personnel costs, a logical avenue would be to reduce crew size and, at the same time, increase the productivity of crewmen. This procedure will enable the collection system to provide the same services with less personnel.

Conclusions. The following conclusions resulted from a consideration of the system costs.

Regardless of the kind of equipment that was being used, the initial cost of the equipment, and the number of days per week the equipment was being used, the daily equipment costs were of the same general magnitude for all systems. The equipment costs for System 6 with the detachable container equipment and mother truck were significantly greater than the equipment costs for the other systems.

The daily personnel costs were related directly to the crew size.

For every system studied, the daily personnel costs were significantly more than the daily equipment costs. The manpower to equipment ratios averaged 1.4 for one-man crews, 3.0 for two-man crews, and 4.5 for three-man crews.

The incremental effect of an increase in equipment costs of $1,000 was small in comparison with an effective increase in labor costs per crewman of $0,50 per hour.

Since daily personnel costs are significantly more than the daily equipment costs, cost reduction programs should look first in the area of personnel costs. Personnel costs can be lowered by improving personnel productivity, by reducing the numbers of personnel or both. There is a strong tendency for personnel productivity to increase as crew size decreases.

Since incremental cost effects of an increase in equipment cost of $1,000 are small in comparison with an increase in the effective labor rate of $0.50 per hour, compromising equipment or crew performance for the sake of a lower equipment cost appears to be counter productive.

SECTION III

EVALUATION AND PREDICTION PROCEDURES

General

Two general methods can be used by the local manager to evaluate his system in terms of the systems studied. The first method is to use the study data provided in SECTION II. The second method is to use mathematical models or equations. Both methods will be considered in this section.

Use of System Study Data

Where the local system meets the definition of one of the systems studied, a direct comparison of local data can be made with the data in the tables of SECTION II. Where the local system does not meet the definition of one of the study systems, the method used in presenting the study data can be used in making an analysis of the local system performance. All of the data of SECTION II can be used as guides for a reasonable expected performance if the local system were to change to meet the definition of the system being considered.

Even though the local system may not match one of the study systems, the data provided in SECTION II can still be used for analyzing the local system performance. Considerations for using the data are provided in the following paragraphs under the same system factors that were considered in SECTION II.

Analysis by Type of Equipment. The minimum expected weight per cubic yard of Table 4 provides reasonable standards that are applicable to equipment used regardless of other system factors. If the densities of 500, 700, and 900 pounds per cubic yard are not being achieved routinely with "full" loads for light, medium, and heavy duty packing equipment, respectively, there is an obvious mismatch between the performance capabilities of the equipment and the other system parameters. Under this condition the manager should determine the reasons for not achieving the proper density and take appropriate corrective action. Some of the conditions which may lead to light densities include the following:

Packer capacity too large for the designated route area.

Packer capability too great for the designated route area.

Planned or actual collection time too short to service enough homes to fill the packer.

The time of leaving the route for the disposal point is being dictated by conditions other than having a full load.

Equally important with obtaining "full" loads is a consideration of the number of loads being collected per crew per day. This number should be the least possible consistent with obtaining full loads. When there is a proper match of the vehicle capabilities with the route and crew characteristics,minimizing the number of loads per day will maximize the collection time. This should be a primary objective of the collection manager.

None of the systems studied used a front loader for the residential collections. Front loaders are used for this purpose to a limited extent. Front loaders are classified as light duty from a compaction standpoint and should obtain densities from 550 to 600 pounds per cubic yard. A density of 550 pounds per cubic yard would be a good general planning figure for "full" loads with front loaders.

<u>Analysis by Crew Size</u>. The crew performance data of Tables 5, 6, 7, and 8 will provide reasonable standards for evaluating the

crew performance of the local system. The most significant items are associated with the productivity of the individual crewman in terms of homes served per collection hour and tons collected per collection hour. If the local performance is reduced to the productivity of individual crewmen, then this can be compared to the study system data. This procedure will enable the productivity of four-man and larger crews to be compared on an equitable basis with study systems.

The second most important factor is the percent of productive time both during the collection phase of the operations and for the total activities. The non-productive time should be reduced to the lowest possible amount based on the specific conditions of the local collection system.

By comparing the crewman productivity and the productive time of the local system with an appropriate study system, the local manager can determine whether or not changes to his system are necessary. If the crewman productivity and percentage of productive time are too low, the local manager should review the conditions that are contributing to the lost or non-productive time. Some of these conditions may include the following: excessive break time, excessive waiting time, frequent travels off the collection route and, especially, back to the motor pool. In making his review, the local manager should also consider reducing the crew size as a means of increasing productivity and increasing the percentage of productive time.

Analysis by Frequency of Collection. For curb and alley systems, the information provided by Table 9 can be used as performance guides by the local manager for frequencies of collection of once and twice weekly. This information is most usable as standards for managers who are contemplating a change in the frequency of collection.

Analysis by Storage Point. Only curb and alley and backyard storage point locations were considered in this study. The backyard service was limited to the use of the tote-barrel and the data in Table 10 were limited to the two-man crews for the purpose of making direct comparisons. Data were not obtained in this study for backyard systems using a crew size larger than two men; therefore, no direct comparisons with study system data can be made for larger crew sizes. More definitive performance data for three-man curb and alley systems can be found under other system parameters.

Analysis by Incentive System. Tables 11 and 12 provide the study system performance data structured according to incentive system. The systems include one-, two-, and three-man crews and curb and alley and backyard storage points. The general pattern of performance by incentive system, as indicated by the data of Table 11, is generally the same regardless of the crew size and regardless of the storage point location. The same general trend would probably apply to the larger crew sizes, as well. The ranges of hours worked per week for each incentive system are probably representative of most systems. Any system performance outside of these ranges should probably be reviewed closely. The local manager should take a close look at the amount of overtime being paid to the personnel operating under the standard day system, and if it appears to be excessive, review closely the productivity factors. Where overtime appears to be excessive, the task incentive system should be strongly considered.

The incentive system productivity factors of Table 12 are probably good targets. If the local system productivity factors are significantly below these levels, the manager should review the operational performance to determine the reasons and institute appropriate corrective action based on the local conditions.

Analysis by Type of Storage Container. The equation

$$Y = 0.489 - 0.008X_1 + 0.013X_2$$

Where Y = collection minutes per hour

X_1 = percent one-way items

X_2 = pounds per home per collection

provides a general relationship between the percent of one-way items and the weight per home per collection as they affect the time required to service a home. This equation was based on the performance of the nine curb and alley systems studied. The equation should be a reasonable predictor for systems which closely approximate the systems studied. This equation indicates that the local manager should try to create conditions that will tend to increase the percentage of one-way items.

Analysis by Productivity and Efficiency Measures. The basic information regarding productivity and efficiency measures for all of the study systems is provided by Table 3. These are the most important factors to be considered in comparing local systems with the study systems. Productivity should be compared on a crewman basis. Since all indices are based on the performance of System I, a convenient method is provided for making comparisons among systems. Where there is a significant adverse difference between the local system and the study system, the local manager should determine the reasons and take appropriate correction action based on local conditions. The factors that have a direct influence on the homes served per collection hour and tons collected per collection hour should be reviewed first.

The best method for making a comparison of the local system with a study system is by use of the collection cost per service per week and the collection cost per ton. The local total costs can be determined from the procedure of Figure 11. The total costs can be converted to collection costs, and collection cost per home served per week, and collection cost per ton by the formulas of Figure 12. Using the local collection costs and the performance factors of the study systems, the constructed collection cost per home served per week and the constructed collection cost per ton can be determined. These constructed costs can be compared directly with the costs based on local performance. If there is a significant adverse difference between the constructed costs and the local costs, the manager should determine the reasons and take appropriate corrective action. The factors that have a direct influence on crew productivity should be reviewed first.

Use of Regression Analysis

Productivity Equations

Selected parameters from the DAAP data were subjected to regression analysis in order to obtain methematical equations that related to productivity measures. Three dependent variables (Y) were considered for analysis and included the following:

Collection minutes per service

Services per collected hour

Tons collected per collection hour

Each of the dependent variables was considered in terms of the following independent variables:

X_1 = pounds per service per collection

X_2 = crew size

X_3 = percent one-way items

X_4 = collection miles per day

All of the equations were of the form of:

$$Y = aX_1 + bX_2 + cX_3 + dX_4 + e.$$

For each dependent variable, the data were stratified into three groups as follows:

Curb and alley collecting once weekly

Curb and alley collecting twice weekly

Backyard collecting once weekly

The equations that resulted from these regressions define the dependent variables in terms of the operational performance of the systems studied. The equations, however, cannot be used to predict a performance outside the limits of the systems studied. For example, the equations cannot be used to predict the performance of a four-man curb and alley system or a three-man backyard system or a two-man backyard system collecting twice weekly. Because there exists many systems that closely approximate the definition of the study systems, the regression models should have a broad general application.

In the regression equations for curb and alley systems collecting twice weekly, and only these systems, the crew size numbers of 1, 2, and 3 can also be used to represent type of equipment. In this case, the number 1 represents the side loader, the number 2 represents the detachable container system, and the number 3 represents rear loading equipment.

