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SEATTLE SOLID WASTE UTILITY

GARBAGE BY THE POUND

PILOT PROJECT SUMMARY

April 1991

Funded by the U.S. Environmental Protection Agency

WASHINGTON UTILITIES AND [illegible] COMMISSION
No. TG-940411 Ex 67

ABSTRACT

This report is an analysis of the Seattle Solid Waste Utility Garbage by the Pound Pilot Project. The project involved research and field testing to examine the possibility of weighing and recording residential garbage at the curb for billing by the pound. The project was supported by a grant from the U.S. Environmental Protection Agency. The project coordinator for the City of Seattle was Hans Van Dusen with analysis assistance provided by Lisa Skumatz of SERA, Seattle, WA.

Garbage by the Pound Pilot Project

CONTENTS

1.0 SUMMARY

Variable customer fees have become an essential element in developing efficient and equitable billing systems for residential garbage collection. Rate incentives reward customers for recycling and waste reduction and allow agencies to recover program costs. Billing, based on the level of garbage generated by the customer, requires some form of measured or metered collection. Metered garbage systems could be based on measurement by volume or weight. Several forms of volume-based systems have been successfully implemented in many communities; fees are reflective of the number of cans, bags, or tagged garbage collected. The purpose of the Garbage by the Pound Pilot Program was to evaluate if weight-based rates could provide another metering approach.

A weight-based system could be even more flexible and convenient, but there has been only limited testing and no full-scale implementation. The Seattle Solid Waste Utility conducted the Garbage by the Pound Pilot Program between February 1990 and February 1991 to examine the potential for a weight-based garbage collection and billing system. The program was funded by the U.S. Environmental Protection Agency and involved background research, field testing equipment, and surveying customers.

This exploration of relevant equipment and projection of customer behavior was to establish a basic proof of concept, not a final blueprint or solution. The project objective was not to design a final weighing system, but rather, to determine if there are significant technical, system, or attitudinal barriers to considering full implementation. Broad parameters were considered to allow for potential application to any municipality, not just Seattle. The project findings included in this report are a starting point for additional study by Seattle and other communities for implementation of residential garbage billing by weight.

No developed residential weighing systems were discovered during initial program research. A few companies had begun to experiment with modifying hydraulic cart tippers to weigh residential garbage carts. These systems were neither available for leasing nor compatible with the small customer containers used in Seattle. The Solid Waste Utility developed its own affordable, integrated system for easy implementation into Seattle's manual collection process. At the end of the pilot program, the Solid Waste Utility also had the opportunity to lease a semi-automated cart-based weighing system for a brief six-week test.

For the manual system, a small industrial crane scale, a bar code scanning gun, and a portable data terminal were mounted to the rear of a single packer truck. Three collection routes were selected for testing in South Seattle. Bar code labels were attached to all 1500 waste containers on the test routes to identify the corresponding households. The operator was required to hang each container on the crane scale hook and scan the container label with the scanning gun. Weights and label identifications were stored in the

data terminal. This system required no major changes to the collection process. The 1500 pilot customer received introductory information, six biweekly sample bills (with comparisons to the current variable can rates), and a customer survey. Customers continued to pay their normal variable can rate bills.

The system performed surprisingly well, meeting virtually all the needs of the Seattle pilot program. It allowed for convenient, quick, and affordable implementation. It produced accurate and reliable data for sample billing with very little down time. For the operator, it was easy to learn and use, but extended collection times slightly (about 10%). Although the system was a success in the pilot program, it may not be sufficient for full-scale implementation. The system requires operator interaction, in hanging the can and scanning the label, allowing the potential for human error and increased collection time.

Analysis of the pilot customers' sample bills produced encouraging results. The average weights of waste per household showed a declining trend over the twelve-week experiment, even with customers not actually paying the weight-based bills. On average, the total per household drop was about 15% (3.5 pounds) over the course of the experiment. Mini-can customers (subscribers to 19 gallon containers) actually showed an average cumulative decrease of about 23%. For comparison, non-participating household in South Seattle showed no decreasing (or increasing) trend over those same twelve weeks.

Customer response to the pilot program survey was very supportive. Almost 60% of all respondents reported they were moderately or very satisfied with the pilot program. The majority of respondents (54%) even preferred a Garbage by the Pound System, while fewer (24%) preferred the current variable can system. The program was the most popular with the respondents who put out the least garbage. The respondents indicated many features and advantages that they liked about the Garbage by the Pound program. Their greatest concern was their impression that the program might be expensive to implement. Many of the respondents (66%) felt that additional funds should not be spent if the program is more expensive. Overall, a Garbage by the Pound system appears to be acceptable, and maybe even desirable, to the customers if it is affordable.

After completing the field testing and sample billing with the crane scale system, the Solid Waste Utility conducted a six-week test with a leased cart-based weighing system. No bills or mailings were sent to the customers, but it was an opportunity to examine the potential for a more automated design. The modified hydraulic cart tipper was being developed by Toter, Inc. The system used load cell and radio frequency technology to automatically weigh and identify garbage carts during the normal collection process. The prototype system produced inconsistent results, but showed promise for a potentially marketable solution.

A few companies have begun testing and even marketing similar systems that modify hydraulic cart tippers for weighing residential garbage. None have produced proven

results with sufficient accuracy and reliability, but all are making rapid progress. Integrated cart-based designs have excellent potential for automatically weighing waste and identifying household waste with little operator interaction or extra collection time. The equipment appears to be affordable with onboard expenses (modifications to the truck) in the $5,000 to $10,000 range. Hopefully, in a couple years, a few companies should have competitive, guaranteed products available.

If the products develop, then weight-based collection and billing could be easily implemented in communities using or considering cart-based collection. Communities without cart based collection must consider initiating product development in a different direction or modifying cart tipping system for their needs. (Emptying small cans or bags into a container fixed on the tipper may be an option.) All communities must consider the complications and expenses that a new system will incur with new equipment, customer and employee education, and contractor or union contracts. The advantages and limitations will be different for each community.

The Seattle Solid Waste Utility will not consider full implementation of a Garbage by the Pound program until later in the decade. A primary limitation is the current contracts with garbage collection contractors which expire in 1998 and are based on the current variable can system. In addition, Seattle has many other programs still ramping up and a successful variable can system. Already, however, the rate incentives of the variable can system are becoming less variable, with 87% of customers now subscribing to one or fewer cans. In the future, the Solid Waste Utility could look to a weight-based operation to continue to encourage customers to reduce waste levels.

Many municipalities may have the opportunity to implement a weight-based system sooner. Farmington, Minnesota and Durham, North Carolina have already begun their own pilot programs. The research and testing of the Seattle pilot program indicates that Garbage by the Pound could be technologically feasible and acceptable to customers. In theory, the system could have tremendous advantages to a municipal agency and its customers, offering reliable revenue recovery, simple disposal and collection procedures, and clear and continuous incentives to reduce and recycle.

2.0 INTRODUCTION

Many communities across the nation have an urgent need to reduce the amount of waste disposed by their customers. They may be motivated by a need to meet legislated recycling goals, conserve landfill space, satisfy recycling proponents, or other reasons. Rate incentives are becoming a more acceptable method of providing inducement for the customers to work with solid waste managers in solving the crisis.

Recycling programs and existing volume-based rate systems have proved to be very effective in reducing the disposed waste. However, because rate payers must subscribe to a discrete number of cans or bags for weekly service, the effectiveness of a volume-based system may be limited for several reasons:

- With variable can systems, customers are charged on the basis of the service level they subscribe to, not based on the amount of service they actually use on a week-to-week basis. There is no reward to the customer for putting out less than their subscription level.

- Customers at the lowest subscription level may not achieve any further savings no matter what behaviors they adopt. It may not be practical to continue to reduce the size of the lowest subscription to half-cans, quarter-cans, or smaller bags because of inventory and other practical difficulties.

- Under either bag/tag or variable can systems, customers must reduce their waste by a whole bag-full or whole can-full in order to see any savings. The increments by which they are rewarded for their waste reduction activities are too large.

- Variable bag/tag or can systems can be confusing and inconvenient. Customers must decide on a "normal" subscription level, and take extra action for any changes. The jurisdiction may need large inventories of different can sizes, and have a network for providing bags or tags.

If customers' bills could vary more directly with the amount of waste actually disposed, waste reduction and recycling incentives would be further enhanced and landfill space would be conserved. A weight-based system could offer fair and flexible billing incentives. In addition, systems that measure waste by weight have some basic advantages over volume-based measurement systems:

- Quick measures of small volume increments would be difficult to implement, but scales are a well-known and proven technology. No volume measurement system can match the convenience and availability of scale systems.

- Metering service on the basis of weights is well accepted by customers in other applications

- Landfills are often charged on the basis of weight.

Landfills don't fill up because they are too heavy, but because they are too full. Many landfills even charge on the basis of volume. However, any one measure that is used is a proxy for all the factors that impact the ultimate demise of a landfill. Weights provide a convenient, well-accepted proxy that provides small increments and requires no special judgment at the curb. The important characteristics are the precision and flexibility of a measurement system, not whether volume or weight is specifically more relevant to solid waste dilemmas.

Billing by metering has long been accepted in other residential services such as electricity, water, phone, and natural gas. Adopting a weighing system in waste collection would transfer the responsibility of measuring the quantity of waste from the customer to the collector. Collectors weigh the waste rather than customers fitting the waste within a prescribed bag or can. Developing reliable equipment will be essential to gaining the trust of the customer.

Weight-based rates would be fair to customers, would increase customer awareness of the impact of throwing out more waste, would improve waste reduction incentives, and would lead to reductions in the total amount of waste disposed.

3.0 BACKGROUND OF RELEVANT TECHNOLOGY

The background research for the Garbage by the Pound pilot program produced valuable information on the variety of technologies that are being applied to weighing garbage. The section provides an overview of the many possibilities that were considered for the pilot program and should be evaluated by any municipality considering a weight-based system.

The availability of guaranteed, reliable, and accurate equipment is vital to the successful development of a weight-based collection system. The equipment must produce the correct weight for the correct customer every time. Preliminary research indicates that equipment for these applications is rapidly being developed. It is technically feasible to weigh and record residential waste, but many relevant products are still in preliminary stages. Weighing equipment is not prohibitively expensive, but many systems may slow down collection times. Almost all systems tend to incorporate four basic components.

All system designs can be considered an integration the following components:

- **electronic weighing mechanism:** to weigh the garbage
- **electronic identification:** to identify the customer
- **onboard computer with programming:** to store garbage weights, customer identification, and route information
- **office computer or billing system with programming:** to process weights and identification and produce bills

There is at least preliminary equipment available to perform all the needed functions. Many components have already been developed for similar applications.

Some companies are beginning to market entire integrated systems, but in many cases, the designs and solutions for each component can be considered independently. Different types of collection services and jurisdictions will require different integrated solutions. In each municipality, the specific design requirements are influenced by the specific elements of the current collection service and the desired functions of the future service.

Important, relevant factors include:

- current form of service,
- current collection equipment and containers,
- current and projected waste generation levels,
- current billing system,
- form of collection contracts,
- density and geography of neighborhoods,
- and overall population.

Some of the applicable technology for an appropriate system has only recently been developed. The choices are limited for both integrated systems and individual components. Some of the obvious criteria to consider when comparing or evaluating potential design solutions are listed below.

Evaluation Criteria

Collection time/labor costs: How much more or less labor time and costs does the equipment require to service the current customer base?

Convenience: How much knowledge and training is required to operate the new equipment? What will be the effect on contracted hauler or labor negotiations? How convenient will service be for the customer?

System compatibility: How does the new equipment work with current collection equipment and household containers? What new, related equipment will be required?

Accuracy: Does the equipment provide consistent, accurate results? What is the possibility for human or equipment error?

Durability: Will the equipment endure and perform in the harsh environment of outdoor garbage collection? Will the equipment function while subject to adverse weather, truck jolting and vibration, and continual abuse?

Cost: What is the cost to purchase and maintenance the equipment? What is the cost of related equipment?

