City of Kissimmee Solid Waste Collection System

Larry W. Walter
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CITY OF KISSIMMEE
SOLID WASTE COLLECTION SYSTEM

BY

LARRY W. WALTER
B.S.E., Florida Technological University, 1974

RESEARCH REPORT

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Engineering
in the Graduate Studies Program of the College of Engineering
at the University of Central Florida, Orlando, Florida

Orlando, Florida
1980
Every year the average American throws out more and more garbage. In the next five years, it is projected to increase 20-25 percent. This garbage, termed solid waste, is stored, collected, hauled and disposed of in some manner. The objective of this report has been to evaluate the City of Kissimmee's one-man residential solid waste collection system.

The study results indicated this generation rate of the City to be 3.28 pounds per person per day, or 29.1 pounds per home per pickup.

The productivity equations developed from the City data did not compare well with the results of EPA.

Also indicated in this report is the effect of the percent pickup factor in a solid waste collection system and its effect on system productivity.

Dr. Martin P. Wanielista, PE
Research Report Coordinator
ACKNOWLEDGMENT

I wish to thank everyone who contributed and made this report possible. I would also like to add my special thanks to the following: Kissimmee Mayor Ken Smith, Kissimmee City Manager Ken Hammons, and the Kissimmee City Commissioners, Ken Maher, Allen Smith, Dr. George Gant, and Bruce Van Meter for their continued support. Mr. George Mann, Jr., Director of Public Works and Engineering in Kissimmee for his constructive suggestions and constant support throughout the study period. Mr. Lynn Hauman and Mrs. Lucille Crosby for their excellence in drafting of the tables and figures contained in this report. Mr. Bill Beville, Kissimmee Public Works Superintendent, Mr. Buck Davis, Kissimmee Sanitation Superintendent, and Gary Kuhns, Engineering summer student for their repeated effort in helping to collect the study data. My faculty advisor, Dr. Martin P. Wanielista for his unceasing support and constructive suggestions.

My very special thanks to my wife Lausanne for her patience, support and all the time she spent typing this report.
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CHAPTER I

INTRODUCTION

Every year the average American throws out more and more garbage. In the next five years, it is projected to increase 20-25 percent. This garbage, termed solid waste, is stored, collected, hauled and disposed of in some manner. With increasing solid waste production, along with ever increasing inflation, the cost of solid waste handling is becoming phenomenal.

With the introduction of Proposition 13 in California, and other similar tax reduction mandates, such as TRIM (TRuth in Millage) in Florida, cities and counties come under an additional hardship to keep costs down. Although solid waste collection is usually a self-supporting service to the public, which avoids some of the problems caused by tax reduction, this cost should be at a minimum to the taxpayer.

The means to survive this situation, and to maintain the same level of service, is to operate a productive and cost effective system. The means to accomplish this is to define the factors that influence the collection system. The system with 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.
Objective

The objective of this report is to evaluate the City of Kissimmee's residential solid waste collection system. This report will provide system operation data, in terms of system productivity that may be compared to existing study information. This comparison will provide information that can be used to assess the adequacy of the present collection system, and provide design information that can be used to optimize the day-to-day collection operation, and to evaluate the future needs of the community.
CHAPTER II

SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

The City of Kissimmee, Florida faced with the problem of inefficient solid waste collection, coupled with rising operating costs to the public and centered in one of the fastest growing areas in the country, embarked on a study program to analyze and produce a solid waste collection system that is not only efficient, but cost effective to the public.

The major emphasis of this report has been to furnish information that can be used to design and evaluate collection routes. Items considered for study were generation rate, route break down in times, tons hauled, along with time per location, homes collected per collection hour, and tons collected per collection hour.

Study results indicated that 82 percent of the total work day was spent collecting solid waste, while 12 percent of the total work day was spent traveling or hauling to and from the disposal site. Likewise, 3 percent of the time was spent at the disposal site, while 3 percent of the time was spent as off-route time.

In comparing the city's study results to those study results of the Environmental Protection Agency, there is an indication that the city has a less productive system in terms of time per location, homes collected per collection hour, and tons collected
per collection hour. But this author feels there is some discrepancy in the EPA's data formulation, indicating higher productivity than may actually exist.

Since the main emphasis of this report is to detail the constraints effecting route performance and evaluation, the cost to operate this system has not been included as part of this report.

**Recommendations**

It is recommended that the city continue their study on solid waste collection. This will allow the city to evaluate any additional needs in the system as they occur.

Costs also should be included into the system analysis. This will give the city a cost comparison to other cities and to private haulers.

Further work should be devoted to the development of computer programs for the use of evaluating system efficiency and cost effectiveness for the City of Kissimmee.

**Conclusions**

The following conclusions were derived from the analysis of this study:

1. Generation Rate equaled 3.28 pounds per person per day, or 29.1 pounds per home per pickup.

2. Collection time averages 82 percent of the total work day.

3. Haul or travel time averages 12 percent of the total work day.

4. Site and off-route time averages 3 percent each of this total work day.
5. Percent pickup averaged 67.6 percent with a standard deviation of 7.6 percent.

6. Tons picked up per day averaged 7.28 tons with a standard deviation of 1.77 tons.

7. Time per location averaged 0.81 minutes with a standard deviation of 0.12 minutes.

8. Homes collected per collection hour averaged 76 homes, with a standard deviation of 12.1 homes. Homes serviced per collection hour averaged 112 homes, indicating the effect of the percent pickup factor.

9. Tons collected per collection hour averaged 1.18 tons, with a standard deviation of 0.28 tons.

The above information was formulated to develop productivity equations presented in more detail in the text. These productivities compared very well with the data collected and indicated that the three routes of the city are well balanced at this time. The information also indicated Route 2 as the potential heaviest route in the system and the need for continued monitoring of that route.

Although much information has been generated by this study, more is still needed to fill the lack of information in this area.
CHAPTER III

BACKGROUND

The City of Kissimmee solid waste collection history is probably not different from many other small communities. The city was incorporated in 1883. In the "Revised Ordinance of the Town of Kissimmee" in 1892, Section 71, the city had one of its first solid waste ordinances.

Quote: Sec. 71. No person shall deposit on any of the streets or sidewalks or lots within the business portion of the town, or on any public square, any sweepings of any stores, dwellings, offices, shops or booths, or any paper, hair, chips, bones, peelings, slops, straw, trash, rubbish, or wastings of any kind whatsoever; but he is hereby required to put any accumulations as specified in a box or suitable receptacle, and place the same out at the edge of the sidewalk in the street in front of the premises occupied by him, each and every morning by 8 o'clock A.M., at which house such accumulations shall be removed by scavenger carts; and any person violating the provisions of this section shall, upon conviction, be fined not exceeding $5 for each offence.

There is no information about the number of pickups then, but apparently the scavengers collected everyday, and the citizens were required to have the waste at the street side in disposable containers.

A budget found in the commission minutes of March 5, 1907, indicated there was only one scavenger and his salary was $50.00 per month. Garbage and trash collections were under the supervision of the Town Marshall.

Apparently Kissimmee experienced growth in those early years,
probably due to boat traffic on the Kissimmee River, and trash began to accumulate faster than one man could pick in one day. According to the Minutes of August 4, 1908, the City Commission gave its first solid waste management request, as quoted below.

The scavenger was instructed to devote his time to cleaning up and hauling trash on following days, Tuesday in north Kissimmee, and Thursdays in south Kissimmee, and citizens be requested to have trash in Boxes or Bbls, and placed convenient for the scavenger to get to on days mentioned.

The city apparently felt the need to change collection days for trash pickup, instead of adding additional personnel.

The Revised Ordinance of 1936, regarding scavengers (solid waste collections), Sec. 167, was unchanged from that of 1892. But, by this time, the scavenger was under the supervision of the Health Department of the City and the operating budget was $2,420.00 for that year.

Although the records are slim, backdoor and alley pickup must have begun in the late 1940's, possibly after the war. A dump truck type vehicle, with two or three collectors was used. The budget for the Sanitation department had risen to $15,000 per year.

Somewhere around the early 1960's, the Sanitation department became part of the Public Works Department, with an average yearly budget of $40,000.

In the early 1970's, Disney World came into the picture, creating a new burden for the Sanitation division. In 1974, the Sanitation division had grown to 16 employees with a budget of $177,000.00.

In an effort to trim an already deficit budget, and to review
a collection service charge of $1.50 per customer per month set in 1965, the city revised the 1965 ordinance in 1974, increasing the collection service charge to $2.50 per month per customer. This ordinance also made curb side pickup and disposable containers mandatory. With this Revision, the Sanitation personnel dropped to nine employees and were serving 3200 residences, with a budget of $157,000. During this period, the city was collecting twice a week, using two rear loaders and collecting trash on "a-call" basis.