Of the four independent variables considered, only one is wholly outside of the control of the solid waste collection manager. This one is the generation rate or pounds per service per collection. The other variables can be controlled to some extent. The crew size is completely within the control of the manager. The percent of one-way items may be influenced by the manager. This influence may range from prescribing bags be used completely to the creating of conditions whereby the use of more bags will be encouraged and used. The collection miles per day may also be influenced by the manager. By more efficient micro-routing and by placing some reasonable restrictions on travel for breaks, which may be included in the collection phase of operations, the manager can favorably influence the collection miles per day to keep them at a minimum.

In general, the four independent variables have the following effects on the collection operations:

An increase in generation rates adversely affects productivity parameters and increases cost.

An increase in crew size increases production and also increases the cost of providing service.

An increase in the percentage of one-way items increases productivity and decreases the cost of providing services.

An increase in collection miles decreases productivity and increases cost.

Collection Minutes Per Service. On-route collection minutes per service is one of the parameters directly related to the productivity of collection operations. The equations that resulted from the regression analyses were as follows:

Curb and Alley Collecting Once Weekly

$$Y = 0.76 + 0.01X_1 - 0.07X_2 - 0.05X_4$$

Curb and Alley Collecting Twice Weekly

$$Y = 0.44 + 0.01X_1 - 0.24X_2 + 0.01X_4$$

Backyard Collecting Once Weekly

$$Y = 0.75 + 0.01X_3$$

All three equations can be expected to provide excellent results in projecting the collection minutes per service.

Services Per Collection Hour. Services per collection hour is one of the parameters directly related to the productivity of collection operations. The equations that resulted from the regression analyses were as follows:

Curb and Alley Collecting Once Weekly

$$Y = 94.63 - 1.06X_1 + 0.55X_3 + 2.77X_4$$

Curb and Alley Collecting Twice Weekly

$$Y = 57.20 - 2.55X_1 + 54.14X_2 + 1.14X_3$$

Backyard Collecting Once Weekly

$$Y = 74.84 - 0.68X_3$$

All three equations can be expected to provide excellent results in projecting the number of services per collection hour.

Tons Per Collection Hour. Tons per collection hour is one of the parameters directly related to the productivity of collection operations. The equations that resulted from the regression analyses were as follows:

Curb and Alley Collecting Once Weekly

$$Y = 0.16 + 0.01X_1 + 0.14X_2 + 0.01X_3 + 0.12X_4$$

Curb and Alley Collecting Twice Weekly

$$Y = 1.72 + 0.02X_1 + 0.78X_2 + 0.03X_3$$

Backyard Collecting Once Weekly

$$Y = 0.52 + 0.02X_1 - 0.01X_3$$

The first equation should be used cautiously because a significant amount of the variations in the DAAP data were not explained by the designated variables. The other two equations should provide excellent results in projecting the tons collected per collection hour.

SECTION IV

SUMMARY

This study has produced a great wealth of valid information concerning the productivity and cost efficiency from selected residentail solid waste collection operations and the interrelationship of the key factors that effect the productivity of the collection operation. Data were obtained over the period of one year for each of the 11 specifically defined systems. A concerted effort was made to select only highly productive systems for this study. Also, the most productive four routes of each system were selected for study. The study data, then, represent reasonable productivity targets for similar systems. It is expected that this information will give residential solid waste collection managers everywhere a valuable tool for appraising the productivity and cost efficiency of their operations. In addition, it is hoped that this study will stimulate other approaches for improving collection system productivity.

Each system was defined according to operating parameters which can be controlled by the collection system manager. These factors included the type of equipment, crew size, frequency of collection, point of collection, collection methodology, and the incentive system. Bags and cans were prescribed as the storage container for all systems. The significance of each factor, as it relates to productivity and cost efficiency, was determined for each system and collectively for several groups of systems. The general conclusions that were reached from an analysis of the factors were summarized at the beginning of this volume and also in SECTION II under the analysis of each factor.

All of the factors considered did have a significant impact on productivity and cost efficiency. How significant each factor would be with a specific system would depend on the objectives and conditions of that system. The individual factors were analyzed separately in this study. There was no effort to determine the collective effects of all factors on a given system. In applying the results of this study to a local situation, it is suggested that the organizational objectives be clearly established before any detailed analysis is made. Once the goals have been defined, then the study factors can be considered as alternatives for meeting the desired goals. The affects of making changes in the study factors can then be determined or predicted in a logical manner as they apply to a specific situation.

Finally, the conclusions that were reached in this study should be applicable in the general situation. All residential collection system managers should be able to apply the results and conclusions from this study to their own operations and should strive to do so. It is also recognized that regardless of how desireable it may be to implement certain study procedures, this becomes practical only if it is feasible under the political constraints of the organization. The solid waste manager, at best, can accomplish only what is politically feasible in his organization.

APPENDIX I

DAAP STANDARD DATA

The DAAP computer program was designed to facilitate the analysis of the daily collection route data that were obtained from the study effort. In order to eliminate the local cost differences that existed among the various systems being studied, standard costs were used. Costs for services being performed would then be primarily a function of the operational performance. Insofar as possible, the standard costs that were used were the average costs for all of the systems and were as follows:

Initial Cost of Vehicles

Capacity (cu yds)	Side Loader	Rear Loader
13		$15,900
16		$16,700
18		$17,000
20		$22,700
25	$23,900	$23,900
33	$30,000	
Detachable Container Vehicle plus 1/4 cost of mother truck	$28,100	

Depreciation

The depreciation period is five years.

Maintenance Cost Per Year

Maintenance cost (first year) = .055 X initial cost of vehicle.

Consumable Costs

Fuel - $0.17 per gallon. Engine oil - $0.23 per quart.

Insurance and Fees

The yearly cost of insurance and fees is $1,200 per vehicle. The effective cost of insurance for one detachable container route (including mother truck) is $1,500 per year.

Salaries (dollars per hour)

Driver - $4.34. Collectors - $4.15. The effective cost of the detachable container crew (including mother truck driver) is $4.93 and $4.73 for the driver and collector respectively.

Fringe Benefits

Fringe benefits are 18.3 percent of salary.

Personnel Overhead

Personnel overhead is 13.1 percent of salary.

Overtime Factor

Overtime factor of 1.5 for drivers and collectors.

The daily cost of depreciation, maintenance, and insurance and fees is a function of the number of normal work days for each of the systems. The number of normal work days that was used in the program for each of the systems is listed below:

System	Number of Work Days
1	260
2	255
3	310
4	261
5	261
6	208
7	260
8	252
9	207
10	255
11	260

In determining the cost of equipment, the 1972 replacement cost was used as the standard. Where 1972 equipment was being used in conjunction with the system studies this cost was used. No problems were encountered with the costs of the side loading equipment. There was a considerable range of costs associated with the rear loading equipment depending on whether the equipment was designed for medium or heavy duty packing and depending on the chassis and packer make. Average costs were determined for medium duty packing equipment, and these were used.

There was a wide variation in the maintenance costs reported by the participating agencies. Looking at the reported maintenance costs for the first yearly increment of equipment use and comparing these with the reported purchase price indicated a maintenance cost of between five and eight percent. The yearly maintenance costs were averaged and converted to a percent. The value of five and one-half percent was used.

The average of the reported fuel and engine oil unit costs, salaries, fringe benefits and personnel overhead rates was used. Personnel overhead included all supervisory personnel and other support personnel that were directly related to the collection operation.

APPENDIX 2

DATA ACQUISITION AND ANALYSIS PROGRAM

DAAP COMPUTER PROGRAM OUTPUT

COLLECTION SYSTEM DESCRIPTION REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

SYSTEM NUMBER	OPERATING AGENCY	TOTAL NUMBER OF ROUTES	TYPE OF EQUIP	CREW SIZE	COLLECT PER WEEK	POINT OF COLLECT	COLLECTION METHODOLOGY	INCENTIVE SYSTEM	UNION REPR.	TYPE OF STORAGE CONTAINERS % BAGS	% CANS	% MISC
01	PUBLIC	4	SL	1.0	1	CURB-ALLEY	ONE-SIDE	TASK	NO	34.0	52.0	14.0
02	PUBLIC	4	SL	1.0	1	CURB-ALLEY	ONE-SIDE	8 HR DAY	NO	26.0	53.0	21.0
03	PUBLIC	4	SL	1.0	2	CURB-ALLEY	ONE-SIDE	TASK	YES	29.0	53.0	18.0
04	PRIVATE	4	RL	2.0	1	CURB-ALLEY	ONE-SIDE	TASK	YES	56.0	28.0	16.0
05	PUBLIC	4	RL	2.0	1	CURB-ALLEY	ONE-SIDE	8 HR DAY	YES	85.0	6.0	9.0
06	PUBLIC	4	DC	2.0	2	CURB-ALLEY	ONE-SIDE	TASK	YES	19.0	61.0	20.0
07	PUBLIC	4	RL	3.0	1	CURB-ALLEY	BOTH SIDES	TASK	YES	56.0	28.0	16.0
08	PUBLIC	4	RL	3.0	1	CURB-ALLEY	BOTH SIDES	8 HR DAY	YES	25.0	47.0	28.0
09	PUBLIC	4	RL	3.0	2	CURB-ALLEY	BOTH SIDES	TASK	YES	46.0	41.0	13.0
10	PUBLIC	4	RL	2.0	1	BACKYARD	TOTE-BARREL	TASK	NO	2.0	96.0	2.0
11	PUBLIC	4	RL	2.0	1	BACKYARD	TOTE-BARREL	8 HR DAY	YES	33.0	55.0	12.0

