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EVALUATION OF THE WEIGHT-BASED COLLECTION PROJECT IN FARMINGTON, MINNESOTA
A MITE PROGRAM EVALUATION

by

SCS Engineers
Cincinnati, Ohio 45202

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DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement CR-818238 to the Solid Waste Association of North America (SWANA). It has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies, and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (USEPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the USEPA to perform research to define our environmental problems, measure impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the USEPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This publication is part of a series of publications for the Municipal Solid Waste Innovative Technology Evaluation (MITE) Program. The purpose of the MITE Program is to: 1) accelerate the commercialization and development of innovative technologies for solid waste management and recycling, and 2) provide objective information on developing technologies to solid waste managers, the public sector, and the waste management industry.

E. Timothy Oppelt
Risk Reduction Engineering Laboratory

PREFACE

The MITE Program is managed by the USEPA Office of Research and Development (ORD). The purpose of the MITE Program is to 1) accelerate the commercialization and development of innovative technologies for solid waste management and recycling, and 2) provide objective information on developing technologies to solid waste managers in the public and private sectors.

These goals are met by selecting, through a competitive process, technologies and programs that have been submitted to USEPA through its annual solicitation. The proposals are reviewed and the most promising projects are selected for inclusion in the program. Once selected, USEPA, with the cooperation of the technology developer, formulates an evaluation plan which emphasizes the costs, effectiveness and environmental impacts of the technology. Each project consists of a field demonstration and an associated evaluation. The MITE Program is administered by the SWANA. SWANA coordinates an Advisory Committee review and assists the formulation of the evaluation plans.

A limited number of this and other MITE evaluation reports will be available at no charge from USEPA's Center for Environmental Research Information, 26 West Martin Luther King Drive, Cincinnati, Ohio 45268. Requests should include the USEPA document number found on the report's cover. When the supply is exhausted, additional copies can be purchased from the National Technical Information Service, Ravensworth Building, Springfield, Virginia 22161.

ABSTRACT

This project evaluates a test program of a totally automated weight-based refuse disposal rate system. This test program was conducted by the City of Farmington, Minnesota between 1991 and 1993. The intent of the program was to test a mechanism which would automatically assess a fee for the quantity of waste which a waste generator sets out on the curb for collection.

This evaluation consists of the following:

- A summary of the proposal which the City of Farmington submitted to the USEPA to participate in the MITE Program;
- A description of the equipment that was used;
- A chronology of events that occurred during the test period;
- An analysis of the test program;
- A description of some of the difficulties encountered during the development of the system;
- An overview of current and pending technology; and
- Recommendations on approaches to be taken by solid waste managers in using a weight based pricing system and by equipment manufacturers in developing equipment for this application.

The weight-based refuse disposal rate system which was tested by the City of Farmington operated with significant obstacles. Therefore sufficient test and field data was unavailable to validate or disprove the estimates of cost savings and waste diversion made by the City of Farmington in its proposal to the USEPA MITE Program. However, this test program did provide information which will be useful in the institution of future weight-based refuse disposal systems.

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ACKNOWLEDGMENTS

This report was prepared under the coordination of Lynnann Hitchens, USEPA MITE Project Manager at the Risk Reduction Engineering Laboratory, Cincinnati, Ohio. Contributors and reviewers of this report include Charlotte Frola and Dianne DeRoze of SWANA, Russ Mathys the City Engineer, and Robert Williamson, who was the Solid Waste Coordinator, City of Farmington.

This report was prepared for USEPA's MITE Program by Timothy Smith, Karen Luken, and Anthony DiPuccio of SCS Engineers.

SECTION 1

INTRODUCTION

In 1993, the City of Farmington, Minnesota completed a test program of a weight-based refuse disposal rate system. The intent of the project was to test a mechanism which would use a scale to weigh refuse containers as they were being emptied into the collection vehicle. The scale would be connected to a computer inside the cab. The computer would record the weight and identification number of the containers emptied at each address.