The following sections provide general outlines of the types of equipment available to meet each design component. Table 3.1 lists specifications of equipment designed for the weighing function of a weight-based collection system. In addition, Section 5 describes the specific equipment used in the Seattle pilot project.

3.1 WEIGHING MECHANISMS

The actual garbage weighing mechanism is the most critical and, unfortunately, least developed component of a complete system. Only recently has there been significant testing and development of technology designed specifically for weighing individual household garbage. Traditionally, the garbage industry has only focussed on weighing the large volumes of packer and hauling trucks and, more recently, dumpsters. Weighing the smaller volumes of individual households requires more refined technology.

Weighing residential garbage during collection is a difficult, but surmountable, challenge. It demands measuring relatively small weights to certifiable standards in a harsh and abusive environment. The scale must overcome the effects of truck vibrations, steep inclines and extreme rugged use. With few directly transferable products, this application requires the testing and development of new designs. Older products that may have some relevance include truck body load cells and crane scales. Most of the testing and development of new products has focussed on the modification of automated cart tippers. Table 3.1 provides a listing of costs and specifics of current relevant weighing products.

Truck Body Load Cells

Historically, the most basic and proven onboard weighing device is a network of truck frame load cells. Load cells are strategically placed steel blocks with electronic sensors that translate the stress resulting from an applied load. In many industries load cells are attached to a truck frame to measure the weight carried by the truck. These systems can only be used for measuring truckloads of garbage and not residential cans. Load cells under a multi-ton compactor body cannot accurately measure an additional 30 pounds. Producers of these systems, however, have developed a variety of onboard computer hardware and software for data storage and analysis, which is transferable to residential weighing systems.

Crane Scales

Crane scales are a traditional product of the scale industry that may be applicable to some residential weighing operations. A crane scale is a hook underneath an electronic load cell, producing an electronic output of the weight of any object on the hook. A crane scale could be used in a very simple system of hanging each garbage can from the hook before dumping. **A crane scale system was selected for Phase I of the Seattle Pilot Project.** The specific system design is covered in Section 5.1.

Crane scales are produced by many major scale companies for a variety of commercial applications and are usually certified to meet all official accuracy requirements. They are

a proven and experienced product, with an established network for convenient repair and replacement. A crane scale for weighing residential garbage must produce an electronic output (i.e. RS232 out) and be guaranteed for rugged, outdoor conditions.

A crane scale system is easily adapted to a collection system using primarily manual garbage collection (no carts or hydraulic tippers). No major equipment changes would be needed to these manual collection systems. However, providing uniform garbage cans makes it easier to assume a uniform tare weight. The manual weighing of each garbage container will require additional collection time and costs unless garbage levels (and number of cans) are significantly reduced. The manual loading and unloading of the scale also allows for potential human error. In general, the system would be fairly inexpensive and simple to use, but may involve too much operator interaction and extra time.

Cart Tippers

The most significant and relevant product development is in the area of cart tipper modifications. The collection industry produces a variety of cart tippers for dumping large residential garbage carts (60 and 90 gallon). The hydraulic mechanisms are individual units attached to truck bodies for semi-automated or fully automated cart tipping. In the residential sector the carts are primarily 90 gallon wheeled plastic containers. With semi-automatic tippers, the operator is required to wheel the cart to the tipper. With fully automated arms, the tipper picks up the cart from the curb, and the operator never leaves the cab.

A few scale companies and collection equipment companies have begun developing systems to modify cart tippers by incorporating a weighing mechanism. Companies are developing both new tipping systems and supplemental units to modify existing, old tippers.

Over the past few years, similar technology has been successfully incorporated into front loading dumpster collection trucks. Many companies have incorporated this onboard weighing technology to improve and monitor volume-based dumpster bidding. Actual billing by weight is not common. Most of these new dumpster weighing products have been reliable and accurate, but they will require major modifications to meet the accuracy demands of weighing the much smaller weights of household containers. As with any weighing mechanism, a modified cart tipper must address the difficulties of steep inclines, weather changes, vibrations, major shocks, and rugged use.

There are two methods for weighing garbage on a cart tipper, using either load cells or a pressure transducer. Load cells are usually incorporated in the supporting structure of the entire tipper. Pressure transducers measure changes in the hydraulic pressure from the additional garbage load. Pressure transducers are generally cheaper but tend to be less reliable. Changes in hydraulic fluid pressure and viscosity due to changes in fluid

temperature must be considered in hydraulic designs.

Testing for both technologies has involved both static and dynamic weighing. In static weighing, the garbage cart is lifted to a designated point and then paused to record the weight at that point. The tipper must pause at a point where consistent geometry of loads is maintained. Different arrangements of garbage in a can and street inclines can be troublesome in static weighing. The pause must be repeated on the way down with an empty cart if individual tare weights are desired.

In dynamic weighing, there is no pause. A series of changing weights or pressures may be recorded and analyzed. A dynamic system requires more sophisticated software to arrive at a single weight. Changes in hydraulic fluid due to temperature are more complicated in a dynamic system. In general, dynamic measurements tend to be more complicated but more reliable. Dynamic weighing also does not require the added pause time.

Early systems have performed with accuracy levels of 1% to 10%. The systems adapt easily into current automated collection procedures and generally require very little operator interaction. Individual systems are convenient to use but may be complicated to repair and maintain. **A semi-automated dynamic tipping system with load cells was selected for Phase II of the Seattle Pilot Project (see Sections 5.3 and 5.4).**

For municipalities without a current cart-based system, there are other factors to consider when switching from a manual to an automated collection system. Any cart-based system will introduce a change in expenses for collection time, cart costs, and workmen's compensation/injuries. The customers may face the mixed incentive of having a larger waste container, while receiving weight-based bills. In addition, customers will face the convenience or inconvenience of maneuvering and storing large carts.

Another option may be to empty the contents of standard, private bags and cans into a single cart that is permanently attached to the tipper for weighing. Any significant attachments, such as large carts, may effect the mobility and clearance of the truck. This design is untested, but may offer more flexible implementation.

Most progress and developments in garbage weighing mechanisms should be in the area of cart tipper modifications. Modified cart tippers will be the first products specifically marketed for weighing residential waste.

Table 3.1: Products for Weighing Residential Waste

Company	Product	Technology	Projected Accuracy	Date Available	Cost Estimate	Test Locations
1. Seattle Pilot Phase I						
Measurement Systems Int. Seattle, WA (206) 433-0199 Attn: Matt Hense	Crane Scale: 5260 Crane Unit and 3600 Indicator	load cell	± .1% certified	currently available	$2750	Seattle 9/26/90 - 12/17/90 Ed Steyh (206) 684-7666
2. Seattle Pilot Phase II						
Toter, Inc. Statesville, NC (800) 288-6837 Attn: Flemming Atkin	Modified semi-automatic cart tipper	load cell radio frequency	± 1 lb.	January '92	$7500 all onboard inc. tipper	Seattle 1/24/91 - 2/28/92 Ed Steyh (206) 684-7666
3. Others						
Wray-tech Instruments Stamford, CT (203) 325-0665 Attn: David Wray	WT6000R Attachment retrofit cart tipper	pressure transducer bar codes on route sheet	± 1%-2%	currently available	$8600 all onboard modifications	Farmington, MN Begin April '91 Robert Williamson (612)463-7111
	(Wray-tech is also developing other residential and commercial waste weighing designs.)					
Filing Scale Co. Twinsburg, OH (216) 425-3092 Attn: Joe Mandansi	Attachment to cart tipper	load cells	± .1%	currently available	$4500 scale only (no ID)	Durham, NC May - July '91 Tom Bastable (919) 560-4105
Zoeller Waste Systems Germany (415) 526-6857 in U.S. Attn: Daniel Holm	Modified cart tippers	?	?	May '92	?	Germany
MTB, Inc. Austria	?	?	?	?	?	Kossen, Austria
SI/Lodec Inc. Seattle, WA (206) 244-6100 Attn: Bill Rigby	Retrofit to semi- and fully automated tippers	pressure transducers foreign design	± 1 kg (2.2 lb.)	?	$4500 weighing equipment only	negotiating with foreign designer
	(SI/Lodec also produces commercial waste weighing systems)					

3.2 IDENTIFICATION OF CUSTOMER

An efficient weighing system will require electronic customer identification to quickly identify each customer during collection. Each weight must be associated with a customer account or address.

Manual entry of address

The most primitive form of identification is manual entry of customer identification by the operator voice, pen or keyboard. A similar option is entering the weight manually on a printed or electronic route display. All of these designs are limited in reliability and efficiency. This design is slow, inconvenient, and susceptible to human error.

Pre-programmed route

The route-following technique could be improved with an onboard portable computer. The computer would store a entire route and produce each account/address in the order that they are usually serviced. The operator would only need to push one button to verify the correct address. Edit commands would allow an operator to include changes in the route during collection.

This system has never been developed or tested. The design requires operator understanding and interaction to facilitate any impromptu route changes. The system must also be adaptable to the collection of one route by different collection trucks and operators on the same day. Significant programming and precise data entry would be required to ensure a properly functioning system.

Bar codes on route sheet

Bar code technology offers some valuable opportunities for rapid customer identification. Bar coded route sheets or books are currently used on some commercial routes for weighing and identifying dumpsters. As each dumpster is weighed, the operator scans a bar code label on the route sheet for the correct customer.

All of the above systems are primarily suited for use in the cab of a collection truck. They would be most appropriate for routes with fully automated collection and easily identifiable residences. Identification would be more difficult on routes with dense housing, alleys, and where an operator collects a few house before returning to the cab.

Bar code labels on containers

Another option for bar code technology is directly labeling waste containers. Each container would receive a bar code label and the truck would have a portable bar code scanner. There are only a few manual scanners designed to operate under the abuse and weather of collection conditions, primarily either certain contact wands or non-contact guns. Fixed automatic scanners cannot currently operate with the low voltage and high vibration conditions of a collection truck. Labels are produced with durable adhesive and laminate to survive abusive elements. Customer identification can also be printed on the labels for easy and continual verification by customer.

For each container the operator must manually scan the label with a gun or wand. Labeled containers and portable scanners have already been successfully implemented on garbage and recycling routes for inventory and credit monitoring. **Bar coded container labels were tested in Phase I of the Seattle Pilot Project (see Section 5.1).** It is a quick and easy system, but the reliability is dependent on durable scanners and labels and correct operator use.

Radio Frequency

Radio frequency technology offers the most automated identification. Radio frequency systems involve a transmitter/receiver antenna mounted to the truck and passive transponders mounted to collection containers. The antenna transmits a radio frequency signal which is returned by the transponder in a form that identifies the container. The reception range is small enough so that only one container can be in range at a time. A properly designed system will function automatically, with no operator interaction. **A radio frequency system was tested in Phase II of the Seattle Pilot Project (see Section 5.4).**

Radio frequency is a relatively new by widely used technology. More durable, compact, and inexpensive products are continually being introduced. Currently, individual tags cost between $5 - $10 in bulk quantities, a major expense in city-wide implementation. The tags should perform accurately for 6-10 years.

Labeled containers, with bar codes or radio frequency, involve the expense and complications of tag distribution. After distribution, cart switches between customers can add additional complications. Container identification would be more difficult for the customer with radio frequency tags.

3.3 ONBOARD DATA STORAGE

An integrated system will include an onboard computer to store linked weights and customer identification received from the scale and identification components. A full day or week of customer identifications and their respective garbage weights can then be instantly downloaded to the office or centralized billing computer after collection.

Onboard computers also offer a wide array of route monitoring opportunities. The computer can be programmed to produce or record information on each customer, on truck and operator efficiency, route summaries, and other relevant information. (Detailed route monitoring may be controversial development between labor unions, management, or customers.) Custom programming allows a municipality to design software for their data needs.

There have been many small portable, affordable computers developed primarily for commercial and industrial inventory applications. In addition, portable computers have been are commonly used by many other public service utilities for meter reading. Only a few, however, are designed to meet the rugged conditions of garbage collection. Units should be environmentally sealed with sufficient shock, vibration, and weather protection. These computers are often only as big as a portable telephone and offer custom programming and easy link up with data input (scale and scanner) and output (billing computer) feeds.