In 1979, the Sanitation division again found itself operating with a deficit budget, created by an out-dated service charge, high equipment maintenance costs, and an increase in residential pickups to 4300.

In late 1979, an in-house study was implemented in an effort to define the problem areas and create a more efficient solid waste program.

The results of the study were as follows:

1. Increase collection charge from $2.50 to $4.50 per month per customer.
2. Decrease salary and maintenance budget by changing from three-man rear loaders to one-man side loaders.
3. Set up equipment renewal plan using revenues from service charges.
4. Set up a continuing study program to monitor the system.
5. Modified old incentive program for drivers of the one-man trucks.
6. Set up new procedures for enforcing the Collection Ordinance.
7. Set up complete new routing procedures for the entire city.
Although there was an increase in residential pickups, the Sanitation division employees dropped to seven, with a budget of $194,000. The new system was organized as follows:

1. 1-Supervisor.
2. 3-Refuse truck drivers with new one-man side loading trucks.
3. 1-Trash truck driver with a new trash truck.
4. 2-Back-up refuse truck drivers.

From the population projections of the East Central Florida Regional Planning Council, see Table 1, the city recognized the possible demand to the collection system in the next 10-20 years. In view of this situation, the city implemented a time and motion study in an effort to accumulate a data base of reliable and factual performance data that can be used by the city to evaluate and design additional collection routes. The time and motion study is the basis of this report.

It may be interesting at this point to compare the collection system of 1892 to the collection system of 1980, and note the similarities. See Table 2. The quote "The more things change, the more they remain the same", may be true in this case.
**TABLE 1**  
**PROJECTED POPULATION FOR KISSIMMEE 1977 - 1986**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976 est</td>
<td>12,080</td>
</tr>
<tr>
<td>1977</td>
<td>12,700</td>
</tr>
<tr>
<td>1978</td>
<td>13,600</td>
</tr>
<tr>
<td>1979</td>
<td>14,200</td>
</tr>
<tr>
<td>1980</td>
<td>14,800</td>
</tr>
<tr>
<td>1981</td>
<td>15,400</td>
</tr>
<tr>
<td>1986</td>
<td>17,500</td>
</tr>
</tbody>
</table>

**SOURCE:** EAST CENTRAL FLORIDA REGIONAL PLANNING COUNCIL  
URBAN AREA TRANSPORTATION STUDY PROJECTIONS, MODIFIED BY GLATTING, BROPHY, SHAHEEN & ASSOC., INC.

**NOTE:** POPULATION STATISTICS REFER TO PERMANENT YEAR ROUND POPULATION ONLY & DO NOT COUNT THE SIZABLE NUMBER OF SEASONAL RESIDENTS (est. at 2,000)

**PROJECTED NUMBERS OF HOUSEHOLDS FOR KISSIMMEE**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PERSONS/HOUSEHOLD</th>
<th>NO. OF HOUSEHOLDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976 est</td>
<td>2.65</td>
<td>4,550</td>
</tr>
<tr>
<td>1977</td>
<td>2.68</td>
<td>4,740</td>
</tr>
<tr>
<td>1978</td>
<td>2.71</td>
<td>5,020</td>
</tr>
<tr>
<td>1979</td>
<td>2.73</td>
<td>5,200</td>
</tr>
<tr>
<td>1980</td>
<td>2.76</td>
<td>5,360</td>
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<tr>
<td>1981</td>
<td>2.78</td>
<td>5,340</td>
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<tr>
<td>1986</td>
<td>2.83</td>
<td>6,180</td>
</tr>
</tbody>
</table>

**SOURCE:** GLATTING, BROPHY, SHAHEEN & ASSOC., INC.

**NOTE:** HOUSEHOLD STATISTICS REFER TO PERMANENT YEAR ROUND HOUSEHOLDS ONLY & DO NOT COUNT SEASONAL HOUSEHOLDS.
## TABLE 2
COLLECTION SYSTEM COMPARISON

<table>
<thead>
<tr>
<th></th>
<th>1892</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EQUIPMENT</strong></td>
<td>OPEN TOP WAGON</td>
<td>SIDELOADER</td>
</tr>
<tr>
<td><strong>CREW SIZE</strong></td>
<td>1-MAN</td>
<td>1-MAN</td>
</tr>
<tr>
<td><strong>STORAGE POINT</strong></td>
<td>FRONT AT SIDEWALK</td>
<td>FRONT AT CURB</td>
</tr>
<tr>
<td><strong>INCENTIVE SYSTEM</strong></td>
<td>TASK</td>
<td>TASK</td>
</tr>
<tr>
<td><strong>STORAGE CONTAINERS</strong></td>
<td>DISPOSABLE</td>
<td>DISPOSABLE</td>
</tr>
<tr>
<td><strong>COLLECTION FREQ.</strong></td>
<td>EVERYDAY</td>
<td>TWICE A WEEK</td>
</tr>
</tbody>
</table>
CHAPTER IV

SYSTEM ANALYSIS

The primary purpose of this study effort was to accumulate a base of reliable and factual performance data that can be used by solid waste collection managers of the City of Kissimmee, to evaluate their systems performance and also to evaluate other reasonable alternatives.

All data collected will be representative of the present city collection system. Presently, the city is using three 20 yard Leach Side Loaders and are collecting residential solid waste on a twice-a-week basis. The system operates under a 40 hour task incentive system. It is very important under the incentive system that each routes' work loads are balanced. But, in order to balance system performance, work loads must be defined as productivity.

Productivity

Productivity is defined as work per unit time. In this study, productivity shall be defined by three parameters as follows:

1. Collection minutes per service.
2. Services collected per collection hour.
3. Load collected per collection hour.

Although the data being collected will produce the above productivity parameters, there are fixed constraints which will
directly affect productivity. These fixed constraints are collection system constraints, which might increase or decrease system productivity. These system constraints, and their influence on productivity and efficiency, have been studied by the Environmental Protection Agency in their Summary Report, Volume I "Residential Collection Systems" SW-97c.1. The following is an outline summary of the conclusions and data that resulted from that study effort.2

**Equipment**

It was pointed out that in almost all cases, equipment compaction and load capacity was underutilized for the second load to the disposal site. This resulted in relatively more time being spent in transporting, and less time being spent collecting. The collection and transport equipment should be matched carefully to the Route and crew characteristics, in order to maximize collection time. See Table 3 and Figure 1.

**Crew Size**

The productivity per crew man in terms of tons collected per hour and homes serviced is greatest with a one man crew. The productive work time is 97 percent compared to 70 percent for two and three men crews. The two and three men crews have non-productive crewmen during the haul phases of a collection route, which amounts to 30 percent of the work day.2 See Tables 4, 5, 6, & 7.

**Frequency of Collection**

Productivity in terms of homes collected per hour was greatest
# TABLE 3

## EQUIPMENT PERFORMANCE DATA

<table>
<thead>
<tr>
<th>SYSTEM NUMBER</th>
<th>TYPE</th>
<th>AVERAGE SIZE (CU. YD.)</th>
<th>AVERAGE LOADS PER DAY</th>
<th>AVERAGE WEIGHT PER DAY (TONS)</th>
<th>AVERAGE WEIGHT (TONS)</th>
<th>RATIO ALL OTHERS TO FIRST LOAD</th>
<th>STUDY RESULTS</th>
<th>EXPECTED RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>SL</td>
<td>25.0</td>
<td>1.8</td>
<td>9.44</td>
<td>6.43</td>
<td>0.61</td>
<td>515</td>
<td>500</td>
</tr>
<tr>
<td>2</td>
<td>SL</td>
<td>25.0</td>
<td>1.6</td>
<td>9.00</td>
<td>5.93</td>
<td>0.83</td>
<td>474</td>
<td>500</td>
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<tr>
<td>3</td>
<td>SL</td>
<td>33.0</td>
<td>1.0</td>
<td>5.73</td>
<td>3.69</td>
<td>0.60</td>
<td>345</td>
<td>500</td>
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<tr>
<td>4</td>
<td>RL</td>
<td>20.0</td>
<td>2.4</td>
<td>12.62</td>
<td>9.02</td>
<td>0.65</td>
<td>744</td>
<td>900</td>
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<tr>
<td>5</td>
<td>RL</td>
<td>24.2</td>
<td>1.9</td>
<td>14.49</td>
<td>5.85</td>
<td>1.00</td>
<td>390</td>
<td>500</td>
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<tr>
<td>6</td>
<td>DC</td>
<td>8.0</td>
<td>4.4</td>
<td>6.96</td>
<td>1.56</td>
<td>0.74</td>
<td>662</td>
<td>700</td>
</tr>
<tr>
<td>7</td>
<td>RL</td>
<td>20.0</td>
<td>2.2</td>
<td>12.65</td>
<td>6.61</td>
<td>1.14</td>
<td>525</td>
<td>700</td>
</tr>
<tr>
<td>8</td>
<td>RL</td>
<td>23.0</td>
<td>1.6</td>
<td>9.72</td>
<td>5.98</td>
<td>0.77</td>
<td>693</td>
<td>700</td>
</tr>
<tr>
<td>9</td>
<td>RL</td>
<td>20.0</td>
<td>2.3</td>
<td>14.10</td>
<td>8.35</td>
<td>0.77</td>
<td>614</td>
<td>700</td>
</tr>
<tr>
<td>10</td>
<td>RL</td>
<td>20.0</td>
<td>1.0</td>
<td>6.18</td>
<td>2.38</td>
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<td>522</td>
<td>700</td>
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<tr>
<td>11</td>
<td>RL</td>
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<td>3.86</td>
<td>0.67</td>
<td>522</td>
<td>700</td>
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</tbody>
</table>

### NOTES:

1. Assumed densities based on expected performance by manufacturers of equipment.
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.

