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of Transportation

**Urban Mass
Transportation
Administration**

Bus Fare Collection System Assessment

Dynatrend Incorporated
21 Cabot Road
Woburn, MA 01801

May 1986
Final Report

UMTA Technical Assistance Program

Technical Report Documentation Page

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16. Abstract

An assessment was conducted to examine the impact that rising fare levels are having on bus transit fare collection systems. Problems have been reported with regard to the handling of dollar bills and lost revenue. This report addresses these problem areas which have arisen or grown more significant as a result of increased fares (to or near the one dollar level), and the continued use of fare collection systems designed for coins only. Eight bus transit systems were visited: Chicago Transit Authority, Washington Metropolitan Area Transit Authority, Seattle Metro, Greater Cleveland Regional Transit Authority, AC Transit (Oakland, CA), Tri-County Metropolitan Transit District of Oregon (Portland), Dallas Transit System, and Sacramento Regional Transit District. Findings are presented for each of the problem areas based on data collected during the visits. Long-term and short-term changes in procedures, equipment, and policies designed to bring relief are recommended.

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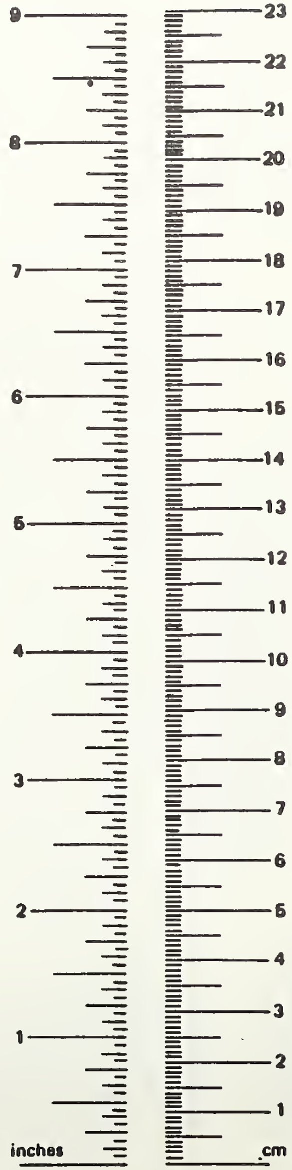
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

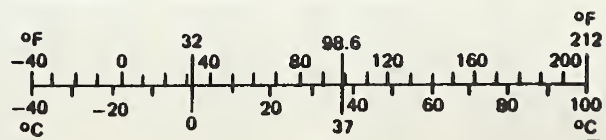
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This Final Report presents the results of an investigation designed to assess two key problem areas with regard to bus fare collection systems and the use of dollar bills. The problem areas identified are:

- o bill handling
- o lost revenue.

The work was performed under sponsorship of the Urban Mass Transportation Administration (UMTA) through a contract with the Transportation Systems Center. Mr. Joseph S. Koziol, Jr., Code DTS-43 of the Office of Systems Assessment, Safety and Security Division was the contract Technical Monitor. Messrs. Vincent R. DeMarco and George Izumi of the Office of Technical Assistance, UMTA, were the fare collection program managers.

The assessment reported herein was based on data furnished by eight transit systems via on-site data collection which involved observation of the fare collection process and interviews with personnel responsible for operations, maintenance, and finance. Contact was made with the General Managers of the selected transit systems by the American Public Transit Association (APTA). The General Managers responded to APTA and designated their representative to support this bus fare collection system assessment.

Data collection was possible because of the full cooperation and generous support provided by the participating bus transit systems. The following persons were the principal point of contact within their respective organizations, and they gave their full support to enable the collection of data required to achieve the goals of this bus fare collection system assessment:

Mr. Paul J. Kole
Group Manager, Finance
Chicago Transit Authority

Mr. Lloyd H. Johnson
Senior AFC Engineer
Washington Metropolitan Area
Transit Authority

Mr. James E. Munson
Manager of Accounting
Seattle Metro

Mr. Donald G. Yuratovac
Director of Service Development
Greater Cleveland Regional
Transit Authority

Mr. Richard Fratus
Controller
AC Transit (Oakland, CA)

Mr. Phillip Selinger
Manager, Maintenance Program
Tri-County Metropolitan Transportation
District of Oregon (Portland)

Mr. Richard L. Jarrett
Project Manager for Electronic
Farebox Implementation
Dallas Transit System

Mr. J. Greg Miller
Controller
Sacramento Regional Transit District

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EXECUTIVE SUMMARY

This investigation was prompted by the transit-expressed need to obtain, assess, and document system data related to bus fare collection problems in the areas of bill handling and lost revenue, and to determine and recommend improved methods to minimize or eliminate these problems. Over the past several years, transit systems have had to increase farebox revenue to offset increased operating expenses resulting from economic inflation and from the reduced Federal operating assistance income. At many transit systems, fares approaching and exceeding one dollar are now being deposited into and processed by equipment that were originally designed to collect a low fare composed of only a few coins. It is the combination of the dollar fare with use of old equipment and not fully developed procedures that are the major contributing factors for the current problem.

Eight transit systems were included in this investigation for purposes of acquiring data from which to assess the problems and needs. These bus transit systems included: Chicago Transit Authority, Washington Metropolitan Area Transit Authority, Seattle Metro, Greater Cleveland Regional Transit Authority, AC Transit (Oakland, CA), Tri-County Metropolitan Transportation District of Oregon (Portland), Dallas Transit System, and Sacramento Regional Transit District. In reviewing candidate systems, telephone contact was initially made with most of the 46 transit systems listed in the Section 15 Report having 250 or more revenue vehicles. Available resources and management considerations necessitated that the study be limited to eight transit systems. Final selection of the eight systems was based on consideration of: total revenue, number of dollar bills received, farebox revenue, type of fare collection system, procedures and equipment, failure rate, maintainability experience, recent equipment upgrade, and willingness to cooperate. To provide comparative data, this investigation included transit systems with problems and transit systems without problems.

It was found that the appearance of the dollar bill in the farebox has resulted in significant increases in the cost of fare collection. For bus systems using equipment that does not provide separate slots for bills and coins, and does not separate bills and coins in the vault, increased costs are due to: (1) extra handling to unfold, flatten, face, stack, and count bills,

(2) additional security, (3) failures due to dollar bills jamming the equipment, and (4) increased maintenance. It is estimated based on this investigation that on the average it costs about six cents to handle each bill. The investigation indicated that new electronic bill accepting fareboxes can eliminate or greatly reduce many of the bill handling problems, but the fareboxes may have high maintenance costs because of their complexity. It is interesting to note that at one system which uses new bill accepting electronic fareboxes, the bill handling costs amounted to nearly ten cents. This cost comparison of registering and non-registering fareboxes does not include the fare theft and fare abuse cost factors.

To reduce the flow of cash into the farebox, all transit systems investigated offer non-cash fare media. Passes are the most common form of non-cash fare media, and are offered by all systems. Some systems went to great lengths to reduce the possibility of counterfeiting passes while other systems believed the problem to be minor and the costs to thwart counterfeiting would not be offset by increased revenue.

The cost of operating a non-cash media fare collection system is generally less than that of a cash fare collection system. Cost comparisons were made considering only material and personnel expenses, but no amortization of facilities or equipment.

It was noted that as the number of different methods (passes, tickets, and tokens) for fare collection increases, so do costs. The transit systems lose the economies-of-scale that could be gained if a single system dominated.

It was found that the cost of fare collection for the transit systems studied, except for the self-service system, ranged from 1.4% to 4.9% of the revenue collected; the specific cost of bill handling ranged from 2.5 cents per bill to ten cents per bill and these costs included counting, adverse impact of bills on equipment which increases maintenance cost, security costs, and the losses from deposition of half-bills.

Estimates were made for the loss of revenue due to theft and fare abuse for systems using fareboxes that do not separate bills and coins. (Revenue loss data were not available from transit systems using fareboxes which separate bills and coins.) Based on a sample size of two systems, WMATA and TRIMET, the mean revenue loss was estimated to be 4.8%, and the fare loss at the one-sided upper bound 90% confidence level was estimated to be 7.1%; this is interpreted to mean that there is only one chance in ten (100-90) that the true fare evasion loss will exceed 7.1%.

Based on the data collected, short-term and long-term approaches for alleviation of the problem are recommended.

Short-Term Approaches

(1) Require passengers to display unfolded bills and coins before depositing fares into the fare box.
(2) Require a surcharge if payment is made using a dollar bill.
(3) Require use of tickets and front door departure where zone fares are used.
(4) Conduct testing to assess magnitude of revenue loss to provide data for efficient application of resources to reduce losses.
(5) Require all money handling personnel to wear pocketless garments.
(6) Install CCTV cameras where money is unsecured.
(7) Publicize the losses resulting from fare abuse to make the public aware of the problems, and encourage the use of the We-Tip program.

Long-Term Approaches

(1) Upgrade farebox equipment by introduction of electronic fareboxes which have separate paths for bills and coins.
(2) Offer two methods for fare collection, one cash and the other non-cash and work to have one strongly predominant over the other.
(3) Dispense all transfers via automatic equipment, and require payment of a fee to discourage casual purchase by passengers who have no intention to use one.
(3) For systems with registering fareboxes, develop a statistical testing software package to flag significant changes in revenue collected that may require investigation.

1. INTRODUCTION

Transit systems have had to increase farebox revenue to offset increased operating expenses resulting from the economic inflation and reduced Federal operating assistance income. Today, fares approaching and exceeding one dollar, i.e., the "dollar fare," are being deposited into and processed by equipment designed to collect a low fare composed of a few coins. It is the combination of the dollar fare, use of old equipment, and inadequate procedures that have led to the major bus fare collection problems today.

The objective of this bus fare collection system assessment was to obtain, assess, and document transit system data and needs related to two key bus fare collection problem areas:

(1) bill handling; and
(2) lost revenue.