Any successful unit must have sufficient operating speed to quickly process the dual inputs. In addition, the unit must include dual feeds to accept both the scale and identification inputs. Some form of manual (keyboard) entry is also essential for any instance where either the scale or identification input is missing or incorrect.

Developers of entire weighing systems will have already integrated onboard data storage hardware. The onboard hardware usually includes a permanent computer board and a detachable portable device for up and down loading. They usually offer customized programming to meet customer needs.

An additional feature to consider is incorporating a some form of removable data cartridge. In the case of any equipment breakdown, related or unrelated, the cartridge and all important data could be easily switched to another system or truck to minimize down time. A data cartridge also allows for quick and convenient up and down loading of data.

3.4 OFFICE COMPUTER

Office computer hardware and software will be required to manipulate data received from collection and produce customer bills. The amount of new equipment and programming required will depend on what is already available for current billing. The equipment and programming for communications between office and onboard computers is usually fairly insignificant in size and cost. Other service utilities have successfully used systems based on communicating customer information between portable collection computers and office personal computers or mainframe computers. Programming and equipment for processing on the office computer can be provided by either contracted services or in-house technicians.

4.0 SEATTLE SOLID WASTE UTILITY FIELD TESTING

The primary work of the Garbage by the Pound Pilot Project was a six-month field test of relevant equipment to establish the viability of the concept and investigate customer reaction. The field tests involved two phases. Phase I involved a three month test of manual weighing equipment, mailing sample bills, and a project survey. The Phase I system was designed for quick and convenient incorporation into the current Seattle collection system. The equipment established basic feasibility and produced accurate weights for sample billing and revenue calculations. Phase II involved a one-month test focussed on examining more automated weighing equipment.

4.1 SWU PHASE I OPERATIONS AND PERFORMANCE

Phase I of the Pilot program involved a three month field test on three collection routes in South Seattle. The prototype weighing system used a certified crane scale and a bar code scanning gun, both wired into a portable computer. All three components were attached to the rear of the packer truck (see Diagram 4.1). A bar code label was attached to each pilot customer container for identification.

The 1500 pilot customers received start-up information and then six bi-weekly sample bills to compare how billing by weight might compare to the current system. After the field testing the customers received and returned a survey on the program.

Table 4.1: Phase I Operations Summary

Field test dates:
- 9/26/90 - 12/17/90

Collection truck:
- 1 rear-loading packer
- 1 operator

Containers:
- 19 and 32 gallon
- uniform containers

Customers:
- 1500, 3 routes
- weekly collection

Equipment:
- 500 x .5 lb. crane scale
- bar code scanning gun
- portable computer
- bar code labels

Equipment cost:
- $8,000

Mailings/customer:
- 6 sample bills
- 1 billing summary
- 1 program survey

Equipment selection

Initial selection of equipment was limited by primarily three factors: current collection system, available technology, and program budget.

The current Seattle collection system is based on a variable can rate structure; customers subscribe to certain number and size of containers for weekly pick-up. The desired container is provided by the contractor, and only waste in contractor-provided containers is collected from. The pilot test was coordinated through the collection contractor for South Seattle. In South Seattle, there are almost no large garbage cans, customers subscribe to only one or more 19 or 32 gallon plastic can. Collection is primarily manual dumping with one-man, rear-packer trucks.

At the time of the pilot program, there was no available equipment designed for weighing garbage in a manual collection system. Even automated cart tipping systems were only in preliminary development stages. In addition, full-scale testing of a cart-based system in Seattle would be an expensive and complicated endeavor. Seattle's system of variable can rates and the predominance of small containers is not currently compatible with automated cart-based collection.

The best opportunity for immediate implementation was to design a prototype system using off-the-shelf products for manual weighing and collection of small containers. The primary components (scale, scanner, data terminal) were selected for their ability to integrate within the system and survive the harsh environment. Specifications of the Phase I system are listed in Table 4.2.

The weighing mechanism was a small, industrial crane scale and indicator. The MSI 5260 Crane Unit and the MSI 3600 Magnum Indicator provided a combination that was durable, weatherproof and produced output data via RS232. The MSI units are locally produced allowing for immediate delivery and service. The Crane Unit contains a hook with a 1.3" opening and a sealed load cell for measuring weight. The Indicator receives voltage differentials from the crane unit and produces a digital display and a digital feed to the RS232.

The Symbol LS-8500 HV Scanner and the MSI PDT-LS Data Terminal are also designed to operate in adverse conditions. The scanner has a high visibility laser to perform sighting and reading in all outdoor lighting. The data terminal has input terminal for feeds from both the scanner and the scale. The terminal displayed customer address, label number, and full container weight at each residence.

The data terminal was programmed by Systems Technical Sales (STS) of Seattle to retrieve and store data automatically unless interrupted by the operator. The operator had capabilities to manually correct or enter any information not being received. The data terminal was uploaded and downloaded once a week with updated customer information.

Labels were purchased from the recycling program in the City of St. Louis Park, Minnesota. They were designed with adhesion and laminate to last outdoors on waste containers.

Diagram 4.1: Phase I System Design

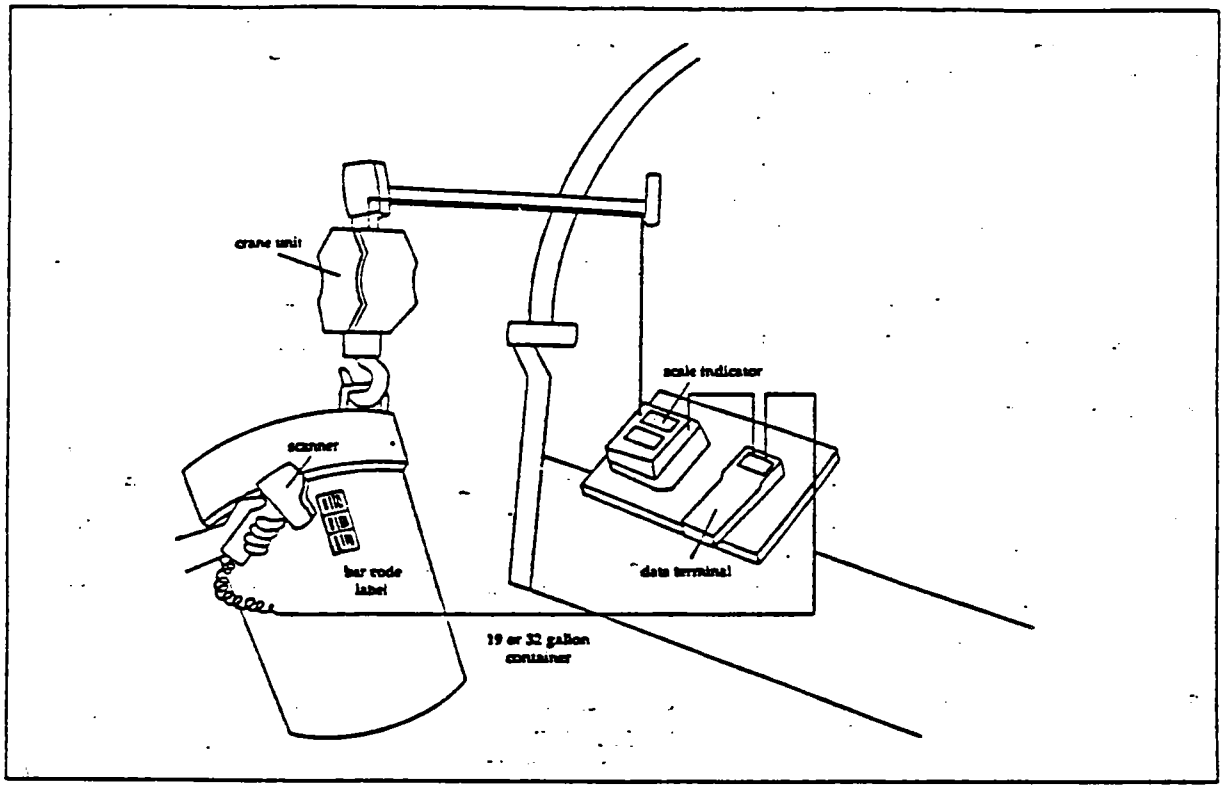


Table 4.2: Phase I Equipment Specifications

Company	Product	Specification	Costs
Measurement Systems Int. Seattle, WA	Crane scale: MSI 5260 Crane Unit MSI 3600 Indicator	± .1% accuracy sealed units	$2750
Symbol Technologies c/o Systems Technical Sales Seattle, WA	Bar code scanner: LS-8500 HV Scanner	high visibility visible laser diode sealed against outdoor weather and shock	$1300
MSI Data Corp c/o Systems Technical Sales Seattle, WA	Data terminal: PDT-LS	256 KB RAM Memory battery powered scale and scanner communications environment seal	$650 used/recond. ($2400 new)
Systems Technical Sales Seattle, WA	programming for data terminal	Custom UBASIC program for application	$2400

Procedure

The operator was required to hang each container on the hook by the container handle and scan the bar code label with the gun. A uniform tare weight was used because all containers are provided by contractors. The few customers with 60 or 90 gallon carts were ignored (less than 1%).

Route Selection

Route selection was aimed at achieving a demographic range and balance. Routes in three different Seattle neighborhoods (Fauntleroy, Beacon Hill, and Skyway) were selected for testing. The pilot project started with about 1500 customers from these routes, but about 500 customers were lost from the project after six weeks, due to contractor route changes.

Rate Selection

As one method of enhancing the robustness of the test information, we decided to expose the customers to two different levels of rate incentives and examine whether the two groups reacted differently during the course of the experiment. Our objective was to provide one set of test rates that had a larger "variable cost" component in the rate. The 1500 customers were randomly split into two groups, for the different rate structures

Table 4.3: Weekly Rates for Sample Bills

	basic fee	pound fee (0 - 25 lb.)	pound fee (25+ lb.)
Rate A	$1.91/wk	+$.054/lb.	+$.095/lb.
Rate B	$1.25/wk	+$.08/lb.	+$.12/lb

(Variable can rates: mini-can = $2.67/wk, one-can = $3.44/wk, two-can = $5.69/wk)

Rate B represents a variable rate component that was approximately 48% higher for the first block of service and 26% higher for the second block of service. The first set of rates provided a 75% marginal penalty for disposal above 25 pounds per week, and the second set of rates provided a 50% penalty for extra weekly poundage.

Although it might have been desirable to examine reactions to rates that had even higher

penalties for excess waste, our flexibility in manipulating these rates was somewhat limited. The rate schedules were calculated to approximate the current Seattle rate levels for the mini, one, and two-can customers. We did not want to dramatically change the level of revenues to be collected, nor deviate significantly from the cost-of-service model. We felt that it was important that customers should start with a rate that would reasonably approximate current rates on average for their subscription level. We wanted changes in the level of bills to be the result of changes in behavior, and not be confounded by dramatic modifications to the structure of the starting point.

Sample Bills

Customers received six bi-weekly sample bills during the twelve-week field test. Bills were sent every other week to provide enough feedback during the field test. The customers in each of the two groups were provided with the formula for calculating the rates at the bottom of each bi-weekly "sample bill" that they received. In this way they could potentially understand and estimate the direct rate impact of disposing of less waste.

One significant weakness of results from this type of analysis is that the rates were not actually experienced by any of the customers. Their rates were not changed over the course of the experiment. Instead, they were sent sample bills, and told what they would have saved if the sample Garbage by the Pound rates were charged.

It is unclear whether the behavioral impacts from an actual implementation of weight-based rate program will be the same, lower, or stronger than those mentioned in this report for the following reasons:

- Impacts may be stronger than those shown in the experiment because customers did not actually save money during this experiment, so the incentive was diluted.

- Impacts may be weaker than during the experiment because of issues related to billing frequency. If this type of system is implemented in a jurisdiction with infrequent billing, the impact may be lessened because savings are not realized soon after the behavior change.

- The persistence of behavioral changes is a significant issue in conservation programs of all types. This experiment was of relatively short duration. However, the fact that this type of system change affects the customer's bill, which arrives on a regular and recurring basis, bodes better for ultimate behavioral changes than a one-shot educational or other non-recurring program.