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
DETAILED VEHICLE - CREW REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	SIZE AND TYPE	AGE EQUIP (YEARS)	EQUIPMENT COST PER OPERATING DAY (DOLLARS)				AVG CREW SIZE	CREW HOURLY LABOR RATE (DOLLARS)		HOURS WORKED PER WEEK	
			DEPRECI-ATION	MAINTE-NANCE	CONSUM-ABLES	INSURANCE AND FEES		DRIVER	COLLECTOR	PLANNED	ACTUAL
01-01	25.0-SL	1.0	18.38	5.06	3.44	4.62	1.0	5.70	0.00	40.00	28.61
01-02	25.0-SL	1.0	18.38	5.06	4.25	4.62	1.0	5.70	0.00	40.00	31.13
01-03	25.0-SL	1.0	18.38	5.06	5.68	4.62	1.0	5.70	0.00	40.00	29.31
01-04	25.0-SL	1.0	18.38	5.06	4.54	4.62	1.0	5.70	0.00	40.00	29.43
02-01	25.0-SL	1.0	18.75	5.15	2.06	4.71	1.0	5.70	0.00	40.00	33.94
02-02	25.0-SL	1.0	18.75	5.15	2.03	4.71	1.0	5.70	0.00	40.00	34.08
02-03	25.0-SL	1.0	18.75	5.15	2.12	4.71	1.0	5.70	0.00	40.00	32.88
02-04	25.0-SL	1.0	18.75	5.15	2.19	4.71	1.0	5.70	0.00	40.00	34.06
03-01	33.0-SL	1.0	19.35	5.32	3.00	3.87	1.0	5.70	0.00	48.00	37.89
03-02	33.0-SL	1.0	19.35	5.32	3.02	3.87	1.0	5.70	0.00	48.00	38.67
03-03	33.0-SL	1.0	19.35	5.32	3.11	3.87	1.0	5.70	0.00	48.00	37.33
03-04	33.0-SL	1.0	19.35	5.32	3.06	3.87	1.0	5.70	0.00	48.00	38.62
04-01	20.0-RL	1.0	17.39	4.78	4.13	4.60	2.0	5.70	5.45	40.00	38.98
04-02	20.0-RL	1.0	17.39	4.78	3.51	4.60	2.0	5.70	5.45	40.00	33.20
04-03	20.0-RL	1.0	17.39	4.78	3.91	4.60	2.0	5.70	5.45	40.00	37.26
04-04	20.0-RL	1.0	17.39	4.78	4.01	4.60	2.0	5.70	5.45	40.00	33.07
05-01	23.6-RL	1.0	18.31	5.04	3.54	4.60	2.0	5.70	5.45	40.00	34.22
05-02	24.3-RL	1.0	18.31	5.04	3.90	4.60	2.0	5.70	5.45	40.00	35.68
05-03	24.9-RL	1.0	18.31	5.04	3.59	4.60	2.1	5.70	5.45	40.00	35.98
05-04	24.0-RL	1.0	18.31	5.04	3.90	4.60	2.1	5.70	5.45	40.00	34.84

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
DETAILED VEHICLE - CREW REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	SIZE AND TYPE	AGE EQUIP (YEARS)	EQUIPMENT COST PER OPERATING DAY (DOLLARS)				AVG CREW SIZE	CREW HOURLY LABOR RATE (DOLLARS)		HOURS WORKED PER WEEK	
			DEPRECI- ATION	MAINTE- NANCE	CONSUM- ABLES	INSURANCE AND FEES		DRIVER	COLLECTOR	PLANNED	ACTUAL
06-01	8.0-DC	1.0	27.02	7.43	2.04	7.21	2.1	6.48	6.22	32.00	23.23
06-02	8.0-DC	1.0	27.02	7.43	2.00	7.21	2.0	6.48	6.22	32.00	22.98
06-03	8.0-DC	1.0	27.02	7.43	2.08	7.21	2.0	6.48	6.22	32.00	23.01
06-04	8.0-DC	1.0	27.02	7.43	2.00	7.21	2.0	6.48	6.22	32.00	24.08
07-01	19.9-RL	1.0	17.46	4.80	1.82	4.62	3.0	5.70	5.45	40.00	24.67
07-02	20.1-RL	1.0	17.46	4.80	1.75	4.62	3.0	5.70	5.45	40.00	28.22
07-03	20.0-RL	1.0	17.46	4.80	1.99	4.62	3.0	5.70	5.45	40.00	27.61
07-04	20.0-RL	1.0	17.46	4.80	1.72	4.62	3.0	5.70	5.45	40.00	23.62
08-01	24.5-RL	1.0	18.97	5.22	3.53	4.76	3.0	5.70	5.45	40.00	40.80
08-02	18.5-RL	1.0	13.49	3.71	2.41	4.76	3.0	5.70	5.45	40.00	38.96
08-03	24.6-RL	1.0	18.97	5.22	3.08	4.76	3.0	5.70	5.45	40.00	38.41
08-04	24.3-RL	1.0	18.97	5.22	2.88	4.76	3.0	5.70	5.45	40.00	38.74
09-01	20.0-RL	1.0	21.93	6.03	4.95	5.80	3.0	5.70	5.45	40.00	30.33
09-02	20.0-RL	1.0	21.93	6.03	4.98	5.80	3.0	5.70	5.45	40.00	21.99
09-03	20.0-RL	1.0	21.93	6.03	3.20	5.80	3.0	5.70	5.45	40.00	21.61
09-04	20.0-RL	1.0	21.93	6.03	4.54	5.80	3.0	5.70	5.45	40.00	27.66
10-01	20.0-RL	1.0	17.80	4.90	1.32	4.71	2.0	5.70	5.45	40.00	32.06
10-02	20.0-RL	1.0	17.80	4.90	1.23	4.71	2.0	5.70	5.45	40.00	30.59
10-03	20.0-RL	1.0	17.80	4.90	1.35	4.71	2.0	5.70	5.45	40.00	31.52
10-04	20.0-RL	1.0	17.80	4.90	1.42	4.71	2.1	5.70	5.45	40.00	31.13
11-01	13.6-RL	1.0	12.85	3.53	1.84	4.62	2.0	5.70	5.45	40.00	34.88
11-02	13.2-RL	1.0	12.23	3.36	2.12	4.62	2.0	5.70	5.45	40.00	34.37
11-03	19.4-RL	1.0	17.46	4.80	1.65	4.62	2.0	5.70	5.45	40.00	34.59
11-04	13.7-RL	1.0	12.23	3.36	2.04	4.62	2.0	5.70	5.45	40.00	35.18

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
DETAILED ROUTE OPERATIONS REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	MOTOR POOL TO ROUTE (PER DAY) MILES	MOTOR POOL TO ROUTE (PER DAY) HOURS	COLLECTION OPERATION (PER DAY) MILES	COLLECTION OPERATION (PER DAY) HOURS	TRANSPORT OPERATION (PER DAY) MILES	TRANSPORT OPERATION (PER DAY) HOURS	TO ROUTE, COLLECTION, TRANSPORT (PER DAY) MILES	TO ROUTE, COLLECTION, TRANSPORT (PER DAY) HOURS	DISCHARGE POINT (LOADS PER DAY) INCIN	DISCHARGE POINT (LOADS PER DAY) LAND FILL	DISCHARGE POINT (LOADS PER DAY) XFER STA	AVG WT COLLECTED (PER DAY) (TONS)	AVG LOADS (PER DAY)
01-01	9.3	0.39	11.7	3.77	45.3	1.55	66.3	5.70	0.0	1.8	0.0	8.93	1.8
01-02	9.0	0.30	9.0	4.06	49.9	1.83	67.9	6.19	0.0	1.7	0.0	9.24	1.7
01-03	7.5	0.30	9.0	3.67	47.9	1.79	64.4	5.76	0.0	1.7	0.0	9.99	1.7
01-04	7.7	0.31	12.3	3.84	41.4	1.67	61.4	5.82	0.0	1.8	0.0	9.59	1.8
SUM	33.4	1.30	42.1	15.34	184.5	6.84	260.0	23.47	0.0	7.1	0.0	37.74	7.1
AVG	8.4	0.32	10.5	3.83	46.1	1.71	65.0	5.87	0.0	1.8	0.0	9.44	1.8
YTD	8.4	0.32	10.5	3.83	46.1	1.71	65.0	5.87	0.0	1.8	0.0	9.44	1.8
02-01	1.8	0.12	8.8	4.76	21.7	1.85	32.3	6.72	0.0	1.5	0.0	9.12	1.5
02-02	2.1	0.15	6.8	4.44	25.4	2.20	34.2	6.79	0.0	1.7	0.0	9.05	1.7
02-03	1.2	0.12	6.4	4.48	22.4	1.95	30.0	6.55	0.0	1.6	0.0	9.05	1.6
02-04	0.3	0.18	2.4	4.55	5.8	2.04	8.6	6.77	0.0	1.7	0.0	8.78	1.7
SUM	5.4	0.56	24.5	18.24	75.3	8.04	105.1	26.84	0.0	6.6	0.0	35.99	6.5
AVG	1.4	0.14	6.1	4.56	18.8	2.01	26.3	6.71	0.0	1.6	0.0	9.00	1.6
YTD	1.4	0.14	6.1	4.56	18.8	2.01	26.3	6.71	0.0	1.6	0.0	9.00	1.6
03-01	7.7	0.36	13.9	4.93	21.8	1.00	43.4	6.30	0.0	1.0	0.0	5.48	1.0
03-02	7.5	0.39	11.8	4.91	22.3	1.14	41.5	6.43	0.0	1.0	0.0	5.76	1.0
03-03	9.3	0.38	13.7	4.68	22.0	1.09	45.0	6.16	0.0	1.0	0.0	5.71	1.0
03-04	7.5	0.32	15.7	5.00	22.6	1.06	45.8	6.38	0.0	1.0	0.0	5.98	1.0
SUM	32.0	1.46	55.0	19.53	88.7	4.29	175.7	25.28	0.0	4.1	0.0	22.93	4.1
AVG	8.0	0.36	13.7	4.88	22.2	1.07	43.9	6.32	0.0	1.0	0.0	5.73	1.0
YTD	8.0	0.36	13.7	4.88	22.2	1.07	43.9	6.32	0.0	1.0	0.0	5.73	1.0