### SOURCE:

RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975
FIG. 1. AVERAGE WEIGHT PER LOAD (1st LOAD, OTHERS)

SOURCE: RESIDENTIAL COLLECTION SYSTEMS, VOLUME I, EPA/530/SW-97c.1, MARCH 1975
### TABLE 4
CREW PERFORMANCE DATA (CURB AND ALLEY SYSTEMS)

<table>
<thead>
<tr>
<th>SYSTEM NUMBER</th>
<th>CREW SIZE</th>
<th>HOMES SERVED PER CREW PER DAY</th>
<th>HOMES SERVED PER CREW PER COLLECTION HOUR</th>
<th>TONS COLLECTED PER CREW PER DAY</th>
<th>TONS COLLECTED PER CREW PER COLLECTION HOUR</th>
<th>SYSTEMS COLLECTING ONCE WEEKLY</th>
<th>INDEX</th>
<th>TONS COLLECTED PER CREWMAN PER COLLECTION HOUR</th>
<th>INDEX</th>
<th>SYSTEMS COLLECTING TWICE WEEKLY</th>
<th>INDEX</th>
<th>TONS COLLECTED PER CREWMAN PER COLLECTION HOUR</th>
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<tr>
<td>1</td>
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<td>410</td>
<td></td>
<td>107.3</td>
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<td>107.3</td>
<td>1.00</td>
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<td>254</td>
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<td>9.00</td>
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<td>5</td>
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<td>14.49</td>
<td>3.1</td>
<td>57.7</td>
<td>0.54</td>
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<td>3</td>
<td>407</td>
<td></td>
<td>104.5</td>
<td>12.65</td>
<td>3.3</td>
<td>34.9</td>
<td>0.33</td>
<td>1.1</td>
<td>0.44</td>
<td>1.1</td>
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<td>3</td>
<td>306</td>
<td></td>
<td>62.7</td>
<td>9.72</td>
<td>2.0</td>
<td>20.9</td>
<td>0.19</td>
<td>0.7</td>
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* COLLECTION HOUR = ON-ROUTE TIME

SOURCE:
RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975
<table>
<thead>
<tr>
<th>SYSTEM NUMBER</th>
<th>CREW SIZE</th>
<th>ON-ROUTE ACTIVITIES</th>
<th>TOTAL ACTIVITIES</th>
</tr>
</thead>
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<td>RELATIVE TIME ON ROUTE</td>
<td>RELATIVE PRODUCTIVE TIME</td>
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<td>63.7</td>
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<td>75.0</td>
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<td>5</td>
<td>2</td>
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</table>

**SOURCE:**
RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975
# Table 6

**Marginal Productivity (Curb and Alley Systems)**

<table>
<thead>
<tr>
<th>Crew Size</th>
<th>Homes Per Crew Per Hour</th>
<th>Marginal Increase in Productivity Homes Per Crew Per Hour</th>
<th>Tons Per Crew Per Hour</th>
<th>Marginal Increase in Productivity Tons Per Crew Per Hour</th>
<th>Homes Per Crewman Per Hour</th>
<th>Marginal Decrease in Productivity Homes Per Crewman Per Hour</th>
<th>Tons Per Crewman Per Hour</th>
<th>Marginal Decrease in Productivity Tons Per Crewman Per Hour</th>
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<tr>
<td>1 Man</td>
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<td>---</td>
<td>82.4</td>
<td>---</td>
<td>1.9</td>
<td>---</td>
</tr>
<tr>
<td>2 Man</td>
<td>122.9</td>
<td>40.5</td>
<td>2.5</td>
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<td>59.9</td>
<td>22.5</td>
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<td>0.7</td>
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<tr>
<td>3 Man</td>
<td>122.6</td>
<td>(0.3)</td>
<td>2.9</td>
<td>0.4</td>
<td>40.8</td>
<td>19.1</td>
<td>1.0</td>
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<tr>
<td></td>
<td><strong>AVERAGE OF ALL SYSTEMS</strong></td>
<td></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING ONCE A WEEK</strong></td>
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<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
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<tr>
<td>1 Man</td>
<td>81.5</td>
<td>---</td>
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<td>---</td>
<td>81.5</td>
<td>---</td>
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<tr>
<td>2 Man</td>
<td>115.2</td>
<td>33.7</td>
<td>2.9</td>
<td>0.6</td>
<td>56.6</td>
<td>24.9</td>
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<tr>
<td>3 Man</td>
<td>83.6</td>
<td>(31.6)</td>
<td>2.7</td>
<td>(0.2)</td>
<td>27.9</td>
<td>28.7</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
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<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
<td><strong>AVERAGE OF ALL SYSTEMS COLLECTING TWICE A WEEK</strong></td>
</tr>
<tr>
<td>1 Man</td>
<td>84.2</td>
<td>---</td>
<td>1.2</td>
<td>---</td>
<td>84.2</td>
<td>---</td>
<td>1.2</td>
<td>---</td>
</tr>
<tr>
<td>2 Man</td>
<td>138.4</td>
<td>54.2</td>
<td>1.7</td>
<td>0.5</td>
<td>66.6</td>
<td>17.6</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>3 Man</td>
<td>200.5</td>
<td>62.1</td>
<td>3.3</td>
<td>1.6</td>
<td>66.5</td>
<td>0.1</td>
<td>1.1</td>
<td>(0.3)</td>
</tr>
<tr>
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<td><strong>MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS</strong></td>
<td></td>
<td><strong>MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS</strong></td>
<td></td>
<td><strong>MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS</strong></td>
<td><strong>MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS</strong></td>
<td><strong>MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS</strong></td>
<td><strong>MOST PRODUCTIVE PARAMETERS FROM ALL SYSTEMS</strong></td>
</tr>
<tr>
<td>1 Man</td>
<td>107.3</td>
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<td>---</td>
<td>107.3</td>
<td>---</td>
<td>2.5</td>
<td>---</td>
</tr>
<tr>
<td>2 Man</td>
<td>138.4</td>
<td>31.1</td>
<td>3.1</td>
<td>0.6</td>
<td>66.6</td>
<td>40.7</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>3 Man</td>
<td>200.5</td>
<td>62.1</td>
<td>3.3</td>
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<td>66.5</td>
<td>0.1</td>
<td>1.1</td>
<td>0.4</td>
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</table>

**Source:**  
Residential Collection Systems, Volume 1, EPA/530/SW-97c.1, March 1975
TABLE 7
RANGES OF CREW AND CREWMAN PRODUCTIVITY (CURB AND ALLEY SYSTEMS)

<table>
<thead>
<tr>
<th>SYSTEM NUMBER</th>
<th>CREW PRODUCTIVITY</th>
<th>CREWMAN PRODUCTIVITY</th>
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<tr>
<td></td>
<td>HOME PER COLLECTION HOUR</td>
<td>TONS PER COLLECTION HOUR</td>
</tr>
<tr>
<td></td>
<td>RANGE</td>
<td>AVERAGE</td>
</tr>
<tr>
<td>1</td>
<td>92-124</td>
<td>107</td>
</tr>
<tr>
<td>2</td>
<td>50-68</td>
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<td>77-92</td>
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<tr>
<td>4</td>
<td>94-135</td>
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<td>110-165</td>
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<td>6</td>
<td>130-159</td>
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<td>7</td>
<td>87-125</td>
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<td>58-66</td>
<td>62</td>
</tr>
<tr>
<td>9</td>
<td>179-226</td>
<td>200</td>
</tr>
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</table>

* COLLECTION = ON-ROUTE

SOURCE:
RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975
for the twice-a-week collections system. However, productivity in terms of tons collection per hour was greatest for once-a-week collection system. It was noted that the twice-a-week system collected 50 percent more homes, required 33 percent more crews and equipment, and collected 20 percent less weight per hour than the once-a-week collection system. See Table 8.