Equipment and Procedure Performance

The Phase I system was only a fairly crude assembly of functional components, yet proved to be a reliable and convenient design. The process was incorporated easily into the collectors regular collection pattern. Operation was simple and straightforward, allowing the operator to smooth out any mistakes with manual editing. The equipment suffered four days of equipment failure during the thirty-six days of testing. Each piece of equipment had a day of malfunctioning and all problems were eliminated from future occurrence.

The scale produced reliable and accurate measurements throughout the experiment. Scanning was easy, quick, and reliable. All stickers remained on containers and provided continual quick reads over the duration of the testing.

Added collection time varied, but on average less than an hour was added to an eight hour shift (about 10% more collection time). The collector, Larry Litche, was very positive about the equipment performance. He appreciated the editing capability and the continuous display of customer label number, address, and weight for verification. Encouraged by the ease of use, he believed the system could work city-wide with a few programming modifications.

It is unlikely that this particular equipment would be suitable for permanent implementation. The system is slow and relied on some operator interaction, allowing for human error. Collection times would be further increased if a varying tare weight was required at each residence. This type of manual system may not have the support of integrated development and maintenance offered by proposed automated systems, but all the components are currently available, guaranteed, and inexpensive.

Customer Reaction

In general, customers were supportive of pilot project. They displayed confidence in the concept and equipment. Specific analysis of the pilot customer survey provided in Section 6.0 indicated customer reaction was favorable with concern for implementation costs. The following section reviews the effects of the pilot program on customer disposal tonnage.

4.2 PHASE I TONNAGE ANALYSIS

This section examines changes in tonnage of waste collected from the pilot customers over the course of the experiment. The analysis provides an indication of changes in customer disposal behavior as a reaction to the pilot program. Results can only be interpreted loosely, with the analysis based on imperfect data from a short term program and without real financial incentives for the customer.

Major findings:

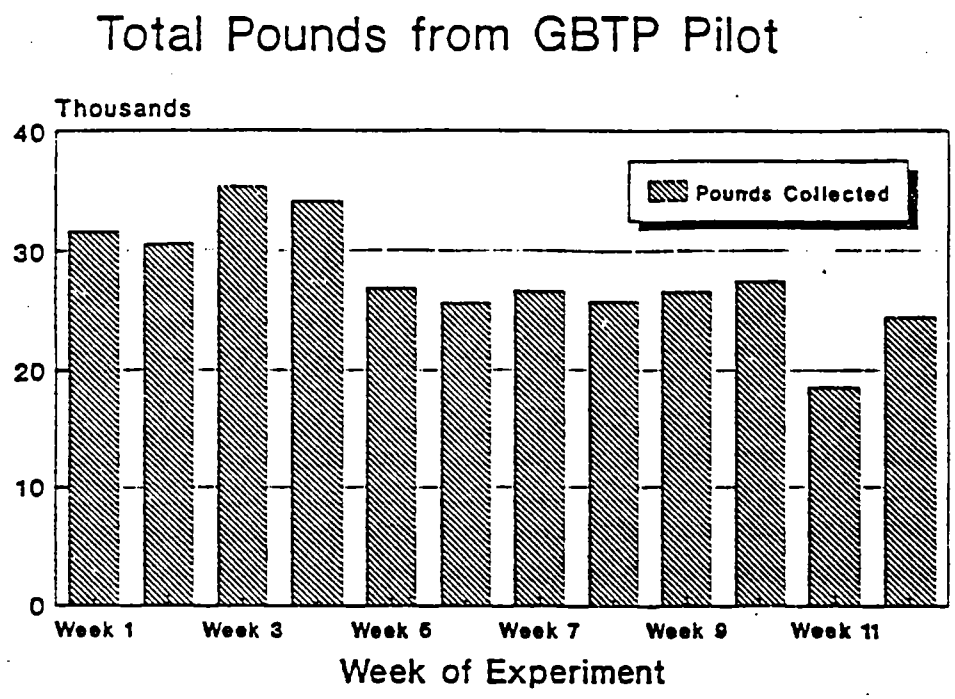
- Tonnage on a per-household basis decreased over the period of the experiment for pilot customers, with a decrease of a significant 0.3 (1.4%) pounds per week. This represents about a 15% drop in average pounds per household over the course of the experiment.
- In comparison, aggregate tonnage for non-participating customers over the same period showed no significant increasing or decreasing trend.
- Mini-can pilot customers decreased their waste by an impressive 2.1% per week, or 23% over the course of the experiment. One can customers decreased their waste disposed by approximately 1.4% per week.

Tonnage Results over the Sample Period

The total pounds collected over the course of the Garbage by the Pound (GBTP) experiment are shown in Figure 4.2. The loss of the re-routed customers shows up in the fifth week of the data. Figure 4.3 shows the decline in the pounds of waste put out by the average participating household. Statistical analysis shows that the average household put out about 23.9 pounds per week at the beginning of the experiment, and decreased the set-out by about 0.32 pounds per week to finish the experiment disposing of about 20.3 pounds per week. This decline is shown in Figure 4.4, and represents a 15% decline overall (1.4% per week). This decrease is statistically significant from zero.

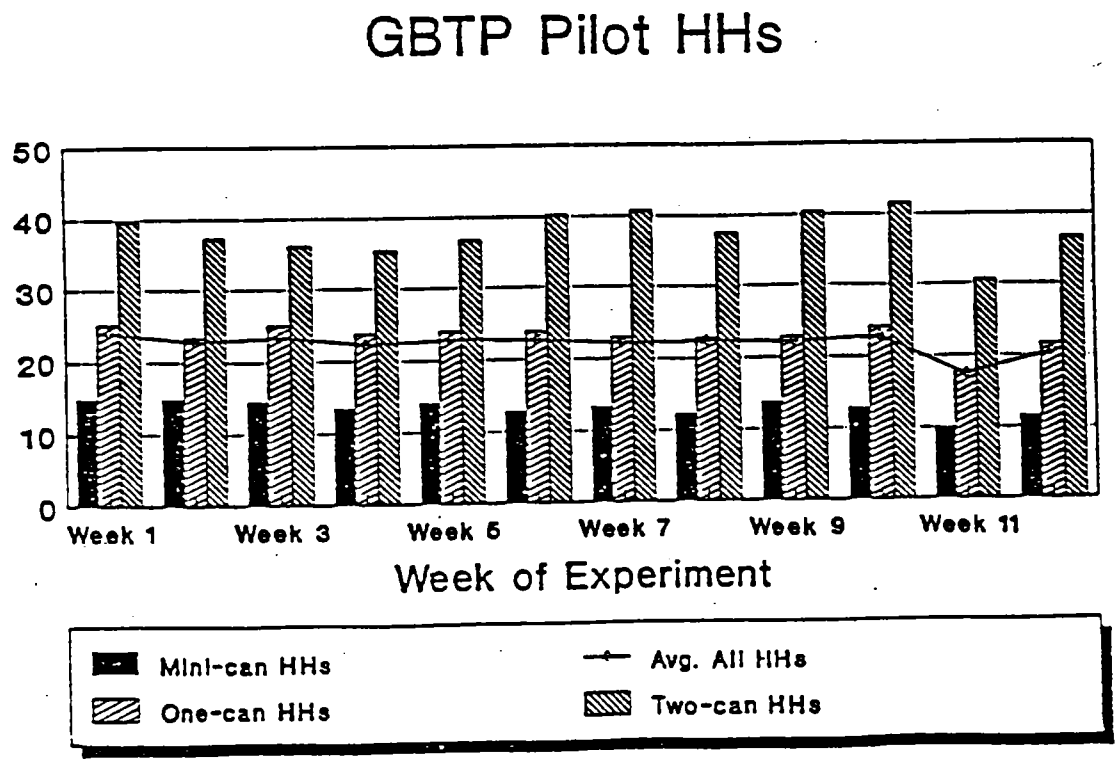
There was no significant decline in tonnage over the course of the experiment for non-participants, based on statistical analysis of the aggregate daily residential tonnage collected. This analysis examined the tonnage data for the contractor collecting from Seattle's south contract area, the area in which the experiment was conducted.

Figure 4.2: Total Weekly Pounds Collected



All customers

Figure 4.3: Average Weekly Pounds Collected per Household (HH)



Excluding dropped (re-routed) HHs

The tonnage decline found under the experiment appears to be significantly different from the tonnage pattern shown by non-participants. The analysis implies the pilot customers probably would not have shown a trend of declining tonnage without the pilot program. Of course, there may be other factors involved, including a non-representative population sample, economics, and other factors.

Results for Different Subscription Levels

Significant tonnage decreases were observed for all subscription levels. Customers at each subscription level reduced disposal tonnage by about 3-4 pounds for the entire 12 weeks. Figure 4.3 shows the average weekly pounds of waste collected per household for all pilot customers, mini-can customers, one-can customers, and two-can customers.

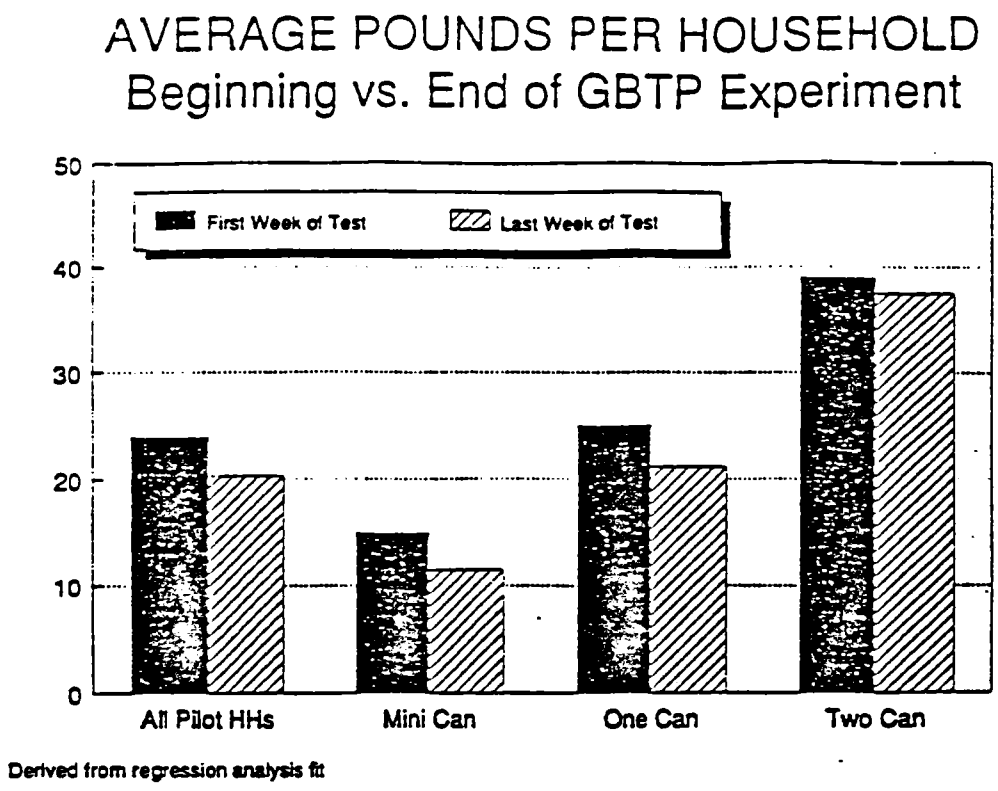
The differences between the average weight per set out for different subscription levels shows that mini-can customers reduced their waste to approximately 11.5 pounds per week from 15 pounds. The average 32-gallon (one-can) customer decreased to about 21.1 pounds from 25 pounds. Two can customer showed an average end-experiment set out of 37.5 pounds per week, down from about 39 pounds.

The weekly decreases in tonnage for mini-can customers is dramatic. Mini-can customers decreased their waste by an impressive 2.1% per week, or 23% over the course of the experiment. One can customers decreased their waste disposed by approximately 1.4% per week. These estimates of pound decreases are all significantly different from zero. The two-can customer response was too small to be considered different from zero.