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
DETAILED ROUTE OPERATIONS REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	MOTOR POOL TO ROUTE (PER DAY) MILES	MOTOR POOL TO ROUTE (PER DAY) HOURS	COLLECTION OPERATION (PER DAY) MILES	COLLECTION OPERATION (PER DAY) HOURS	TRANSPORT OPERATION (PER DAY) MILES	TRANSPORT OPERATION (PER DAY) HOURS	TO ROUTE, COLLECTION, TRANSPORT (PER DAY) MILES	TO ROUTE, COLLECTION, TRANSPORT (PER DAY) HOURS	DISCHARGE POINT (LOADS PER DAY) INCIN	DISCHARGE POINT (LOADS PER DAY) LAND FILL	DISCHARGE POINT (LOADS PER DAY) XFER STA	AVG WT COLLECTED (PER DAY) (TONS)	AVG LOADS (PER DAY)
04-01	6.4	0.32	9.9	5.24	32.9	2.15	49.2	7.71	0.0	1.5	1.0	13.21	2.5
04-02	5.3	0.24	11.6	4.64	29.7	1.65	46.6	6.53	0.0	1.4	0.9	11.74	2.3
04-03	6.6	0.31	9.0	5.03	31.4	2.00	47.0	7.33	0.0	1.4	1.1	12.60	2.4
04-04	6.7	0.27	9.8	4.33	36.4	1.90	52.9	6.50	0.0	1.4	0.9	12.87	2.3
SUM	25.1	1.14	40.3	19.24	130.3	7.69	195.7	28.07	0.0	5.6	3.8	50.41	9.4
AVG	6.3	0.29	10.1	4.81	32.6	1.92	48.9	7.02	0.0	1.4	1.0	12.60	2.4
YTD	6.3	0.29	10.1	4.81	32.6	1.92	48.9	7.02	0.0	1.4	1.0	12.60	2.4
05-01	4.8	0.27	12.7	4.37	28.9	1.67	46.4	6.31	0.0	2.0	0.0	13.67	2.0
05-02	4.4	0.26	13.9	4.75	30.7	1.63	48.9	6.65	0.0	2.0	0.0	14.94	2.0
05-03	3.6	0.24	12.9	5.03	28.4	1.78	44.9	7.05	0.0	1.9	0.0	14.74	1.9
05-04	4.4	0.30	12.8	4.55	31.8	1.90	49.0	6.75	0.0	1.9	0.0	14.62	1.9
SUM	17.2	1.07	52.3	18.70	119.8	6.99	189.2	26.76	0.0	7.8	0.0	57.97	7.7
AVG	4.3	0.27	13.1	4.68	29.9	1.75	47.3	6.69	0.0	1.9	0.0	14.49	1.9
YTD	4.3	0.27	13.1	4.68	29.9	1.75	47.3	6.69	0.0	1.9	0.0	14.49	1.9
06-01	2.4	0.15	21.0	4.06	12.0	1.42	35.4	5.63	0.0	0.0	4.3	6.71	4.2
06-02	2.4	0.15	22.0	4.25	10.9	1.22	35.3	5.63	0.0	0.0	4.3	6.83	4.3
06-03	2.3	0.17	20.7	4.01	12.6	1.45	35.6	5.64	0.0	0.0	4.5	7.10	4.5
06-04	2.3	0.20	18.4	4.25	12.3	1.42	33.0	5.87	0.0	0.0	4.6	7.21	4.5
SUM	9.4	0.67	82.0	16.58	47.9	5.52	139.3	22.77	0.0	0.0	17.7	27.86	17.6
AVG	2.4	0.17	20.5	4.14	12.0	1.38	34.8	5.69	0.0	0.0	4.4	6.96	4.4
YTD	2.4	0.17	20.5	4.14	12.0	1.38	34.8	5.69	0.0	0.0	4.4	6.96	4.4
07-01	5.0	0.23	11.3	3.77	12.8	0.89	29.0	4.89	0.0	2.0	0.0	11.61	2.0
07-02	1.9	0.12	8.7	4.40	14.0	1.08	24.7	5.60	0.0	2.3	0.0	13.17	2.3
07-03	5.5	0.34	11.5	3.81	17.9	1.29	34.9	5.44	0.0	2.1	0.0	12.20	2.1
07-04	2.5	0.11	10.6	3.64	12.4	0.94	25.5	4.68	0.0	2.5	0.0	13.64	2.5
SUM	14.8	0.80	42.1	15.62	57.1	4.20	114.0	20.62	0.0	8.9	0.0	50.62	8.9
AVG	3.7	0.20	10.5	3.91	14.3	1.05	28.5	5.16	0.0	2.2	0.0	12.65	2.2
YTD	3.7	0.20	10.5	3.91	14.3	1.05	28.5	5.16	0.0	2.2	0.0	12.65	2.2

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
DETAILED ROUTE OPERATIONS REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	MOTOR POOL TO ROUTE (PER DAY)		COLLECTION OPERATION (PER DAY)		TRANSPORT OPERATION (PER DAY)		TO ROUTE, COLLECTION, TRANSPORT (PER DAY)		DISCHARGE POINT (LOADS PER DAY)			AVG WT COLLECTED (PER DAY) (TONS)	AVG LOADS (PER DAY)
	MILES	HOURS	MILES	HOURS	MILES	HOURS	MILES	HOURS	INCIN	LAND FILL	XFER STA		
08-01	1.1	0.17	2.7	5.09	39.1	2.68	42.8	7.94	0.0	1.7	0.0	10.67	1.7
08-02	0.8	0.10	7.9	4.92	31.6	2.53	40.3	7.55	0.0	1.7	0.0	9.27	1.7
08-03	1.7	0.27	4.0	4.88	31.8	2.22	37.6	7.38	0.0	1.3	0.0	8.94	1.3
08-04	0.8	0.17	3.2	4.65	35.3	2.57	39.4	7.39	0.0	1.5	0.0	10.01	1.6
SUM	4.5	0.71	17.8	19.54	137.8	10.01	160.1	30.26	0.0	6.2	0.1	38.89	6.3
AVG	1.1	0.18	4.5	4.88	34.4	2.50	40.0	7.57	0.0	1.6	0.0	9.72	1.6
YTD	1.1	0.18	4.5	4.88	34.4	2.50	40.0	7.57	0.0	1.6	0.0	9.72	1.6
09-01	10.0	0.54	8.2	5.23	31.1	1.76	49.3	7.52	0.6	1.4	0.0	12.58	2.0
09-02	7.4	0.22	8.9	3.62	35.9	1.60	52.2	5.43	0.0	2.5	0.0	14.70	2.5
09-03	6.2	0.14	12.1	3.93	30.4	1.27	48.6	5.34	0.0	2.5	0.0	16.22	2.5
09-04	16.8	0.42	12.3	4.74	36.1	1.59	65.2	6.75	1.7	0.6	0.0	12.92	2.3
SUM	40.4	1.32	41.4	17.52	133.4	6.21	215.2	25.05	2.3	7.1	0.0	56.42	9.4
AVG	10.1	0.33	10.4	4.38	33.4	1.55	53.8	6.26	0.6	1.8	0.0	14.10	2.3
YTD	10.1	0.33	10.4	4.38	33.4	1.55	53.8	6.26	0.6	1.8	0.0	14.10	2.3
10-01	1.1	0.12	6.6	5.21	7.4	1.01	15.1	6.34	0.0	1.0	0.0	6.07	1.0
10-02	1.2	0.19	4.9	5.01	5.0	0.87	11.1	6.08	0.0	1.0	0.0	6.14	1.0
10-03	3.3	0.24	7.3	4.91	6.5	1.05	17.0	6.20	0.0	1.0	0.0	6.34	1.0
10-04	0.4	0.06	8.6	5.10	5.3	0.99	14.3	6.15	0.0	1.0	0.0	6.17	1.0
SUM	6.0	0.61	27.4	20.23	24.1	3.93	57.5	24.77	0.0	4.1	0.0	24.72	4.1
AVG	1.5	0.15	6.9	5.06	6.0	0.98	14.4	6.19	0.0	1.0	0.0	6.18	1.0
YTD	1.5	0.15	6.9	5.06	6.0	0.98	14.4	6.19	0.0	1.0	0.0	6.18	1.0
11-01	2.5	0.19	5.5	5.30	20.4	1.42	28.4	6.91	0.0	2.0	0.0	6.20	2.0
11-02	1.8	0.16	7.6	5.33	17.0	1.33	26.4	6.81	0.0	2.0	0.0	6.53	2.0
11-03	2.3	0.13	6.8	5.67	15.1	1.08	24.2	6.87	0.0	1.6	0.0	6.18	1.6
11-04	2.7	0.20	6.3	5.58	17.9	1.18	27.0	6.96	0.0	2.0	0.0	5.83	2.0
SUM	9.4	0.68	26.2	21.88	70.4	5.01	106.0	27.56	0.0	7.6	0.0	24.74	7.6
AVG	2.4	0.17	6.6	5.47	17.6	1.25	26.5	6.89	0.0	1.9	0.0	6.18	1.9
YTD	2.4	0.17	6.6	5.47	17.6	1.25	26.5	6.89	0.0	1.9	0.0	6.18	1.9

