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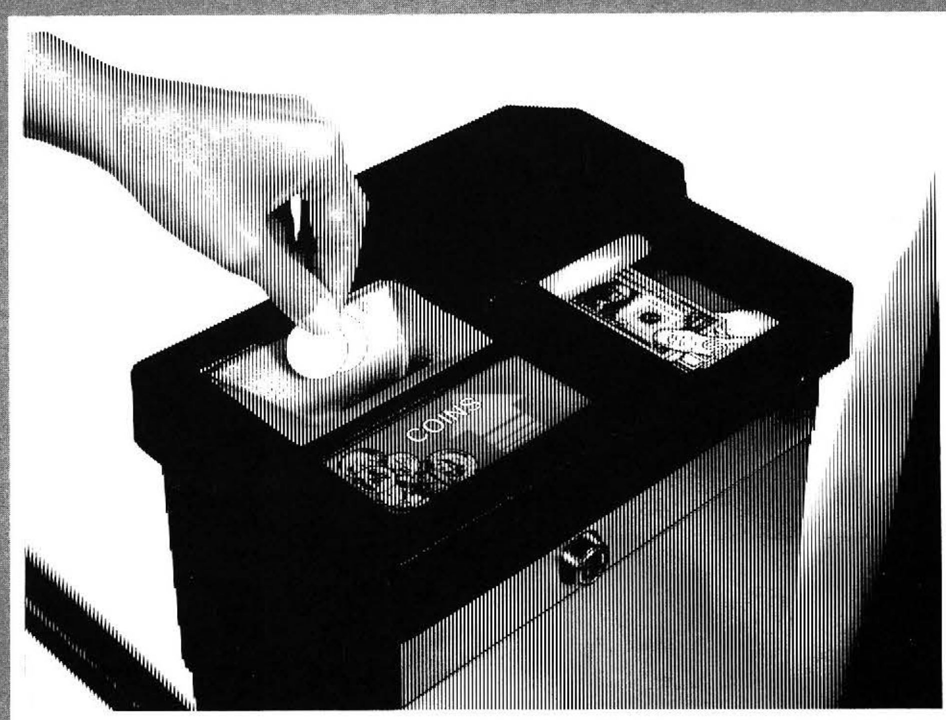
U.S. Department of Transportation
Urban Mass Transportation Administration

Evaluation of Electronic Registering Fareboxes

Prepared by
Booz·Allen & Hamilton, Inc.

Final Report
January 1984



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16. Abstract

This report presents the findings of an evaluation of electronic registering fareboxes in use at four transit systems: Dallas Transit, Phoenix Transit, Southeastern Pennsylvania Transportation Authority, and the Metropolitan Suburban Bus Authority of East Meadow, New York. Performance measures were developed to assess farebox accuracy, reliability, maintainability, security and installation and operating costs. Data collected from the transit systems in each of these areas is presented along with discussions of the types of problems which have been experienced with the electronic registering fareboxes to date. This study is one element in an UMTA-sponsored program to achieve more uniform data collection, analysis and reporting among the transit systems and to improve communications about fare collection problems.

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PREFACE

This evaluation of electronic registering fareboxes was performed as part of the bus transit fare collection program being conducted by the Transportation Systems Center (TSC) Office of Systems Assessment. The work was sponsored by the Urban Mass Transportation Administration (UMTA) Office of Bus and Paratransit Systems. This study is one element of a large program which addresses three major problem areas in bus transit fare collection: bill handling, farebox limitations and lost revenue.

Technical guidance for this study was provided by the contract technical monitor, Joseph S. Koziol of TSC. Additional technical guidance was provided by Vincent R. DeMarco and George I. Izumi of the UMTA Office of Bus and Paratransit Systems.

The Booz, Allen officer in charge of this assignment was James A. Mateyka. The work was directed by Ronald J. Ross. Kathryn E. Derr collected and analyzed the data and prepared the findings.

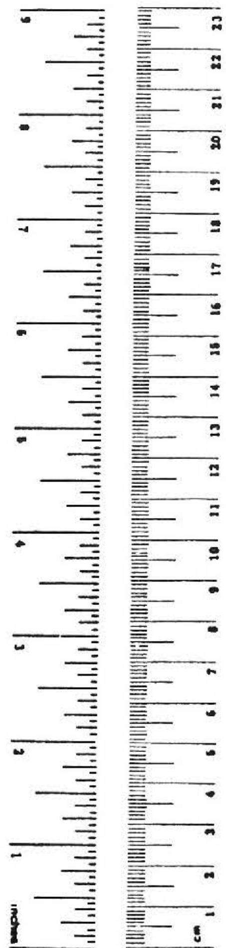
Farebox performance data and staff assistance was provided by the participating transit systems. The contributing managers included:

- John P. Gallagher, Metropolitan Suburban Bus Authority
- Barbara A. Titus, Southeastern Pennsylvania Transportation Authority
- James E. Wiesehuegel, Dallas Transit System
- J. S. Loe, Phoenix Transit System.