The purpose of weight-based pricing is to charge users of the system for the weight of the refuse which is disposed. At the end of each billing period each resident would receive a bill which lists a service charge and a disposal charge. The service charge would be relatively equal for all system users (but may reflect the number of containers served), and the disposal charge would be based on the actual weights recorded for that service address throughout the billing cycle.

The test program was selected for evaluation by MITE which is sponsored by the USEPA. SWANA, as USEPA's representative, retained SCS Engineers (SCS) to evaluate the test program and determine the applicability of the equipment and technology to other cities.

The test program encountered significant equipment failures, primarily in the weighing equipment which was in a developmental stage. This document provides an evaluation of the progress of the project throughout the test period, notes the particular successes and failures of the project, and possible alternatives for further study and/or testing.

This report is comprised of 6 sections. Following this Introduction, Section 2 is a summary of the original proposal from the City of Farmington (City) to the USEPA, dated October 25, 1991. Section 3 describes the actual equipment used and includes a chronology of events during the test period. Section 4 is an evaluation of the test program, and describes some of the difficulties encountered during the development of the system. Section 5 provides a narrative on the current state-of-the-art, citing the status of products being developed for weight-based pricing systems. Section 6 recommends approaches to be taken by solid waste managers in using a weight-based pricing system and by equipment manufacturers in developing equipment for this application.

SECTION 2

PROPOSED PROJECT

DESCRIPTION OF THE CITY

Population

The waste shed area for this project was comprised of approximately 2,200 residential customers and 135 commercial customers. Total population of the waste shed area was approximately 7,000.

Geography

The City of Farmington is located approximately 20 miles southwest of Minneapolis/St. Paul, Minnesota. The City is primarily flat and mostly residential. The average annual snowfall is 26 inches, and the average annual precipitation is 49 inches.

Waste Management System

Prior to the test project, all residential and commercial customers in the waste shed area were served by municipal collection operations which have been in place for over forty years. The system consisted of two trucks, with each truck stopping approximately 500 times per day, 251 days per year. The refuse was collected weekly using two automated side-loading vehicles. Under the automated system, special wheeled carts were placed at or near the curb on collection day. The carts ranged in size from 30 gallons to 100 gallons. The collection vehicle had a mechanical arm which was controlled by the driver. At each stop, a gripper would clasp the refuse container and the mechanical arm transported the container to the truck, emptied the contents into the truck's hopper, and replaced the container at the curb. Throughout this process, the vehicle operator remained in the truck.

The City also operated a weekly recyclable materials collection program which accepted newspaper; corrugated containers; office paper; glass, ferrous, plastic, and aluminum containers; household batteries; catalogues and magazines; and used motor oil. Prior to the test project, the recycling program was achieving a 56 percent weekly set-out rate.

System Evolution

According to the proposal, each collection vehicle would be fitted with weight sensing and recording equipment. Originally a Wray-Tech (Stratford, CT) weight sensing device was to be used. This sensing device would compare the hydraulic pressure required to lift a full container to the pressure required to lift an empty container and use the pressure difference to calculate the weight. This system, when tested by the manufacturer, was unable to consistently record accurate weights. Therefore, a decision was made to test a traditional weighing system that uses load cells.

The City decided to use a GSE load cell system. This system uses a load cell placed between the gripper and mechanical arm. It would measure the weight of the container through the strain on the mechanical arm. A detailed description of this system is in Section 3. This was a static-weigh system, that is, the mechanical arm was required to stop its lifting motion for an instant to allow the sensing device to measure the weight.

The proposal indicated that the weight sensing unit would transmit the net weight of the refuse in the container to an on-board computer. The computer would record the weight of the container along with the customer address being served. The customer address would be provided via a bar-code reader, which was positioned over a computerized route sheet. When service at one address was complete, the operator would advance the route sheet under the bar code reader and the computer would input the information into a new record for each service account.

In a parallel project, the City would also test a passive transponder unit. This unit's radio-frequency identification (RFID) chip would be placed on each customer's cart. When the cart was emptied, a receiver would detect the serial number of the transponder and send the information to the on-board computer. The computer would associate that serial number to an existing account address, and input the data.

