

THE GARBAGE OF THE MID CONTINENT: ITS GENERATION AND COLLECTION

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Introduction

Solid waste collection is a major industry in almost all cities in the world. While the service is frequently both financed and provided directly by the city, some communities have chosen to contract the activity to private firms while others have essentially a competitive system whereby private firms charge individual customers for the service and no public funds are involved. A major purpose of this study is to investigate cost differences among these modes of operation. A related question is the extent of economies of scale in refuse collection. If economies are widespread, they would suggest that it may be efficient to organize waste collection districts rather than having decentralized systems.

The problem of collection is closely related to the waste generation process. Systems are usually designed to collect all the waste placed out for collection in order to reduce the health problems and other negative externalities which uncollected refuse would produce. Thus higher levels of waste would be expected to be associated with higher collection capacities or frequencies, as well as higher costs. In order to design a refuse collection system it is important to identify and measure those factors which influence the production of waste.

This study estimates waste generation functions, cost curves, and collection capacities for a cross-sectional sample of midwestern cities in the United States. Following a brief literature review, the article discusses the survey methods and nature of the data. The following sections present the empirical results for waste generation, collection costs, and collection capacity. There is a brief discussion and evaluation of contracts for private collection of municipal refuse and of user charges as a method of financing collection. The article concludes with a summary and suggestions for future work.

Background and Problems

Previous work in this area may be categorized as data gathering, theoretical, and empirical. One of the best known and most in depth references for municipal

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collection systems in the United States was prepared by the American Public Works Association [1]. It is a compilation of the collection practices of almost 1,000 cities. While the data are of high quality, the analysis is weak and generally unsubstantiated. The U. S. Department of Health, Education, and Welfare (Muhich, Klee, and Hampel [8]) undertook the most extensive survey of solid waste collection practices. Approximately 6,300 communities were surveyed, but the data were generally qualitative and did not stress the economic, managerial, or financial characteristics of the collection systems. Other recent descriptive work and data gathering efforts include Office of Science and Technology [14], National Center for Resource Recovery [9], Feldman [4], and Cononna and McLaren [3]. Although these studies provide useful suggestions for municipal officials who deal with collection systems, their empirical analyses are generally quite weak.

One of the best theoretical studies of the waste generation process is Wertz [15]. Using a modification of the standard economic model of consumer behavior and comparative statics analysis, he develops several hypotheses which are tested in a later section of this paper. In particular, he predicts that the generation of household waste:

(1) will be a positive function of income. This relationship follows from assuming either that waste is a constant proportion of consumption while consumption increases with income or that products purchased predominantly by high income groups lead to relatively large levels of waste.

(2) will be a negative function of the explicit price of collection. As collection costs increase, households are expected to change their consumption pattern so that less waste is produced.

(3) will be a positive function of the frequency of collection. As intervals between the dates of refuse collection increase, households are more likely to purchase garbage disposals and trash compactors and incur higher storage costs. All these adjustments tend to reduce the volume of waste generated by households.

(4) will be a positive function of the quality of the collection service. For example, if the place where the refuse is collected switches from the front yard to the back yard, service is usually considered to have been improved. More waste may be produced as a result because the households' cost of preparing waste for collection is reduced.

There have been few empirical studies of the waste generation process. One notable exception is Quon, Tanaka, and Charnes [11]. They compared the amount of refuse collected in neighborhoods in Chicago with different collection frequencies. They found that areas with twice a week collection service generated substantially larger quantities of refuse than similar areas with only once a week service. However, they analyzed only two parts of Chicago and did not show that the neighborhoods differed only in the frequency of service.

The Hirsch study [6] is one of the best known empirical analyses of the costs of solid waste collection. His data were gathered from 24 municipalities in the St. Louis area. He found that collection frequency, pickup location, and population density were the most important factors in explaining the costs of residential solid waste collection. There was no evidence of significant economies of scale.

Hirsch and similar investigations, for example Clark, Grupenhoff, Garland, and Klee [2], Savas [12], and Kitchen [7] have important results. However, there generally are some serious weaknesses. For example, with the exception of the Savas study, the sample size is usually small, the distinction between public and private collectors either is unclear or not made at all, user charges, if any, are not well specified, and cost data obtained from municipal budgets may include more than just the costs of collecting refuse unless major adjustments are made. As is discussed in the next section, the data collected for this study are likely to be more accurate than the information used in most other analyses.