This report is intended to quantify for the bus transit community the magnitude of the problems that some transit systems are faced with and point out some methods for alleviation of these problems. With continued inflation, and the real spectre of drastically reduced Federal assistance, the "dollar fare" problem will afflict more and more bus transit systems.

Bill handling refers to the problems created by the use of dollar bills to pay fares. The presence of large numbers of dollar bills has created problems related to:

(1) increased labor requirements because bills are handled manually unlike coin processing which is performed by automatic equipment, and

(2) increased failure rates and maintainability requirements for farebox equipment which was designed for coins only and not intended to accept bills.

Lost revenue refers to the difference between the revenue due the transit system for service provided to passengers, and the funds that are eventually deposited into the transit system's bank. Lost revenue is comprised of two principal elements:

(1) fare evasion, i.e., underpayment or non-payment by passengers; and
(2) theft of fares by employees of the transit system.

The work reported herein is an extension of an earlier investigation[1,2] sponsored by UMTA/TSC to understand better the operations and problems of existing fare collection systems; this assessment was conducted during the mid-1982 to early 1984 time period.

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[1] Bill Handling Problems in Bus Fare Collection by Carlos de Moraes and Joseph Motola, Custom Engineering, Inc., U.S. DOT, UMTA, Report No. DOT-TSC-UMTA-82-43, October 1982.

[2] Evaluation of Electronic Registering Fareboxes, prepared by Booz-Allen & Hamilton, Inc., UMTA-MA-06-0120-83-2, DOT-TSC-UMTA-83-52, Final Report, January 1984.

2. SELECTION OF TRANSIT SYSTEMS

The data base for this bus fare collection system assessment was collected during visits to eight transit systems. It was decided that the transit systems selected for the assessment would be drawn from among the larger systems, i.e., those which predominate nationally in terms of number of vehicles and revenue. The premise was that those transit systems that had larger farebox revenue and received large numbers of bills could be expected to have the greatest problems and hence their experiences would be of national significance. Eight transit systems were selected to provide broad enough coverage without making the assessment unwieldy.

A brief examination was made of data appearing in the Section 15 Report[3] to determine the relationship between the size of the transit system as measured in total number of revenue vehicles and total passenger revenue. Table 1 relates the category of the transit system with the total number of such systems within the size category, their total number of revenue vehicles, and total passenger revenue. (It should be noted that both bus and rail vehicles were used to determine the size category of the transit system. For the category of 1000 or more revenue vehicles, rail vehicles represent 25% of the total. For the other categories, rail vehicles represent less than 6% of the total.)

Table 1 shows that within the three largest category groupings of transit systems (250 or more revenue vehicles), there are a total of 46 systems. These represent about 14% of all transit systems, and include about 78% of all revenue vehicles in service and 87% of all passenger revenue collected.

Telephone contact was made with 42 of the 46 transit systems whose revenue vehicles were 250 or greater, i.e., the top three categories indicated in the Section 15 Reporting System. The objective of the telephone contact was to obtain some characteristic information with which to base the selection of

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[3] National Urban Mass Transportation Strategies, Second Annual Report, Section 15 Reporting System, by Stephen J. Morin, U.S. Department of Transportation, Urban Mass Transportation Administration, UMTA-MA-06-0107-82-1, June 1982.

TABLE 1
SUMMARY OF TRANSIT SYSTEMS ACCORDING TO
CATEGORIES BASED ON NUMBER OF REVENUE VEHICLES

CATEGORY OF TRANSIT SYSTEM (BASED ON NUMBER OF REVENUE VEHICLES)	TRANSIT SYSTEMS IN EACH CATEGORY		NO. OF REVENUE VEHICLES IN EACH CATEGORY		PASSENGER REVENUE IN EACH CATEGORY	
	Number	Percent	Number	Percent	$M	Percent
1000 or more	15	4.7	35,601	56.6	1,552	72.1
500 to 999	9	2.8	6,039	9.6	143	6.6
250 to 499	22	6.9	7,705	12.2	189	8.8
100 to 249	37	11.5	5,881	9.3	134	6.2
50 to 99	55	17.1	3,934	6.3	84	3.9
25 to 49	70	21.8	2,319	3.7	36	1.7
less than 24	113	35.2	1,463	2.3	16	0.7
TOTALS	321	100.0	62,942	100.0	2,154	100.0

transit systems for inclusion in the assessment. This information included the following:

- o total farebox revenue collected daily;
- o number of dollar bills received daily;
- o type of fare collection equipment;
- o security of revenue collected;
- o farebox failure rate and maintainability;
- o recent fare collection and/or revenue collection and processing upgrade; and
- o willingness to participate in the assessment.

Based on the findings of the telephone contacts, eight transit systems were selected for this assessment and these choices are presented in Table 2.

These eight transit systems were selected for site visits and data collection because they accepted and processed a substantial number of dollar bills, and provided a diverse cross section of methods and equipment of the 46 transit systems in the category of 250 or more revenue collection vehicles. Although they represent only 2.5% of all transit systems, they include 16% of all revenue vehicles and 50% of all passenger revenues. It is also believed that the findings should have applicability to those transit systems whose fare is approaching the one dollar level, and where bills are appearing in ever increasing numbers.

The American Public Transit Association (APTA) made the initial contact with the transit system, and requested their participation in the assessment.

TABLE 2
BUS TRANSIT SYSTEMS SELECTED FOR INVESTIGATION
ARRANGED ACCORDING TO CATEGORY OF TRANSIT SYSTEM

CATEGORY OF TRANSIT SYSTEM, NO. OF REVENUE VEHICLES	TRANSIT SYSTEM[1]
1,000 or more	Chicago Transit Authority Washington Metropolitan Area Transit Authority Seattle Metro Greater Cleveland Regional Transit District
500 to 999	AC Transit (Oakland, CA) Tri-County Metropolitan Transportation District of Oregon (Portland)
250 to 499	Dallas Transit System Sacramento Regional Transit District

[1] The order of transit systems presented in this table and in this report follows the order from largest to smallest number of revenue vehicles as presented in the Section 15 Report.

3. DESCRIPTION OF FARE COLLECTION SYSTEMS

This section describes the eight transit systems first collectively, then individually, in detail.

Table 3 presents some pertinent fare collection system characteristics. This table shows (1) the number of peak hour buses on the road each weekday, (2) the number of passengers using the bus system each weekday, (3) the annual revenue collected from passengers by all methods, i.e., cash, passes, tokens, and tickets, (4) the type of fare box in service and whether coins and bills are commingled or separated, (5) the method used for validation that the correct fare has been paid, (6) the fare paid by passengers, and (7) the fare structure, i.e., a flat fare or a zone fare.

All transit systems provided passes for sale to their passengers; most are sold as monthly passes, but some sell weekly and biweekly passes. The first three columns which show number of buses, number of passengers carried, and annual revenue collected are related to size of the transit systems included in the assessment. Two systems have fareboxes which register the fare deposited and also provide a method for easy validation by the operator. Only three of the transit systems visited had a flat fare structure; most had a zone fare structure. Note that as the number of zones increases the range of fare values also increases.

Table 4 shows the percentages of passenger revenue collection by the different fare media, i.e., coins, bills, tokens, tickets, and passes. Table 4 also shows the total fare revenue (all forms) each weekday, and the fare revenue that is received by the transit system, i.e., summation of coins, bills, tokens, tickets and passes. Some transit systems encourage the sale and use of non-cash fare media by offering discounts and convenient sale locations to passengers. It can be seen that non-cash revenue ranges from a low of 18% for AC Transit to a high of 58% for Tri-County Metropolitan Transit District of Oregon (Portland). It is difficult to understand why these differences exist

TABLE 3
BUS FARE COLLECTION SYSTEM CHARACTERIZATION

TRANSIT SYSTEM	PEAK HOUR NUMBER OF BUSES PER WEEKDAY	NUMBER OF PASSENGERS PER WEEKDAY	ANNUAL REVENUE COLLECTION $M	TYPE OF FARE BOX	VALIDATION	FARE $	FARE STRUCTURE
Chicago Transit Authority	1913	1,544,000	221	Duncan Acceptafare (cash[1] commingled)	Operator	0.90	Flat
Washington Metropolitan Area Transit Authority	1462	550,000	94	Keene Vacuum (cash commingled)	Operator	0.75 to 2.90	Six Fare Zones
Seattle Metro	846	216,000	45	Keene and Omar Johnson (cash commingled)	Operator	0.60 to 0.90	Two Fare Zones
Greater Cleveland Regional Transit Authority	610	273,000	33	Duncan Acceptafare (cash commingled)	Operator	0.85	Flat Fare
AC Transit (Oakland, CA)	794	250,000	29	Duncan Faretronics (cash separated)	Operator & Farebox	0.60 to 1.75	Three Fare Zones
Tri-County Metro. Transportation District of Oregon (Portland)	493	167,000	19	Keene (cash commingled)	Operator & Inspectors	0.75 to 1.25	Three Fare Zones
Dallas Transit Authority	445	149,000	18	GFI Cents-a-Bill (cash separated)	Operator & Farebox	0.50 to 1.25	Three Fare Zones
Sacramento Regional Transit Authority	190	90,000	7	Duncan Farescan (cash separated)	Operator	0.75	Flat Fare

[1]Cash includes both bills and coins.