Other Findings

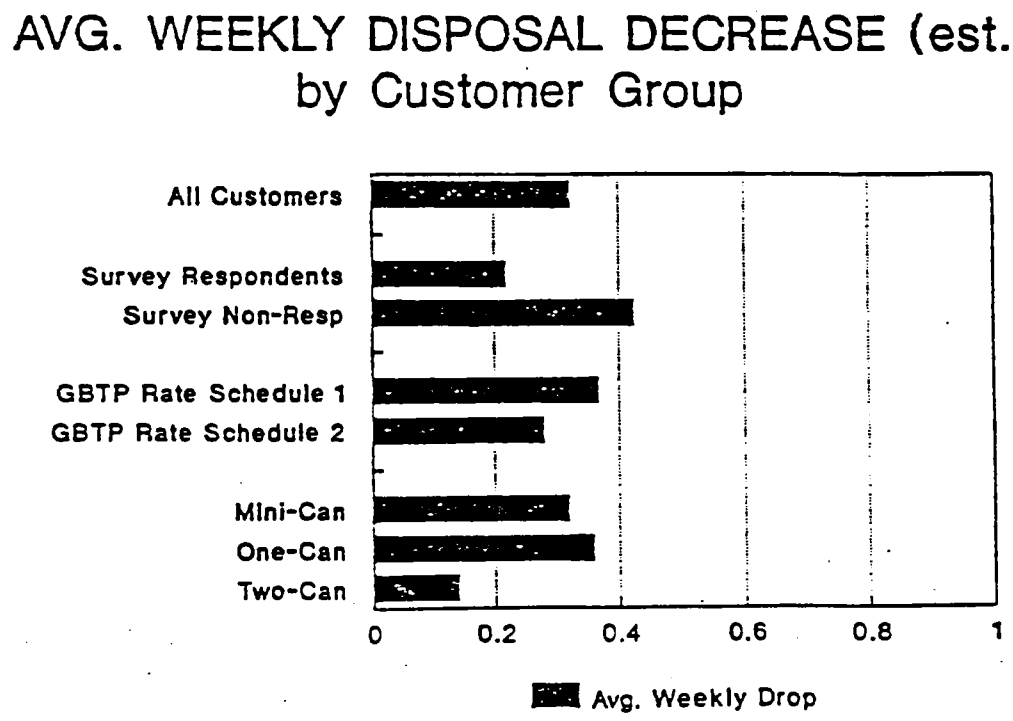
Figure 4.5 shows various decreases in weekly disposed pounds for different customer categories. There was no evidence of a significant difference in the rate of weekly decreases between customers with the two different pilot rate schedules. On a cumulative basis, those customer with rate schedule A (with a lower variable cost incentive ended up with lower average weekly set outs (19.5 pounds verses 21.1 pounds). This was an unexpected result and may reflect that Rate B (with higher variable costs) allows customers to set out more pounds and still have lower bills up to 25 pounds. This results may also reflect that customers did not actually pay the sample bills. Customers who responded to the survey ended up at lower levels of waste and tended to decrease their tonnage less rapidly, but the differences were not found to be statistically significant.

Figure 4.4: Beginning vs. End of Pilot



Derived from regression analysis fit

Figure 4.5: Average Weekly Disposal Decrease



Excluding dropped (re-routed) HHs

4.3 PHASE I REVENUE ANALYSIS

This section examines the impacts of the Garbage by the Pound project on projected revenues over the course of the experiment. This analysis summarizes the levels of mock bills received by the customers and the levels of potential revenues that would be received by the Utility. All revenues in the pilot project are entirely a function of the rate schedules chosen.

Major findings:

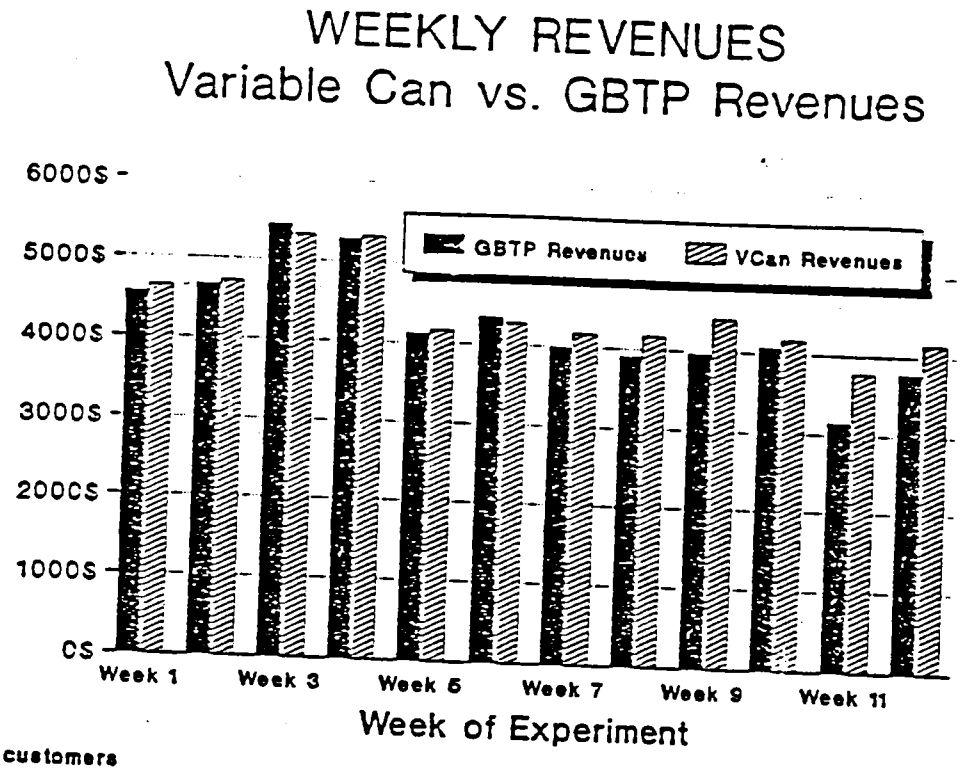
- *Under the specific case of the rate designs used in this 12-week experiment*, customer revenues would have been 3% lower than with the less flexible variable can rates.
- Customers reduced their bills over the course of the experiment. *Under the specific rate designs used in this experiment*, mini-can and one-can customers showed steady reductions of almost 4 cents per week in their bills (about 1%). ...These savings are statistically significant.
- Jurisdictions considering implementation of a system like this need to plan for customer adjustments of tonnage that may affect the stream of revenues.

Over the entire experiment, the Garbage by the Pound project would have generated total revenues only $1,750 (or about 3.3%) less than would have been generated under a continuation of the variable can rate system. That translates to a savings of about $1.05 per average customer over the three month experiment.

Weekly Revenue Stability

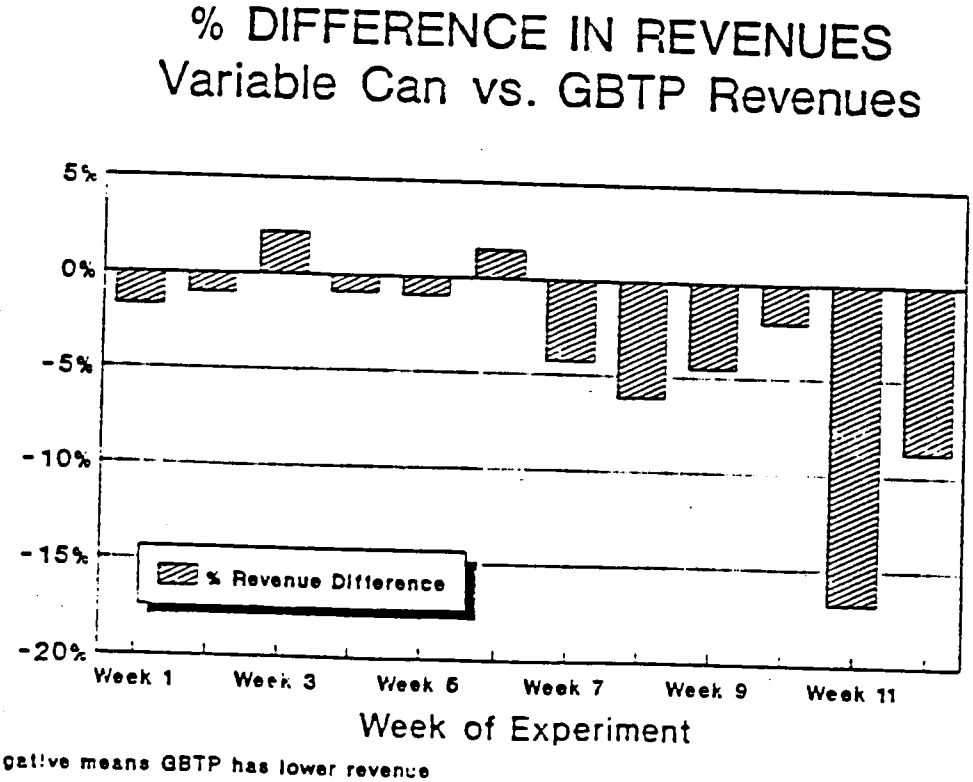
Figures 4.6 and 4.7 summarize the impact on the weekly total revenues. Figure 4.6 compares the total Garbage by the Pound (GBTP) mock invoices for each week against the bills that those same customers were paying for standard variable can service. This figure compares total revenues billed, and therefore, decreases significantly after a significant number of households were "re-routed" out of the pilot study (average per-household figures are presented later). The revenues track very closely; however, the

Figure 4.6: Weekly Revenues



All customers

Figure 4.7: Percent Difference in Revenues



Negative means GBTP has lower revenue

differential between the GBTP revenues and the variable can revenues is increasing. The time line for the percentage differences is shown in Figure 4.7. Recall that the rate signals were established in order to provide approximately the same rates for customers if they maintained their current behavior.

Over the course of the experiment, the potential savings that customers experienced increased. On average, customers started out the experiment paying about $0.04 per week more on their mock bills. By the end of the experiment, those customers would have paid about $0.30 less than they would have paid under Seattle's standard variable can rates. This was a significant trend (at the 95% confidence level), with customers achieving a $0.037 (or 1.1%) drop in their weekly bills each week (on a continuing basis) by reducing their waste. The total decline over the life of the experiment was about 10%.

Revenue Impacts by Subscription Level

The impacts by can levels are also of interest. Note, however, that all these results are contingent on the *level and design* of the rates that were charged. The straight tonnage results were discussed in the previous section.

Table 4.4 provides simplified examples of the distribution of customer savings for each of the various subscription levels. The table compares one-month sample billing under GBTP to the monthly billing with variable can rates. The table was calculated using data from weeks 3-6 of the project. During this period, the equipment and system had a chance to "settle down", and we had not yet experienced the route changes that led to the loss of a significant number of customers.

Table 4.4: Customer Savings Distribution (weeks 3-6)

Savings/Month	Mini-can (407 cust.)	One-can (1019 cust.)	Two-can (136 cust.)
pay > $5 more	6.9%	14.6%	15.4%
pay $3-$5 more	3.7%	6.8%	3.7%
pay $1-$3 more	10.6%	10.3%	5.1%
< $1 change	25.6%	12.6%	5.9%
save $1-$3	31.4%	22.2%	4.4%
save $3-$5	16.2%	19.7%	8.8%
save > $5	5.7%	13.8%	56.6%

We have also calculated the approximate level of savings for each can size over the course of the experiment. Mini-can customers would have saved $175 overall, or about 1.7%. One-can customers would have saved $220, or about 0.07% of anticipated

revenues. Two can customers would have paid $1,098 less, or would have experienced a 14% savings compared to their regular variable can bills.