Data and Survey Methods

The data used in our analysis of solid waste collection systems were obtained from several sources. National census data provided demographic information and the basis for selecting the sample cities, while two sets of questionnaires and personal interviews served as the major sources of specific information for each city.[1] The initial sample consisted of all cities with populations between 25,000 and 180,000 in the four states of Illinois, Indiana, Michigan, and Ohio, a total of 159 communities. By restricting the analysis to these four states, climate and other environmental factors were held relatively constant and at levels near the national average. As a result, it was not necessary to account for these variables explicitly in the analysis. The lower cutoff for population was necessitated by limitations in the data published by the U. S. Bureau of of the Census [13]. The upper limit removed the 11 largest cities in the four states from the sample. They were eliminated because of difficulties in collecting data comparable to the information in the smaller cities. The largest cities all had municipally operated systems, but their operations were generally highly decentralized and would have required considerable effort to collect all the necessary data.

Data were collected from three types of systems: municipally financed, owned, and operated ("municipal"); municipally financed but privately operated, usually with an exclusive contract ("private contract"); and privately operated, competitive systems with relatively little governmental control ("private competitive"). Some relatively minor adjustments to the raw data were made to account for variations in accounting techniques and the comprehensiveness of the collection systems. In particular, depreciation had to be added to most

[1] A more complete discussion of the data is available in Petrovic [10].

of the reported cost figures, the cost of commercial and industrial collection had to be subtracted, population density figures had to be adjusted to account for the presence or absence of collection from apartments, systems had to be placed on a common fiscal year, and the volume of refuse collected had to be expressed in the same unit of measurement. The data are summarized in the appendix as Tables 1-3.

The Waste Generation Function

Since there are no data available which directly measure the amount of generated refuse, the estimation of the waste generation process relies on the information for collected refuse. Thus it is implicitly assumed that all generated waste is actually collected. If self-disposal, via such methods as burning, littering, and self-delivery to landfills or recycling stations, is significant and varies among communities, the waste generation estimates will be inaccurate. However, there is no evidence that this problem is serious. Marginal costs incurred by households for placing additional refuse out for collection are usually low. Thus we expect self-delivery and littering to affect only small amounts of waste. While many of the communities have public or private recycling programs, they also collect a small proportion of total refuse.

Based primarily on the work by Wertz, we hypothesized that the amount of generated (and collected) refuse from households in a community would vary positively with the number of units served and income per capita. In addition, we would expect the amount of refuse generated would fall if an explicit user charge were imposed and would increase if the quality of the collection service improved. While climate should influence the amount of refuse produced, it is not explicitly in the empirical analysis because of the limited variation within the sample. When we analyzed these variables the following results were obtained:

$$(1)\quad V = -1045.89 + 1.15X_1 - 3239.2X_2 + 1.24X_3 + 2380.1X_4, \qquad R^2 = .73$$

$$\quad (0.31) \quad (12.43) \quad (1.66) \quad (1.68) \quad (1.17) \qquad F = 32.48, \quad n = 65$$

where

V = volume, measured in tons per year

X_1 = number of housing units serviced by the waste collection system

X_2 = the financing dummy variable, which equals one if the community has an explicit charge for refuse placed out for collection and equals zero otherwise

X_3 = annual personal income per capita

X_4 = the quality of service dummy variable, which equals zero if the refuse pickup location is only at the street curb and equals one if other locations, especially the back yard, are possible

Student's t statistics are written in parentheses below the coefficients for the independent variables. Using a two-tailed test, the coefficients for X_1, X_2, and X_3 are significantly different from zero at the 90 percent confidence level and have the expected signs. The quality of service variable, X_4, has the expected sign but is insignificant.[2] The results suggest that the amount of refuse produced is a normal economic good and decreases with an increase in the explicit or implicit price of collection.

There is little multicollinearity among the independent variables. Other forms of equation (1) did not significantly improve the results. In particular, unlike Quon, Tanaka, and Charnes, we found that frequency of service, in particular, changing from once a week to twice a week collection service, did not affect the amount of refuse produced.

An example may best illustrate the implications of equation (1). Utilizing the mean number of units served in the sample, 15,083, and the mean income per capita, $3,725, the waste generation equation indicates that a city with these average characteristics, without explicit user charges, and with curb side pick-up service could expect to generate and collect about 21,000 tons of refuse per year from their residential customers. This figure is equivalent to approximately 2.6 pounds per person per day.