Under the proposed project, the information contained in the on-board computers would be downloaded daily into the main computer located in the City offices.

City Goals

The primary objective of this project was to implement a weight-based billing system. Each customer's disposal charge would be based on information gathered each time a customer was serviced. The customer would then be billed for the disposal cost plus a service fee.

Since the refuse collector pays for disposal based on the weight of material in each truck, a weight-based billing system would result in each customer paying the actual disposal cost of the refuse. This was seen to have advantages over a volume-based system where two customers can be charged different disposal cost for the material which weighs the same.

In addition to the primary objective described above, the City made the following projections at the outset of this project:

1. Waste abatement (diversion) would increase 10 to 20 percent over current levels.

2. The cost of the collection operations would be reduced by 5 percent.

3. Efficiency at the recyclable materials sorting center would increase through greater recyclable quantities.

4. Specialty markets would be developed for uncommon wastes generated by commercial customers.

Organization Structure

The day-to-day task oversight was assigned to Mr. Robert Williamson, Solid Waste Coordinator. His duties included project management, budget and contract administration, local business knowledge, and liaison between various City groups and the public. Mr. Williamson is no longer a City employee, but remains an independent consultant on the project. He is still very involved in the weight-based refuse billing program.

Technical oversight of the project was conducted by Mr. Russ Matthys, Assistant City Engineer. He was responsible for the testing, installation, and maintenance of the hardware used on the vehicles.

The administrative duties were assigned to Mr. Wayne Henneke, the City's Finance Director. His duties included Budget Administration, Contract Management, and assistance to Mr. Williamson.

The City Administrator, Mr. Larry Thompson, was responsible for general project direction. Overseeing the entire project was Mr. Thomas Kaldunski, the City's Public Works Director.

The solid waste collection crews had the responsibility of facilitating the installation and operation of the hardware, using the system, and reporting its status to the Solid Waste Coordinator.

Anticipated Costs

According to the proposal, modification of the City's existing computer system would cost $5,000. The cost for the load sensing and recording equipment was projected at $9,500 per truck (total of $19,000 for two trucks). The cost for this system was projected to be $0.019 per stop over five years.

Revenues were anticipated to increase by an increase in the amount of recyclable materials. The City's economic study which was included in the proposal anticipated an increase in revenues of approximately $0.0225 per stop.

In addition to these revenue increases, a transportation and disposal cost avoidance of $80 per ton ($0.16 per stop) would also be realized. Thus, the cost of the equipment would be offset by the additional revenues and the avoided-cost savings. The proposed project was estimated to result in a savings of $0.1635 per stop, or $205,000 over five years ($0.1635 * 2 trucks * 627,500 stops divided by 5 years = $205,000 divided by 5 years).

Steps Needed to Implement the Plan

The City planned to install the equipment in November, 1991 and operate the system until April, 1992. During this period, the system was proposed to be fully operational, gathering weight data for each customer, although the weight-based billing would not take place until after April, 1992. This period was also anticipated to be used for fine tuning the system and the equipment.

SECTION 3

SYSTEM DEVELOPMENT

INTRODUCTION

This section describes the weight-based system which was to be instituted by the City. The project activities are described in chronological order.

The information was gathered through interviews with Mr. Russ Mathys, the Assistant City Engineer; Mr. Robert Williamson, the Solid Waste Coordinator during the project; Ms. Charlotte Frola, the Project Officer for SWANA; and Mr. Tom Ulicny, Marketing Manager for GSE, the scale manufacturer. Further data was gathered through documents and correspondence generated by the City, the USEPA, SWANA, and SCS Engineers.

DESCRIPTION OF THE SYSTEM

The test employed a combination of weight-reading equipment, address and location recording systems, and on-board computer systems. As discussed in Section 1, the project was to test a system whereby the weight of each customer's refuse would be determined by on-board scales, and both the weight and customer address would be recorded on the on-board computer. The information would be downloaded from the on-board computer to the main computer in the City offices at the end of each day. The City would then base refuse bills on the actual weight of refuse set out for disposal by each customer.