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01-01	5.23	50.97	20.92	31.50	45.62	77.13	37.45	3236.28	0.00	8.64	0.19	9.88
01-02	3.75	51.10	23.08	32.31	45.62	77.93	62.02	2700.51	0.C0	8.43	0.20	10.40
01-03	4.11	50.58	24.67	33.74	45.62	79.36	200.39	3146.46	0.00	7.94	0.19	9.88
01-04	4.21	51.60	22.41	32.60	45.62	78.22	130.66	3125.08	0.C0	8.16	0.17	8.84
SUM	17.30	204.26	91.07	130.15	182.49	312.64	430.53	12208.33	0.00	33.18	0.75	39.00
AVG	4.32	51.C7	22.77	32.54	45.62	78.16				8.29	0.19	9.75
YTD	4.32	51.07	22.77	32.54	45.62	78.16				8.29	0.19	9.88
02-01	1.31	54.15	20.98	30.66	45.79	76.45	111.25	0.00	41.23	8.39	0.30	15.60
02-02	1.63	49.55	24.57	30.63	45.11	75.74	44.86	0.00	8.04	8.37	0.29	15.08
02-03	1.40	51.89	22.54	30.73	45.10	75.83	32.77	0.00	31.95	8.38	0.31	16.12
02-04	2.05	51.41	23.10	30.79	45.76	76.55	47.28	0.00	26.58	8.72	0.29	15.08
SUM	6.38	207.00	91.19	122.81	181.75	304.57	236.15	0.00	107.81	33.86	1.19	61.88
AVG	1.60	51.75	22.80	30.70	45.44	76.14				8.46	0.30	15.47
YTD	1.60	51.75	22.80	30.70	45.44	76.14				8.46	0.30	15.60
03-01	4.44	60.45	12.28	31.55	45.62	77.17	30.17	2948.96	0.00	14.08	0.36	18.72
03-02	4.64	58.92	13.63	31.56	45.62	77.19	26.69	2755.92	0.C0	13.41	0.38	19.76
03-03	4.82	58.76	13.70	31.66	45.62	77.28	136.54	3155.21	0.00	13.53	0.34	17.68
03-04	3.90	60.54	12.79	31.61	45.62	77.23	106.49	2757.35	0.C0	12.92	0.42	21.84
SUM	17.81	238.66	52.41	126.38	182.49	308.87	299.90	11617.43	0.00	53.94	1.50	78.00
AVG	4.45	59.66	13.10	31.60	45.62	77.22				13.48	0.37	19.50
YTD	4.45	59.66	13.10	31.60	45.62	77.22				13.48	0.37	19.24

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04-01	5.01	81.83	33.53	30.91	89.47	120.37	88.57	1885.78	0.00	9.11	0.23	11.96
04-02	4.45	84.88	30.19	30.28	89.25	119.53	144.86	3674.53	0.C0	10.18	0.23	11.96
04-03	4.99	82.27	32.67	30.68	89.25	119.93	123.71	2323.38	0.00	9.52	0.23	11.96
04-04	5.03	79.95	35.05	30.78	89.25	120.03	153.28	3839.63	0.C0	9.33	0.23	11.96
SUM	19.49	328.93	131.43	122.64	357.21	479.85	510.43	11723.33	0.00	38.15	0.92	47.84
AVG	4.87	82.23	32.86	30.66	89.30	119.96				9.54	0.23	11.96
YTD	4.87	82.23	32.86	30.66	89.30	119.96				9.54	0.23	11.96
05-01	5.27	85.82	32.87	31.49	92.46	123.95	318.20	0.00	293.10	9.07	0.22	11.44
05-02	4.94	89.37	30.64	31.85	93.11	124.96	174.81	0.00	375.01	8.36	0.19	9.88
05-03	4.41	92.13	32.52	31.54	97.52	129.06	128.49	0.00	465.01	8.75	0.23	11.96
05-04	5.64	85.64	35.89	31.85	95.31	127.17	180.75	0.00	358.94	8.70	0.22	11.44
SUM	20.26	352.96	131.92	126.74	378.40	505.14	802.26	0.00	1492.06	34.88	0.86	44.72
AVG	5.07	88.24	32.98	31.68	94.60	126.28				8.72	0.21	11.18
YTD	5.07	88.24	32.98	31.68	94.60	126.28				8.72	0.22	11.44
06-01	3.95	107.03	37.55	43.70	104.84	148.54	302.43	5714.23	0.00	22.12	0.54	28.08
06-02	3.93	110.53	31.76	43.66	102.56	146.22	205.19	5662.88	0.00	21.40	0.53	27.56
06-03	4.53	104.41	37.72	43.74	102.92	146.66	169.24	5246.53	0.00	20.64	0.53	27.56
06-04	4.93	106.57	35.75	43.66	103.59	147.25	251.97	5083.75	0.00	20.43	0.45	23.40
SUM	17.34	428.55	142.78	174.77	413.91	588.68	928.83	21707.39	0.C0	84.60	2.05	106.60
AVG	4.34	107.14	35.70	43.69	103.48	147.17				21.15	0.51	26.65
YTD	4.34	107.14	35.70	43.69	103.48	147.17				21.15	0.51	26.52
07-01	7.61	124.57	29.39	28.69	132.87	161.56	39.21	12756.37	0.C0	13.92	0.41	21.32
07-02	3.58	126.89	31.03	28.63	132.87	161.50	63.94	9938.68	0.00	12.26	0.38	19.76
07-03	10.01	113.28	38.45	28.87	132.87	161.74	65.11	10459.37	0.00	13.26	0.39	20.28
07-04	3.81	125.34	32.32	28.60	132.87	161.47	90.63	13726.05	0.C0	11.84	0.40	20.80
SUM	25.01	490.08	131.19	114.79	531.49	646.27	258.88	46880.46	0.00	51.28	1.58	82.16
AVG	6.25	122.52	32.80	28.70	132.87	161.57				12.82	0.39	20.54
YTD	6.25	122.52	32.80	28.70	132.87	161.57				12.82	0.39	20.28

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08-01	3.66	108.98	57.43	32.48	137.58	170.06	292.61	0.00	1168.54	15.94	0.48	24.96
08-02	2.14	104.54	53.83	24.37	136.14	160.51	328.96	0.00	747.34	17.31	0.69	35.88
08-03	6.10	109.46	49.84	32.03	133.37	165.40	393.57	0.00	113.76	18.50	0.50	26.00
08-04	3.81	105.58	58.44	31.83	136.01	167.83	450.07	0.00	774.69	16.76	0.53	27.56
SUM	15.70	428.57	219.54	120.71	543.09	663.80	1465.20	0.00	2804.32	68.52	2.20	114.40
AVG	3.93	107.14	54.88	30.18	135.77	165.95				17.13	0.55	28.60
YTD	3.93	107.14	54.88	30.18	135.77	165.95				17.13	0.55	28.60
09-01	14.66	142.27	47.87	38.71	166.09	204.80	89.76	8539.42	0.00	16.28	0.48	24.96
09-02	8.14	136.55	60.40	38.74	166.35	205.09	121.96	15583.10	0.00	13.95	0.47	24.44
09-03	5.31	150.54	48.51	36.96	167.40	204.36	145.93	15999.46	0.00	12.60	0.42	21.84
09-04	12.86	143.95	48.11	38.30	166.62	204.92	203.55	10676.74	0.00	15.86	0.55	28.60
SUM	40.96	573.31	204.90	152.71	666.46	819.17	561.21	50798.71	0.00	58.70	1.92	99.84
AVG	10.24	143.33	51.23	38.18	166.62	204.79				14.67	0.48	24.96
YTD	10.24	143.33	51.23	38.18	166.62	204.79				14.67	0.48	24.96
10-01	2.20	97.51	18.94	28.73	89.92	118.65	33.33	4632.72	0.00	19.55	0.32	16.64
10-02	3.77	97.46	16.99	28.64	89.58	118.23	9.79	5472.80	0.00	19.26	0.32	16.64
10-03	4.59	93.53	20.05	28.76	89.42	118.18	19.42	4869.00	0.00	18.64	0.33	17.16
10-04	1.19	100.43	19.52	28.83	92.31	121.14	18.72	5265.68	0.00	19.62	0.32	16.64
SUM	11.76	388.93	75.50	114.96	361.24	476.19	81.27	20240.21	0.00	77.07	1.29	67.08
AVG	2.94	97.23	18.88	28.74	90.31	119.05				19.27	0.32	16.77
YTD	2.94	97.23	18.88	28.74	90.31	119.05				19.27	0.32	16.64
11-01	3.14	86.08	23.10	22.83	89.48	112.31	100.67	0.00	12.76	18.12	0.42	21.84
11-02	2.63	87.70	21.80	22.33	89.81	112.13	84.78	0.00	0.00	17.17	0.47	24.44
11-03	2.20	97.33	18.53	28.53	89.52	118.05	64.76	0.00	22.33	19.11	0.49	25.48
11-04	3.17	89.90	19.08	22.25	89.91	112.16	93.56	0.00	27.76	19.24	0.48	24.96
SUM	11.13	361.01	82.51	95.94	358.71	454.65	343.78	0.00	62.85	73.63	1.86	96.72
AVG	2.78	90.25	20.63	23.98	89.68	113.66				18.41	0.46	24.18
YTD	2.78	90.25	20.63	23.98	89.68	113.66				18.41	0.47	24.44