METRIC CONVERSION FACTORS

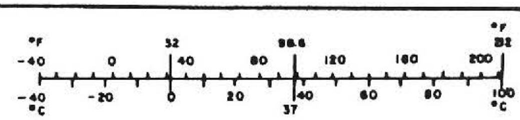
Approximate Conversions to Metric Measures

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



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	35	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



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EXECUTIVE SUMMARY

This report presents the results of an evaluation of electronic registering fareboxes in use at four transit systems. The study involved developing measures of farebox accuracy, security, reliability and maintainability, reviewing operational data at the transit systems and collecting on-site data necessary to calculate the farebox performance measures. During the study interviews were conducted with the transit system maintenance managers and bus drivers to elicit recommendations for improving the farebox design and performance. Since the transit systems did not experience high dollar bill volumes the farebox capacity and performance under high bill volume conditions were not tested.

The four transit systems included the Dallas Transit System, the Phoenix Transit System, the Metropolitan Suburban Bus Authority (MSBA) and the Southeastern Pennsylvania Transportation Authority (SEPTA). Key findings and recommendations of the study are summarized in the following paragraphs.

KEY FINDINGS

1. The Electronic Registering Fareboxes Manufactured by General Farebox, Inc. and Duncan Industries Have Similar But Not Interchangeable Modular Designs

The fareboxes operated by the Dallas Transit System were manufactured by General Farebox, Inc. and those operated by the Phoenix Transit System, SEPTA and MSBA were manufactured by Duncan Industries.* Both fareboxes have a modular design in which individual modules can be replaced onboard the bus. Thus, when a major module such as a coin mechanism, bill transport, electronic chassis, driver's keypad or cash vault develops a failure, a spare can be quickly substituted and the failed component returned to the maintenance area to be repaired.

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* Dallas is the first transit system to install the GFI farebox fleetwide. The installation was completed in December 1982, Consequently the GFI farebox has accumulated fewer months of operating experience than the Duncan farebox.

2. Based on the Data Collected, the Fareboxes Studied had an Average Counting Accuracy of 96 Percent or Better

Fourteen days of farebox operating data from three of the four transit systems was analyzed. Based on this data, the mean absolute deviation of all farebox readings from the daily total cash revenues ranged from .34 to 4 percent among the three transit systems. Assuming that counting accuracy is defined as 100 percent minus the absolute deviation of the total farebox readings, this performance is equivalent to an accuracy level ranging from 96 to 99.66 percent.

3. The Counting Accuracy of Individual Fareboxes Ranged From 91.4 to 98.9 Percent

When the contents of individual fareboxes were segregated and counted in audits performed by the transit systems, the deviations in counting accuracy ranged from -8.6 to 1.1 percent. The average deviation for all individual farebox audits examined ranged from -.57 to -.32 percent. Thus, on the average, individual fareboxes deviated from their cash revenue count by approximately one half of one percent.

4. On the Average, One Farebox was Capable of Operating From Three to Four Weeks Between Failures

Farebox failure data was collected from the transit systems. Based on the data examined, one farebox was capable of operating from 19 to 24 days between failures on the average. The mean number of fare transactions between farebox failures ranged from 3,474 to 5,075. Of the major farebox modules, the most frequent failures occurred in the electronic chassis, the bill transport and the coin mechanism:

- The electronic chassis was the location of from 16 to 42 percent of farebox failures.
- The bill transport was the location of from 10 to 35 percent of farebox failures.
- The coin mechanism was the location of from 21 to 32 percent of farebox failures.

5. Failures Often Result from Passengers Dropping Pocket Debris into the Farebox

Non-currency items such as chewing gum, paper, pills, nails and rivets have been recovered from the coin mechanism following the removal of jams. The bill transport has been jammed when a very worn, folded or damp dollar bill has been inserted. Other principal causes of reported farebox failures include:

- Chassis power downs following voltage spikes
- Misadjustment of the bill transport rail or belt causing bills to crumple
- Dirt and dust entering transistor photocells and LED displays
- The farebox coin mechanism being jolted into the bypass mode when the bus drives over a pothole.