Equation (1) permits an estimate of the amount of generated residential refuse without also including commercial or industrial solid waste. This separation is important since the collection systems for the latter types of refuse are often separate from the residential collection system. The results of this equation provide an accurate method for predicting landfill charges where these prices are based on volume. Projected volume figures could also be used to forecast the date at which a landfill would reach capacity and, coupled with the cost equations estimated below, calculate the increased costs which would result from annexing an area to the city.

The Cost Equation

Initially we specified that the costs of collecting residential solid waste would depend on the quantity of refuse, factor prices, the service quality, the type of operator (municipal or private), distance to disposal site, percentage of housing units which are apartments, and population density. However, because of problems in the quality and scope of the data, some modifications had to be made.

The most important substitution was the use of "the number of housing units served" as a proxy for "the quantity of refuse collected." This modification was made because the volume data were available for fewer cities, were less accurate than the information for units served, but still had a high correlation with units served (0.82). A positive relationship between total cost and number of housing units served was, of course, expected.

Factor prices were also expected to be positively related to the level of system costs. While capital costs were found to vary insignificantly among the

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[2]Removing the insignificant variables from this regression and the following ones did not appreciably change the results.

communities, there were major differences in wage rates. However, because the subsample of municipal systems was the only one for which data on the labor variable were available, it was only in using this subsample that the importance of labor cost was shown. Wage information was not available from the private collectors with any consistency or reliablity.

Pickup location and the frequency of the collection service were the two aspects of service quality which were measured. Both of them proved to be highly significant in explaining cost variations among the communities. High quality service, as indicated by other than curb side pickup locations and frequent locations, would be expected to require increased collection costs.

The type of operator was included in the analysis to determine whether there were significant cost differences between public (municipal) and private (contract or competitive) systems. The sign and magnitude of this variable have important policy implications for the design of collection systems.

The distance to the disposal site, percentage of housing units which are apartments, and population density attempt to describe specific operating characteristics of the collection systems. Longer distances would be expected to be associated with higher costs. Data for this variable were available only for the municipal subsample. A community with a large percentage of apartments might be expected to have relatively low collection costs because apartments are usually close together so that there is little travel time between stops. Furthermore, apartments frequently have central locations for trash disposal. Similarly, population density would be expected to have a negative sign. As housing units become more concentrated additional collections can be made per unit of time.

Using data from the 83 cities which provided complete information, the following results were obtained:

$$\text{(2)}\quad \underset{(3.22)}{TC = -205{,}885.7} + \underset{(17.74)}{28.16X_1} + \underset{(3.61)}{155{,}261X_4} + \underset{(3.56)}{26.01X_5} + \underset{(2.55)}{92{,}665.5X_6} -$$

$$\underset{(1.96)}{-62{,}408.73X_7} + \underset{(0.23)}{417.92X_8},$$

$R^2 = .83$
$F = 60.70$
$n = 83$

where

TC = total cost per year

X_5 = population per square mile

X_6 = weekly collection frequency

X_7 = the operator dummy variable, which equals zero if the collection system is operated by the municipality and equals one if it is operated by private firms

X_8 = percentage of housing units in the community which are apartments

The other variables are as previously defined. With the exception of X_8, all the coefficients are significant at the 90 percent level or better and have the predicted signs. However, as measured by the Goldfeld-Quandt test [5], there is significant heteroscedasticity in equation (2). As a result, the significance test for the coefficients may produce misleading results, although the estimates are unbiased. However, the use of subsamples in subsequent cost equations eliminated that problem.

In a hypothetical city with the average characteristics of the sample, the average cost per housing unit per year was approximately $32. The marginal cost, or the cost of servicing one additional unit for a year, was $28. Marginal cost and average cost information would aid a city in determining the appropriate user charge. The marginal cost information is especially important where there is competition among private firms. However, caution should be used in comparing the marginal and average costs because of the large and significant negative value of the intercept term. As systems become smaller the equation nonsensically implies that costs will become negative. The results of this equation are valid only within the population range of the cities sampled.

The results also indicate it is less costly to switch from once a week to twice a week collection service than it is to change from curb side pickup to back yard collection. In a city with the average characteristics of the sample, twice a week collection costs 19 percent more than once a week collection, whereas back yard collection costs 35 percent more than curb side pickup.