TABLE 4
BUS FARE REVENUE COLLECTION BY TYPE OF PAYMENT

TRANSIT SYSTEM	TOTAL FARE REVENUE COLLECTION PER WEEKDAY, $	PERCENT OF TOTAL FARE COLLECTION REVENUE					
		COINS, %	BILLS, %	TOKENS, %	TICKETS, %	PASSES, %	TOTAL, %
Chicago Transit Authority	707,800	34	26	11	0	29	100
Washington Metropolitan Area Transit Authority	299,300	51	18	5	3	23	100
Seattle Metro	144,000	48	4	0	12	36	100
Greater Cleveland Regional Transit Authority	106,800	39	19	0	29	13	100
AC Transit (Oakland, CA)	92,000	66	17	0	4	13	100
Tri-County Metro. Transportation District of Oregon (Portland)	62,200	31	11	0	18	40	100
Dallas Transit Authority	58,000	48	12	0	2	38	100
Sacramento Regional Transit Authority	21,500	45	18	0	23	14	100

without an in-depth investigation of the level of non-cash fare media discounts, convenience of purchasing non-cash fare media, advertising policy and expenditures by the transit system, cost of the fare, and the attitude of the community served by the system. Also to be noted from Table 4 is the percentage of dollar bills that are deposited. Bill collection percentages range from a maximum of 26% for Chicago Transit Authority to a low of 4% for Seattle Metro.

The cash fare collection process has five principal elements and these include:

(1) payment of cash (including tokens) into the farebox;

(2) removal of cash fares from the cashbox into a portable vault located at the buses' place of garaging;

(3) transfer of portable vault from the garage to the counting facility;

(4) counting of money, and

(5) transfer to the bank.

The sections that follow present a description of the fare collection and fare counting process at the eight transit systems visited as well as information gathered about passes and tickets.

3.1 CHICAGO TRANSIT AUTHORITY (CTA)

CTA uses the Duncan Acceptafare which was originally designed to accept coins only and to register payments. This farebox no longer has the ability to register payment and collects both coins and bills. Collection of small numbers of bills generally does not present a problem. On some bus routes upwards of 600 bills can be collected before the scheduled return to the garage; large quantities of bills present a problem since they readily fill the cashbox and then begin to form a column from the cashbox through the farebox throat that leads to the deposit plate. The cashbox design uses an interlock system that causes the box to lock when it is removed from the farebox housing. This interlock mechanism is activated by rotation of the cashbox within the farebox; if a continuous column of bills extends through the throat, when the cashbox is rotated, some dollar bills are carried into the clearance space between the cashbox and the vault and can create a jam. To remove a jammed cashbox it is sometimes necessary to remove the entire farebox from the bus and exert sufficient torque on the cashbox to break a retaining pin and so enable extraction of the cashbox. After the cashbox is removed in a normal operating procedure (no jam) at the garage, it is carried to the portable vault, inserted, and rotated, a procedure which results in an unlocking of the cashbox and dumping of cash into the portable vault. Any bills and coins that are above the throat remain in the farebox and must be probed for by hand, extracted, placed into a special purpose cashbox, and dumped into the portable vault. If there is trouble free operation, the empty cashbox is returned to the vault in the farebox.

Bills and coins are commingled in the portable vault. At the counting facility, after the vault is opened, the coins and bills do not flow out naturally due to the binding effect caused by the presence of bills; it becomes necessary to probe the portable vault manually to force the flow of cash. This situation results in further damage to the bills. After the portable vault is emptied, bills and coins are separated. CTA counts its coins using automatic equipment. After the coins are counted and before the next portable vault arrives, CTA counting room personnel count bills; they process about 38,000 of the 185,000 bills received daily. Bills are unfolded, flattened, faced, and stacked manually; counting is done via automatic equipment. The bills CTA does not process internally are bagged and sent to the bank for counting at a cost of $25 per thousand bills.

CTA is one of the two transit system visited that uses tokens.

CTA also sells a monthly pass that can be used an unlimited number of times; the price of the pass is based on 44 rides per month. CTA is very conscious of the need for pass security to inhibit counterfeiting. Pass production is performed in-house and CTA goes to great measures to defeat any potential attempts to counterfeit their pass. First, rare archival pictures of Chicago are used to make the pass unique. Second, the passes are printed using pastel colors and ultra-violet (UV) metallic ink both of which do not readily reproduce on copying machines. Third, the word VOID is printed on the pass, but it is not visible; it only becomes visible when the pass is copied. Fourth, a strip of Polaroid's Polarproof tape is used on the pass as a unique authenticating feature. Fifth, the pass receives a serial number. All materials used in production must be accounted for; CTA's internal audit group monitors the final printing, storage, and distribution, and is also responsible for the security of the printing plates.

3.2 WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY (WMATA)

WMATA uses the Keene Vacuum System which was designed to accept both bills and coins and deposit them into separate containers; these fareboxes do not register. The 53,000 bills that are received daily on the average is greater than the system design capacity. Receipt of large numbers of bills has required some minor procedural changes at the garage. After the bus arrives at the garage, the contents of its cashbox are removed by a vacuum system. An interlock system allows the cashbox to open only after the vacuum hose is inserted. The bills are vacuumed out into cannisters that are housed in a steel structure near the pulling island. Next, the coins are vacuumed out into a portable vault housed in the same steel structure as the bill cannisters. Due to the tremendous number of bills being received, some bills are commingled with coins and so are carried into the coin vault. WMATA counts all of its coins and bills. Coins are separated on a multi-level shaker table, counted, and bagged. The contents of the coin vault are emptied onto a conveyor belt and the bills that are mixed with coins are separated via a blower.

Tokens are sold by WMATA to the passengers at about a 5% discount when purchased in bulk; a flash pass is also sold that is valid for two weeks and represents a savings to the passenger if used every weekday. Commuter tickets are also sold, but there is no discount available. These tickets are deposited into the farebox and subsequently deposited into the bill container. No sales fees are paid to commercial vendors.

3.3 SEATTLE METRO

Seattle Metro collects both bills and coins which are commingled in non-registering Keene, Cleveland Model 4 and Omar Johnson drop-boxes. After the bus returns to the garage, the cashbox is removed and exchanged for an empty one. The cashboxes with currency are placed onto a locked rack in a secured room. When cashier personnel arrive at the garages, they empty the cashboxes into bags and transport the bags to the counting facility. At the counting facility the bags are emptied onto a tray and the bills are removed manually. Coins and tickets drop on to a blower table where an air current blows the tickets off. The coins are separated on a multi-level shaker table, counted, and bagged. Bills are unfolded, flattened, faced, and stacked by hand and counted via automatic equipment.

Passes are produced for Seattle Metro by an outside vendor via award based on competitive bidding. The Metro accounting department is responsible for accountability of all materials used in the production process. Passes are priced on the basis of 32.5 uses per month. Metro estimates the pass holder uses it 42 times during the month which results in an average discount of 23%. In addition, some 30 employers provide a 10% or more pass subsidy for their employees.

To defeat copying of passes using copying machines, Metro has developed a pass that incorporates three different features. The top third of the pass consists of words printed on a reflective foil material; the reflective quality spoils any attempt at reproduction. The middle third consists of very fine line figures with lines close together on a pastel background that are printed using UV metallic ink; color reproduction results in a "halo" effect, i.e., a blotch. The bottom third of the ticket consists of a color strip with the month printed on top; the strip changes color in a reproduction machine. It is believed that, through incorporation of these features into their pass, the counterfeiting threat has been minimized.

3.4 GREATER CLEVELAND REGIONAL TRANSIT AUTHORITY (RTA)

RTA uses the Duncan Acceptafare farebox to collect both coins and bills which are commingled; the registering capability is no longer functioning. The Duncan farebox is similar to the one used by CTA; however, the problems associated with the collection of bills are not as severe as CTA's. Jamming of the cashbox is not a problem because the number of bills collected is significantly smaller than the number collected by CTA. RTA takes in about 20,000 dollar bills per day. They count all of the bills and coins internally.

RTA sells weekly and monthly flash passes, the prices of which are based on ten rides per week and 40 rides per month, respectively. Based on careful assessment, RTA has found that a flash pass (1) produced in-house, (2) using plain paper stock, (3) without a serial number, and (4) dispensed in stacks of fixed quantities provides adequate security. Outside distributors of RTA passes and tickets receive a one and one-half percent commission.

3.5 A.C. TRANSIT (OAKLAND, CA)

A.C. Transit uses the Duncan Faretronics farebox in its buses for collection of coins and dollar bills. These fareboxes register the fare by type of fare being collected. Both coins and bills deposited by passengers are displayed to the driver. Visual inspection is relatively quick and easy. After the buses return to their garage, the two cashboxes, one for coins and one for bills, are emptied into separate vaults by the pullers. After the cashboxes are removed, the fare data, which includes date, route number, time of day, and the number of different fare types, is extracted electronically. Brinks has a contract to pick up the vaults at the garage and to count the revenue and deliver it to the bank.

A.C. sells tickets valid for a single ride in strips of 10 and 20. Monthly passes with unlimited use are also sold. Commercial sales outlets receive a five percent commission. A.C. believes they have defeated the counterfeiting problem through use of a foil background on their passes. Any attempt at reproduction results in a black image on the reproduced copy.

3.6 TRI-COUNTY METROPOLITAN TRANSPORTATION DISTRICT OF OREGON (TRIMET)

TRIMET was using a self-service fare collection system at the time of this assessment. This system requires all passengers to have a proof of payment on their person at all times while riding on the bus. Passengers using cash, deposit the fare using both bills and coins into Keene fareboxes. These fareboxes were originally designed for coins only; bills are now being deposited and are commingled with the coins. Payment of correct fare depends on visual inspection by the driver. After paying the fare, the driver activates the controller which in turn activates the fare receipt dispenser which issues a proof of payment so that the passenger has a receipt, denoting the time when and the zone where the trip was initiated. In a self-service system, the passenger has the responsibility for obtaining a ticket when boarding that is properly marked with the time and zone. Fare inspectors are used to insure compliance with the self-service system by performing a check on the validity of the tickets held by a small random sample of passengers. Fare evaders are cited by the inspectors and are subject to a fine.

Fare data is stored within the on board controller. After the bus returns to the garage at the end of the day, the cashbox is removed from the farebox vault and an empty cashbox is installed. The cashboxes that were removed are stacked on a cart and transported by TRIMET to their counting facility. The cashboxes are emptied and the bills are separated manually.