Storage Point Locations

The productivity of backdoor pickups to curb and alley pickups was approximately one-half in terms of tons collected per collection hour and homes served per collection hour. See Table 9.

Incentive Systems

There were two incentive systems investigated in the Environmental Protection Agency study. They were the Task Incentive system and the Standard Day system. The Task Incentive system employees are paid a base wage to complete a set work task, regardless of hours worked, usually less than 40 hours per week. The Standard Day system employees are paid an hourly wage and are required to work the time paid, regardless if the task is already completed.

The productivity of the Task Incentive system tends to be greater than the productivity of the Standard Day system. The Standard Day collection system has a tendency to expand into overtime operation.

Storage Containers

The increase in percent of disposable containers reduces the
## TABLE 8

**FREQUENCY OF COLLECTION DATA**

<table>
<thead>
<tr>
<th>SYSTEM NUMBER</th>
<th>POUNDS PER HOME PER COLLECTION</th>
<th>POUNDS PER HOME PER WEEK</th>
<th>HOMES SERVED PER WEEK</th>
<th>HOMES SERVED PER COLLECTION HOUR</th>
<th>COLLECTION COST PER HOME PER WEEK</th>
<th>COLLECTION COST PER HOME PER COLLECTION HOUR</th>
<th>TONS COLLECTED PER COLLECTION HOUR</th>
<th>COLLECTION COST PER TON</th>
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<td>1</td>
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<td>46.2</td>
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<td>71.0</td>
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<td>49.3</td>
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<td>0.16</td>
<td>2.6</td>
<td>6.54</td>
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<td>5</td>
<td>50.5</td>
<td>50.5</td>
<td>2,876</td>
<td>123.3</td>
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<td>0.15</td>
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<td>7</td>
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<td>62.2</td>
<td>2,034</td>
<td>104.5</td>
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<td>0.30</td>
<td>3.3</td>
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<td>64.9</td>
<td>1,531</td>
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<td>0.36</td>
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<tr>
<td>AVG.</td>
<td>57.4</td>
<td>57.4</td>
<td>2,053</td>
<td>93.4</td>
<td>0.22</td>
<td>0.22</td>
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<td>7.43</td>
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<tr>
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<td>28.2</td>
<td>56.3</td>
<td>1,231</td>
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<td>0.29</td>
<td>1.2</td>
<td>10.42</td>
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<td>1,147</td>
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<td>0.37</td>
<td>1.7</td>
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<td>66.1</td>
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<td>10.26</td>
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<tr>
<td>AVG.</td>
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<td>57.1</td>
<td>1,361</td>
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<td>0.33</td>
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**SOURCE:**

*RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975*
### TABLE 9
#### STORAGE POINT DATA

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

**SOURCE:**
RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975
time required to service a home, and increases the number of homes served per collection hour.\(^2\) See Table 10.

**Generation Rate**

An increase in Generation Rate increases the time required to service a home and decreases the number of homes served per collection hour.\(^1\)

**Summary**

The following is a summary regarding productivity and efficiency:

1. Collection equipment should be matched to route and crew characteristics.
2. One-man crews productivity is greater than multi-man crews.
3. Twice-a-week pickups served more homes per collection hour, and collected less tons per collected hour, than once-a-week pickup.
4. Curbside is more productive and costs less than backyard services.
5. Task incentive systems tend to be more productive than the standard day systems.
6. Increase in percent of disposable containers decrease home service time.
7. Increase in generation rate increases home service time.

**Ranking of Factors**

All the constraints considered above are inter-dependent of each other to some degree. It is hard to isolate the effect each would have on a system as an independent factor. However, Table 11 is an attempt to rank the constraints in order of productivity, cost efficiency, and relative effect of each factor.\(^2\)
### TABLE 10
STORAGE CONTAINER DATA

<table>
<thead>
<tr>
<th>SYSTEM NUMBER</th>
<th>AVERAGE NUMBER OF CONTAINERS PER COLLECTION</th>
<th>AVERAGE NUMBER (AND PERCENT) OF STORAGE CONTAINERS</th>
<th>CURB AND ALLEY SYSTEMS — BAGS AND CANS</th>
<th>PERCENT ONE WAY ITEMS</th>
<th>PERCENT TWO WAY ITEMS</th>
<th>HOME SERVED PER COLLECTION HOUR</th>
<th>DAAP COLLECTION TIME PER HOME (MIN)</th>
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<tbody>
<tr>
<td>1</td>
<td>4.5</td>
<td>1.5 (34.0)</td>
<td>2.3 (52.0)</td>
<td>0.7 (14.0)</td>
<td>48.0</td>
<td>52.0</td>
<td>107.3</td>
</tr>
<tr>
<td>2</td>
<td>5.1</td>
<td>1.3 (26.0)</td>
<td>2.7 (53.0)</td>
<td>1.1 (21.0)</td>
<td>47.0</td>
<td>53.0</td>
<td>55.7</td>
</tr>
<tr>
<td>3</td>
<td>3.0</td>
<td>0.9 (29.0)</td>
<td>1.6 (53.0)</td>
<td>0.5 (18.0)</td>
<td>47.0</td>
<td>53.0</td>
<td>84.2</td>
</tr>
<tr>
<td>4</td>
<td>4.6</td>
<td>2.6 (56.0)</td>
<td>1.3 (28.0)</td>
<td>0.7 (16.0)</td>
<td>72.0</td>
<td>28.0</td>
<td>107.0</td>
</tr>
<tr>
<td>5</td>
<td>5.5</td>
<td>4.6 (85.0)</td>
<td>0.4 (6.0)</td>
<td>0.5 (9.0)</td>
<td>94.0</td>
<td>6.0</td>
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<td>2.5</td>
<td>0.5 (19.0)</td>
<td>1.5 (61.0)</td>
<td>0.5 (20.0)</td>
<td>39.0</td>
<td>61.0</td>
<td>138.4</td>
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<td>6.1</td>
<td>3.6 (56.0)</td>
<td>1.5 (28.0)</td>
<td>1.0 (16.0)</td>
<td>72.0</td>
<td>28.0</td>
<td>104.5</td>
</tr>
<tr>
<td>8</td>
<td>5.9</td>
<td>1.5 (25.0)</td>
<td>2.7 (47.0)</td>
<td>1.7 (28.0)</td>
<td>53.0</td>
<td>47.0</td>
<td>62.7</td>
</tr>
<tr>
<td>9</td>
<td>2.7</td>
<td>1.2 (46.0)</td>
<td>1.1 (41.0)</td>
<td>0.4 (13.0)</td>
<td>59.0</td>
<td>41.0</td>
<td>200.5</td>
</tr>
<tr>
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<td>1.2</td>
<td>0.0 (2.0)</td>
<td>1.2 (96.0)</td>
<td>0.0 (2.0)</td>
<td>4.0</td>
<td>96.0</td>
<td>72.1</td>
</tr>
<tr>
<td>11</td>
<td>4.3</td>
<td>1.4 (33.0)</td>
<td>2.4 (55.0)</td>
<td>0.5 (12.0)</td>
<td>45.0</td>
<td>55.0</td>
<td>44.4</td>
</tr>
</tbody>
</table>

**Backyard Systems - Tote - Barrel**

**Source:**
RESIDENTIAL COLLECTION SYSTEMS, VOLUME 1, EPA/530/SW-97c.1, MARCH 1975
TABLE II
FOR ALL SYSTEMS

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>ORDER FOR PRODUCTIVITY</th>
<th>RELATIVE MAGNITUDE OF EFFECT</th>
<th>ORDER FOR COST EFFICIENCY</th>
<th>RELATIVE MAGNITUDE OF EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>POINT OF COLLECTION</td>
<td>1</td>
<td>58</td>
<td>1</td>
<td>52</td>
</tr>
<tr>
<td>CREW SIZE (PER CREWMAN)*</td>
<td>2</td>
<td>38</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>FREQUENCY OF COLLECTION</td>
<td>3</td>
<td>36</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>INCENTIVE SYSTEM</td>
<td>4</td>
<td>26</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>PERCENT ONE-WAY ITEMS (PER PERCENT)**</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

* 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.

SOURCE:
RESIDENTIAL COLLECTION SYSTEMS, VOLUME I, EPA/530/ SW-97c.1, MARCH 1975
Environmental Protection Agency Study Results

The constraints that directly influence productivity have been reviewed. Using this information, the Environmental Protection Agency mathematically related these factors to productivity equations. All the equations were in this form of \( Y = aX_1 + bX_2 + cX_3 + dX_4 + e \). The dependent variables (\( Y \)), considered for analysis included the following:

1. Collection minutes per homes serviced.
2. Services collected per collection hour.
3. Tons collected per collection hour.