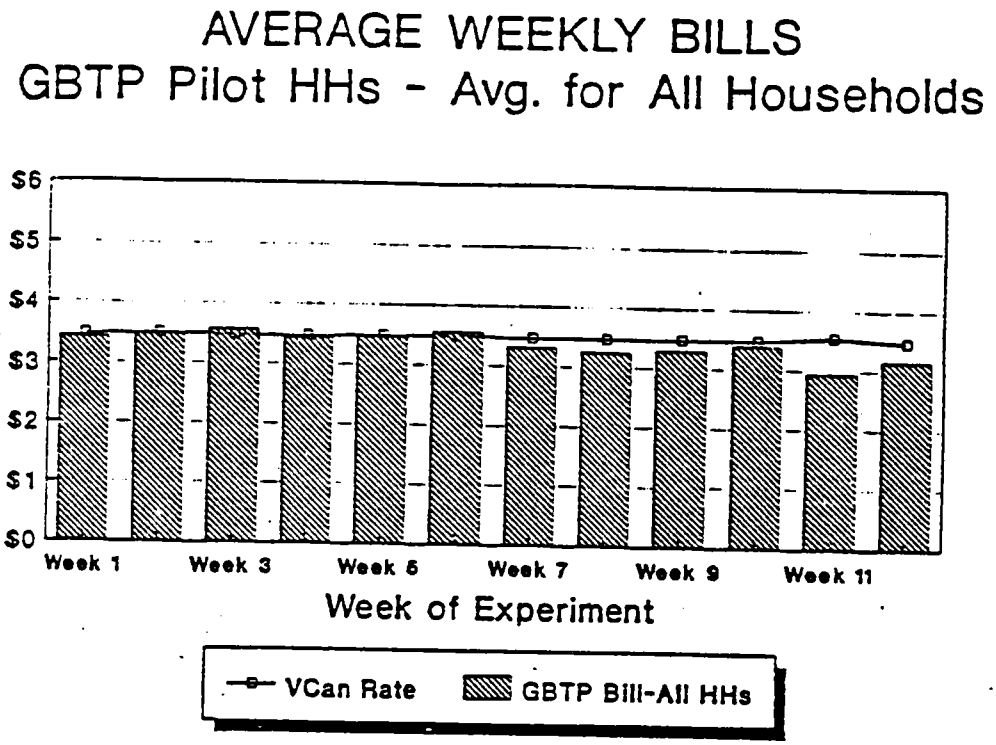
The two can customers received a much higher level of average savings based on the mock bills than the one-can and mini-can customers. This is a reflection of the assumptions of Seattle's current variable can rate structure. The two-can customers pay a rate representing twice as much waste as the one can customers, but, as we found out in this experiment, they don't actually put out nearly twice as much waste. One-can customers set out about 25 pounds in the beginning of the pilot. Two can customers set out about 39 pounds (only 56% more).

Figures 4.8a-4.8d show the pattern of mock bills for the customers in the pilot program. The figures show the weekly pattern of GBTP bills for each subscription level compared to the actual weekly subscription level under the existing variable can rates. Regression analysis confirms the significance of the downward trend in the bills, as mentioned above.

Other Findings

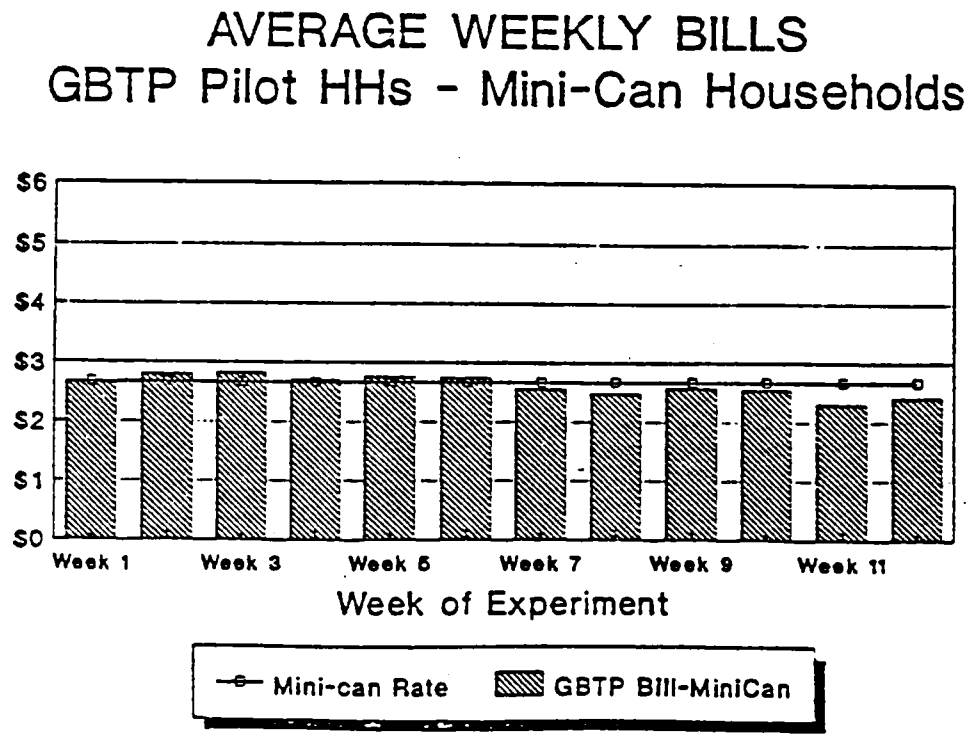
The experiment also produced significant differences (at the 95% confidence level) between customers that did and did not respond to the survey. The respondents ended up saving more on the sample bills. The pilot customers on rate schedule B (with higher variable cost incentives) saved slightly more on the sample bills, even though they produced slightly higher weights.

Figure 4.8a: Average Bills, All Households



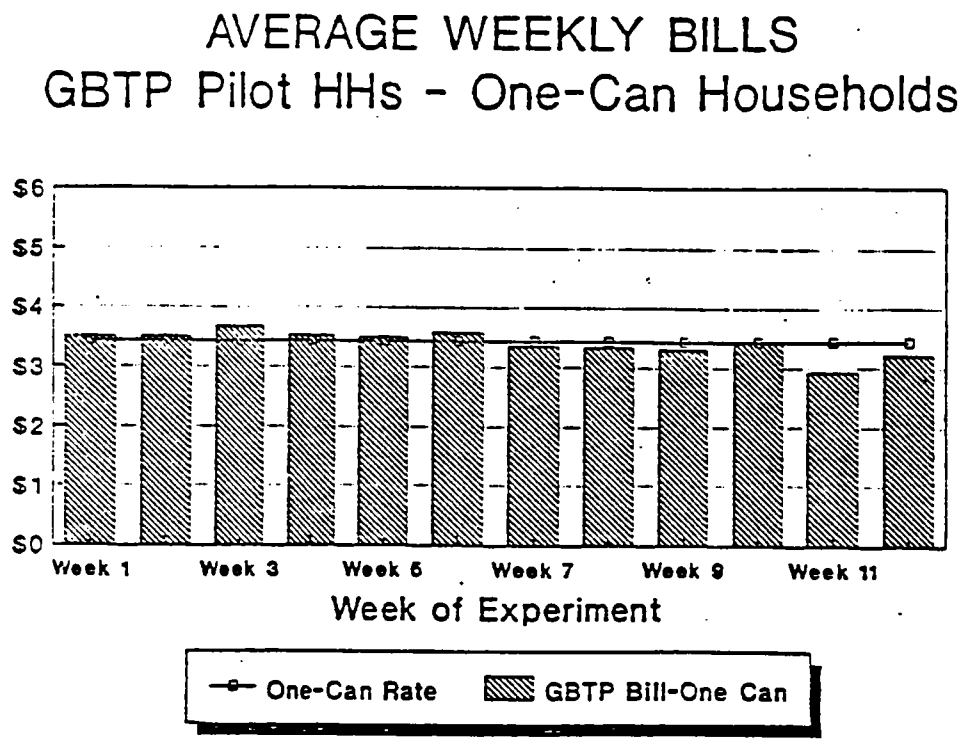
Excluding dropped (re-routed) HHs

Figure 4.8b: Average Bills, Mini-Cans



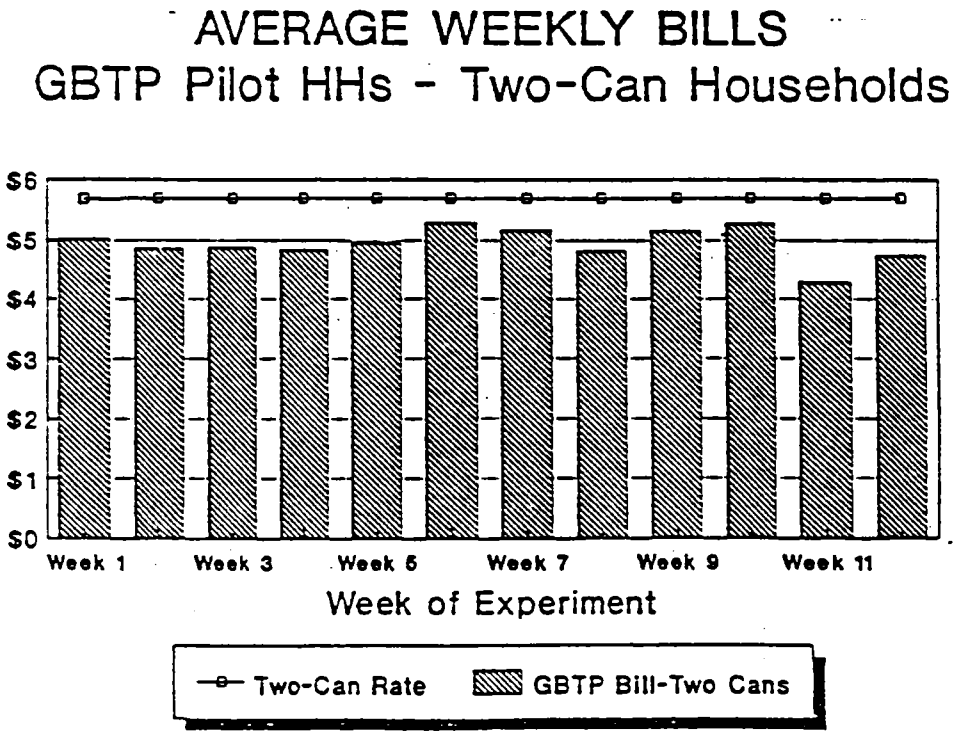
Excluding dropped (re-routed) HHs

Figure 4.8c: Average Bills, One-Cans



Excluding dropped (re-routed) HHs

Figure 4.8d: Average Bills, Two-Cans



Excluding dropped (re-routed) HHs

4.4 SWU PHASE II OPERATIONS AND PERFORMANCE

The second phase of the pilot program was a one-month test of automatic weighing equipment. No information or sample bills were sent to these customers. The onboard equipment involved a cart tipper supported by load cells, a radio frequency transmitter/receiver, a permanent computer board, and a portable data storage computer. Passive transponder tags were attached to individual customer containers for identification (see Figure 5.9). The entire system was designed and leased by Toter, Inc.