TRIMET provides both tickets and passes for their passengers. Retail outlets receive two percent of the value of the tickets and passes sold after sales exceed $5,000. Passengers using tickets have their tickets validated by means of a ticket validator which is connected to the controller to enable storage of transaction data. A ten-ride ticket is available. Tickets can be used for one hour of unlimited rides within the appropriate zone(s). The ticket validator on-board the bus clips off a numbered tab and prints the date, time, and zone on the back of the ticket. TRIMET has also been experimenting with stationary automatic ticket vending machines; currently four are in field test, and are maintained by an outside contractor.

Monthly flash passes are also available. To make their pass resistant to counterfeiting via use of a color copying machine, TRIMET uses (1) bright Day-Glo colors which reproduce as dull colors, (2) intricate patterns that halo when copied, and (3) incorporate a bright foil that does not reproduce well.

3.7 DALLAS TRANSIT SYSTEM (DTS)

DTS uses the GFI Cents-a-Bill registering farebox. This farebox accepts both bills and coins, displays the deposit to the driver, presents a digital readout of the deposit, and stores passenger fare payment data in its memory. Coins and bills are deposited into separate slots and are stored in a cashbox with separate compartments, but the bills are not stacked. Data is recorded by the operators which categorizes cash paying passengers travelling in each of five zones, passes used in each zone, transfers lifted, reduced fares, and special tickets. When the bus returns to the garage, the cashbox is removed via a system of interlocks and the coins and bills which are separated enter separate compartments within the garage vault. During this cashbox emptying process an optical probe is used to extract the data stored within the farebox. This data is sent by hard wire to computer memory. DTS can use the data to ascertain that the bank receipts are in agreement with the monies deposited into the cashbox. The data collected is summarized daily by route, and the printout displays the current data recovered from the farebox, plus data for the same day of the week for the five previous weeks. This is done so as to provide a baseline with which to detect the existence of significant changes.

Both passes and cards (punch-type) are sold to passengers. Dallas does not pay for the sales service provided by commercial vendors of passes and cards. A pass costs $45 per month and the charge is based on 33 rides per month. DTS will sell the pass to employers for $43, and the employers are expected to sell the pass to their employees for $41 or less. Passes and cards are printed by a vendor who has been selected following a competitive bid. Both passes and cards are serialized. No counterfeiting has been observed.

3.8 SACRAMENTO REGIONAL TRANSIT DISTRICT (SRTD)

SRTD uses Duncan Farescan non-registering fareboxes. A small number of Duncan Faretronics registering fareboxes are also in service. Both of these fareboxes were designed to handle dollar bills. Coins and bills are deposited into separate slots, displayed to the operator, and deposited into separate cashboxes. The counting facility and garage are co-located. When the bus returns to the garage the cashboxes are emptied into vaults, the opening of which is on the garage side and the container on the counting facility side. During the emptying process, the fare data is retrieved from the registering fareboxes. On a random basis, cashboxes are exchanged rather than emptied and replaced. These cashboxes are counted individually and the value of their contents are reconciled with the farebox printout. SRTD reported that the registering farebox had a 98% reconciliation accuracy during their acceptance tests.

Passengers can purchase both monthly passes and tickets. Pass production is sent out for competitive bid. The printer is responsible for buying all paper and ink, and produces a three-color pass from artwork prepared by SRTD. During pass printing, SRTD personnel are on the printer's premises overlooking the security aspects of the process.

4. BILL HANDLING PROBLEMS

Bill handling problems are defined as problems that result in reduced revenue and/or increased costs due to the acceptance of dollar bills by the transit system. These problems include cost of processing, damage to farebox equipment, and fare loss. This section discusses the first two aspects of bill handling. The revenue loss problems connected with bills is discussed in Section 5.0.

The combination of inflation and reduced Federal operating assistance has resulted in the need to raise fares. At many transit systems, as the fare approaches and exceeds one dollar, more and more bills are deposited into the fareboxes. At the transit systems studied, the percentage of dollar bills received ranged from 4% to 26% of fare revenue. Increases in the number of bills received can be expected at transit systems throughout the United States in the near future.

Some transit systems, but none visited in this study, with fares at and above one dollar have a policy not to accept bills. (CTA tried to implement a policy of not accepting bills, but had to abandon it because of public resistance.) Such a policy has made it difficult for passengers, who do not have access or financial means to use non-cash fare media, to gain convenient access to the system. As bus fares increase, it can be expected that the demand on the part of the public served to be allowed to use bills will increase unless the transit system can provide an alternative that is easily available. It would be difficult to imagine a business establishment that refuses to accept dollar bills because of the complications they present.[4]

The problems of bill processing can best be illustrated via comparison with coin processing. With coins, it is possible to create a system such that from the instant the coin is deposited by the passenger into the farebox, there is

[4] Telephone companies are, of course, a major exception. The telephone companies do provide credit cards which allows the customer to make an operator-assisted call at somewhat greater cost than the direct dial call.

no need for human intervention in the collection, sorting, counting, and bagging process. Coins can move in a "sealed pipeline" unless there is some need for equipment maintenance. This automation allows the processing to be relatively swift, efficient, and secure from the viewpoint of reduction in the possibilities of theft.

Bill processing includes the following steps:

- o unfolding;
- o flattening;
- o facing;
- o stacking; and
- o counting.

At the transit systems visited, these steps all require human intervention; counting was the only part of the process mechanized. (It is possible to have these steps performed by the user and equipment. For example, user interaction with dollar bill changers results in a completely processed bill. To permit the authentication test to assess that the bill is legal tender, a flat bill in a preferred orientation must be inserted into the bill accepting slot. Thus, the user performs the unfolding, flattening, and facing steps and the changer mechanism does the stacking and counting.)

The GFI Cents-a-Bill used by Dallas, the Duncan Faretronics used by A.C., and the Duncan Farescan used by Sacramento have separate slots and separate storage compartments for bills, but the bills are not stacked. Since the bills drop into a pile, they must be faced and stacked at the counting facility. Chicago, Washington, Cleveland, Seattle, and Portland all use drop-type boxes which require that the unfolding, flattening, facing, and stacking steps all be performed manually. All transit systems visited use bill counting equipment. WMATA has a Mosler Toshiba CF-400 Currency Processing System which can count, sort, and face bills. Facing is a two step process. In a stack of bills, there is a maximum of four different orientations. After the bills are run through the CF-400 on the first pass, the number of orientations are reduced to two. The portrait is either face up (or face down), but the lettering is right side up or upside down, i.e., four orientations are reduced to two orientations. The bills are run through the CF-400 a second time, after which the portrait on all the bills is up (or down) and the lettering on each bill is in the same direction, i.e., the bills are faced.

It was found that bills from drop type fareboxes which must be unfolded, flattened, faced, and stacked by hand could be handled at a rate of about 430 bills per hour. Bills which are deposited in an unfolded configuration and are not co-mingled with coins, only require facing and stacking by hand. It was found that this process could be performed at twice the rate for processing bills from drop type fareboxes, or about 860 bills per hour.

Table 5 presents, for each transit system studied, the total farebox revenue which includes both cash and the prepayment of fares, the cost of collection of farebox revenue, and the cost of fare collection as a percentage of total farebox revenue. Fare collection costs include material costs and personnel costs primarily, and do not include amortization of facilities and equipment. Also presented is information about the type of farebox in service, the fare payment validation method, and the method of dollar bill deposition into the farebox. It can be seen that the present cost of fare collection ranges from a low of 1.4% for Seattle Metro to a high of 4.9% for AC Transit not including TRIMET at 16.4% which has introduced self-service fare collection[5].

Table 6 presents the cost of collection of cash and non-cash farebox revenue. It can be seen that the cost of collection of non-cash revenue is not always lower than the cost of collection of cash. This is probably due to the influence of fixed costs of non-cash fares such as sales and distribution. These fixed costs must be offset by higher pass and ticket sales to realize a lower percentage collection cost than that of cash fare collection.

It was observed during visits to the counting facilities, that they were not in continuous operation at all transit systems. There would be periods when the sorting and counting machines would be idle and awaiting the arrival of the next shipment of cash. This excess equipment could be used to count the

[5]The higher cost for TRIMET results from the need for fare inspectors to enforce self-service, and from the high maintenance costs for their onboard equipment.

TABLE 5
ANNUAL COST OF COLLECTION OF FAREBOX REVENUE

TRANSIT SYSTEM	TYPE OF FARE BOX	METHOD OF BILL DEPOSITION	FARE PAYMENT VALIDATION METHOD	TOTAL FAREBOX REVENUE, $K/YEAR	COLLECTION COST OF ALL FARE REVENUE, $K/YEAR	COST AS % OF FARE REVENUE
Chicago Transit Authority	Duncan Acceptafare (Non-Registering)	Folded	Operator	221,400	9,950	4.5
Washington Metropolitan Area Transit Authority	Keene Vacuum (Non-Registering)	Folded	Operator	93,600	2,630	2.8
Seattle Metro	Keene and Omar Johnson (Non-Registering)	Folded	Operator	45,000	609	1.4
Greater Cleveland Regional Transit Authority	Duncan Acceptafare (Non-Registering)	Folded	Operator	33,400	977	2.9
AC Transit (Oakland, CA)	Duncan Faretronics (Registering)	Flat	Operator and Farebox	28,800	1,402	4.9
Tri-County Metro. Transportation District of Oregon (Portland)	Keene (Non-Registering)	Folded	Operator and Inspectors	19,500	3,200	16.4
Dallas Transit Authority	GFI Cents-a-Bill (Registering)	Flat	Operator & Farebox	18,100	734	4.1
Sacramento Regional Transit Authority	Duncan Farescan (Non-Registering)	Flat	Operator	6,700	127	1.9