A second cost equation was estimated for the municipally operated systems. More data were available for this subsample.

$$(3)\quad TC = \underset{(4.98)}{-635{,}288.6} + \underset{(15.43)}{33.79X_1} + \underset{(2.74)}{140{,}171X_4} + \underset{(1.53)}{13.15X_5} + \underset{(3.39)}{126{,}159X_6} +$$

$$+ \underset{(1.84)}{3784.65X_8} + \underset{(3.17)}{1881.11X_9} - \underset{(.671)}{2160.11X_{10}}, \qquad R^2 = .87,\ F = 46.52,\ n = 55$$

The variables are as previously defined with the addition of

X_9 = average weekly wage per crew member

X_{10} = distance to the disposal site, in miles

All the coefficients are significant at the 90 percent confidence level and have the predicted signs except for the coefficients of X_5 and X_{10}, which have incorrect signs but are also insignificant.

The interpretations of the results from equations (2) and (3) are generally straightforward. Of particular importance is the large negative coefficient for the "operator" variable, X_7. It suggests that the costs of operating a solid waste collection system tend to be less for a private firm under contract to the community than for a municipally operated system.[3] The typical or average city

[3]No conclusion can be reached for the private firms operating in a competitive environment because no reliable cost data were available from them.

could reduce its costs by approximately 13 percent by switching from a municipal to a private contract system.

Other mathematical forms of equations (2) and (3) were investigated but did not significantly improve the results. In particular no economies or diseconomies of scale were found in the output range indicated by this sample.

The variable "distance to the disposal site" (X_{10}) was expected to be positively related to total costs, under the assumption the longer it takes to empty a load of refuse, the more travel time, as compared to collection time, is incurred. However, this relationship was found to be insignificant. The most likely explanation for this anomaly is the use of transfer stations. Rather than having each collection truck drive to the landfill, those cities with distant landfills have frequently found it cost efficient to build transfer stations, centrally located intermediate facilities where solid waste is switched from the specialized collection trucks to vehicles more suited for long-haul transportation. At the transfer stations the waste is compacted a second time so that several loads of refuse from collection trucks can be hauled together to the disposal site.

For approximately 20 percent of the communities in the sample, "distance to the disposal site" was interpreted as distance to the transfer station rather than to the landfill. The relatively short distance to the transfer station coupled with the costs of operating this facility is likely to create a situation where some cities with short distances to the disposal site have low total system costs (non-transfer station cities) while others with the same values for the independent variables might have high costs (transfer station cities). The use of transfer stations thus created a data problem which undoubtedly led to the insignificant relationship between total cost and distance to the disposal site. In short, the true distance was inadequately determined by the variable actually measured.

The incorrect sign for the population density variable (X_5) in equation (2) may similarly be due to the inability of that variable to measure accurately the intended characteristic, in this case, the concentration of collection units. For example, a city might be characterized as a sparsely populated city by the population density variable when, in fact, the residential portion of the city, where the collection system operates, is highly concentrated. The rest of the community might consist of vacant land or commercial and industrial properties. This hypothesis was examined by subdividing the municipal subsample into two groups: relatively low density self-contained cities and relatively high-density suburbs in major metropolitan areas. In each of these cases population density had an insignificant coefficient.

Collection Capacity

The major capital costs in solid waste collection systems are highly dependent on the number and size of the collection trucks. Thus it is especially useful to develop an approach to predict the amount of collection capacity which will be used in a particular community.

Not surprisingly, the most significant variable affecting the amount of capacity employed by a system is number of units served. The larger the size of the community the greater will be the capacity required, ceteris paribus. In addition, distance to the disposal site was also found to be positively correlated with collection capacity. This factor indicates the amount of time the crew must spend in non-collection activities. Long distances to the disposal site suggest that larger trucks would be optimal. One way to minimize the number of trips is to collect the refuse with larger trucks. Similarly we might expect improvements in the quality of service to require additional capacity. For example, more crews and trucks may be needed for back yard than front yard pick-up service because in the former case less refuse will be collected per period of time.

Furthermore, frequency of pickups is also positively related to collection capacity. A city with twice a week collection will incur a travel distance about twice that of a city with once a week collection and, therefore, will require additional collection trucks. The per capita income of the city also seems to affect the equipment purchases. A city with a good tax base might purchase more equipment than one in a precarious financial condition. Unfortunately, if it purchases higher quality equipment rather than simply larger or more trucks, the cubic yard measure used here to indicate collection capacity will not be able to capture the effect.