The independent variable (\( X_1, X_2, X_3, \) and \( X_4 \)) were defined as follows:

\[ X_1 = \text{Pounds collected per service per collection.} \]
\[ X_2 = \text{Crew size.} \]
\[ X_3 = \text{Percent one-way items.} \]
\[ X_4 = \text{Collection miles per day.} \]

Of the four independent variables, Generation Rate is the only one outside the control of the solid waste manager. The other variables as reviewed earlier, can be manipulated to increase productivity effect. With the use of regression analysis, the Environmental Protection Agency developed the following productivity equations for one man side loaders.

1. **Collection Minutes Per Service** for curb pickup collecting twice weekly.
   \[
   Y = 0.44 + 0.01X_1 - 0.24X_2 + 0.01X_4
   \]
2. **Services Per Collection Hour** for curb pickup collecting
twice weekly.

\[ Y = 57.20 - 2.55X_1 + 54.14X_2 + 1.14X_3 \]

3. Tons Per Collection Hour for curb pickup collecting twice weekly.

\[ Y = 1.72 + 0.02X_1 + 0.78X_2 + 0.03X_3 \]

For the purposes of this report, only the information needed to compare the City of Kissimmee solid waste collection system was extracted from the Environmental Protection Agency's Study. For information regarding other collection systems, please review EPA/530/SW-97c.1 "Residential Collection Systems."
CHAPTER V

DATA GENERATION

Data, although very important to Solid Waste Management, can be time consuming and expensive to collect. A Solid Waste Management Study is usually referred to as a Time and Motion Study.

As the name implies, times and distances traveled are recorded for each phase of the collection operations. On the basis of previous work, the operations phases may be resolved into four unit operations; 1-pickup, 2-haul, 3-at-site, 4-off-route. These operations may be defined as follows:

1. Pickup - Pickup refers to the time it takes when the very first pickup is made to the last pickup is made and the truck is loaded, ready to go to the disposal site.

2. Haul - Haul is the time it takes from the collection route to disposal site and the same on the return trip. It may also include that time from the motor pool to the collection route, and the time from the disposal site back to the motor pool.

3. At-site - At-site is the time spent at the disposal site.

4. Off-route - Off-route is the non-productive time during the work day.

This information is then assembled to describe the system mathematically in terms of productivity. The form used for Route information is shown in Figure 2.

Data recorded on these forms may be collected in two ways.
<table>
<thead>
<tr>
<th>Activity</th>
<th>Time</th>
<th>Miles</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leave Motor Pool</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leave Route</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrive at Landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leave Landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resume Collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leave Route</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrive at Landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leave Landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resume Collection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leave Route</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrive at Landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leave Landfill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrive at Motor Pool</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity</th>
<th>Start</th>
<th>Finish</th>
<th>No. Homes Served</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lunch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breakdown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PROBLEMS — COMMENTS

FIG. 2. ROUTE INFORMATION
First, the forms may be filled out by the drivers of each route, daily. This can become a problem for the drivers. In an effort to do a good job of data recording, his job as a collector may suffer.

Secondly, the forms may be filled out by the aid of mechanical recorders. This relieves the driver of any duty except collecting solid waste as he would normally do.

The City of Kissimmee felt that mechanical recorders would provide better results, more consistently, and therefore, proceeded to implement a mechanical recording system.

The recorders used by the City were a Servis Speed Recorder, Model S-70-A. These recorders are capable of recording times, distances traveled, speed, starts and stops. This information is recorded on a circular 12 hour chart as shown in Figure 3. The recorders use a manual wind clock for timing and operate even when the truck is not in operation.

The wide marks on the outer edge of the chart in Figure 3 show travel or busy time. The vehicle was moving at those times. The fine lines show when the vehicle was standing or not moving. The travel time record is made by a spring loaded pendulum and operates by the motion of the vehicle.

The next recording on this chart shows the vehicle speed in MPH at any given time. Any change in speed causes a corresponding change in the position of the stylus on the chart and the resulting record is a speed-time graph.

The inner recording area of the charts is divided into five
FIG. 3. RECORDER CHART
narrow bands of concentric circles. Each band represents one mile.

When the vehicle is in motion, the mileage recording stylus moves across this a distance corresponding to the miles covered by the vehicle. One complete traverse of the stylus across and back represents 10 miles.

Although the Recorder gave a detail record of the daily times, distances and speed, the travel record was not accurate enough to show the actual number of stops made during the collection operation. Therefore, a mechanical counter was added to the truck to do this. The counters were attached to the hand parking brake lever, which is only used when the truck stops to pickup waste. Each time the lever is released, it was counted as one pickup.

In an effort to determine the accuracy of the Recorders and Counters, each route was ridden for one week and data collected by hand to calibrate the recorders. The recorders turned out to be extremely accurate. Since the counters were counting location stops instead of customers, a detailed evaluation was undertaken to establish the difference between customers and stop locations.

The complete billing record was compared to physical stops in the fields for each route, and the comparisons are shown in Table 12. The total relationship between stop locations and actual customers turned out to be in the 97 percent level. With this high correlation relationship, the counters were assumed accurate. The cost to implement this data collection system turned out to be $272.00 per truck.
### TABLE 12

**COMPARISON OF ACTUAL LOCATION STOPS TO CUSTOMERS BILLING**

<table>
<thead>
<tr>
<th>ROUTE</th>
<th>CUSTOMERS</th>
<th>LOCATIONS</th>
<th>ROUTE</th>
<th>CUSTOMERS</th>
<th>LOCATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>694</td>
<td>674</td>
<td>2</td>
<td>797</td>
<td>797</td>
</tr>
<tr>
<td>2</td>
<td>797</td>
<td>713</td>
<td>3</td>
<td>678</td>
<td>658</td>
</tr>
<tr>
<td>3</td>
<td>678</td>
<td>750</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL CUSTOMERS 4306, TOTAL LOCATIONS 4176**

*RATIO OF CUSTOMERS TO LOCATIONS = 0.97*
One of the other problems encountered in this study was the weight-volume relationship. The Osceola County landfill does not weigh vehicles entering its landfill. Other means of weighing vehicles had to be arranged. Finally, permission was granted to have the vehicles weighed at the pulp wood yard outside the city. Each day the drivers were instructed to weigh their first full load and record the residential count on the form shown in Figure 4.

From this point, data was collected on each route and each day as possible. The data then was transferred from the chart to the Route Information form, Figure 2. This information then was broken down into more detailed information as shown in Figures 5, 6, & 7. From these forms the information can be used to develop route characteristics, and productivity comparisons.
## Driver Worksheet

<table>
<thead>
<tr>
<th>Date</th>
<th>Day</th>
<th>Driver</th>
<th>Route No.</th>
<th>Truck No.</th>
<th>First Load - Gross WT.</th>
<th>No. Stops, First Load</th>
<th>Total No. of Stops</th>
<th>LBS.</th>
</tr>
</thead>
</table>

*FIG. 4. DAILY SUMMARY DRIVER WORKSHEET*
<table>
<thead>
<tr>
<th>ROUTE I.D.</th>
<th>To Route</th>
<th>First Load</th>
<th>Other</th>
<th>Total</th>
<th>Haul</th>
<th>At-Site</th>
<th>Off Re.</th>
<th>Total Mile</th>
<th>Total Wk.</th>
<th>Per.</th>
<th># Of Trips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mi</td>
<td>Min</td>
<td>Mi</td>
<td>Hrs</td>
<td>Yd</td>
<td>Mi</td>
<td>Hrs</td>
<td>Yd</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SUM**

**AVG.**

**SUM**

**AVG.**

**Overall Sum**

**Overall Avg.**

**SUM**

**AVG.**

**SUM**

**AVG.**

**Overall Sum**

**Overall Avg.**

**FIG. 5. TIME BREAK DOWN FROM**
<table>
<thead>
<tr>
<th>Route I.D.</th>
<th>Gross Wt. Tons</th>
<th>Load Comp. Wt. Tons</th>
<th>Tons per Collection Hour</th>
<th>Tons per Day</th>
<th>Tons per Location</th>
<th>Day Locations per Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SUM</td>
<td>AVG</td>
<td>OVERALL SUM</td>
<td>AVG</td>
<td>OVERALL AVG</td>
<td>OVERALL AVG</td>
</tr>
</tbody>
</table>

**FIG. 6. WEIGHT BREAK DOWN FORM**
<table>
<thead>
<tr>
<th>ROUTE I.D.</th>
<th>Ratio Wk. Hrs. To Std. Day</th>
<th>Ratio Coll. Hrs. To Work Hrs.</th>
<th>Ratio Haul Hrs. To Work Hrs.</th>
<th>Ratio At-Site Hrs. To Work Hrs.</th>
<th>Ratio Coll. MI. To Total MI.</th>
<th>Ratio Haul MI. To Total MI.</th>
<th>Min. per Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVG.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVG.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall AVG.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVG.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>AVG.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall AVG.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER VI

STUDY RESULTS

The results of this study will define more thoroughly the operational phases of solid waste collection. These phases, collection time, haul time, at-site time, and off-route time are needed to define a collection route. The collection route may be defined mathematically as follows:

\[ T_t = C_t + H_t + S_t + N_p \]

Where: \( T_t \) = Total work day.  
\( C_t \) = Total collection time.  
\( H_t \) = Total haul or travel time.  
\( S_t \) = Total time spent at the disposal site.  
\( N_p \) = Total non-productive time.