According to Russ Mathys, if the program would have become fully operational, each customer would be charged a standard fee to collect and transport waste to a disposal facility. All customers would be assessed the same fee, which was estimated to range between $20.00 and $25.00 per household per month. Each customer would then be assessed $.02 to $.03 cents for each pound of garbage which they place out on the curb for disposal. This charge would pay for the disposal costs at the landfill.

The weight of the refuse was determined through the use of load cells placed in between the truck's mechanical arm and gripper. The Rapid Rail (The Heil Company, Chattanooga, TN) refuse collection mechanical arm uses a gripper mechanism to secure the container to the extended mechanical arm.

The system was designed to record the weight at the beginning of each container cycle. To complete one cycle the mechanical arm is extended, the gripper wraps around the container and the container is lifted a few feet off the ground. The mechanical arm is stopped and the weight is recorded. The mechanical arm is retracted, lifts the container, empties it into the truck, and then replaces the container at the curb.

The load cells were designed to be placed between the gripper mechanism and the mechanical arm.

The strain of the gripper (created by the downward force of the weight) is measured by the load cells and translated to weight. The weight information is transmitted through wires to the cab of the truck.

The cab contained a Mars hand-held computer which recorded the weight information from the load cells. The Mars computer associated the weight information with address information supplied by one of two systems.

The first address system to be tested consisted of a computer-generated route sheet printed for each daily route, including customer name, address, and a bar code. The route sheet was fed into a modified printer which served simply as a mechanism to feed the route sheet under the bar code reader inside the cab. When the computer received weight information from the load cells, it triggered the bar code reader to identify the address on the route sheet. After recording the address and weight information, it notified the printer mechanism to advance the route sheet to the next address.

The second address system to be tested involved attaching a Trovan radio-frequency identification (RFID) transponder on each refuse container. The RFID chip released coded information which was received by an antenna mounted on the truck. The identification code of the container was sent to the Mars on-board computer, which translated the information into address identification.

CHRONOLOGY OF EVENTS

During the summer months of 1991, the City of Farmington expressed an interest in the concept of a weight-based billing system for refuse collection. SWANA, which assists the USEPA with the MITE Program, contacted the City and recommended that an application be submitted to USEPA for inclusion in the MITE Program. The City submitted a successful application to the USEPA on October 25, 1991.

Prior to submitting the October 25, 1991 application to USEPA, the City had begun its research into available technology which could be used for weight-based collection. The City rejected the Wray-Tech system which measured the increase in the hydraulic pressure needed to lift the mechanical arm after the container was attached. City engineers concluded that the cold temperature in the City during the winter would have a significant impact on the ability of the system to record accurate weights.

Following approval of the MITE Program application, the City selected GSE (Farmington Hills, Michigan) to manufacture the load cells for the test program. GSE's primary market is load cells and weighing systems for light manufacturing including automobile and aerospace assembly line applications. The company had no previous experience with refuse applications.

Initially, the cost of the RFID transponders was prohibitively high for the funds available from the City. Therefore, the City decided to test the bar code system. However, shortly after the Project began, the cost of the RFID system was reduced to an accessible level, and the City decided to include both the bar code and the RFID system in the test.

In April of 1992, the first load cells were installed on the mechanical arm of the Rapid Rail truck. Tests were conducted with 90 gallon and 300 gallon carts. Initial testing indicated that the 300 gallon carts were not weighed accurately. A very short time after the load cells were initially installed, a weld broke on the load cells causing the gripper mechanism to fall off the mechanical arm. The manufacturer indicated that this was due to a lack of specifications on the amount of weight to which the load cells would be subjected. The load cells were sent back to GSE and were rebuilt with a 500 pound capacity. Field testing resumed in July 1992.

The RFID antenna was also delivered in April 1992 and was installed on one of the two grippers.

RFID chips were attached to the corresponding side of 60 test customers' containers.