TABLE 6

ANNUAL COST OF COLLECTION OF CASH AND NON-CASH FAREBOX REVENUE

TRANSIT SYSTEM	CASH COLLECTED[1], $K	COST OF CASH COLLECTED, $K	COST AS % OF CASH COLLECTED	NON-CASH FARE MEDIA RECEIPTS[2], $K	COST OF NON-CASH FARE MEDIA, $K	COST AS % OF NON-CASH FARE MEDIA RECEIPTS
Chicago Transit Authority	160,100	8,660	5.4	61,300	1,290	2.1
Washington Metropolitan Area Transit Authority	69,000	1,810	2.6	24,600	820	3.3
Seattle Metro	23,400	493	2.1	21,600	116	0.5
Greater Cleveland Regional Transit Authority	19,400	595	3.1	14,000	382	2.7
AC Transit (Oakland, CA)	23,800	1,016	4.3	5,000	386	7.7
Tri-County Metro. Transportation District of Oregon (Portland)	8,200	1,990	24.3	11,300	1,210	10.7
Dallas Transit Authority	11,200	558	5.0	6,900	176	2.6
Sacramento Regional Transit Authority	4,100	123	3.0	2,600	4	0.2

1 Includes tokens

2 Passes, tickets, etc.; no tokens

cash equivalent (in coins) of the non-cash receipts at probably little or no extra cost to the transit system. Another point to be made is that the use of non-cash fare media is an additional cost burden to the transit system. It should not be surprising that the total cost of fare collection should increase as the number of fare collection options increase. A single method of fare collection allows for the economies-of-scale wherein the fixed costs can be spread over a larger base. The economy-of-scale consideration should prompt the transit system to attempt to make one method of fare collection, dominant. There are other considerations, however, that may necessitate the use of two or more fare collection methods even though multiple fare collection systems increase costs. For example, CTA farebox equipment is being seriously damaged by the deposition of large quantities of bills; the fareboxes are being jammed, and the unjamming methods result in damage to the equipment. The sale of non-cash fare media offers relief from more frequent jamming since it directs money away from the farebox.

Table 5 shows the overall percentage cost of fare collection. Fare collection is made up of two main elements: cash and non-cash fare media. The percentage costs of fare collection for these elements were shown in Table 6. Cash is comprised of bills and coins (including tokens). The costs of collection of these fare categories is presented in Tables 7 and 8 respectively. Table 7 shows the costs for bill handling, and also shows the number of bills collected via the farebox each weekday. The component pieces of bill handling are bill processing, maintenance, security costs, and half-bill losses. Bill processing which includes unfolding, flattening, facing, stacking, and counting, refers to the additional cost resulting from the need to provide manual labor to count bills. The cost of processing each bill received, as shown in Table 7, ranges from a low of 1.5 cents per bill to a high of 6.4 cents per bill. The wide range in cost is due to productivity, labor, and quantization effect. Productivity is a measure of the output by labor; labor may range from minimum hourly wage earners to well paid earners; and the quantization effect is the need to specify at least one person for a job or part-time job although there may not be sufficient work to keep the person busy throughout the work shift. Maintenance costs refer to the additional resources needed to either counteract the increased failure rate to old fareboxes resulting from the interaction of bills, or provide both scheduled

TABLE 7
COST OF BILL HANDLING

TRANSIT SYSTEM	NO. OF BILLS RECEIVED EACH WEEKDAY	BILL PROCESSING COST CENTS/BILL	MAINTENANCE COST CENTS/BILL	SECURITY COSTS CENTS/BILL	HALF BILLS COSTS CENTS/BILL	TOTAL COSTS CENTS/BILL
Chicago Transit Authority	185,000	3.2	3.6	2.6	0.6	10.0
Washington Metropolitan Area Transit Authority	53,000	1.7	1.2	~0.0	0.7	3.6
Seattle Metro	6,000	4.5	0.5	~0.0	1.5	6.5
Greater Cleveland Regional Transit Authority	20,000	1.5	0.5	~0.0	0.5	2.5
AC Transit (Oakland, CA)	15,000	(1)	(2)	~0.0	0.0	---
Tri-County Metro. Transportation District of Oregon (Portland)	7,000	6.4	0.9	~0.0	0.7	8.0
Dallas Transit Authority	7,000	1.0	8.7	~0.0	0.0	9.7
Sacramento Regional Transit Authority	5,000	1.2	(2)	~0.0	0.0	---

(1) Brink's counts their bills.
(2) Data not acquired.

TABLE 8
ANNUAL COST OF COIN AND TOKEN HANDLING

TRANSIT SYSTEM	COINS AND TOKENS COLLECTED $K	COST OF COINS AND TOKENS COLLECTED, $K	COST AS % OF COINS AND TOKENS COLLECTED
Chicago Transit Authority	102,220	2,870	2.8
Washington Metropolitan Area Transit Authority	52,420	1,210	2.3
Seattle Metro	21,520	371	1.7
Greater Cleveland Regional Transit Authority	13,040	426	3.3
AC Transit (Oakland, CA)	19,110	(1) ---	---
Tri-County Metro. Transportation District of Oregon (Portland)	6,010	(2) ---	---
Dallas Transit Authority	9,010	346	3.8
Sacramento Regional Transit Authority	2,540	(2) ---	---

(1) Brink's counts their bills.
(2) Data not acquired.

and preventive maintenance to more sophisticated fareboxes capable of accepting bills. Security costs refer to the additional security being provided due to the increase in the number of bills. Half bills refers to the practice by some passengers of cutting a bill in half and folding it around a piece of paper stock so the folded half bill resembles a whole bill. The transit systems loses fifty cents for each half bill deposited. The total impact of bill handling is shown in Table 7 where it can be seen that the cost of bill handling ranges from a low of 1.8 cents per bill to 10.0 cents per bill. (Note that the Total Costs in cents/bills in Table 7 is also a percentage and can be compared with the percentages of collection costs shown in Tables 5 and 6.)

The costs of coin and token handling are shown in Table 8 and range from 1.7% to 3.8%. These costs are lower than the costs of bill handling due mainly to less intensive labor requirements and maintenance costs. If the value of the bills collected appeared instead as coins and tokens, most of the costs of bill handling would disappear. There would be some incremental costs to coin and token handling but these costs should be small at most transit systems. This is true since it was observed at the transit systems visited that the coin and counting equipment was not running at full capacity. The process was often shut down following the completion of one batch of coins and tokens while awaiting the arrival of the next batch.

4.1 BILL COUNTING

The sections that follow present a discussion of bill counting methods at the eight transit systems visited.

4.1.1 Chicago Transit Authority (CTA)

AT the time of this study, CTA was receiving about 185,000 bills per weekday; this was down from 300,000 bills per day just prior to the Ban-the-Buck campaign. CTA's counting room had a staff of 18 people working in bus fare counting prior to the appearance of large numbers of dollar bills. Processing of the dollar bill has required a doubling of the counting room staff. At present there are 29 full-time employees plus seven full-time temporary employees. CTA personnel are currently counting about 38,000 bills per day at a cost of 5.9 cents per bill, and the bank counted the remaining 147,000 bills at a cost of 2.5 cents per bill ($25 per thousand bills). It appears that the major reason for the significant difference of these numbers is the labor rate. The average cost per bill for 185,000 bills is 3.2 cents per bill. CTA is experimenting with the use of full-time temporary employees to determine whether they can count bills at a cost less than the bank charges.

4.1.2 Washington Metropolitan Area Transit Authority (WMATA)

WMATA has increased the counting room staff from three full-time persons to a total of 19 persons. Of these 16 additional persons, four hold full-time temporary positions; six hold part-time permanent positions, and six hold part-time temporary positions. The added personnel costs being increased due to bill handling is about $450,000 per year or about 1.7 cents for each bill.

4.1.3 Seattle Metro

Seattle Metro receives on the average 6,000 dollar bills per day, and estimate the bill handling cost to be about 4.5 cents per bill.

4.1.4 Greater Cleveland Regional Transit Authority (RTA)

RTA counts the 30,000 bills received daily in-house. The presence of bills has required the addition of six bill counting personnel who hold full-time positions and receive full benefits. These people are paid $5.00 per hour, and with their full fringe benefit, the cost of bill handling to RTA is about one cent per bill.

4.1.5 A.C. Transit (Oakland, CA)

A.C. Transit has contracted with Brinks to count their revenue. They receive about 15,000 bills per day. There is no separation of costs between coins and bills that is available to A.C. Transit from Brinks. Prior to the introduction of the Duncan Faretronics fareboxes, A.C. Transit had Cleveland Johnson fareboxes in service. They estimated their costs to handle bills at that time to be about 11 cents per bill.

4.1.6 Tri-County Metropolitan Transportation District of Oregon (TRIMET)

TRIMET receives about 7,000 bills per day, and requires the labor of 3.5 full-time equivalent persons. This results in a cost of about 6.4 cents per bill.

4.1.7 Dallas Transit System (DTS)

DTS collects about 7,000 bills per day through its GFI Cents-a-Bill farebox. The bills enter the farebox in a flat configuration and are not co-mingled with coins. The counting room person can shuffle a pile of bills into a stack which then must be faced by hand and counted by machine. This activity is accomplished by one person and the cost of bill processing to DTS is about one cent per bill.

4.1.8 Sacramento Regional Transit District (SRTD)

SRTD received the smallest number of bills of all transit systems visited, about 5,000 per day. With the Duncan Faretronics and Duncan Farescan fareboxes in service, bills arrive flat and separated from coins. SRTD requires about 0.8 of a full-time equivalent person to process the bills which results in a cost of 1.2 cents per bill.

4.2 MAINTENANCE OF EQUIPMENT

The resources needed to maintain farebox equipment has increased due to the appearance of large numbers of dollar bills. The largest transit systems using fareboxes never designed for bills or receiving more bills than the design specification have experienced a substantial increase in maintenance costs. It has been found that those transit systems that have recently acquired the new fareboxes, that accept and store bills separately from coins, also have experienced a substantial increase in maintenance effort. Bills tend to jam the older more simple fareboxes and the new electronic fareboxes seem to suffer from higher failure rates due to their greater complexity. Maintenance costs in units of cents/bill are presented in Table 7.