The estimated equation was

$$\text{(4)} \quad CC = \underset{(1.52)}{-53.82} + \underset{(9.58)}{.0075X_1} + \underset{(1.97)}{.016X_3} - \underset{(0.341)}{6.61X_4} + \underset{(2.30)}{31.60X_6} + \underset{(1.59)}{1.78X_{10}}, \quad R^2 = .634,\ F = 19.74,\ n = 63$$

where

CC = collection capacity, measured in cubic yards and all the other variables are as previously defined

All the coefficients are significant at the 90 percent confidence level except for the intercept term, the income variable (X_3), and the quality of service variable (X_4).

A study of the signs and magnitudes of the coefficients of the frequency of collection variable (X_6) in equations (1) - (4) indicates that doubling the collection frequency from once a week to twice a week reduces the amount picked up per collection by approximately one-half. However, the refuse trucks will have to travel approximately twice the distance to collect this reduced volume. This increase in distance traveled requires that trucks spend additional time on the road and necessitates additional capital. Equation (4) suggests collection capacity will increase 21 percent on average when frequency is increased from once a week to twice a week. This increased capacity, along with the associated labor expenses, accounts for the increased costs associated with additional collection frequency in the cost equations.

The Analysis of Contracts and User Charges

In this section we discuss several of the provisions in the contracts between private refuse collection systems and communities. In addition we examine the characteristics of the user charges employed by the few systems, both public and private, which use them to finance the service, either in whole or in part. Because of the variety of contracts and user charges in the sample, this section will be more descriptive than the preceding ones.

Two of the major aspects of contracts are (i) the mechanism used to adjust the fee or prices when costs change; and (ii) the number and form of rules or constraints on the practices of the collection company. The typical adjustment clause found in the sample permitted a total or partial increase in price for each percentage increase in wage costs. This procedure is based on the supposition that wages constitute the largest and one of the most rapidly increasing components of total cost. This type of adjustment clause has several drawbacks. It weakens hard bargaining on the part of management in labor negotiations. Since labor costs in all the contracts are defined solely as wages, this provision encourages management to substitute wage increases for improvements in fringe benefits. A third problem is undoubtedly the most serious. If wage costs are increasing faster than the other components of total cost, it is conceivable that the adjustment clause would increase total profits thus encouraging the contractor to increase wages.

A few systems have contracts in which the fee is adjusted on the basis of changes in the Consumer Price Index. While this technique does incorporate an inflation index, it is not ideal because it is not directly related to the costs of the solid waste collection industry. This procedure allows the operator to gain or lose from cost increases unrelated to actual costs.

The contracts in the sample varied considerably in their control over the activities of the contractors. These constraints included requirements that an office be established to hear complaints, each truck prominently display the name and the telephone number of the contractor, daily complaint reports be delivered to the mayor's office, city litter barrels be picked up free, a specific number of trucks be used, wages be no less than the equivalent city wages, routes and crew sizes be a certain number, and the contractor must provide a vehicle for the city's inspector of sanitation. While these controls may confer benefits, it must be realized that they are not costless. The requirements could become so onerous that the number of bidders for the contracts is severely reduced.[4]

The city should certainly specify the number of pickups per week, the hours of collection, the types of containers and refuse which are acceptable, and the pickup location (e.g., front curb or back yard). Seldom should any effort be made to specify the number of routes, the pay of the collectors, the number or size of trucks, or the crew size. These are management decisions best made by the contractor in an attempt to lower costs.

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[4]The contract specifications may be actually designed in such a way that only one particular firm would bid for the contract.

There are essentially two methods which have been used to finance solid waste collection systems. By far the most common is to use part of the revenue from general tax collections, primarily property taxes. In this case the costs of obtaining the revenue are low, but refuse collection service is undoubtedly underpriced. That is, the incremental costs of placing more refuse out for collection are virtually zero from the point of view of a single household. However, the costs of providing this additional collection service are not zero from the point of view of the collector. The average cost of collection in this sample ranged from approximately $31 to $34 per collection unit per year. This underpricing is rational only if alternative financing methods are associated with prohibitively high administrative costs or if the externalities of uncollected refuse are so high that the incremental price should be zero.

The alternative method of financing solid waste collection systems is user charges, either alone or in combination with general tax revenues. While a "pure" user charge would be a fee which varied with the amount of refuse collected, no community uses this precise method because of the high costs involved in operating such a system. Instead the "user charges" found in this sample were, with only three exceptions, uniform for each household receiving service regardless of the amount of refuse placed out for collection. Expressed on a monthly basis, the average charge was $2.33 per unit with extra charges common for additional service and discounts for the elderly or indigent.