The Minnesota State Department of Weights and Measures expressed an interest in the performance of the on-board weighing system, and indicated it would review the test and advise the City on national standards. The national weights and measures requirements for on-board weighing systems are established by the National Institute of Standards and Technology (NIST). An on-board weighing system is defined as a weighing system designed as an integral part of, or attached to, the frame, chassis, lifting mechanism, or bed of a vehicle, trailer, industrial truck, industrial tractor, or forklift truck. The National Conference on Weights and Measures has concluded that these systems should meet Class III scale requirements, as outlined in NIST handbook 44. Class III standards allow a tolerance level of accuracy of one pound for the first 500 pounds, two pounds for 501 to 2,000 pounds, and three pounds for 2,001 to 4,000 pounds.

When testing resumed in July, there were problems keeping the system attached to the truck. The gripper mechanism fell off when the load cells broke twice during testing. City engineers suggested that the load cells were still being overloaded and subjected to unexpected forces due to the rocking, lifting, and sudden changes in direction of the lifting mechanical arm. The load cells were returned to the manufacturer to be completely rebuilt.

Although the load cells during this phase of the project appeared to be less durable than desired, the accuracy of the weights recorded was fairly good. Approximately 90 percent of all weights recorded on the truck were within 2 pounds of accuracy. However, since the containers weighed less than 500 pounds the project was not producing conformance with Class III standards. Accuracy was determined by weighing the customer refuse containers first with a certified digital scale (with an accuracy of one-tenth of a pound), then weighing the container with the on-board system.

The placement of the RFID antenna on the gripper was a problem. The size of the antenna (16 x 8 x 4 inches) caused the antenna to be accidentally snagged on either the truck body or the container during the cycle.

In March 1993, the rebuilt load cells were received by the City and installed on the collection vehicle. While the capacity of the heavy-duty load cells was no longer a problem, the load cells began to deteriorate within 90 days of installation due to the salt on the City roads.

The next two months of testing encouraged the City to plan to generate mock weight-based bills in April 1993 and to begin billing customers based on weight beginning July 1993. The scales were achieving accuracy within 2 pounds approximately 90 percent of the time.

By August 1993, the City engineers had enlisted the help of a local welder/designer to modify the existing antenna placement on the mechanical arm. The new system employed a separate hydraulic mechanical arm onto which the antenna was attached. The antenna mechanical arm would follow the truck's main mechanical arm through the dumping cycle and place the antenna in close proximity to the container without actually touching the main mechanical arm. This system was successful in increasing the longevity of the antenna and eliminating the possibility that the antenna would fall off or be subject to impact.

At this point, the load cells had been redesigned to withstand greater forces, the RFID system was working properly, the bar code system was working properly, and the billing software was generally satisfactory. However, the Department of Weights and Measures determined that the City could not bill the customers by weight unless the system could conform to Class III standards. The system was not able to achieve this accuracy standard.

In November 1993 the load cells were again removed for repairs to the inner workings and wiring. At this point, the City was reluctant to spend more money on the repair, so the project was suspended.

FINDINGS

A comparison of the two address identification systems shows that the bar code reader ensures accurate identification of addresses, but requires the route to be performed in the exact sequence printed on the route sheet. Occasional changes in the route (such as going out of the way for a missed container) were possible, but difficult. The RFID system allowed unlimited flexibility in the collection sequence, but antenna placement on the truck proved critical to accurate reception of the Radio Frequency Signal.

The system successfully maintained the accuracy of calibration. Before the truck began a route, it lifted a container with a known amount of weight. The scale was then calibrated. During the course of the route, the City engineers took the calibration container to the truck to test the calibration under field conditions. This testing procedure generally achieved consistently successful results.

Through their testing, the City engineers concluded that the load cells' accuracy was greatly affected by various factors. The slope of the truck, whether the result of a hill or a crowned road, affected the readings. Wind speed over 10 knots varied the weight readings by 2 to 5 pounds. Containers loaded with heavy items on top or liquids, which moved or settled after the container was lifted, resulted in weight shifts up to 16 pounds. Since these phenomena are not specific to the hardware used in the test project, a successful resolution was not reached.