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01-01	392.	1962.	45.5	45.5	0.58	1.27	104.1	2.4	104.1	2.4	161.30
01-02	375.	1874.	49.3	49.3	0.65	1.32	92.3	2.3	92.3	2.3	150.68
01-03	415.	2077.	48.1	48.1	0.53	1.10	113.1	2.7	113.1	2.7	170.27
01-04	459.	2294.	41.8	41.8	0.50	1.20	119.5	2.5	119.5	2.5	173.64
SUM	1641.	8207.	184.7	184.7	2.26	4.89	429.1	9.9	429.1	9.9	655.90
AVG	410.	2052.	46.2	46.2	0.56	1.22	107.3	2.5	107.3	2.5	163.97
YTD	410.	2052.	46.2	46.2	0.56	1.22	107.3	2.5	107.3	2.5	163.97
02-01	249.	1247.	73.1	73.1	1.15	1.57	52.4	1.9	52.4	1.9	134.31
02-02	259.	1295.	69.9	69.9	1.03	1.47	58.3	2.0	58.3	2.0	135.00
02-03	244.	1222.	74.0	74.0	1.10	1.49	54.5	2.0	54.5	2.0	134.98
02-04	261.	1307.	67.1	67.1	1.04	1.56	57.5	1.9	57.5	1.9	127.03
SUM	1014.	5072.	284.1	284.1	4.32	6.08	222.7	7.9	222.7	7.9	531.33
AVG	254.	1268.	71.0	71.0	1.08	1.52	55.7	2.0	55.7	2.0	132.83
YTD	254.	1268.	71.0	71.0	1.08	1.52	55.7	2.0	55.7	2.0	132.83
03-01	424.	1272.	25.9	51.7	0.70	2.70	85.9	1.1	85.9	1.1	125.65
03-02	402.	1207.	28.6	57.2	0.73	2.56	82.0	1.2	82.0	1.2	122.34
03-03	448.	1344.	25.5	51.0	0.63	2.46	95.6	1.2	95.6	1.2	134.79
03-04	366.	1099.	32.6	65.3	0.82	2.51	73.2	1.2	73.2	1.2	121.50
SUM	1641.	4922.	112.6	225.2	2.88	10.23	336.7	4.7	336.7	4.7	504.29
AVG	410.	1231.	28.2	56.3	0.72	2.56	84.2	1.2	84.2	1.2	126.07
YTD	410.	1231.	28.2	56.3	0.72	2.56	84.2	1.2	84.2	1.2	126.07

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04-01	510.	2549.	51.8	51.8	0.62	1.19	97.3	2.5	96.8	2.5	159.04
04-02	510.	2548.	46.1	46.1	0.55	1.19	109.9	2.5	109.9	2.5	167.55
04-03	514.	2572.	49.0	49.0	0.59	1.20	102.2	2.5	102.2	2.5	160.22
04-04	515.	2575.	50.0	50.0	0.50	1.01	118.9	3.0	118.9	3.0	178.68
SUM	2049.	10244.	196.8	196.8	2.25	4.58	428.3	10.5	427.8	10.5	665.49
AVG	512.	2561.	49.2	49.2	0.56	1.15	107.1	2.6	107.0	2.6	166.37
YTD	512.	2561.	49.2	49.2	0.56	1.15	107.1	2.6	107.0	2.6	166.37
05-01	549.	2744.	49.8	49.8	0.48	0.96	125.6	3.1	121.8	3.0	188.10
05-02	633.	3163.	47.2	47.2	0.45	0.95	133.1	3.1	128.4	3.0	194.16
05-03	559.	2796.	52.7	52.7	0.54	1.02	111.1	2.9	98.7	2.6	176.74
05-04	561.	2805.	52.1	52.1	0.49	0.93	123.4	3.2	113.2	3.0	188.32
SUM	2302.	11508.	201.9	201.9	1.95	3.87	493.2	12.4	462.1	11.6	747.32
AVG	575.	2877.	50.5	50.5	0.49	0.97	123.3	3.1	115.5	2.9	186.83
YTD	575.	2877.	50.5	50.5	0.49	0.97	123.3	3.1	115.5	2.9	186.83
06-01	544.	1088.	24.7	49.4	0.45	1.81	134.0	1.7	125.7	1.6	179.69
06-02	549.	1098.	24.9	49.8	0.47	1.87	129.0	1.6	126.4	1.6	175.87
06-03	549.	1098.	25.9	51.8	0.44	1.70	136.7	1.8	133.0	1.7	183.27
06-04	653.	1306.	22.1	44.1	0.39	1.77	153.8	1.7	147.7	1.6	194.22
SUM	2295.	4589.	97.5	195.1	1.74	7.14	553.5	6.7	532.8	6.5	733.05
AVG	574.	1147.	24.4	48.8	0.44	1.79	138.4	1.7	133.2	1.6	183.26
YTD	574.	1147.	24.4	48.8	0.44	1.79	138.4	1.7	133.2	1.6	183.26
07-01	391.	1956.	59.4	59.4	0.58	0.98	103.6	3.1	51.8	1.5	174.32
07-02	424.	2120.	62.1	62.1	0.62	1.00	96.4	3.0	48.2	1.5	167.19
07-03	408.	2042.	59.7	59.7	0.56	0.94	107.2	3.2	53.6	1.6	178.39
07-04	403.	2017.	67.6	67.6	0.54	0.80	111.0	3.8	55.5	1.9	189.19
SUM	1627.	8136.	248.8	248.8	2.30	3.71	418.2	13.0	209.1	6.5	709.08
AVG	407.	2034.	62.2	62.2	0.58	0.93	104.5	3.3	52.3	1.6	177.27
YTD	407.	2034.	62.2	62.2	0.58	0.93	104.5	3.3	52.3	1.6	177.27

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
COLLECTION CREW PRODUCTIVITY REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	HOMES SERVED PER DAY	HOMES SERVED PER WEEK	AVERAGE WEIGHT COLLECTED PER HOME PER COLLECTION (LBS)	AVERAGE WEIGHT COLLECTED PER HOME PER WEEK (LBS)	COLLECT TIME PER HOME PER COLLECTION (MINUTES)	COLLECT TIME PER 100 LBS. (MINS)	CREW PRODUCTIVITY HOMES SERVED PER COLLECTION HOUR	CREW PRODUCTIVITY WEIGHT HANDLED PER COLLECTION HOUR (TONS)	COLLECTOR PRODUCTIVITY HOMES SERVED PER COLLECTOR PER COLLECTION HOUR	COLLECTOR PRODUCTIVITY WEIGHT HANDLED PER COLLECTOR PER COLLECTION HOUR (TONS)	INDEX OF PRODUCTIVITY
08-01	349.	1746.	61.1	61.1	0.87	1.43	68.7	2.1	34.4	1.1	132.41
08-02	229.	1147.	80.9	80.9	1.29	1.59	46.6	1.9	23.3	0.9	135.43
08-03	331.	1653.	54.1	54.1	0.89	1.64	67.7	1.8	33.9	0.9	125.86
08-04	316.	1580.	63.4	63.4	0.88	1.39	67.9	2.2	34.0	1.1	134.48
SUM	1225.	6125.	259.4	259.4	3.93	6.05	250.9	8.0	125.6	4.0	528.18
AVG	306.	1531.	64.9	64.9	0.98	1.51	62.7	2.0	31.4	1.0	132.04
YTD	306.	1531.	64.9	64.9	0.98	1.51	62.7	2.0	31.4	1.0	132.04
09-01	847.	1694.	29.7	59.4	0.37	1.25	162.0	2.4	81.0	1.2	199.92
09-02	862.	1724.	34.1	68.2	0.25	0.74	238.4	4.1	118.9	2.0	281.33
09-03	962.	1925.	33.7	67.4	0.25	0.73	244.9	4.1	121.0	2.0	290.68
09-04	744.	1487.	34.7	69.5	0.38	1.10	156.7	2.7	78.0	1.4	203.73
SUM	3415.	6830.	132.3	264.5	1.25	3.81	802.0	13.3	398.9	6.6	975.66
AVG	854.	1707.	33.1	66.1	0.31	0.95	200.5	3.3	99.7	1.7	243.92
YTD	854.	1707.	33.1	66.1	0.31	0.95	200.5	3.3	99.7	1.7	243.91
10-01	368.	1838.	33.0	33.0	0.85	2.57	70.6	1.2	69.5	1.1	110.24
10-02	365.	1827.	33.6	33.6	0.82	2.45	73.0	1.2	72.4	1.2	111.46
10-03	357.	1786.	35.5	35.5	0.82	2.32	72.8	1.3	72.5	1.3	115.51
10-04	367.	1837.	33.6	33.6	0.83	2.48	72.0	1.2	67.3	1.1	114.27
SUM	1458.	7288.	135.7	135.7	3.33	9.82	288.3	4.9	281.7	4.8	451.48
AVG	364.	1822.	33.9	33.9	0.83	2.46	72.1	1.2	70.4	1.2	112.87
YTD	364.	1822.	33.9	33.9	0.83	2.46	72.1	1.2	70.4	1.2	112.87
11-01	266.	1330.	46.6	46.6	1.19	2.56	50.2	1.2	50.0	1.2	102.27
11-02	234.	1168.	55.9	55.9	1.37	2.45	43.8	1.2	43.3	1.2	107.32
11-03	240.	1198.	51.6	51.6	1.42	2.75	42.3	1.1	42.1	1.1	100.70
11-04	231.	1155.	50.5	50.5	1.45	2.87	41.4	1.0	40.9	1.0	98.20
SUM	970.	4852.	204.5	204.5	5.43	10.64	177.7	4.5	176.3	4.5	408.48
AVG	243.	1213.	51.1	51.1	1.36	2.66	44.4	1.1	44.1	1.1	102.12
YTD	243.	1213.	51.1	51.1	1.36	2.66	44.4	1.1	44.1	1.1	102.12