Of the three cities that based their charges on the amount of refuse collected rather than a fixed charge per household, two cities (Barberton, Ohio and Lansing, Michigan) charged their users on a per bag basis. The cities themselves sold the bags, with a typical charge being 25 cents per bag. However, these charges only raised 54 percent of the revenue needed to run the system. The two cities that required payment on a bag-by-bag basis are the best examples of true user charges. The amount that residents in these cities pay for the collection service varies depending on how many bags of refuse they set out for collection. These systems also have the advantage of saving time for collectors since they do not have to spend time replacing garbage cans on the curb. The fees should also tend to encourage reductions in volume. Since the bags did not raise 100 percent of the revenue needed to operate the system, the additional revenues had to be raised through property taxes. The third city (Alliance, Ohio) charged one rate for three or fewer 20 gallon containers and another higher rate for more containers. In the case of Alliance, the service charge varied only incrementally with increased usage of the collection service.

One possible reason for employing user charges is to give the residents the opportunity to choose between public and private collectors. A city might provide the basic level of service, while a private collector might serve that segment of the population desiring additional services. If the real objective is to allow for competition, the system must be designed to be self-sufficient, regardless of the negative externalities involved. Otherwise, the residents choosing the private contractor will also be paying for part of the municipal collection costs through their city taxes. Only two municipal systems (South Bend, Indiana and Mansfield, Ohio) were competing with private firms for customers. One city collected 94 percent of its expenses while the other collected 140 percent of its expenses, and these cities had 25 percent and 66 percent of their markets respectively. Although this appears to be an anomaly, the sample size of two does not allow for valid generalizations. The city that had 25 percent of its market (South Bend) had only been in the collection business for four years. It is not clear whether the additional flexibility offered the residents or the potential efficiency that might occur from introducing competition into the system can justify the increased costs involved when two or more collection trucks drive up the same street to service their own particular customers. No tentative conclusions are available from the cost analysis because South Bend's actual costs were higher than the predicted level and Mansfield's costs were lower than expected.

A second reason for using direct charges is to improve the allocation of resources in the public sector. This is accomplished by allowing the users to pay for the quantity and quality of service they care to use. The cost of these services is borne more directly by the users. Another benefit of direct charges involves making the cost of the service more visible. Each resident will know exactly what the service will cost. Increased demand for additional services, like back yard pickup, can be met immediately by increased supplies of this service. At the same time, economic waste could be eliminated in the supply of the service. If no one is willing to pay the price for back yard pickup, this service could be discontinued. Explicit costs tend to encourage citizens to use only what they are willing to pay for and eliminate the guesswork involved in determining what levels of service the residents really want because the residents can provide this information directly in the market place.

To derive the full benefit of direct charges, they should be two-dimensional. Rates should vary with both the quantity and quality of the service. On the quantity side, if larger amounts of refuse are collected, the fees should be higher. With respect to quality, if additional services, such as back yard pickup or the removal of larger bulky items are provided, again the fees should be higher. Only one city (Alliance, Ohio) had a system with this degree of flexibility. Curb side service for three or fewer 20 gallon cotainers sold for $8.40 per quarter whereas the same service for four or more containers was $11.40 per quarter. Collector carryout service for three or fewer containers was $15 per quarter while four or more containers cost $21 per quarter. The two cities mentioned previously which charged for the service by selling bags clearly had a system where the cost was related to volume or quantity. Two other cities that offered back yard service at higher rates also had service or quality related charges. However, the remaining 20 cities studied simply charged a flat fee for one service level regardless of the amount of refuse collected.

Summary and Conclusions

This study used a new and carefully constructed data base to estimate waste generation functions, cost equations, and collection capacity relationships for household refuse. Although few communities impose true user charges which are based on the quantity of refuse placed out for collection, we found that the imposition of such fees is likely to have a major effect on the quantity of refuse produced. Unlike other studies we found that frequency of service did not affect the amount of refuse produced, although it did have a substantial effect on the collection costs. No economies of scale were found which would suggest that there is unlikely to be substantial cost savings attained by establishing regional collection systems. On the other hand, private operators were found, on average, to be more efficient than municipal systems.