The unstable nature of the weighing platform (i.e., the refuse vehicle) was also found to have an adverse effect on the accuracy of the weighing system. In addition to environmental influences described above, other factors were identified which affected the accuracy. These factors include:

- Condition of the truck (vibrations due to the tuning of the engine).
- Experience and training of collection crew.
- Inflation of tires (amplification of engine vibrations).

Without a successful resolution to the impediments to the accuracy of the system, the Class III standards will be difficult for any system to achieve. Alternative systems are reviewed in Section 4.

SECTION 4

PERFORMANCE EVALUATION

INTRODUCTION

This section summarizes the main obstacles to the success of the test project and a discussion of alternative activities which, if implemented, may have produced a more desirable result. In evaluating obstacles and alternative activities, a "hind sight" approach has been taken.

The purpose of this section is to provide a review of the approach taken and equipment selected by the City. Current levels of technology were used as a means of comparison with the equipment selected by the City.

OBSTACLES

General

The obstacles which affected the project's success fell into three categories:

- Durability of the load cells
- Accuracy of weighing equipment
- Container identification antenna placement

Load Cells

The load cells broke or needed repair frequently throughout the test period. The load cell manufacturer, GSE, had no previous experience with refuse collection applications. GSE indicated in an interview that no specifications were given regarding the forces to which the load cells would be subjected. Neither the City nor the Heil Company (manufacturer of the refuse truck body and lifting arm) were able to provide specific details on the forces experienced by the mechanical arm in lifting, accelerating and changing direction, emptying, and replacing containers. This generally resulted in a trial and error approach. As a result, the first load cells delivered were not sufficient to withstand the strains of the application.

The load cell manufacturer and the City did not form a partnership in executing this project. For example, the City purchased the load cells from GSE, which charged the City for repairs. As a result, the extent of field testing was somewhat limited by the ability of the City to pay for equipment repairs. It appears that GSE was interested in determining if its existing products could be used in a new market (refuse industry), but was reluctant to absorb the cost of research and design needed to modify the products.

Accuracy

The project was never able to consistently achieve Class III standards for accuracy of the weighing equipment. The most significant factors affecting accuracy were environmental factors which the equipment could not accommodate (distribution of weight in container, slope of road, etc.). These factors were discussed in Section 3. Interviews with City personnel after the test period indicated that the mechanical arm provides an unstable platform for weighing the containers, and is a major obstacle to the achievement of Class III standards (accuracy within one pound, assuming a 500-pound scale). Many City staff members and equipment manufacturers interviewed compared standards currently in Canada and Europe, where the accuracy level allows variance of one kilogram (2.2 pounds). Because the increment for these standards is more than double the United States increment, it allows about half the accuracy required by United States standards.

City staff indicated that driver training and understanding generally affected the accuracy of the weighing system. Drivers who were less careful and less interested in the project were harder on the equipment, possibly contributing to the short life span of the load cells.

Container Identification System

The placement of the antenna proved difficult because of the relatively short (less than 18 inches) distance required between the antenna and the container-mounted transponder. The antenna was initially mounted on the mechanical arm, but this location allowed the antenna to be knocked against the truck and damaged. As noted in Section 3, a mechanical hydraulic arm was designed to bring the antenna within range of the transponder during the unloading cycle.

ALTERNATIVE ACTIVITIES

Load Cells

When the City decided to purchase load cells from GSE, it could have provided GSE performance specifications as opposed to design specifications. The difference between the two is a shift of the source for expertise for repairs or defects from the City to the manufacturer. A simplified example of a performance specification is the following: "The load cells shall be able to function properly on an automated mechanical arm of the City's refuse truck." The design specification which this statement could replace is as follows: "The load cells shall be able to lift containers weighing an average of 100 pounds." The first statement shifts the responsibility of discovering what stresses exist on a refuse truck to the manufacturer, while the second statement assumes that the only stress is a 100 pound weight.

The early load cells broke because the forces experienced on a refuse vehicle were unknown to GSE at the time they designed the load cells. Either the City engineers or GSE engineers could have conducted research to determine these forces and develop a system which could withstand them.