Specific findings concerning maintenance at the eight transit systems visited follows.

4.2.1 Chicago Transit Authority (CTA)

Prior to the appearance of large numbers of bills, the fareboxes were maintained by two machinists. With the present flood of bills, eleven machinists are now dedicated to farebox repair. It was found that the principle mode of failure is due to a jam in the cashbox; force must be exerted to remove the cashbox from the farebox vault and it is the damage resulting from this process that adds to maintenance. The jam is created when a large number of bills fill the cashbox and then begin to form a column from the cashbox into the receiving area of the farebox. To extract the cashbox from its vault, it is necessary to rotate the cashbox. This motion activates a mechanical interlock system which unlocks the cashbox, and allows it to be withdrawn from the farebox. When the cashbox is rotated, if a solid column of bills extends from the farebox into the cashbox, some bills can be carried into the clearance space above the cashbox thus creating a jam. To undo this type of jam, the farebox must sometimes be removed from the bus. A lever is then used to break a pin to enable the cashbox to be withdrawn. Application of these extraction forces deform the cashbox which then requires repair in addition to a new pin. Cashbox repairs and/or rebuilding has jumped about tenfold to a current average of 125 incidents per week.

4.2.2 Washington Metropolitan Area Transit Authority (WMATA)

Maintenance requirements for farebox repair has increased from three to eight full-time persons plus one inspector. The failure rate of the fareboxes is about 75 per week, and on the average about five boxes per week require repair as a result of damage inflicted during burglary.

The average repair takes about 30 minutes. GFI, the successor company to Keene, can provide parts, but according to WMATA, at exorbitant prices. The maintenance shop has been using other vendors to fabricate spare parts at a significant savings.

4.2.3 Seattle Metro

Metro's fareboxes were designed to accept coins only. As a consequence, the interlock gate at the top of the cash box can jam when bills are deposited. To correct the jam, it is often necessary to remove the farebox from the bus.

Metro has received a grant from UMTA to increase the size of the cashbox. This has helped to reduce the number of filled cashboxes, but the jamming problem still remains.

4.2.4 Greater Cleveland Regional Transit Authority (RTA)

RTA uses the same type farebox as the one used by CTA, i.e., the Duncan Acceptafare. The maintenance staff has grown from two to three persons. This small growth is due in part to the decrease by 200 of the number of buses on the road today as a result of lower ridership in comparison to the number in service at the time when the Duncan fareboxes were acquired in 1979. The surplus boxes serve as a repository of spare parts. There are 15 to 20 farebox failures per week.

4.2.5 A.C. Transit (Oakland, CA)

AC's fareboxes were designed to handle both bills and coins. The equivalent of ten full-time persons are assigned to farebox maintenance.

4.2.6 Tri-County Metropolitan Transportation District of Oregon (TRIMET)

TRIMET's fareboxes were designed to handle coins only. In the presence of a large quantity of bills, the interlock at the top of the vault can jam. Correction of this situation sometimes requires the removal of the farebox. Farebox maintenance is handled by one full-time equivalent person; prior to the appearance of the dollar bill at the farebox, only one-half of a full-time equivalent person was needed.

The on-board self-service equipment, that is, the controller, ticket dispenser, and ticket validator require significant maintenance resources. A total of 11 full-time equivalent repair persons are required to maintain this equipment. (These costs are not included in Table 7.)

4.2.7 Dallas Transit System (DTS)

DTS experiences on the average about 70 farebox failures per month; during a one month period there are about 10,000 bus runs. With the predecessor coin-only farebox system, one maintenance person, five farebox pullers, and six counting personnel were required. Following introduction of the GFI farebox, the mix of support people changed to six maintenance persons, six farebox pullers, and three counting personnel. The net change was an increase of three people to support the revenue collection process.

An important point made by DTS personnel is that installation of the new farebox system to solve a set of problems led to problems of its own, i.e., solution of the bill handling problems led to the need for greater maintenance support. It is important to look at the total system aspect of an improvement to determine whether the benefits, i.e., reduction in fare theft and fare abuse, gained from its installation exceeds the cost of its support.

4.2.8 Sacramento Regional Transit District (SRTD)

SRTD's fareboxes were under warranty at the time of the visit, and SRTD personnel were only responsible for minor repairs.

4.3 REVENUE SECURITY

This section describes some of the physical security measures taken by the transit system to enhance revenue security. The costs of revenue security are presented in Table 7.

4.3.1 Chicago Transit Security

CTA has a supervisor oversee the cashbox pulling process at the garages. In addition, a Chicago policeman is on duty at the pulling islands. The area of activity at the pulling islands is under closed circuit television (CCTV) surveillance.

A police officer is posted at the entrance to the central counting facility. Entry through a controlled room is only given to employees and to unknown persons who are accompanied by employees. It is necessary to sign in and out of the facility.

Counting room personnel change from street clothes to work coveralls in a locker room. This room is locked during the work day and can be entered only in the presence of supervisory personnel who maintain key control. Plans are underway to install CCTV's to monitor the counting process.

Chicago police escort the money truck during transfer of revenue from the garage to the counting facility and from the counting facility to the bank.

4.3.2 Washington Metropolitan Area Transit Authority (WMATA)

Revenue is transported from the garage vaults via a WMATA truck to the central counting facility. There are five persons on the truck; four from revenue and one from the Treasurer's office.

To gain entry to the counting facility, it is necessary to pass through two doors with cipher locks. CCTV's monitor the counting process; transit police are located in a separate room within the counting room and view the CCTV screen. Employees working in the counting room dress in street clothes.

WMATA is constructing a new facility which will include revenue processing.

4.3.3 Seattle Metro

At the main garage, the farebox vaults are replaced with an empty vault each evening as the buses pull in. At the other garages, the buses are parked in a secure parking area. Farebox vaults are replaced only every other day. The money vaults are secured in a locked rack overnight. Cashier personnel empty the racks and transport the money bags to the counting room. There is control on personnel who can enter the money room as well as on their actions while there.

Seattle Metro does not use armed guards or escorts. The trucks used to transport money to the counting room at the main garage are radio equipped. Drivers must check-in as they drive along predetermined routes. However, a police escort is used when the counted cash is transported to the bank.

4.3.4 Greater Cleveland Regional Transit Authority (RTA)

The counting room space is under the surveillance of three TV cameras. TV outputs are sequentially displayed on a TV screen located in the Director's office. Personnel counting coins wear coveralls, and personnel counting bills wear street clothes.

RTA is constructing a revenue counting facility.

4.3.5 A.C. Transit (Oakland, CA)

Revenue is picked up at the garages by Brinks and transported to their facility for counting and subsequent deposit at the bank.

4.3.6 Tri-County Metropolitan Transportation District of Oregon (TRIMET)

When the buses pull into the garage at the end of the day, the vaults are pulled and replaced by an empty one. The monied vaults are stacked on a cart for pick-up by the TRIMET van and transported to the counting room daily. The vans are in radio contact with the dispatcher during the entire route. Van personnel are unarmed.

The day's receipts are transported to the bank daily via an armed car service company.

4.3.7 Dallas Transit System (DTS)

DTS has personnel in the vicinity of the counting facility 24 hours a day.

A lie detector test can be administered to any one or groups of employees at any job level at any time.

4.3.8 Sacramento Regional Transit District (SRTD)

SRTD requires all cash handling personnel to wear pocketless coveralls. They have hired security guards to provide protection about the external perimeter of their facilities. An armored car service transports the cash from the counting facility to the bank.

5. LOST REVENUE

The second major objective of this assessment was to determine the level of lost revenue. Lost revenue can be divided into two major categories. First, there is the difference between the revenue due the transit system for service provided to passengers and the funds that are eventually deposited into the transit system's bank. Second, there is the loss in revenue that results from theft of fares collected, i.e., by criminal activity internal and external to the transit system.

This section presents a discussion of methodologies to assess the level of lost revenue and describes a tentative empirical model for prediction of lost revenue.

5.1 METHODOLOGIES FOR ASSESSMENT OF LOST REVENUE

There are at least two methods for arriving at the level of lost revenue; these are the micro- and macro-methods.

5.1.1 Micro-Assessment

Micro assessment is based on identification of the various sources of loss, and quantification of the dollar value from each of the sources. Table 9 presents a listing of specific sources of losses that can be used to generate an estimation of total revenue loss. This table was prepared from the viewpoint of including all the possible sources for loss of revenue. Before an attempt is made to quantify the level of loss, it is best to examine the sources and either eliminate the ones that are probably not too significant, or evaluate them after more significant loss sources are quantified.