To maximize the productivity of a collection system, it should be noted that collection time should be maximized while the haul time, at-site time, and non-productive time should be minimized. To show a comparison of how these times are broken up into a collection day, note Figure 8. The City study results indicate that 82 percent of a total work day is used in collecting solid waste, while the remaining 18 percent of the work day is broken up into haul time, at-site time, and non-productive time as 12 percent, 3 percent, and 3 percent respectfully.

The data results will be presented in subsections as follows:
PERCENT OF WORK DAY

RATIO OF COLLECTION TIME TO TOTAL WORK DAY
82 %

RATIO OF HAUL TIME TO TOTAL WORK DAY
12 %

RATIO OF AT-SITE TIME TO TOTAL WORK DAY
3 %

RATIO OF OFF-ROUTE TIME TO TOTAL WORK DAY
3 %
1. Generation Rate.
2. Site time.
3. Off-Route time.
4. Haul time.
5. Tons hauled per day.
6. Percent pickup.
7. Time per location.
8. Homes collected per collection hour.
9. Tons collected per collection hour.

**Generation Rate**

The generation rate may be defined as the weight of refuse discarded per person per home per day, or weight discarded per pickup per home. It is a constraint that the Solid Waste Manager has little if no control over. The waste generation of each community will vary due to community personalities. Even different routes within the same community may and will differ in their generation rate. Therefore, it is very important that each Solid Waste Manager has some idea of the waste that is generated in his community. The generation rate is easily derived by weighing collection vehicles and calculating the average weight per home picked up. By weighing collection vehicles on a continuous basis, yearly waste variations may be determined. In some cases, waste consistency is needed. This of course entails more detailed analysis of the waste.

The City of Kissimmee's waste generations are shown in Figure 9.
POUNDS PER PICKUP

ROUTE 1 AVERAGE 32.3 lbs.
S = 5.7 lbs.

ROUTE 2 AVERAGE 33.4 lbs.
S = 4.7 lbs.

ROUTE 3 AVERAGE 29.3 lbs.
S = 6.4 lbs.

1st. WEEKLY PICKUP AVERAGE 33.9 lbs.
S = 6.2 lbs.

TOTAL SYSTEM AVERAGE 31.7 lbs.
S = 5.9 lbs.

2nd. WEEKLY PICKUP AVERAGE 29.1 lbs.
S = 4.6 lbs.
Shown are the average generations for each Route, the average generation for the first weekly pickup, the second weekly pickup, and the average for the entire collection system. It must be noted that the first of the week pickup has the highest average weight per pickup. This is likely due to the four day generation period for the first of the week pickup compared to a three day generation period on the second weekly pickup.

For comparison, Orange and Brevard Counties generate 4.06 pounds per person per day, and the City of Kissimmee generates 3.28 pounds per person per day. This generation difference may be due to the small data base for Kissimmee at this time. Once data is generated over a years period, there may be a closer correlation between the generation rates.

It is also noted that the generation rate in pounds per person per day is slightly higher on the second weekly pickup, compared to the first weekly pickup, 3.51 pounds per person per day compared to 3.07 pounds per person per day respectively. This would possibly lead to the belief that most of the residents not picked up on the first weekly pickup, put their seven day accumulation of waste out for collection on the second weekly pickup.

**Site Time**

Site time, is the time spent at the disposal site unloading. This time may vary according to disposal site conditions and use by other haulers. The City of Kissimmee uses the Osceola County Sanitary Land Fill, located just west of town. This site has an
unpaved access to the fill area, and becomes difficult to ingress in wet weather. This has been a dry summer, and the data collected does not show the effect of wet weather conditions in the land fill.

The City averages 8.13 minutes per trip at the land fill and averages two trips per day. That is 16.23 minutes per day, or 3.0 percent of the total work day. If the wet weather condition caused the site time to double, it would only cause the at-site time to increase to 6.0 percent of the total work day, and this would not have a large effect on total route time. What may have a large effect on route time, is the effect the condition of the landfill may have on collection equipment. Collection equipment operating in the landfill has a tendency for costly breakdowns, with extended periods of down time. Drivers must be cautioned not to over tax equipment just to lower at-site times.

**Off-Route Time**

Off-route time is that time spent during the collection route determined as non-productive time. Examples of non-productive time may be lunch breaks, rest time, weighing time, and morning or afternoon start up and shut down time, which includes checking the conditions of the equipment. Break-downs, although non-productive, have not been considered in the average off-route factors. Break-downs are unpredictable and equipment may be under repair for an undetermined amount of time. For these reasons, breakdown times have been subtracted from the off-route time data. The average off-route data is shown in Figure 10. The city averages 15.5 minutes,
Fig. 10. Average Off-Route Time Data

- ROUTE 1 AVG. 8.4 MIN.'S
  - S = 8.0 MIN.'S

- ROUTE 2 AVG. 27.8 MIN.'S
  - S = 23.2 MIN.'S

- ROUTE 3 AVG. 17.1 MIN.'S
  - S = 18.4 MIN.'S

- TOTAL SYSTEM AVG. 15.5 MIN.'S
  - S = 17.3 MIN.'S
or 3.0 percent of the total work day in off-route time. A point to notice here, is the standard deviation is as large as the mean, indicating a large scatter of the data collected. Of course, a larger data sample is needed, but the fact is the off-route time is difficult to estimate, and depends mostly on the drivers of the collection vehicle. There are some cases when the driver may not even take a lunch break, and other cases where he may take three or four long breaks, plus his lunch time. The data gives no indication of any correlation between work loads and off-route time.

**Haul Time**

Haul time may be defined as the time the collection vehicle is traveling. The collection vehicles may or may not be loaded. Following are examples of travel time:

1. From motor pool to collection route.
2. From one collection route to another.
3. From the collection route to the disposal site.
4. From the disposal site to the collection route.
5. From the disposal site to the motor pool.

Usually the haul or travel time is represented by a travel graph with miles traveled plotted against miles per hour. Most references plotted round-trip miles traveled against miles per hour. This gives a false indication that a collection vehicle always returns to the same location, which is not always the case. In this report, one-way miles are plotted against time to
produce a travel time graph in an effort to more clearly define time used in traveling in general.

Two graphs were developed for this purpose, one plotting miles traveled against miles per hour, and one plotting miles traveled against time in minutes. With the use of Regression Analysis, the data collected best fit the semi-logarithmic equations as follows:

1. Miles traveled (X) vs. miles per hour (Y).
   \[ Y = 21.912 \cdot \log X + 14.49 \]

2. Miles traveled (X) vs. time in minutes (Y).
   \[ Y = 18.025 \cdot \log X - 1.362 \]

The graph of these equations are shown in Figures 11 and 12 respectfully.

These graphs can be easily used by the Solid Waste Managers to define the average time required to travel a distance. However, caution should be exercised when trying to use the travel graph for distances under one mile, because no data was generated in that travel range.

**Tons Hauled Per Day**

The tons hauled per day is directly related to the Generation Rate data. The loaded trucks are weighed and the weight excluding the tare weight is then divided by the customers served to obtain the waste generation in pounds per pickup per home.

Tons hauled per day may also be an indication of truck utilization. First, the tons hauled per day may be reduced to
FIG. II. AVERAGE TRAVEL SPEED GRAPH FOR ONE-WAY DISTANCE GREATER THAN ONE MILE
FIG. 12. AVERAGE TIME GRAPH FOR ONE-WAY DISTANCE GREATER THAN ONE MILE
pounds per cubic yard hauled. This would give an indication if the
tuck compaction system is operating to its fullest potential. Note
Figure 13. A compaction unit operating at a low compaction ratio
would cause more time being spent hauling than collecting, which
would be less productive.