6. <u>The Farebox Modules are Considered by Maintenance Technicians to be Easily Accessible</u>

Each transit system has its own preventive maintenance (PM) routine; differences in PM times are due to differences in the maintenance activities performed or in the design of the farebox. The estimated time to gain access to or replace an individual module of the farebox ranges from 1/2 minute for the cash vault to 7 minutes for the bill transport or driver keypad. The estimated time required to remove a coin mechanism is 2 minutes. Other findings concerning the maintainability of the farebox include:

- Preventive maintenance is required approximately every 2 to 3 months.
- The time to perform preventive maintenance ranges from 2 minutes to clean and lubricate a cash vault to 30 minutes to clean, lubricate and check the operation of a bill transport.
- The estimated mean time to repair a failed bill transport is 30 minutes.
- The estimated mean time to repair a failed coin mechanism is 30 to 60 minutes.
- Repairs of all farebox modules are estimated to require from 30 to 90 minutes.

7. <u>The Farebox Maintenance Staff Needs Sufficient Electronics Skills to Diagnose and Repair Circuit Board and Related Electronics Failures</u>

During the farebox warranty period, farebox maintenance staff may only need to perform preventive maintenance and minor repairs. After the warranty has expired however, all repairs are the responsibility of the transit system. The farebox technicians must be able to troubleshoot failures in the electronic chassis, the coin sensor board and other electronics in the farebox.

Farebox maintenance staff size varies depending on the number of farebox maintenance locations, the extent of repairs performed and the farebox maintenance philosophy of the transit system. The ratio of fareboxes to farebox maintenance staff at the properties studied ranges from 45:1 to 93:1.

The assignment of responsibility for farebox maintenance and revenue security to one group within the transit system financial or accounting department makes sense. The same department that is responsible for maximizing transit revenues will also be most concerned about maintaining the accuracy and reliable performance of the fareboxes.

8. <u>The Incidence of Theft and Vandalism of the Electronic Registering Fareboxes Was Low at the Transit Systems Studied</u>

All four of the transit systems studied believed fare security to be enhanced by the installation of electronic registering fareboxes. The highest reported rate of attempted vandalism was at SEPTA where approximately 10 incidents are reported each year. Usually the vandals unsuccessfully attempt to pry open the farebox door to gain access to the cashbox.

9. <u>Although Farebox Security is Perceived to be Enhanced by the Farebox, Most Transit Systems Have not Observed an Increase in Revenues</u>

Three of the four transit systems estimate that no increase in revenue has occurred as a result of farebox installation. SEPTA estimates that a small percentage increase in revenues has resulted from the farebox installation.

<u>RECOMMENDATIONS</u>

1. <u>The Use of a Standard Definition of a Farebox Failure Would Enhance the Comparison of Farebox Failure Rates Among Different Transit Systems</u>

While collecting data on farebox performance at the four transit systems it was observed that a uniform definition of failure was not in use. The use of a common definition would improve comparisons of failure data among properties. A recommended definition of a failure is: "Any stop or degradation of any fare collection system equipment function that occurs at anytime. The stop or degradation of any one function concurrent with the stop or degradation of any other function shall be considered as separate failures. Careless or deliberate actions of passengers and drivers that result in equipment failures shall not be included in mean time between failure calculations."

2. <u>Transit Systems That are Planning the Procurement of Electronic Registering Fareboxes Should Carefully Document the Provisions and Period of the Warranty</u>

Two transit systems, Phoenix Transit and SEPTA, experienced problems with the farebox manufacturer, Duncan Industries, in obtaining satisfactory warranty service and in defining the actual start date of the warranty. The other two transit systems, Metropolitan Suburban Bus Authority and Dallas Transit, did not report any problems with their farebox warranties. The terms of the farebox warranty, particularly the start date, should be clearly stated in the contract.

3. <u>The Farebox Design can be Improved in the Areas of Reliability and Performance</u>

The farebox manufacturers need to work on improving the reliability of the farebox in the revenue service environment. Ways that this might be achieved include:

- Equipping the coin mechanism with a device to reject debris such as buttons, pills, string, paper and mutilated coins.
- Modifying the keyboard so that it will resist contamination by coffee and cola spills, cigarette burns, and other abuses.
- Improving the farebox design so that a dust cover does not have to be pulled over the farebox to protect it during bus cleaning.

Other recommended product improvements include:

- Changing the design of the bill transport to a drop-in rather than an insert mechanism. Some disabled passengers have difficulty feeding a dollar or ticket into the bill acceptor, and all passengers must stop and guide the bill into the bill acceptor. The result of a delay at the farebox is an increase in the dwell time of the bus at each stop.