Table 9 lists the various sources of losses. Item 1.1, Cash Fare Evasion, is probably the most significant source for revenue loss. Potential problems with passes, particularly counterfeiting, was considered very important by some systems. Other systems felt that the costs to develop and implement a

TABLE 9
BUS FARE COLLECTION REVENUE LOSS BREAKDOWN

1.0 FARE EVASION
- 1.1 CASH
  - 1.1.1 Counterfeit Cash
  - 1.1.2 Underpayment of Fare
- 1.2 NON-PAYMENT
  - 1.2.1 Collusion with Operator
  - 1.2.2 Illegal Entry by Passenger
- 1.3 TOKENS
  - 1.3.1 Tokens Stolen from Authority
  - 1.3.2 Counterfeit Tokens
  - 1.3.3 Unauthorized Production of Tokens
- 1.4 TICKETS
  - 1.4.1 Tickets Stolen from Authority
  - 1.4.2 Counterfeit Tickets
  - 1.4.3 Improper Use of Tickets
  - 1.4.4 Unauthorized Production of Tickets
- 1.5 PASSES
  - 1.5.1 Passes Stolen from Authority
  - 1.5.2 Counterfeit Passes
  - 1.5.3 Expired Passes
  - 1.5.4 Incorrect Use of Passes
  - 1.5.5 Unauthorized Production of Passes
- 1.6 TRANSFERS
  - 1.6.1 Transfers Stolen from Authority
  - 1.6.2 Unauthorized Production of Transfers
  - 1.6.3 Expired Transfers
  - 1.6.4 Incorrect Use of Transfers

2.0 THEFT OF REVENUE COLLECTED
- 2.1 THEFT BETWEEN FAREBOX AND GARAGE VAULT
  - 2.1.1 Theft of Cash at Farebox
    - 2.1.1.1 Fare diverted from farebox by operator
    - 2.1.1.2 Farebox "fished"
    - 2.1.1.3 Farebox burglarized
  - 2.1.2 Theft of Cash during Transfer from Farebox to Garage Vault
- 2.2 THEFT BETWEEN GARAGE AND COUNTING FACILITY
  - 2.2.1 Theft of Garage Vault
  - 2.2.2 Unauthorized Opening and Removal of Cash from Garage Vault
- 2.3 THEFT AT COUNTING FACILITY
  - 2.3.1 Robbery by Outsiders
  - 2.3.2 Skimming by Insiders
- 2.4 THEFT BETWEEN COUNTING FACILITY AND BANK

counterfeit resistant pass was not worth the expense. Transfer abuse was of concern on two levels. First, operators are given books of transfers and return what is left at the end of the day. There is no accountability. Some transit systems reported that people were apprehended selling transfers and at the time of apprehension had large numbers of transfers in their possession. The second level of concern is the purchase of a low cost transfer or taking a free transfer by a fare paying passenger who then gives this transfer to a boarding passenger who should be paying full fare.

Some qualitative information was also collected about theft. After the fare has been deposited into a drop-type farebox, if it does not, for some reason, fall into the cashbox, there is the opportunity for the dishonest operator to "fish" the box. At some garages there have been problems with key control that has resulted in theft. When a farebox is jammed, the money that remains on the inspection plate because it cannot be vaulted is subject to theft. There were also reports of thefts from fareboxes when buses are parked. This type of theft may involve some collusion with employees since the buses, according to procedures at most transit systems (but not at Seattle Metro), must have their cashboxes emptied before being parked.

Based on the information gained during visits to the eight transit systems, the losses due to criminal activity by outsiders after the fare is collected are relatively small. There were reports of fareboxes being burglarized, but no reports of burglary or robbery after the farebox vaults are emptied into the garage vaults. No one was willing to discuss internal theft. It may not be an important loss for some transit systems, but it is certainly the most sensitive one. The various contacts at the eight transit systems were for the most part either reluctant to discuss fare abuse and theft by outsiders or did not honestly have any idea of the magnitude of their revenue loss. There was, however, a consensus that the transit systems were experiencing significant revenue losses.

5.1.2 Macro-Assessment

Macro assessment of lost revenue is based on estimation of the total revenue that should be received compared to the actual receipts; the difference is lost revenue. To conduct a macro assessment, it is necessary to (1) make estimates of the ridership and the value of the service being provided over a given time period, and (2) identify the receipts over this same time period.

Two transit systems had some limited data about losses using macro methods of assessment. WMATA and TRIMET both had made estimates of lost revenue, and this limited data is used to prepare an estimate of revenue loss.

5.2 ESTIMATES OF LOST REVENUE

The annual fare collection revenue loss for WMATA was estimated to be $3.5 million and was based on a quarterly check of ridership against revenue. In addition, the losses resulting from transfer abuse were estimated by WMATA to range from $0.75 million to $3.5 million; a value of $1.5 million is used in this analysis. Counterfeiting of passes and tickets was considered negligible based on experience. This adds up to an estimated $5 million annual loss in revenue. The total annual farebox revenue is $94. x 10^6, so the estimated percentage loss as a ratio of loss to total revenue is 5.3%. This loss is calculated using the equation:

$$K = \frac{L}{R} \times 100 \qquad (1)$$

where K is the estimated percentage loss
L is the annual loss in revenue
R is the total annual farebox revenue

Prior to the introduction of self-service fare collection, TRIMET also conducted a similar macro-analysis of revenue loss and estimated a loss of $775,500 for a total passenger revenue of $18.3 million or 4.2%.

A first estimate made on use of a data set consisting of these two samples is that the sample mean bus fare collection revenue loss, $\overline{x}$, is about 4.8% of total passenger generated revenue. The sample standard deviation, s, is calculated to be 0.0078. With this standard deviation and use of the

Student-t distribution a one-sided upper bound confidence level[6], μ, for the sample mean, $\overline{x}$ can be calculated as follows:

$$\mu < \overline{x} + \frac{t_{(1-\alpha),\nu}\, s}{\sqrt{n}} \qquad (2)$$

where α is the confidence level
ν is the number of degrees of freedom
n is the sample size, and $\nu = n - 1$

From Student-t distribution tables for a 90% confidence level and one degree of freedom (sample size includes only data from WMATA and TRIMET), $\mu < 7.1\%$. Another interpretation of this confidence level is that there is only a 10% chance that the true fare evasion loss exceeds 7.1%.

The use of 4.8% as the mean value for revenue loss and the use of 7.1% as the 90% one-sided upper bound confidence interval for revenue loss may be considered appropriate only for transit systems that use drop-type fareboxes. Bus systems using registering boxes that display the fare deposited are probably experiencing a significantly lower percentage loss than that characterized by the above values. The registering farebox could be expected to have a significant impact on fare abuse and fare theft, but this has not been addressed in this present study.

An empirical revenue loss equation for bus transit systems that could be used to estimate losses was derived in Appendix A, and the value for its coefficients were determined using the WMATA and TRIMET revenue loss data. This empirical equation which is based on average fare and number of passengers has the form:

$$K = \frac{L}{R} \times 100 = 8.6 \left(\frac{R}{P}\right)^{0.76} \qquad (3)$$

where P is the number of passengers carried.

---

[6]Note that a one-sided upper confidence interval was computed because it is of more interest to know the revenue loss that would not be exceeded (at the selected confidence interval) rather than the two-sided confidence interval. The two-sided interval would provide a lower bound as well as an upper bound. In this analysis, the lower bound, i.e., how small the revenue loss could be, is not considered as important.

In equations (1) and (2), the revenue loss is simply represented in statistical terms, whereas in equation (3) the revenue loss is calculated as a function of total revenue and ridership. Both equations are tentative and the results obtained from using them must be treated with caution because of the very small sample size. More revenue loss data are needed.

Table 10 presents the estimated revenue losses for the transit systems visited that use drop-type fareboxes based on the above equations. (Note that equation (3) allows one to make estimates of revenue loss at transit systems using readily available data.) These estimated revenue losses which are shown in Table 10 represent considerable sums of money. For example, a registering farebox costs about $3,500. CTA has 1913 buses on the road during rush hour. If it were possible to recover the entire $10.6 million annual estimated revenue loss (average loss from Table 10) with negligible expense, this sum of money would more than pay the entire acquisition costs of new fareboxes for all its buses in just one year. It may be difficult for the transit system to reduce significantly revenue losses, since there are many different paths for loss as indicated in Table 9. It is necessary to identify the most significant sources and work to reduce these losses so to recover as much revenue as possible. It must also be remembered that all recovery efforts have associated costs; the return of revenue must be greater than the costs to capture it, if there is to be any financial improvement.

TABLE 10
ESTIMATED BUS TRANSIT SYSTEM REVENUE LOSS

TRANSIT SYSTEM	TYPE OF FARE BOX	VERIFICATION	ANNUAL NO. OF PASSENGERS, P IN MILLIONS	ANNUAL FAREBOX REVENUE, $M	LOSS: SAMPLE MEAN APPROACH				LOSS: EMPIRICAL FORMULA APPROACH	
					Average		Upper Bound			
					%	$M	%	$M	%	$M
Chicago Transit Authority	Duncan Acceptafare (Non-Registering)	Drop	481.7	221.4	4.8	10.6	7.1	15.7	4.8	10.6
Washington Metropolitan Area Transit Authority	Keene Vacuum (Non-Registering)	Drop	171.6	93.6	4.8	4.5	7.1	6.6	5.4	5.1
Seattle Metro	Keene and Omar Johnson (Non-Registering)	Drop	67.4	45.0	4.8	2.2	7.1	3.2	6.3	2.8
Greater Cleveland Regional Transit Authority	Duncan Acceptafare (Non-Registering)	Drop	85.2	33.4	4.8	1.6	7.1	2.4	4.2	1.4
AC Transit (Oakland, CA)	Duncan Faretronics (Registering)	Display of Deposit	78.2	28.8	---	---	---	---	---	---
Tri-County Metro. Transportation District of Oregon (Portland)	Keene (Non-Registering)	Drop	52.3	19.5	4.8	0.9	7.1	1.4	4.1	0.8
Dallas Transit Authority	GFI Cents-a-Bill (Registering)	Display of Deposit	46.6	18.1	---	---	---	---	---	---
Sacramento Regional Transit Authority	Duncan Farescan (Non-Registering)	Display of Deposit	28.2	6.7	---	---	---	---	---	---

6. FINDINGS AND CONCLUSIONS

The major finding of this study is that the deposition of large numbers of dollar bills into bus fareboxes has resulted in significant increases in the costs of fare collection. This was true for bus transit systems using fareboxes which were originally designed for coins only or for receipt of small numbers of bills as a percent of their farebox revenue. Increased costs in fare collection were also found for transit systems using fareboxes designed to display and register bills. The many facets of bill problems include:

(1) short changing by passengers (or deposition of half bills);
(2) jamming of the farebox by bills which require removal of the bus from service;
(3) mutilation of bills resulting from damage caused by separation of bills and coins at the counting facility;
(4) increased maintenance requirements;
(5) increased costs to handle the bill, i.e., unfold, flatten, face, stack, and count; and
(6) theft of fare revenue by transit system employees and increased security measures to deter and defeat theft.