DATA ACQUISITION AND ANALYSIS PROGRAM
DAAP COMPUTER PROGRAM OUTPUT
COLLECTION SYSTEM EFFICIENCY REPORT

PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	RATIO WORK TIME TO STD. TIME	RATIO COLLECTION TIME TO TIME WORKED	RATIO EQUIP COST TO MANPOWER COST	RATIO MANPOWER COST TO TOTAL COST	COLLECTION RELATED COSTS: COLLECTION COST PER HOME SERVED	COLLECTION RELATED COSTS: COLLECTION COST PER TON COLLECTED	WEIGHT HANDLED PER COLLECTOR PER DAY (TONS)	AVERAGE WEIGHT PER LOAD (TONS): FIRST LOAD	AVERAGE WEIGHT PER LOAD (TONS): ALL OTHERS	WEIGHT PER CU. YARD FIRST LOAD (POUNDS)	INDEX OF ROUTE EFFICIENCY
01-01	0.72	0.66	0.69	0.59	0.13	5.71	8.93	6.08	3.38	486.6	316.44
01-02	0.78	0.65	0.71	0.59	0.14	5.53	9.24	6.65	3.66	531.9	294.86
01-03	0.73	0.63	0.74	0.57	0.12	5.06	9.99	6.73	4.49	538.4	336.62
01-04	0.74	0.65	0.71	0.58	0.11	5.38	9.59	6.26	4.25	500.9	336.50
SUM	2.96	2.59	2.85	2.34	0.50	21.69	37.74	25.72	15.78	2057.8	1284.41
AVG	0.74	0.65	0.71	0.58	0.13	5.42	9.44	6.43	3.95	514.5	321.10
YTD	0.74	0.65	0.71	0.58	0.13	5.42	9.44	6.43	3.95	514.5	321.10
02-01	0.85	0.70	0.67	0.60	0.22	5.94	9.12	6.29	5.21	503.0	248.03
02-02	0.85	0.65	0.68	0.60	0.19	5.47	9.05	5.90	4.60	472.4	272.47
02-03	0.82	0.68	0.68	0.59	0.21	5.73	9.05	5.85	5.12	467.7	260.14
02-04	0.85	0.67	0.67	0.60	0.20	5.86	8.78	5.67	4.68	453.0	247.11
SUM	3.37	2.70	2.70	2.39	0.82	23.01	35.99	23.72	19.61	1896.1	1027.74
AVG	0.84	0.68	0.68	0.60	0.20	5.75	9.00	5.93	4.90	474.0	256.94
YTD	1.00	0.68	0.68	0.60	0.20	5.75	9.00	5.93	4.90	474.0	256.94
03-01	0.79	0.78	0.69	0.59	0.14	11.03	5.48	5.47	4.06	331.9	207.86
03-02	0.81	0.76	0.69	0.59	0.15	10.24	5.76	5.71	3.09	346.7	207.65
03-03	0.78	0.75	0.69	0.59	0.13	10.29	5.71	5.68	3.62	344.5	229.41
03-04	0.80	0.78	0.69	0.59	0.17	10.13	5.98	5.88	2.88	356.5	200.71
SUM	3.18	3.07	2.77	2.36	0.59	41.68	22.93	22.74	13.65	1379.5	845.64
AVG	0.79	0.77	0.69	0.59	0.15	10.42	5.73	5.69	3.41	344.9	211.41
YTD	0.79	0.77	0.69	0.59	0.15	10.42	5.73	5.69	3.41	344.9	211.41

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ROUTE NUMBER	RATIO WORK TIME TO STD. TIME	RATIO COLLECTION TIME TO TIME WORKED	RATIO EQUIP COST TO MANPOWER COST	RATIO MANPOWER COST TO TOTAL COST	COLLECTION RELATED COSTS: COLLECTION COST PER HOME SERVED	COLLECTION RELATED COSTS: COLLECTION COST PER TON COLLECTED	WEIGHT HANDLED PER COLLECTOR PER DAY (TONS)	AVERAGE WEIGHT PER LOAD (TONS): FIRST LOAD	AVERAGE WEIGHT PER LOAD (TONS): ALL OTHERS	WEIGHT PER CU. YARD FIRST LOAD (POUNDS)	INDEX OF ROUTE EFFICIENCY
04-01	0.97	0.67	0.35	0.74	0.16	6.20	13.14	5.99	4.96	599.0	194.35
04-02	0.83	0.70	0.34	0.75	0.17	7.23	11.74	5.71	4.73	572.1	197.39
04-03	0.93	0.68	0.34	0.74	0.16	6.53	12.60	5.77	4.84	577.2	194.76
04-04	0.83	0.65	0.34	0.74	0.16	6.21	12.87	6.22	5.14	622.4	223.50
SUM	3.56	2.70	1.37	2.98	0.64	26.17	50.34	23.69	19.66	2370.7	809.99
AVG	0.89	0.68	0.34	0.74	0.16	6.54	12.59	5.92	4.92	592.7	202.50
YTD	0.89	0.68	0.34	0.74	0.16	6.54	12.59	5.92	4.92	592.7	202.50
05-01	0.86	0.64	0.34	0.75	0.16	6.28	13.26	8.13	5.80	687.6	219.19
05-02	0.89	0.67	0.34	0.75	0.14	5.98	14.42	8.98	6.00	738.5	217.26
05-03	0.90	0.70	0.32	0.76	0.16	6.25	13.10	9.67	5.68	776.7	191.84
05-04	0.87	0.65	0.33	0.75	0.15	5.86	13.41	9.27	5.91	774.3	219.89
SUM	3.52	2.66	1.34	3.00	0.62	24.37	54.18	36.06	23.38	2977.1	848.17
AVG	0.88	0.66	0.34	0.75	0.15	6.09	13.55	9.02	5.85	744.3	212.04
YTD	1.00	0.66	0.34	0.75	0.15	6.09	13.55	9.02	5.85	744.3	212.04
06-01	0.73	0.70	0.42	0.71	0.20	15.94	6.30	1.57	1.58	392.9	167.88
06-02	0.72	0.74	0.43	0.70	0.20	16.18	6.70	1.57	1.59	392.7	159.11
06-03	0.72	0.70	0.43	0.70	0.19	14.70	6.91	1.56	1.57	389.5	175.52
06-04	0.75	0.71	0.42	0.70	0.16	14.79	6.92	1.56	1.59	389.3	182.25
SUM	2.92	2.84	1.69	2.81	0.75	61.60	26.83	6.26	6.33	1564.5	684.76
AVG	0.73	0.71	0.42	0.70	0.19	15.40	6.71	1.56	1.58	391.1	171.19
YTD	0.73	0.71	0.42	0.70	0.19	15.40	6.71	1.56	1.58	391.1	171.19
07-01	0.62	0.76	0.22	0.82	0.32	10.73	5.80	6.97	4.66	700.5	139.94
07-02	0.71	0.78	0.22	0.82	0.30	9.64	6.58	6.44	5.11	642.1	131.76
07-03	0.69	0.69	0.22	0.82	0.28	9.28	6.10	6.66	4.84	666.5	157.48
07-04	0.59	0.77	0.22	0.82	0.31	9.19	6.82	6.38	4.94	638.5	150.93
SUM	2.60	3.00	0.86	3.29	1.21	38.84	25.31	26.45	19.54	2647.6	580.11
AVG	0.65	0.75	0.22	0.82	0.30	9.71	6.33	6.61	4.89	661.9	145.03
YTD	0.65	0.75	0.22	0.82	0.30	9.71	6.33	6.61	4.89	661.9	145.03