- The addition of a compactor for the bills stored in the cash box. A compactor would increase the number of bills that could be collected by the farebox and possibly reduce the volume of space dedicated to bill storage.

- The development of a method of accepting fares in a multiple-zone transit system without the involvement of the bus driver in manually prompting the farebox on the zones being travelled.

1. OBJECTIVES AND SCOPE OF THE EVALUATION

Under the technical assistance program sponsored by the Urban Mass Transportation Administration (UMTA), the U.S. Department of Transportation has initiated a program in cooperation with the transit industry to address three major problem areas in bus transit fare collection: bill handling, farebox limitations and lost revenues. As part of the program, investigations are being made into equipment that may have the potential for dealing with transit problems in these fare-related areas. This study is one element in a long range plan to achieve more uniform data collection, analysis and reporting among the transit systems and to improve communications about fare collection problems.

Electronic registering fareboxes provide automation of a number of steps in the fare collection process. They employ coin and bill acceptors which count coins, tokens, dollar bills and tickets, and display their value on a digital fare display.

The electronic registering farebox compares the amount inserted by a passenger with the fare structure, audibly signals the driver when the correct fare has been paid, and automatically records the passenger count. Optional capabilities of the farebox include the capability to record and display bus and route/run data and provisions for electronic data transmission.

This report presents the findings of an evaluation of electronic registering fareboxes in use at four transit systems. The evaluation objectives, project participants and scope of the study are described below.

EVALUATION OBJECTIVES

The principal objective of the study was to conduct an evaluation of current operational electronic registering fareboxes by:

- Developing measures of farebox accuracy, security, reliability and maintainability which can be used by all transit systems. Collecting on-site data necessary to calculate the performance measures.

- Review operational data at four transit systems, evaluate the performance of these electronic registering fareboxes and point out some of the problems being experienced.

PROJECT PARTICIPANTS

The organizations that participated in the study include UMTA; the Transportation Systems Center; Booz, Allen & Hamilton, Inc.; the American Public Transit Association (APTA) and four transit systems.

UMTA funded the study under the UMTA Section VI program. UMTA's Office of Bus and Paratransit Systems provided guidance to the study.

Transportation Systems Center (TSC), U.S. Department of Transportation, is conducting the bus transit fare collection program. In this project, TSC was responsible for selecting the number and location of transit systems which would participate in the evaluation, and making the initial contact with them through the APTA.

Booz, Allen & Hamilton Inc. was the contractor responsible for the study. Booz, Allen staff conducted telephone interviews, collected the data on-site at the transit systems, analyzed the data, and prepared the study findings.

American Public Transit Association (APTA) provided a list of transit systems with electronic registering fareboxes to TSC, and participated in the selection of systems for the study. APTA also participated in forming the objectives and scope of the investigation, and made contacts with the transit systems to invite their participation.

Transit Systems, four transit systems voluntarily participated in the project. They provided operations data, maintenance and repair data, and other data relevant to the evaluation of farebox performance in revenue service. The participating transit systems included:

- Metropolitan Suburban Bus Authority (MSBA), East Meadow, New York
- Dallas Transit System, Dallas, Texas
- Phoenix Transit System, Phoenix, Arizona
- Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia, Pennsylvania.

SCOPE OF THE STUDY

This study addresses the performance of electronic registering, bill accepting fareboxes. Data was collected from the transit systems described above to characterize farebox accuracy, reliability, maintainability and security. The data collected represents the experiences of the four transit systems and is not necessarily representative of all transit system experience. This report summarizes the farebox performance measures which were developed, the functions and special design features of the equipment, the capital and operating costs, the maintenance practices used, and recommendations regarding the equipment.

2. FAREBOX FUNCTIONS AND CHARACTERISTICS OF REVENUE COLLECTION SYSTEMS

The fareboxes manufactured by Duncan Industries and General Farebox, Inc. that were included in this evaluation are similar in design and operation. Both require the participation of the bus driver in verifying the authenticity of the deposited fare. This chapter presents a brief overview of the functions of the electronic registering farebox and the characteristics of revenue collection at the participating transit systems.

FAREBOX FUNCTIONS

The principal farebox functions that are common to both fareboxes include the following:

- Bill and Coin Processing. The farebox accepts, counts and registers fares in the form of coins, tokens, dollar bills and tickets.
- Fare Counting and Display. The farebox automatically counts the inserted money and tokens and provides a digital display for the operator of the total value of the deposited fare. The farebox also displays the coins and/or currency in an illuminated inspection plate area for visual verification by the operator.
- Fare Verification. The farebox has internal provisions to count the fare deposited by the passenger and compare the value against a programmed preset amount. The bus driver may select the amount by pressing a button to indicate the type of fare. The farebox is equipped with an audio transducer which sounds a beep when a full fare has been deposited. The farebox can distinguish between types of fares, but the software cannot determine when a fare zone has changed. Thus, in a transit system with a zoned fare structure, the operator must manually key into the farebox the zones being traveled.