Secondly, the total tons hauled per day will give an indication
of total truck size needed to complete a collection route. In a
case where the first load to the disposal site is well compacted and
loaded to truck limit, but the second load is only partially loaded,
then a truck of a different size and compaction might be selected
to only make one trip to the disposal site. Although this may seem
simple, total system averages may not give a correct indication of
tuck use. Note Figure 14. The City of Kissimmee's total system
average, indicates an underutilization of truck size, that a
larger truck may be needed to eliminate the second trip. But, note
the first pickup averages during the week, this illustrates a
good utilization of truck size. Therefore, the first of the week
pickup would control truck size for the collection route. The rea-
son for higher truck loads on the first weekly pickup may be due to
different collection characteristics. For instance, the first
weekly pickup has a four day generation period, instead of three
days as with the second weekly pickup. Also, the percent pickup is
also greater for the first weekly pickup. Percent pickup will be
explained next in this report.
FIG. 13. AVERAGE POUNDS PER CUBIC YARDS

TRUCK RATED COMPACTION

Pounds Per Cubic Yards

ROUTE 3 459 lbs./yd.³
ROUTE 2 475 lbs./yd.³
ROUTE 1 497 lbs./yd.³
TONS HAULED PER DAY

Fig. 14. Average tons hauled per day

- RT. 1 AVG. 7.28 TONS
- S = 2.0 TONS
- RT. 2 AVG. 8.32 TONS
- S = 1.64 TONS
- RT. 3 AVG. 6.53 TONS
- S = 1.03 TONS
- 1st. WEEKLY PICKUP AVG. 8.01 TONS
- S = 1.56 TONS
- TOTAL SYSTEM AVG. 7.27 TONS
- S = 1.77 TONS
- 2nd. WEEKLY PICKUP AVG. 6.47 TONS
- S = 1.66 TONS
- TRUCK CAP. AVG. 10 TONS

TRUCKS AVERAGE TWO TRIPS TO DEPOSAL SITE
Percent Pickup

The percent pickup is that percent of the total number of pickups on a route that are actually picked up. Although not mentioned in any references used for the report, this may have more effect on system design, than any other single parameter.

For example, assume a system has 3000 homes to be collected twice-a-week. And assume a collector may pickup 500 homes a day. A collection manager would need three trucks to handle the job each day, assuming 100 percent pickup. Now assume this route has a 65 percent pickup factor. Although the collector still pickups 500 homes a day, he is able to service 769 homes. With this percent of pickup, the collection manager only needs two trucks to service the route per day. Of course, this is a simple example, but is shows the possible effect of the percent pickup factor. This percent pickup factor may also influence system productivity in the following manner:

1. Productivity of minutes per homes collected may increase due to the additional travel time.

2. Productivity of homes collected per collection hour may decrease due to additional travel time.

3. Productivity of tons collected per collection hour may decrease due to additional travel time.

The reason productivity may change is the increase in travel distance between homes. On an 18 mile collection route with 500 homes, the average distance between homes is 190 feet. But, if the same collection route had a 70 percent pickup factor, the
average distance between homes would be increased to 272 feet. A 40 percent increase in travel distance between collection locations. Although this will increase the time to service one home, the increase time will be off-set by the decrease in the number of homes to be picked up.

The average percent pickup factors for the City of Kissimmee are shown in Figure 15. Please note the second weekly pickup has a lower percent pickup than the first weekly pickup. Also Route 2 tends to have a larger percent pickup than both Routes 1 and 3.

The reason for the change in percent pickup from one route to the other is not obvious, but some conclusions can be drawn from route characteristics. Routes 1 and 3 are comprised mostly of the older sections of town, while Route 2 comprises most of the newly developed subdivisions. Also the housing cost in Route 1 and 3 are generally lower than those in Route 2 by a range of 20 to 40 thousand dollars. Although the data sample is too small at this point to show a comparison between house costs, subdivision age, and percent pickup, general conditions tend to show a possible relationship.

**Time Per Location**

Time per location is a productivity parameter defined as the time in minutes that it takes a collector to service one home. The parameter includes the travel time between homes, the cycling and compaction time, stop sign time, and the actual pickup time of the
PERCENT PICKUP

RT. 1 AVG. 66 %
S = 7.8 %

RT. 2 AVG. 71 %
S = 6.0 %

RT. 3 AVG. 67 %
S = 7.2 %

1st. WEEKLY PICKUP AVG. 70 %
S = 7.4 %

TOTAL SYSTEM AVG. 67.6 %
S = 7.6 %

2nd. WEEKLY PICKUP AVG. 65 %
S = 6.8 %
solid waste at the residence. The time per location is affected by a number of physical parameters.

First, the larger the distance between collection points (or residences) the larger the time per location, assuming all other constraints are the same.

Second, the longer the cycle and compaction time, the larger the time per location, and vice versa, the shorter the cycle and compaction time, the smaller the times per locations.

Third, the larger the generation rate, or longer the accumulation time, the longer the time per location.

Fourth, the larger the percent pickup, the smaller the average time per location. This is due to the average distances between pickups would decrease, resulting in a decrease in travel time and a decrease in time to service a home. But as previously noted, this increase in time per location will be off-set by a decrease in the number of homes to be picked up.

Please note Figure 16, the average time per location is very close in each case. Note the first weekly pickup has a longer accumulation time and a higher percent pickup, which reduces the travel distance between homes, while the second weekly pickup has a shorter accumulation time and a lower percent pickup, which increases the travel distance between homes. This is an indication that the waste collected per pickup and the distance traveled between pickups, play an almost equal role in estimating the time per location for a system. Later in this report, regression analysis shall be used to develop a design equation to
FIG. 16. AVERAGE MINUTES PER LOCATION

MINUTES PER LOCATION

S = STANDARD DEVIATION

RT. 1 AVG. 0.82 MIN.'S
S = 0.12 MIN.'S

RT. 2 AVG. 0.74 MIN.'S
S = 0.09 MIN.'S

RT. 3 AVG. 0.85 MIN.'S
S = 0.11 MIN.'S

1st. WEEKLY PICKUP AVG. 0.83 MIN.'S
S = 0.12 MIN.'S

TOTAL SYSTEM AVG. 0.81 MIN.'S
S = 0.12 MIN.'S

2nd. WEEKLY PICKUP AVG. 0.79 MIN.'S
S = 0.11 MIN.'S
determine the average time per locations using the pounds collected per pickup and the average travel distance between pickup as the independent variables.

**Homes Collected Per Collection Hour**

Homes collected per collection hour is also a productivity parameter and is defined as the number of homes collected during an hour of collecting time. The same physical parameters effecting the time per location also effect the homes collected per collection hour. Of course, the lower the time per location, the higher the total number of homes that can be collected in one hour of collecting time. Note Figure 17. This bar graph shows more homes collected on the secondly weekly pickup then the first. This of course was indicated by the lower time per location, shown in Figure 16. Figure 17 also indicated the actual average number of homes collected per collection hour, while Figure 18 indicates the average number of homes serviced per collection hour. This graph is developed by using the percent pickup factors shown in Figure 15.

For comparison, the Environmental Protection Agency study indicated 84.2 homes collected per collection hour as the average for one man systems collecting twice weekly. The City of Kissimmee averages 76 homes collected per collection hour, which is 11 percent lower than EPA. But, from Figure 16, the City will service 112 homes per collection hour, which is 33 percent higher than the results of EPA. This may not be a good comparison, the EPA tends to indicate that the 84.2 homes collected per collection hour
FIG. 17. AVERAGE HOMES COLLECTED PER COLLECTION HOUR

- RT. 1 AVG. 75 HOMES
  - S = 12.1
- RT. 2 AVG. 85 HOMES
  - S = 10.6
- RT. 3 AVG. 70 HOMES
  - S = 9.3
- 1st. WEEKLY PICKUP AVG. 73 HOMES
  - S = 10.3
- TOTAL SYSTEM AVG. 76 HOMES
  - S = 12.1
- 2nd. WEEKLY PICKUP AVG. 79 HOMES
  - S = 13.2
Fig. 18. Average homes serviced per collection hour:

- Route 1: Average 114 homes
- Route 2: Average 120 homes
- Route 3: Average 104 homes
- 1st Weekly Pickup: Average 104 homes
- Total System: Average 117 homes
- 2nd Weekly Pickup: Average 122 homes
equals the number of homes serviced per collection hour. Of course, additional information from the EPA Study is needed to make this comparison legitimate.

Later in this report, regression analysis will be used to develop a design equation to determine the average homes collected per collection hour, using pounds collected per pickup and the average travel distance between pickups as the independent variables.