Table 4.5: Phase II Operations Summary

Field test dates:
1/24/91 - 2/28/91

Collection truck:
1 rear packer
1 operator

Containers:
90 gallon toters

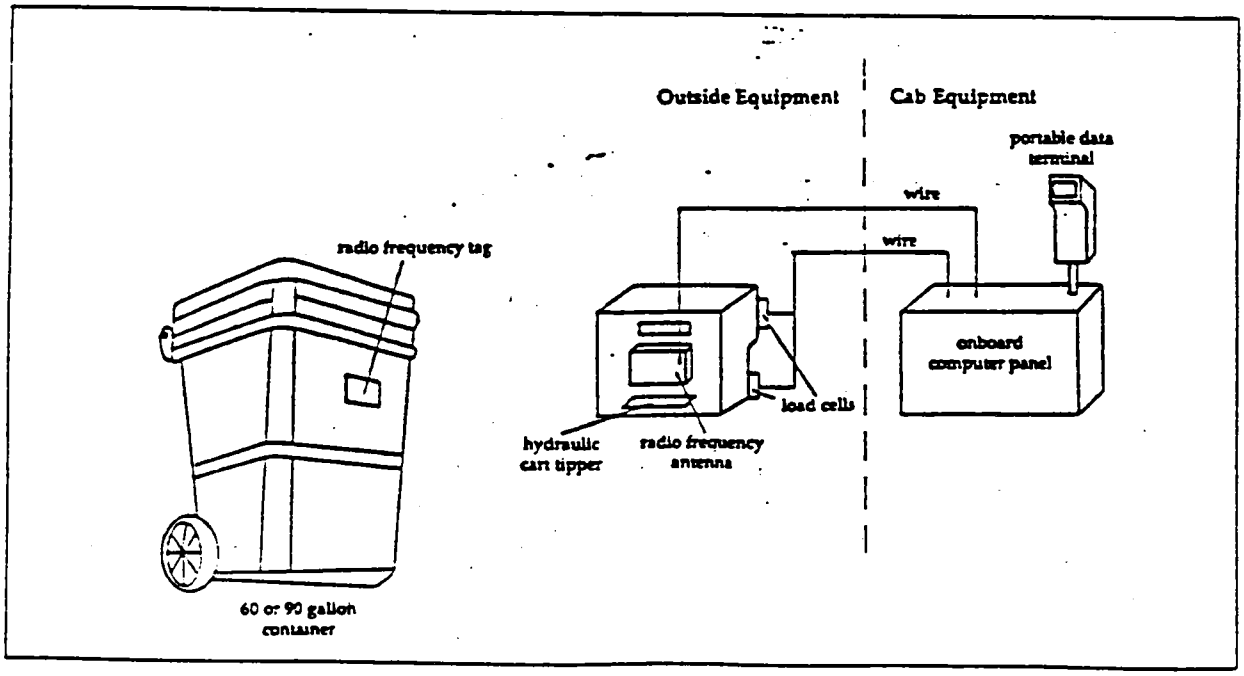
Customers:
249, 1 route
weekly collection

Equipment:
cart tipper w/ load cell
RF transmitter/receiver
radio frequency tags
onboard computer
portable terminal

Equipment cost:
6 week lease

Mailings:
none

Figure 4.9: Phase II System Design



This equipment is being tested and developed by Toter for eventual retail production by 1992. Toter hopes to refine the scale to a degree where it can be nationally certified as a 500 x 1 pound, N type, Class III scale. The system in the pilot test was a primitive prototype.

The Toter System was leased to evaluate the opportunities of a cart-based weighing system. A neighborhood outside the city limits was selected for testing, where many customers have large garbage carts. These 250 customers received temporary radio frequency tags during the one-month test.

The tipper records a number of dynamic weights during the tipping cycle, through the supporting load cells. After the data is downloaded, the office computer calculates the full and empty container weight from the recorded weights. Eventually, onboard software should provide instant gross and net weight displays.

The radio frequency transmitter/receiver antenna is mounted to the outside of the cart tipper. The passive transponder tags are attached to the carts where they contact the tipper. Tags were attached in the field under a plastic plate and plastic welding bead. The antenna receives a tag identification signal before both the up and down tipping cycle.

The collection process is the same as any rear-loading semi-automated tipper system. The collector wheels the cart to the tipper and maneuvers the tipper with a control lever. Weighing and identification is automatically incorporated into the tipping cycle. The weight and identification data is processed by the onboard computer board and stored in the portable data terminal. Both components are in the cab of the truck. The data terminal is downloaded to the office computer at the end of the day.

Performance

The prototype tipper system showed great promise but inconsistent results. The system failed to perform in the field for the first two weeks due to computer programming difficulties. After modifications, however, system performance improved. The system recorded gross and tare weights with little disturbance in the normal tipping cycle. A slight (1 second) pause was required at the top of the tipping cycle to ensure tag identification was received. Collection time was also slower because the equipment was mounted on a rear-loading packer instead of the usual side-loader. The equipment will be transferable to side-loading collection, but multiple tippers will be required.

The prototype system was not developed enough for actual accuracy testing. From preliminary shop tests accuracy appears to be within about $\pm$3%. In the final weeks of testing, the scale calibration was off, probably due to abuse on steep road dips where the tipper had dragged on the ground. This is an important factor to consider in any tipper modifications.

The Toter system still requires significant development before marketable production, but the final product should be an impressive solution for the application. A consistent and user-friendly computer system and national weighing certification will produce a highly attractive product. The speed and convenience of dynamic weighing and RF identification offer an excellent modification to a semi-automated collection system. In general, load cells and RF tags may offer the fastest and most accurate, yet most expensive, opportunities in weighing and identification.

5.0 CUSTOMER SURVEY RESULTS

Survey and Sampling Design

A survey of the pilot program customers on the three selected Phase I garbage routes was conducted to gather information on customer attitudes about the Garbage by the Pound experiment as a pilot test and as a potential future system. Surveys were mailed on January 3, 1991 to all original Phase I pilot program households. A second survey mailing was sent on January 26 to all customers who had not responded.

Of the 1665 surveys mailed out, approximately 740 were returned, for a 44% return rate. Overall, the margin of error is approximately $\pm$ 2.7% or less in representing the pilot test households.

Summary

Generally, customers were fairly favorable about the "Garbage by the Pound" experiment. They were concerned about the potential costs and confusion, but felt that there were a number of positive features that made it a valuable option. According to the pilot customers, Garbage by the Pound would be an acceptable and desirable system, if implementation is not too expensive to implement.

Satisfaction with the Program

The customers on the program were generally favorably disposed to the Garbage by the Pound experiment. Almost 40% of the returns marked they were very satisfied with the experiment, and another 19% were moderately satisfied. Almost 30% were neither dissatisfied nor satisfied. Only 8.4% of the respondents were moderately or very dissatisfied.

Over 81% of the respondents noted that they generally understood the program information and the mock bill that was sent to them. 13% noted that they somewhat understood the information, and about 3% did not understand the information.

Rate and Collection System Preference

One of the most interesting results was that almost 54% of the customers reported they preferred the Garbage by the Pound system to the current rate and collection system. This is an unexpected finding because the equipment used was fairly rudimentary, and the incentives were provided through sample bills rather than actual savings. Almost 24%

preferred the current system, and 15% had no preference between the two.

However, customers had costs in mind as well. About 66% of the customers felt that, if it were more expensive to run than the current system, then additional funds should not be spent to fund the "Garbage by the Pound" system.

As expected, the Garbage by the Pound system was preferred by the customers who generated less garbage on average. The customers who preferred the Garbage by the Pound system had significantly lower garbage set out weights during the experiment. Those customers averaged less than 15 pounds per week, while customers who preferred the current variable can system or had no preference averaged almost 23 pounds per set-out. Similar differences were shown for those customers who were very satisfied with the program (14 pounds/set-out) compared to customers responding less than very satisfied with the program (21 pounds/set-out).

Popular Features

The following were the most popular features associated with the Garbage by the Pound experiment:

67% - I only have to pay for part of a can if I don't fill it.
50% - I would save money on my bill
50% - It is clear what I am paying for
48% - It provides a reminder to reduce my waste
46% - I don't have to pay the same as someone who overstuff cans
33% - There is no subscription level or special tags for extra garbage
32% - It made it easy to monitor the amount of waste I dispose
30% - It is a new and modern method of garbage collection and charges
6% - Noted other features of the program as "likes".

Unpopular Features

The following features were the ones noted as "disliked" by the following percentage of respondents:

49% - It might increase the costs
39% - Garbage may be incorrectly weighed
31% - People might put their waste in my can and I'll have to pay extra.
18% - My can might get moved to another house
18% - It is too much work for the collectors
8% - It is very complex
5% - It is an invasion of my privacy
9% - Noted other features of the program as "dislikes".

Impact as an Incentive

Almost 48% of the customers felt that the "Garbage by the Pound" pilot program gave them an additional incentive to reduce waste and recycle, even though the incentive was only introduced through a mock bill. Approximately 25% of the respondents did not feel the program gave them an incentive, and 24% felt that they couldn't see the incentive during the pilot program, but expected they would if their garbage was really billed that way.

Most of the customers felt that the level of the savings they could achieve based on the per pound charge was about right (54%). More than 13% reported that the charge was probably too low and wouldn't make a difference to them, and 22% felt that the charge per pound was too high.

Recycling and waste reduction activities

The vast majority of customers did not change their methods of recycling or waste reduction activities during the course of this three-month field test -- they either did the activity both before and after the experiment, or never used that waste reduction or recycling method. The percentage of respondents participating in the city curbside program (74%) was similar the "sign-up" rate for all of South Seattle (77%). In addition, 60% claimed participation the curbside yardwaste program compared to 66% of all Seattle customers.

"Representativeness" of Survey Respondents

The respondents to the survey are noticeably different from Seattle's population at large in some characteristics. The average household size for the survey respondents is 2.5. Seattle's average household size is 2.01-2.1. A very rough estimate of the total household income of respondents before taxes is approximately $37,500. This is somewhat lower than the $40,000 per year household income estimated by the City, but not significantly different. The distribution of the average years of schooling for the City and the survey respondents follow. The survey respondents had higher education levels than the city at large.

	City Data	Survey Resp.
Grade school	9.8%	2.3%
Some high school	10.5%	6.2%
High School Graduate	30.0%	15.9%
Some college	21.6%	22.0%
College graduate or higher	28.1%	40.0%

An approximate comparison of ethnic representation is shown below. Generally, the survey respondents included a higher number of minority households. However, the city's statistics also show that minority households in South Seattle represent a higher proportion than city-wide. The percentages can add to more than 100% because multiple answers are possible.

	City Data	Survey Resp.
White/Caucasian	75%	66.4%
Black/African-American	10%	5.7%
Asian	11.8%	20.4%
Hispanic/Latin-American	3.5%	0.9%
Native American	1.4%	1.6%
Other	1.4%	3.0%

One final comparison figure provided by which to gauge the sample population the survey is the percentage of residents by age group.

	City Data	Survey Resp.
Less than 5 years	5.2%	7.2%
Age 5-17	11.4%	10.9%
Age 18-24	13.8%	5.7%
Age 25-44	37.1%	31.5%
Age 45-64	15.3%	23.8%
Age 65 or older	17.1%	20.9%

These comparisons indicate that the survey respondents do not accurately represent the entire city. The respondents tend to have had more years of education, have larger than average households, and include a higher percentage of minorities, particularly Asians. There is also some tendency for the respondent households to consist of older residents, a common result in survey research.

Some of the differences reflect the population trends in North and South Seattle. Data indicates that South Seattle tends to consist of a larger proportion of minority households and include more households with occupants less than 17 years of age. Income levels tend to be somewhat lower in South Seattle. In addition, city reports suggest that the areas with the largest household sizes are predominately in South Seattle.

Generally, the survey results may provide a reasonable representation of the participants in the pilot study. The findings can certainly provide useful information about the level of program acceptance by the pilot customers and the characteristics and waste disposal behaviors of the pilot customers. The results do not suggest strong evidence of a significant bias in comparing tonnage results between pilot households and non-pilot

households. However, the limitations of the survey should always be taken into account in attempting to generalize the results to the larger Seattle community or to other communities considering implementing a weight-based system.

Conclusions

Customers had positive opinions of the idea behind the Garbage by the Pound system. Almost 60% were at least moderately satisfied with the system. They even expressed a preference for the system over the current variable can system (54% reported the result). However, the customers showing a strong preference tended to be those that had the most to gain from a weight-based system. They had significantly lower average weekly set out levels.

This short pilot study did not seem to have a significant impact on the reported waste reduction and recycling behaviors. This may be because the customers already tended to participate or because the pilot test was too short to become involved in new programs. Significant declines in household garbage weights indicate that during the pilot program customers may have become more efficient in the recycling and waste reduction efforts they usually participate in.

The results are encouraging. It appears that customers do not have an overwhelming negative reaction to an innovative program of this type, and may even prefer it to the existing system. The tonnage results indicate that the program may be effective in leading to reduction in waste collected, and customers did not complain of major problems or inconveniences with this system. However, Seattle customers are more familiar with innovative solid waste programs and systems. They may tend to be a more accepting group of customers, and these results may not apply in other communities. However, it does not appear that the negative reaction of customers would need to be a major barrier to implementation of a weighing program.