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PERIOD FOR WHICH DATA APPLIES JANUARY-DECEMBER

ROUTE NUMBER	RATIO WORK TIME TO STD. TIME	RATIO COLLECTION TIME TO TIME WORKED	RATIO EQUIP COST TO MANPOWER COST	RATIO MANPOWER COST TO TOTAL COST	COLLECTION RELATED COSTS: COLLECTION COST PER HOME SERVED	COLLECTION RELATED COSTS: COLLECTION COST PER TON COLLECTED	WEIGHT HANDLED PER COLLECTOR PER DAY (TONS)	AVERAGE WEIGHT PER LOAD (TONS): FIRST LOAD	AVERAGE WEIGHT PER LOAD (TONS): ALL OTHERS	WEIGHT PER CU. YARD FIRST LOAD (POUNDS)	INDEX OF ROUTE EFFICIENCY
08-01	1.02	0.62	0.24	0.81	0.31	10.22	5.34	6.27	6.18	511.7	121.50
08-02	0.97	0.63	0.18	0.85	0.46	11.27	4.64	5.47	5.41	591.9	129.54
08-03	0.96	0.64	0.24	0.81	0.33	12.24	4.47	5.97	9.27	486.4	114.98
08-04	0.97	0.60	0.23	0.81	0.33	10.55	5.02	6.19	6.49	508.9	127.37
SUM	3.92	2.49	0.89	3.27	1.43	44.28	19.47	23.90	27.36	2098.9	493.39
AVG	0.98	0.62	0.22	0.82	0.36	11.07	4.87	5.98	6.84	524.7	123.35
YTD	1.00	0.62	0.22	0.82	0.36	11.07	4.87	5.98	6.84	524.7	123.35
09-01	0.76	0.69	0.23	0.81	0.17	11.31	6.29	7.05	5.50	704.3	140.52
09-02	0.55	0.66	0.23	0.81	0.16	9.29	7.33	6.57	5.30	657.3	206.03
09-03	0.54	0.73	0.22	0.82	0.16	9.28	8.02	7.32	5.75	731.8	193.09
09-04	0.69	0.69	0.23	0.81	0.19	11.14	6.43	6.77	4.83	677.7	141.53
SUM	2.54	2.76	0.92	3.25	0.68	41.02	28.06	27.71	21.38	2771.0	681.17
AVG	0.63	0.69	0.23	0.81	0.17	10.26	7.02	6.93	5.35	692.8	170.29
YTD	0.63	0.69	0.23	0.81	0.17	10.26	7.02	6.93	5.35	692.8	170.29
10-01	0.80	0.81	0.32	0.76	0.27	16.07	5.98	6.01	3.27	600.5	113.05
10-02	0.76	0.82	0.32	0.76	0.27	15.88	6.09	6.12	1.69	611.7	114.36
10-03	0.79	0.78	0.32	0.76	0.26	14.75	6.32	6.29	3.09	629.3	123.50
10-04	0.78	0.82	0.31	0.76	0.27	16.27	5.77	6.14	1.46	614.0	113.78
SUM	3.13	3.23	1.27	3.03	1.07	62.97	24.15	24.55	9.52	2455.5	464.70
AVG	0.78	0.81	0.32	0.76	0.27	15.74	6.04	6.14	2.38	613.9	116.17
YTD	0.78	0.81	0.32	0.76	0.27	15.74	6.04	6.14	2.38	613.9	116.17
11-01	0.87	0.76	0.26	0.80	0.32	13.89	6.17	3.76	2.42	554.2	118.81
11-02	0.86	0.78	0.25	0.80	0.38	13.43	6.45	3.62	2.93	549.9	122.37
11-03	0.86	0.82	0.32	0.76	0.41	15.75	6.15	4.44	2.76	458.4	103.46
11-04	0.88	0.79	0.25	0.80	0.39	15.42	5.76	3.61	2.30	525.7	109.22
SUM	3.48	3.15	1.07	3.16	1.49	58.49	24.53	15.43	10.41	2088.2	453.87
AVG	0.87	0.79	0.27	0.79	0.37	14.62	6.13	3.86	2.60	522.0	113.47
YTD	0.96	0.79	0.27	0.79	0.37	14.62	6.13	3.86	2.60	522.0	113.47

Appendix 3
SELECTED DATA

YEARLY AVERAGES BY SYSTEM

System Number	Tons/Day	Homes/Day	Coll Miles/Day	1-Way Items/Home*	2-Way Items/Home*	Coll Hrs/Day	Trans Hrs/Day	Loads/Day	Lbs/Home/Coll	Min/Home/Coll	Homes/Coll Hr	Coll Cost/Home/Wk	Cost/Home/Wk	Cost/Ton
1	9.44	410	10.5	48	52	3.83	1.71	1.8	46.2	.56	107.3	.13	.19	8.29
2	9.00	254	6.1	47	53	4.56	2.01	1.6	71.0	1.08	55.7	.20	.30	8.46
3	5.73	410	13.7	47	53	4.88	1.07	1.0	28.2	.72	84.2	.29	.38	17.13
4	12.62	512	10.1	72	28	4.82	1.92	2.4	49.3	.56	107.0	.16	.23	9.53
5	14.49	575	13.1	94	6	4.67	1.75	1.9	50.5	.49	123.3	.15	.22	8.72
6	6.96	574	20.5	39	61	4.14	1.38	4.4	24.4	.44	138.4	.37	.51	21.15
7	12.65	407	10.5	72	28	3.91	1.05	2.2	62.2	.58	104.5	.30	.39	12.82
8	9.72	306	4.5	53	47	4.88	2.50	1.6	64.9	.98	62.7	.36	.55	17.13
9	14.10	854	10.4	59	41	4.38	1.55	2.3	33.1	.31	200.5	.34	.48	14.67
10	6.18	364	6.9	4	96	5.06	.98	1.0	33.9	.83	72.1	.27	.32	19.26
11	6.18	243	6.6	45	55	5.47	1.25	1.9	51.1	1.36	44.4	.37	.47	18.41

*From Time Motion Studies

Appendix 4

GENERATION RATE IN POUNDS PER HOME PER WEEK BY SYSTEM

SYSTEM NUMBER	MONTH											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	36.3	37.0	43.2	46.5	55.7	52.3	52.3	55.2	47.6	44.1	44.9	38.8
2	63.2	73.0	74.7	77.2	80.9	78.0	80.2	66.1	69.4	66.9	68.0	63.8
3	50.6	54.9	63.2	65.4	62.7	57.4	61.4	56.0	51.9	50.1	49.9	50.2
4	38.8	36.1	45.1	54.0	61.9	61.3	----	----	52.2	53.3	50.3	37.9
5	46.5	44.4	52.9	55.4	----	60.6	47.1	48.5	----	55.8	52.6	46.6
6	43.5	49.4	46.4	50.5	48.1	48.7	55.4	48.2	49.3	46.4	46.0	53.6
7	50.1	46.4	56.7	63.6	70.4	64.0	70.6	62.2	59.8	59.6	85.8	56.3
8	57.9	48.8	59.6	68.8	76.0	76.9	68.4	71.0	67.8	68.3	63.0	50.5
9	65.0	60.6	63.8	63.2	65.2	68.0	76.9	66.4	66.8	64.7	63.8	68.6
10	32.9	34.3	34.0	34.2	34.9	33.3	33.7	34.4	34.1	33.2	35.1	33.4
11	42.2	37.4	44.9	52.9	63.7	65.3	55.9	54.6	55.8	53.8	51.3	40.3

Appendix 5

COLLECTION RATE IN TONS PER CREW PER DAY BY SYSTEM

SYSTEM NUMBER	MONTHS												AVERAGE TONS PER DAY PER YEAR TOTALS
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	
1	7.35	7.49	8.99	9.43	11.33	10.76	10.73	11.30	9.78	8.93	9.25	7.88	9.44
2	7.87	8.98	9.25	9.41	10.07	9.51	10.32	9.93	8.50	8.38	8.40	8.06	9.00
3	4.99	5.33	6.34	6.72	6.43	5.91	6.41	5.75	5.33	5.15	5.09	5.11	5.73
4	9.72	9.09	11.42	13.92	16.25	15.99	-----	-----	13.50	13.60	13.02	9.55	12.62
5	13.15	12.47	16.15	15.55	-----	17.41	12.69	15.27	-----	15.03	15.27	13.23	14.49
6	6.18	7.06	6.62	7.25	6.83	6.90	7.91	6.96	7.09	6.53	6.55	7.71	6.96
7	10.40	9.59	11.64	13.22	14.55	13.08	12.81	12.49	12.19	12.08	17.75	11.63	12.65
8	8.70	7.34	8.94	10.48	11.32	11.44	10.33	10.57	10.17	10.26	9.53	7.48	9.72
9	13.86	12.92	13.59	13.48	13.90	14.49	16.46	14.15	14.24	13.82	13.61	14.62	14.10
10	5.96	6.19	6.08	6.17	6.28	6.02	6.09	6.47	6.35	6.21	6.33	6.01	6.18
11	5.11	4.58	5.50	6.44	7.83	7.71	6.81	6.63	6.81	6.21	6.17	4.84	6.18

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