**Tons Collected Per Collection Hour**

Tons collected per collection hour may be defined as the average weight in tons collected each collection hour. This is the last of three productivity parameters used in this report. Like the other productivity parameters, tons collected per collection hour depends on the pounds collected per pickup and the travel distances between pickups. Making a comparison with Figures 16 and 17, it is noted that the shorter the time per location, and the more homes collected per collection hour, the smaller the tons collected per collection hour. This gives the indication that more weight will be generated per collection hour if the pounds collected per pickup is high and the distance between pickups is short. For further comparison, the ERA Study averages 1.2 tons per collection hour. Note Table 6, one man system, collecting twice weekly. The City of Kissimmee averages, shown in Figure 19, indicate that 1.18 tons are collected per collection hour. This is a close comparison between City and EPA collected data results.
Later in this report, regression analysis will be used to
develop a design equation to determine the average tons collected
per collection hour, using the pounds collected per pickup and
the average travel distance between pickups, as the independent
variables.
CHAPTER VII

REGRESSION ANALYSIS FOR PRODUCTIVITY EQUATIONS

Data from the City of Kissimmee's time and motion study were subjected to regression analysis to obtain mathematical equations relating the productivity parameters previously mentioned.

Time per locations, homes collected per collection hour and tons collected per collection hour were considered to be dependent variables, \(Y\).

Pounds collected per pickup and the average travel distance between pickups were considered to be the independent variables, \(X_1\) and \(X_2\) respectively.

All of the equations will be of the form of:

\[ Y = a + b_1X_1 + b_2X_2 \]

The equations that resulted from these regressions show the effect of each independent variable on the dependent variables. In general, an increase in pounds per pickup, increases time per location, decreases homes collected per collection hour and increases tons collected per collection hour. An increase in average travel distance between pickups increases time per location, decreases homes collected per location hour and decreases tons collected per collection hour.

The following are the results of this regression analysis:
1. Time per location.

\[ Y = 0.626 - 685 + 0.0001448 X_1 + 0.0051442 X_2 \]

Where: 
- \( X_1 \) = Pounds per pickup
- \( X_2 \) = Average distance between pickup in feet and defined as follows:

\[ X_2 = \frac{\text{Total miles traveled collecting } X}{5280} \]

\[ X_2 = \frac{\text{Total homes on a route } X}{\text{percent pickup}} \]

NOTE: A decrease in the average distance between pickups will result with an increase of the percent pickup factors.

2. Homes collected per collection hour.

\[ X = 136.51 - 0.070163 X_1 - 0.016290 X_2 \]

Where \( X_1 \) and \( X_2 \) are the same as above.

3. Tons collected per collection hour.

\[ Y = 0.494 + 0.032262 X_1 - 0.0013453 X_2 \]

Where \( X_1 \) and \( X_2 \) are the same as above.

To help further show the effects of each independent variable on each dependent variable, Figure 20 is presented.
Fig. 20. Productivity Comparison
CHAPTER VIII

PRODUCTIVITY COMPARISON

In this section, the productivity equations developed from the City of Kissimmee study shall be compared to the Environmental Protection Agency Study results. The three collection routes of the City of Kissimmee shall be used as a basis of comparison.

The study results of EPA, as presented earlier, concludes there are four independent variables to be considered to each productivity equation. These are as follows:

\[ X_1 = \text{Pounds per service per collection.} \]
\[ X_2 = \text{Crew size.} \]
\[ X_3 = \text{Percent one way items.} \]
\[ X_4 = \text{Collection miles per day.} \]

Variables \( X_2 \) and \( X_3 \) shall be considered 1 and 100 respectfully, because the city has one man crews and is required by ordinance that containers shall be disposable. Using this assumption, Table 13 shows the comparison between the two studies. In general, the EPA Study regression results show less time per location, more homes being picked up per collection hour, and more tons collected per collection hour.
### TABLE 13
EPA – CITY OF KISSIMMEE COMPARISON

<table>
<thead>
<tr>
<th>ROUTE</th>
<th>AVERAGE POUNDS PER PICKUP</th>
<th>AVERAGE % PICKUP</th>
<th>COLLECTION MILES</th>
<th>CREW SIZE</th>
<th>PERCENT ONE WAY ITEMS</th>
<th>TOTAL PICKUPS</th>
<th>AVERAGE DISTANCE BETWEEN PICKUPS</th>
<th>TIME PER LOCATION (MINUTES)</th>
<th>ACTUAL HOMES COLLECTED PER COLLECTION HOUR</th>
<th>HOMES SERVED PER COLLECTION HOUR</th>
<th>TONS COLLECTED PER COLLECTION HOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CITY</td>
<td>EPA</td>
<td>CITY</td>
<td>EPA</td>
<td>CITY</td>
<td>EPA</td>
<td>CITY</td>
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<td>CITY</td>
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<td>CITY</td>
</tr>
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<td>1</td>
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<td>19</td>
<td>1</td>
<td>100</td>
<td>674</td>
<td>225.5</td>
<td>0.80</td>
<td>0.71</td>
<td>77.11</td>
<td>142.96</td>
</tr>
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<td>2</td>
<td>33.4</td>
<td>71</td>
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<td>1</td>
<td>100</td>
<td>742</td>
<td>240.5</td>
<td>0.81</td>
<td>0.77</td>
<td>73.90</td>
<td>140.17</td>
</tr>
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<td>3</td>
<td>29.3</td>
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<td>1</td>
<td>100</td>
<td>672</td>
<td>234.5</td>
<td>0.80</td>
<td>0.69</td>
<td>77.75</td>
<td>150.63</td>
</tr>
</tbody>
</table>

* Practical consideration dictates an accuracy to the nearest home.
Time Per Location

The increased time per location noted by the city, indicates the effect of increased travel distance between pickups, caused by the percent pickup factor. EPA Study results lead the Solid Waste Manager to believe that a route of 19 miles in length, with 500 homes to be served, requires the same time per location, as the same route with 300 homes to be served.

This, of course, is not the case. As the distance between pickups increases, the time to service each home will also increase. This is shown in Figure 21. Please note the two graphs intersect at the average distances of 100 feet between pickups. This is a good average distance between homes in a fifth acre lot subdivision with 100% pickup.

Homes Collected Per Collection Hour

The same is true with the homes collected per collection hour. Please note Figure 22. EPA results are much higher than the actual pickups presented by the City results, but again the number of homes served by the City, using the percent pickup factor, intersects with the EPA results approximately at the 100 foot average distances between pickups.

These results tend to lead the assumption that the EPA Study was conducted using an approximate distance between homes of 100 feet.
NOTE: ROUTE HAS 19 COLLECTION MILES & AVERAGES 32.3 lbs per PICKUP.

FIG. 21. TIME PER LOCATION COMPARISON
FIG. 22. HOMES COLLECTED PER COLLECTION HOUR COMPARISON

NOTE: ROUTE HAS 19 COLLECTION MILES & AVERAGES 32.3 lbs per Pickup.

EPA STUDY 142.98

CITY OF KISSIMMEE (HOMES SERVED PER HOUR)

CITY OF KISSIMMEE (ACTUAL PICKUP PER HOUR)

AVERAGE TRAVELED DISTANCE BETWEEN PICKUPS

HOMES COLLECTED PER COLLECTION HOUR

NOTE: ROUTE HAS 19 COLLECTION MILES & AVERAGES 32.3 lbs per Pickup.

EPA STUDY 142.98

CITY OF KISSIMMEE (HOMES SERVED PER HOUR)

CITY OF KISSIMMEE (ACTUAL PICKUP PER HOUR)

AVERAGE TRAVELED DISTANCE BETWEEN PICKUPS

HOMES COLLECTED PER COLLECTION HOUR

NOTE: ROUTE HAS 19 COLLECTION MILES & AVERAGES 32.3 lbs per Pickup.
Tons Collected Per Collection Hour

There is no comparison between the tons collected per collection hour in the study results. EPA's productivity equations do not seem to compare well with the system averages from their study, presented earlier in this report. There is probably a misprint in the equation as it is presented. Their equation indicates that one man can completely fill his truck in only one hour of collecting time.

Noting their time per location results of 0.71 minutes per location, and using an average of 32.3 pounds per pickup, they can pickup approximately 1.36 tons per collection hour. Noting Figure 23, this approximation of weight again intersects the city results at approximately 100 feet between pickups.

Conclusion of Result Comparisons

In conclusion, the results from the EPA regression analysis study do not compare well with that data collected for the City of Kissimmee system. This does not indicate they are wrong in their analysis, but goes to prove that all solid waste systems are individual in nature. Any equations used to describe a solid waste collection system must be specific in nature to the governing constraints of that system.

It should also be noted, that the information formulated using the City of Kissimmee data is only valid within the limits of that data collected, and should be specifically used on systems
E.P.A. RESULT 6.15

E.P.A. APPROX. TONS PER COLLECTION HOUR

CITY OF KISSIMMEE RESULTS

NOTE: ROUTE HAS 19 COLLECTION MILES & AVERAGES 32.3 lbs per PICKUP.

FIG. 23. TONS COLLECTED PER COLLECTION HOUR COMPARISON
of similar characteristics.
REFERENCES CITED