6.0 PLANNING CONSIDERATIONS

There are many direct and indirect factors to consider in relation to the prospect of weighing residential garbage during collection for billing. Considering any form of variable rates in solid waste involves many important related issues that also must be fully evaluated. This section covers some of the specific issues that must be raised in considering a weight-based rate system.

6.1 RATES AND REVENUES

The design of rates and the stability of revenues are interconnected issues that are fundamental to any collection system. All variable rate structures, volume or weight, introduce the potential for less predictable revenues than flat per household fees.

Experience in all metered utilities, including water, sewer, energy, and volume-based garbage service, has shown that rates can be designed to produce predictable revenues. Composite rate structures, combining a fixed and variable fee in customer billing is used by all metered utilities to reflect utility costs and produce stable revenues. In addition, slow responses in aggregate customer behavior prevent drastic surprises.

A composite structure is also very suitable for a weight based weight-based collection system. This would include a fixed service fee plus a variable poundage fee, to reduce the risk of revenue instability. Several specific factors also suggest avoiding a purely variable "per pound" fee:

- A very large component of the cost of providing service to customers is the cost of getting a collection truck to the house. This cost does not vary based on the amount of waste disposed; rather it is a cost that is more "fixed" in nature. Attempting to spread this cost across the pounds collected would require a great deal of confidence in the forecast of pounds to be collected in order to assure that these costs would be collected through rate revenues.

- The higher the level of costs put on the "variable component", the greater the incentive to reduce waste and recycle, but that includes an incentive to reduce waste through illegal dumping and burning.

- Rate designs that allows both a customer charge and a variable rate component have provided successful incentives for conservation of energy and water usage in other utility-type services.

However, the use of a fixed customer charge will decrease the "per pound" incentive of the rate structure. As in the case for a bag/tag or variable can pricing system, the

jurisdiction must use judgment to design its rates to provide a balance between increased incentives for recycling, increased incentives for illegal dumping, and financial stability. The pilot program used a sample composite rate structure. Section 5.1 and 5.3 discuss rate design and resulting theoretical revenues of the pilot project field test.

6.2 COLLECTION CONTRACTS AND NEGOTIATIONS

In municipalities with contracted garbage collection (e.g. Seattle), the weighing would be handled by the collection contractors, and the billing would be performed by the municipality. The municipality will be limited by the data provided by the contractors, and held responsible for all errors. Hopefully, careful, cooperative planning would produce a reliable system, with limited glitches. In entirely municipal or private operations, the weighing and billing would all be handled by one party.

The addition of sophisticated onboard and office weighing and recording equipment could produce expensive renegotiations with either collection contractors or labor unions. Labor unions may also be wary of the opportunity for increased operator monitoring through onboard computer data.

6.3 CUSTOMER SERVICE AND REACTION

Collection and billing of garbage by weight will invite a whole new arena of customer feedback and customer service needs. For jurisdictions changing from another complex variable rate system, the new dilemmas might be a healthy trade.

Billing by weight will require policies, processes, and staff for handling and resolving disagreements with charges on bills. Customers will undoubtedly dispute the weights and subsequent charges on their bill. In addition, a method of charging must be established (and defended) for situations when the collector is unable to record a weight or identification during collection.

Customer attitudes, behavior, and reactions are discussed further in Section 6.0, based on the findings in the Seattle Pilot Project. Customer reactions to any new billing system is dependent on the current billing system. In a weight-based system, the amount of garbage billed for is measured only by the collector, while in a most volume-based systems the amount is measured by both the customer and the collector.

Negative customer reaction could lead to cheating and illegal dumping, creating further confusion in the billing system. Annoyed neighbors may respond by dumping in neighbors' containers or by littering. These difficulties should be avoided or minimized, with careful planning and public education.

The basis of billing by weight, or any variable fee system, is increased customer fairness. A weight-based system could also be simpler and more convenient for the customer, without the confusion of different size containers and special bags or tags for a volume-based system. Switching to larger carts may create initial complaints of inconvenience by any customers. The pilot project customer survey (see Section 6.0) indicated a highly favorable initial reaction to a weight-based system by pilot customers.

Any variable fee system should be accompanied by convenient, well-known, and appropriately priced recycling options for most materials, to allow for an alternative and preferred disposal options.

6.4 WEIGHING CERTIFICATION

The primary legal issue in weighing garbage is the accuracy and certification of weighing equipment. Certification can also be a significant issue in convincing customers and local officials to support a weighing program. Regulation of weighing and measuring devices is handled primarily by local and state weights and measures authorities. In some states there is state-wide regulation. In many other states, large municipalities perform their own regulating and the state oversees the regulating of smaller towns. (Seattle is a self-regulating municipality.)

The extent and severity of local and state regulation covers a wide range. Opinions vary on how much authority weights and measures agencies would have over a garbage weighing device. The Minnesota Weights and Measures Division has declared that if approximate weights are used to estimate a weight-based service charge then the service would not be regulated by Minnesota state law. They concluded that billing would not involve the purchase or sale of a commodity. Others agree that garbage weights would only make up part of a service charge, further discouraging regulation.

Most authorities follow guidelines provided by the National Institute of Standards and Technology (NIST) in the Department of Commerce. The defining text of weights and measures regulation is the annually produced **NIST Handbook 44**, a complete manual for "specifications, tolerances, and other technical requirements for weighing and measuring devices." This attempt at uniformity between states and local agencies across the country is supported by most but not all agencies. There are agencies with far stricter and far looser standards than suggested in the handbook.

A scale manufacturer can gain almost automatic national acceptance with a NIST N type approval by meeting handbook standards. For a commercial scale, Class III certification is required. Class III certification requires at least 500 divisions (increments) below the maximum load, with a tolerance of 1 division, and a recommendation against using the first 20 divisions. (A residential garbage scale might attempt to qualify as a 500 x 1 pound.)

The recommendation, and potential future requirement, against weighing below the first 20 increments could significantly limit the potential for a residential weighing system. In Seattle, single-can customers only put out an average of less than 25 pounds each. A weighing system that could not weigh below 20 pounds would be fairly useless in Seattle. The best opportunity for avoiding this problem is to design a scale so that the tare weight of any container uses at least the first 20 increments. Then any additional weight (garbage) can be weighed to tolerance specifications. A scale with 1 pound increments can be used if the tare weight of a container is at least 20 pounds. (Most 90 gallon garbage carts weigh near 40 pounds.)

What, if any, regulations a garbage scale must meet will depend heavily the local agency. Eventually national standards for this specific application may be considered by NIST, especially considering the inaccuracies of other utility metering (especially water meters).

6.5 ESTIMATED COSTS OF FULL IMPLEMENTATION IN SEATTLE

Any attempt at estimating actual implementation costs can only be based on vague and potentially misleading guesses. The changes and costs involved in any weight-based system will depend on the eventual system design. Very rough guesses are provided below for a rough indication of potential costs, but it is important to interpret these estimates loosely. The numbers are based on implementing a cart-based system, the most expensive scenario.

Table 5.1: Estimates of Direct Costs for City-Wide System in Seattle

1. Contractor Equipment	$/unit	units/city	$
Onboard truck equipment	8,000	45	360,000
Cart identification tags	1 - 15	150,000	1,050,000
Carts (cost difference[1])	45	150,000	6,750,000
Shop equipment, training	50,000	2	100,000

1.cost difference=[cost new carts ($60/each)] - [replacing current containers($15/each)]

2. Contractor Collection			
Increased collection time		+ 10%	600,000/yr.

3. SWU Office Costs	
Billing system revisions (software, training)	100,000
Customer education	50,000

All of the equipment costs listed could be financed over the life of the equipment. Initial implementation costs would only include a small amount of the estimated purchase prices.

Potential program savings include:

- Reduced collection and disposal tonnage
- Elimination of cart switching expenses
- Elimination of "extra" tags network
- Reduced workmen's compensation expenses with semi-automated system

Implementation of a weight-based system will require added expenses. However, most

purchasing of new carts and identification tags for each customer. These per household costs could fall anywhere in a wide range, depending on the system design and product development. Even high estimates would not represent a significant monthly bill increase, with this per-household equipment financed over the life of the equipment. A weight-based system will not likely be cost reducing in Seattle, but the many advantages may justify the affordable costs. Collecting and billing by weight may be even more affordable to other communities, especially if incorporated with other planned system changes including eliminating backyard service and moving from a fixed fee billing system.

7.0 FUTURE DIRECTIONS

For Seattle and other jurisdictions, a system of collection and billing of residential waste by weight may become more and more attractive with time.

7.1 SEATTLE

Seattle's current rate structure, billing based on the number and size of cans, has proven to be a tremendously successful system for providing incentives while generating reliable revenues. In the future, a weight-based system may be a logical progression.

A weight-based collection and billing system in Seattle would offer even better recycling and reduction incentives, with customers saving money on everything they don't throw away each week. A weight-based system may simplify operations for both the Utility and the customer. Weight-based billing would eliminate many of the current complications, including providing and switching different containers sizes and "extras" tags. The new system would also introduce new headaches in equipment malfunctions, customer disagreements, and incorrect collection information.

In theory, weight-based billing would be a natural progression from volume-based billing. In practice, the transition might be more complicated. The Utility has committed significant finances, equipment, contracts, and customer education into achieving an effective variable can rate system. However, the survey respondents in the pilot program preferred a weight-based system to the current system. Implementation of a new weight-based system would require added financing. Estimating the level and distribution of costs is difficult, but a full system appears to be affordable with prudent planning and financing.

Product development in residential garbage weighing has been focussed on using hydraulic cart tippers. Seattle would need to adopt cart-based waste collection or independently develop its own system for weighing small cans and assume the liability of accuracy and reliability. A system of dumping small containers into a permanent onboard weighing cart is also worth considering.

Distributing city-wide carts could be expensive and confusing for the customers. Customers will face a mixed incentive of billing by weight with a larger container for their garbage. Many customers, especially the elderly, find large carts inconvenient, but cart-based systems have been well accepted and even desired in many other jurisdictions.

Seattle is committed to collection contracts through 1996 and maybe 1998. Any significant changes in collection service would be difficult to implement before those dates. Eventually, as customers continue to reduce levels, Seattle could look toward a weighing system to offer more rate variation. Already, 87% of the customers are down to mini-can or one-can service. Seattle's Integrated Solid Waste Management Plan for 1989-94,

adopted by the City Council, includes a long term vision for examining and implementing a weight-based collection and billing system.

Preliminary steps could be taken by requesting program cost estimates from manufacturers and contractors in a few years and reexamining customer needs and sentiment. Even at this point, customers appear to be supportive of a garbage weighing and billing system.

7.2 OTHER COMMUNITIES

The expanding development of weight-based collection and billing has been attracting the attention of communities, manufactures, and media from across the country. All initial testing has been encouraging. Current pilot projects in Farmington, Minnesota, Durham, North Carolina, and other towns in the Untied States, Europe and Australia should produce an even clearer picture of the potential for collecting and billing of residential garbage by weight.

A handful of companies (Table 3.1) have begun to refine equipment to weigh residential waste. If progress continues, than these and other companies should be able to produce a competitive market of reliable, affordable, and certified products to meet the stringent demands of this application. In the meantime, interested communities will have to share the risks of product development.

The best opportunity for implementation will be in communities using or considering a cart-based collection system. The majority of design testing and development is focussed on modifying hydraulic cart tippers. With these systems, automatic weighing and identification could be directly incorporated into the normal cart-based collection operation.

A weight-based rate structure and billing system would offer dramatic improvements in fairness and reduction incentives to communities with no current variable customer fee, and possibly significant improvements to communities with a current volume-based rate structure.

In theory, a weight-based system can offer a community many advantages, but actual success will rest on the development of precise and reliable equipment. All evidence from the Seattle's pilot program indicates that a weight-based system is economically and technically feasible, but a proven system has yet to be revealed.

The pilot testing also indicated that a weight-based system is acceptable, and potentially desirable, to customers and collectors. Implementation, even with guaranteed equipment, would require thorough customer and employee input and education. Careful research and planning should ensure a fairly smooth transition. It is likely that by the end of the decade many communities will operating on a weight-based system.