The equipment manufacturer could have taken a partnership role in the project instead of the vendor role. Many scale manufacturers have carried out research and development of load cells specifically for the waste management industry. If one of these manufacturers had been selected, it would have worked in partnership with the City to develop a functional system. The equipment would have been supplied to the City either free of charge or at minimal cost, and repairs would have been the responsibility of the manufacturer.

This project attempted to show that the concept of weight-based billing could work, but its downfall was that it subjected equipment which was not designed for refuse collection to an application unknown by the equipment designers.

Accuracy

Many scale manufacturers interviewed during this project review indicated that the technology is emerging for semi-automated (i.e., rear-load or side-load) cart tippers with scales able to achieve the Class III standards. All the manufacturers displayed reluctance to attempt development of fully automated collection/weighing systems with Class III compliance ability. The instability of the weighing platform (i.e., the refuse vehicle) prevents the accuracy required. While it is likely that this technology may exist in the future (5 years), it was unavailable for this project.

During the project, City officials hoped that the Weights and Measures standards for refuse applications would be relaxed. It now appears unlikely that this will occur. Class III accuracy sets standards for the accuracy of various weight ranges, for gross, tare, and net weights. For example, a scale with one pound divisions must have a tolerance of one pound for the first 500 pounds, two pounds for 501 to 2,000 pounds, and three pounds for 2,001 to 4,001 pounds. It must meet these standards when it weighs the full container (gross weight), when the container is empty (tare weight), and when it computes the difference in weights (net weight).

An alternative to weighing the container as it is lifted would be to weigh the truck after each container has been emptied. On-board truck scales are currently being manufactured for refuse vehicle applications whereby the scale, which is mounted between the body and the chassis, monitors the total load weight. This type of system would provide a tare weight of the refuse loaded into the truck each time a container is emptied into the truck. Currently, the most common use for this type of truck scale is load monitoring to prevent costly fines for operating a vehicle heavier than permitted by regulation. None of the manufacturers of this type of scale indicated accuracy within Class III standards. However, they also stated that they had never attempted to achieve that level of accuracy.

Thorough driver training could have been conducted to instruct the drivers in the equipment operation and to raise their interest level and understanding of the whole project. This could have resulted in a higher motivation level on the part of the drivers and an interest in the success of the test project.

Container Identification System

The Trovan radio-frequency identification system was ultimately successful in accurately reading the cart-mounted transponders, but not without major modifications to the collection vehicle. The relatively large size and short read range puts this identification system at a disadvantage compared to other systems which have small, flexible antennae with read ranges of up to 4 feet.

Trovan systems use continuous wave full duplex transponder technology. This system continuously sends a power pulse to the transponder (mounted on the container) while simultaneously attempting to receive data from the transponder. Since the transponder has no means of storing the energy received, the power pulse from the antenna must be continuous in order to allow the transponder to transmit its coded data. The potential for interference during data transfer results in the short read range of the antenna.

Working with the existing system, the antenna could have been mounted near the truck's hopper, although this placement may have required relocating of the transponders on each of the containers in the service area. It is possible that this approach may have prevented the need for a separate hydraulic mechanical arm designed specifically for the antenna.

SECTION 5

STATE OF THE ART

Interviews with scale and identification technology manufacturers showed that private companies are currently conducting a significant level of research on weight-based refuse billing systems.

Several scale manufacturers have indicated the expected emergence of Class III - certified scales for semi-automated collection applications before January 1, 1995. Cardinal Scale Manufacturing Company (Webb City, Missouri) has recently developed a system which is now legal for use on a semi-automated rear-load or side load truck. This system places the load cell between the entire lifter mechanism and the vehicle body. The cart is attached to the tipper, and the emptying cycle is activated. The tipper lifts the cart and stops at a predetermined mark. When the cart has come to a stop, the load cell weighs the full container and sends the information to the on-board computer. The tipper is then reactivated to bring the container to the top of the cycle where it is unloaded. On the downward portion of the cycle, the cart is again stopped at the predetermined mark and weighed again to determine the empty (tare) weight. The process of stopping the cycle to weigh the container adds approximately 6 to 10 seconds to the cycle. Compared to the remaining cycle of 7 seconds, an additional 6 to 10 seconds more than doubles the total cycle time.