Bill accepting and registering fareboxes can eliminate nearly all of the previously six enumerated problems. Use of a registering farebox which provides an accurate record of money deposited, insures that these monies have a high probability of being deposited into the bank. It was also found that the bill accepting farebox reduces the cost of counting because bills are separated from the coins in the farebox and, although the bill is not stacked, the counting is eased since there is no need to unfold and flatten the bill. However, it was found that there was a need to increase the application of preventive maintenance resources for the new fareboxes. These fareboxes contain electronic and mechanical modules that are significantly more complicated than drop boxes.

Short changing via deposition of fewer coins than required was noted to be a problem. At many transit systems, the popular way to pay the required fare is with a large number of coins; with the fare nearing one dollar, the bus operator cannot inspect and verify that indeed the proper fare has been deposited into a drop-type of farebox.

To avoid potential problems with the passenger revenue collected via the farebox, transit systems have promoted the use of non-cash media which includes tokens, tickets, and passes. There is some concern over the internal theft of passes and external counterfeiting. Some transit systems took extensive measures to produce a pass that would be difficult to counterfeit by use of (1) rare photos for background scenes, (2) colors that do not copy on ordinary copying machines, (3) metallic inks that result in poor reproduction on copiers, (4) hard-to-secure optical strips that give the pass a unique appearance, and (5) serial numbers. Other systems assessed the reduction in income posed by counterfeiting, weighed this against countermeasure costs and decided a simple unserialized paper pass was adequate, i.e., the costs to thwart counterfeiting would be greater than the losses due to counterfeiting. It must be pointed out that the gains that may be made by reducing the possibility of counterfeiting could be lost if the bus operator is not vigorous in checking whether valid passes are being used by passengers.

It was found that the operating costs of a non-cash media fare collection system is generally less than that of a cash fare collection system. This conclusion does not include the costs of the counting facility space or equipment. If these costs were included the cost of cash fare collection would be even greater than that for non-cash fare collection.

It was also found that the costs of bill counting results in an additional expense to the transit system without any benefit. If the bills were substituted with coins of equal value, then based on counting capacity, the transit system would be capable of counting the coins at little or no additional costs. This statement is made based on several observations that coin counting following delivery of a vault from a garage is completed prior to the arrival of the delivery of another vault. It is this downtime between completion of counting of the contents of one vault until the arrival of the next vault that could be used to count the coin equivalent of bills.

It is also to be noted that as the number of different methods (cash, passes, tickets, tokens) for fare collection increases, so do the costs. Multiplication of fare collection methods requires different organizational structures, which increases the fixed expenses and does not allow for the economies-of-scale that could be obtained by a single method. If all the non-coin fare media were to be converted to coins, the marginal costs to process them would be small because the coin counting system is currently underutilized in most systems. Maintenance costs for counting equipment would be higher and equipment life might be reduced in proportion to the number of coins counted, but this should not be significant.

The sample mean revenue loss resulting from fare evasion and theft for transit systems that use non-registering drop boxes was estimated to be 4.8%. The 90% one-sided upper bound confidence level was estimated to be 7.1%. These estimates were generated using data acquired from two transit systems. Since the sample size is very small, the revenue loss estimate is considered to be tentative. Revenue losses for transit systems using fare boxes that display and register the fare are surmised to be significantly less. There are three reasons for this:

(1) disappearance of half-bills;
(2) elimination of short-changing; and
(3) accountability of funds deposited.

Another related problem, but seemingly more intractable is the problem of the transfer. Bus operators do not have to account for the number of transfers they receive. It has been reported that transfers have been sold to boarding passengers by persons not affiliated with the transit system. Another problem is the passing of transfers, from passengers who request them but do not intend to use them, to boarding passengers.

The section that follows presents some recommendations to provide for alleviation of the fare collection hardships identified during this investigation.

7. RECOMMENDATIONS

7.1 General Recommendations

The recommendations for alleviation of the bus fare collection problems posed at the beginning of this investigation appears to be available. Such a solution would be comprised of introduction of (1) fareboxes that accept bills as well as coins and that register and display the fare collected, and (2) dispensers that release transfers with time and zone data. Such a system may be expensive to acquire, expensive to maintain, and difficult at first to get operators and passengers to use, but it should alleviate the two key problems of concern for this investigation of bill handling and lost revenue. Such a system would provide (1) maximum accountability and so reduce or eliminate fare evasion by passengers and theft by employees, and (2) significantly ease the burden of counting and processing bills. The costs of introduction and upkeep of such a system need to be evaluated to assess whether it will result in a combination of greater fare capture at reduced costs.

7.2 Specific Recommendations

Based on the information collected during the course of this study effort, approaches to alleviation of bill handling problems and lost revenue can be characterized as procedural, equipment, and policy changes.

Procedures refer to the manner in which passengers and operators interact with the fare collection system. For procedural changes to be successful passengers must be willing to comply with the rules and operators must be willing to enforce the rules.

Equipment refers to all mechanical and electronic methods for accepting fare media and processing revenue. This may include, but is not limited to, accepting bills and coins separately, registering, and safeguarding the revenue, validating passes, and cancelling tickets. Based on the current state-of-technology, it is possible to formulate the specifications for and fabricate the required hardware. The issue is whether the hardware would meet its reliability goals and whether the costs to maintain the equipment would be within the projected goals.

Policy refers to the overall rules set forth by the transit system managers governing the collection and counting of fares.

Recommendations using procedures, equipment, and policy are divided into two broad groupings, short-term, and long-term solutions.

Short-Term Approaches[7]

(1) Require passengers to display dollar bills in an opened and flattened state and coins to the operator, prior to deposit into the farebox where drop boxes are still in use. This procedure should greatly reduce the occurrence of the half-bill and reduce short changing of coins.

(2) Discourage the deposition of dollar bills by requiring a surcharge if they are used.

(3) Conduct testing to assess the magnitude of revenue losses, and identify critical areas. Provide resources to reduce the significant sources of fare abuse and theft.

(4) Require all money handling personnel, i.e., both garage and counting facility, to wear pocketless garments and limit casual access to lockers containing their street clothes.

(5) Install CCTV cameras at garage pulling stations and within the counting facility to monitor personnel. Provide a capability to record CCTV output when circumstances require the collection of evidence.

[7]Measures that can be instituted in a short-time (a few months to a year). Short-term approaches can be either retained or replaced after long-term solutions are in place.

(6) Publicize the losses resulting from fare abuse (after it is known) and make passengers aware of the problems so as to heighten the social pressure honest people are willing to bring to bear on dishonest actions. Encourage use of such methods as the We-Tip program which allows passengers to report incidents anonymously and obtain awards. Public school education programs could heighten awareness. (During a recent water shortage crisis, New York City was able to achieve a noticeable drop in water consumption following a public school awareness campaign.)

Long-Term Approaches[8]

(1) Upgrade drop-box non-registering farebox equipment by introduction of registering, bill accepting fareboxes that display bills and coins, count the fare deposited, and separate bills and coins in the cashbox.

(2) Offer no more than two methods for fare collection, i.e., pass and cash, and strive to have one method clearly predominant over the other method to achieve reduction in the costs of fare collection.

(3) Dispense all transfers via automatic ticket equipment on board the bus, and require payment to discourage passengers who take transfers with no intention to use them. Record number of transfers taken daily to allow for statistical testing to assess the extent of transfer abuse.

(4) For systems with registering fareboxes, develop a software package to conduct statistical testing of the farebox data collected to assess whether the revenue variability is due to mere chance or real changes in payments. This type of testing would assess whether the procedures were being conducted properly.

[8]Measures that take a longer time (more than one year). Procurement and installation of hardware is an example of a long-term approach.

APPENDIX

DERIVATION OF EQUATION FOR ESTIMATION OF REVENUE LOSS

The following discussion presents the derivation of an equation that can be used to estimate bus revenue collection loss.

Revenue loss can be described by the following simple equation

$$L = K \cdot R \tag{1}$$

where L = revenue loss

R = total revenue

K = revenue loss factor

Equation (1) can be multiplied and divided by the total number of passengers, P, so

$$L = K \left(\frac{R}{P}\right) P \tag{2}$$

By this rearrangement revenue loss is a function of average fare, i.e., the ratio of total revenue collected to number of passengers carried, multiplied by the number of passengers carried. It is reasonable to expect that the revenue loss is dependent on these two factors.

It could be argued that revenue loss should be directly proportional to the number of passengers served. As the fare increased it could also be argued that the reward for cheating would increase so the temptation would be greater. For this reason the average fare, R/P, would not necessarily be proportional to the revenue loss. A better representation of revenue loss would be:

$$L = 100g \left(\frac{R}{P}\right)^{a} P \tag{3}$$

Dividing both sides of equation (3) by R, gives:

$$\frac{L}{R} = 100\ g \left(\frac{R}{P}\right)^{a-1} \qquad (4)$$

The L, R, and P data estimated by WMATA and TRIMET, allows for computation of the constants a and g which are presented in the following equation:

$$K = \frac{L}{R} = 8.6 \left(\frac{R}{P}\right)^{0.76} \qquad (5)$$

If the WMATA and TRIMET data are accurate representations of loss, then Equation (5) provides an insight into the influence of fare on revenue loss. Equation (5) is partially tabulated below.

R/P	L/R	R/P	L/R
0.0	0.000	0.5	0.051
0.1	0.015	0.6	0.058
0.2	0.025	0.7	0.066
0.3	0.034	0.8	0.073
0.4	0.043	0.9	0.079
0.5	0.051	1.0	0.086

Equation (5) is empirical, and its confirmation awaits the acquisition of more data. Its application is illustrated in the following manner. The total annual farebox revenue, R, for Chicago Transit Authority, for example, is \$220.8 million and the total annual number of passengers, P, is 481.7 million. This results in a value of R/P equal to 0.458; when this value is put into equation (5) above it is determined that the revenue loss factor is 0.0475 (or 4.75%) and the estimated total annual revenue loss obtained by multiplying this fraction by the total annual farebox revenue, R, is estimated to be \$10.5 million.

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