Two areas in this study could benefit from further investigation. One issue is accurately measuring the collection density in a community and determining whether this factor affects the level of cost. We found that population density, even after adjusting for commercial, industrial, and apartment collections, is an inadequate proxy for this variable. A second area for further work is the interaction between collection and disposal costs. As our discussion of transfer stations suggested, it is somewhat misleading to separate completely the collection and disposal activities. Certain practices may raise disposal costs but also lead to compensating savings in collection costs. In general it seems that refuse collection and disposal should be analyzed as a single problem.

APPENDIX

TABLE 1: Results From First Questionnaire: Descriptive Information on Residential Solid Waste Collection Practices

	Illinois	Indiana	Michigan	Ohio	Total
	53 cities	18 cities	36 cities	42 cities	149 cities
Operator					
Municipal	40%	77%	44%	74%	55%
Private-Contract	41%	23%	42%	12%	31%
Private-Competitive	19%	0%	14%	14%	14%
Method of Financing					
General Tax	51%	89%	75%	50%	61%
User Charges	28%	11%	19%	43%	28%
Both Tax and Charges	21%	0%	6%	7%	11%
Collection Frequency					
Once a Week	72%	50%	84%	93%	78%
Twice a Week	26%	33%	8%	7%	17%
Other	2%	17%	8%	0%	5%
Pick up Location					
Curb Pick up	81%	100%	92%	62%	80%
Back Yard	19%	0%	8%	38%	20%

Financing	General Tax	User Charge	Both
Municipal Operators	75%	17%	8%
Private-Contract Operators	60%	20%	20%

Collection Frequency	Once a Week	Twice a Week
Municipal Operators	85%	15%
Private-Contract Operators	94%	6%

Pick up Location	Curb Pick up	Back yard Pick up
Municipal Operators	77%	23%
Private-Contract Operators	90%	10%

TABLE 2: Results From Second Questionnaire Sent to Municipal and to Private-Contract Systems

Municipal Systems

	Illinois 16 cities	Indiana 12 cities	Michigan 12 cities	Ohio 26 cities	Total 66 cities
Unionization					
Union	56%	67%	100%	96%	82%
Non-union	44%	33%	0%	4%	18%
Non-residential Collection					
Collected	12%	58%	83%	61%	53%
No Non-residential	88%	42%	16%	39%	47%

Municipal and Private-Contract Systems

	29 cities	15 cities	22 cities	30 cities	96 cities
Apartment Collection					
Collects Apartments	24%	60%	68%	53%	49%
No Apartments	76%	40%	32%	47%	51%

	Minimum	Maximum	Mean	Median	Sample Size
Collection capacity* (cubic yards)	54	426	119	113.5	66 cities
Distance to disposal site* (one way in miles)	1	28	6.7	5	66
Housing Units Served	5,260	75,666	15,460	13,078	96
Service Charge (per month)	$.75	$8.60	$3.38	$3.00	24
Crew Size*	1	5	2.75	2.5	66
Collector's Weekly Wages*					
Illinois	$ 160	254	194	185.5	16
Indiana	112	176	141	134	12
Michigan	150	235	187	202	12
Ohio	120	225	170	170.5	26
Driver's Weekly Wages*					
Illinois	$ 170	259	208	204.5	16
Indiana	125	180	146	189	12
Michigan	175	250	213	214	12
Ohio	160	250	189	184	26

* Data collected only for the municipal subsamble.

TABLE 3: Results From Second Questionnaire Sent to Systems With Private Competition

City	Number of Firms	Fee per Firm	Fee per Truck	Maximum Allowable Monthly Charge
Wheaton (Ill.)	4	$500	$ 0	$3.50
Kalamazoo (Mich.)	16	50	10	None
Lombard (Ill.)	2	100	0	4.25
Decatur (Ill.)	34	0	100	None
Champaign (Ill.)	44	75	0	None
Mentor (Ohio)	12	15	0	None
Findlay (Ohio)	20	25	0	None
Kettering (Ohio)	8	50	0	4.75
Northbrook (Ill.)	2	300	0	5.20
Highland Park (Ill.)	2	0	25	5.50
Sandusky (Ohio)	15	0	25	None
Urbana (Ill.)	25	100	0	None
Rantoul (Ill.)	2	10	0	None
Downers Grove (Ill.)	4	50	0	4.50
Kent (Ohio)	14	12.50	12.50	None
Jackson (Mich.)	2	400	13	4.31
Mean	13	129.81		4.57
Median	10	50.00		4.50

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