A representative of Mobile Computing Corporation (Toronto, Canada) said that the company has invested over $2 million in the development of a rear- or side-load cart tipper which could meet the Weights and Measures Class III criteria. The company developed the equipment in-house and, following extensive laboratory testing, approached the City of Victoria, Canada for field testing. According to a Mobile Computing Corporation representative, the results have shown consistent accuracy within 0.3 percent.

Weigh-Tronix (Fairmont, Minnesota) has entered into a joint venture with Toter (Statesville, North Carolina) to develop a rear- or side-load cart tipper which would meet the Class III accuracy standards. The companies have completed the design phase, and are presently field testing the system in South Carolina. According to a representative of Weigh-Tronix, the companies plan to bring the product to the market in the fall of 1994.

Structural Instrumentation (Tukwila, Washington) manufactures on-board truck scales capable of weighing the total load carried in the vehicle. The scales, mounted between the truck body and the frame, are not yet capable of achieving the Class III accuracy standards.

Texas Instruments (Austin, Texas) has developed an RFID system which allows much greater flexibility than the system tested by the City. Texas Instruments Registration and Identification Systems (TIRIS) uses pulsed FM transmission, half duplex technology for its transponder identification mechanism. The on-board reader sends a pulse of energy through the antenna to be received by the transponder and stored in a capacitor in the transponder. The pulse of energy lasts approximately 50 milliseconds, after which time the antenna "listens" for a response. The transponder uses the energy stored in the capacitor to send its coded information to the antenna used by the on-board reader. This system allows a read range of up to 4 feet for refuse container applications. The TIRIS system allows the antenna to be mounted on or near the truck's hopper, where the identification takes place as the cart is being emptied. The company claims accuracy levels (i.e., successful identification) of 99.9999 percent.

SECTION 6

RECOMMENDATIONS

Without substantial test data and field demonstration, it is impossible to draw conclusions about the viability and effectiveness of the system which was tested by the City. It is also impossible to validate or disprove the estimates of cost savings and waste diversion made by the City in its proposal to the USEPA MITE Program.

RECOMMENDATIONS FOR FURTHER SYSTEM TESTING

The following recommendations are being made with the recognized constraints in mind, and with the recognition that long-term field testing will be required by a municipality, container manufacturer, or scale manufacturer. It is recommended that the following objectives be incorporated in a field test program:

- Provide for statistical verification that the equipment meets the accuracy requirements as designated by the National Institute of Standards and Technology Class III guidelines.
- Determine the cost of providing collection service before and during the test period. (Include labor, maintenance, equipment amortization, disposal, and other system costs.)
- Develop accurate baseline waste generation and/or disposal data before the test program.
- Measure changes in community diversion rate and recycling rate in comparison to baseline data.
- Measure quality and type of recyclable materials collected (specifically the level of contamination) before and during the test period.
- Measure disposal rates, and make comparisons with baseline data.

RECOMMENDATIONS FOR SYSTEM IMPLEMENTATION

The following recommendations are made to solid waste managers and operations managers for consideration when implementing a weight-based pricing system:

- Performance specifications are important in load cell development. The establishment of performance specifications will provide more control than design specifications.
- Crew and staff should be included in all phases of project development. This may alert operators to any potential design or operational problems.

- Crew training should be considered a necessary part of program implementation.
- Consumer education may be the key to a successful program. Notify the consumer of the rationale behind the collection program, and outline what consumer response is expected (e.g., an increase in diversion/recycling, increased source reduction). Give the consumer options for waste reduction and recycling; identify the ways in which they can minimize their household generation.
- Establish controls for illegal dumping, including enforcement.

REFERENCES

1. Pay As You Throw, Waste Age, September 1993. pp. 29-36.

2. Wired for Waste, World Wastes, August 1993. pp SS1-SS14.

3. City of Farmington, MN, Application to participate in the Municipal Solid Waste Innovative Technology Evaluation Program for the United States Environmental Protection Agency, October 25, 1991.

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