- Data Storage and Transmission. Electronic logic circuits accumulate the value of the inserted fares in a cumulative revenue register. The farebox also can store events, or the number of individual fares in different fare categories. The stored data can be displayed on the farebox on demand by pressing preprogrammed buttons, or it can be transmitted to a microprocessor through a data probe assembly.

FAREBOX DESCRIPTION

The electronic registering farebox dimensions are approximately 40 inches x 12 inches x 12 inches. The farebox is mounted near the bus driver's seat and is positioned so that the driver can reach the keyboard while the boarding passengers face the coin and bill entry slots.

The farebox is capable of accepting dollar bills, coins, tokens and tickets. The value of the deposited fare is registered on a digital display that faces the driver. At the same time, the bill and/or coins are held in view of the driver for verification. The fare is then automatically advanced into the cash vault in the lower part of the farebox. The registered fare amounts are stored until the end of the route or run when the data can be retrieved. Several views of fareboxes are shown in Figures 2-1 through 2-6.

Both the Duncan and GFI fareboxes have similar modular designs. More detailed discussion of each of the major farebox modules is presented in the paragraphs that follow.

(1) Upper Housing

The farebox housing is composed of two parts, the upper housing and the lower housing. The upper housing contains the coin and bill inserts, the coin mechanism, bill transport, electronic chassis, driver's push button panel and driver's digital display.

(2) Lower Housing

The lower housing contains the revenue container or cashbox and the security interlocks for the cashbox. The lower housing is attached to the base plate which is anchored by bolts to the floor of the bus. Figure 2-7 shows the underside of a farebox with its four corner bolts and connecting cabling.

FIGURE 2-1. VIEW OF GFI FAREBOX FACING THE PASSENGER

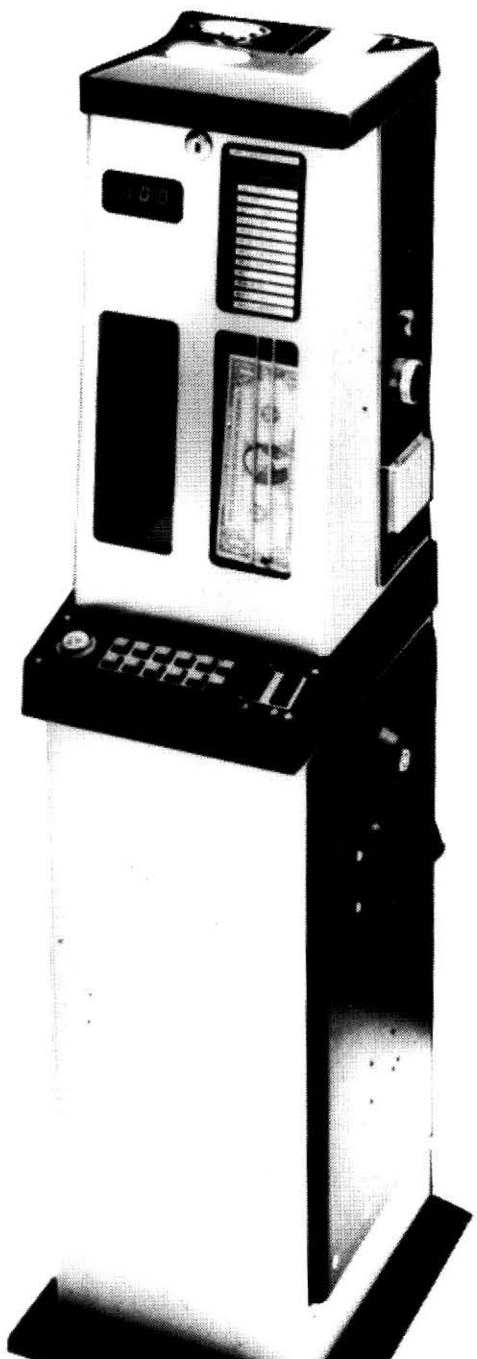

FIGURE 2-2. VIEW OF DUNCAN FAREBOX FACING THE BUS DRIVER

FIGURE 2-3. FARE DISPLAYED TO BUS DRIVER ON GFI FAREBOX

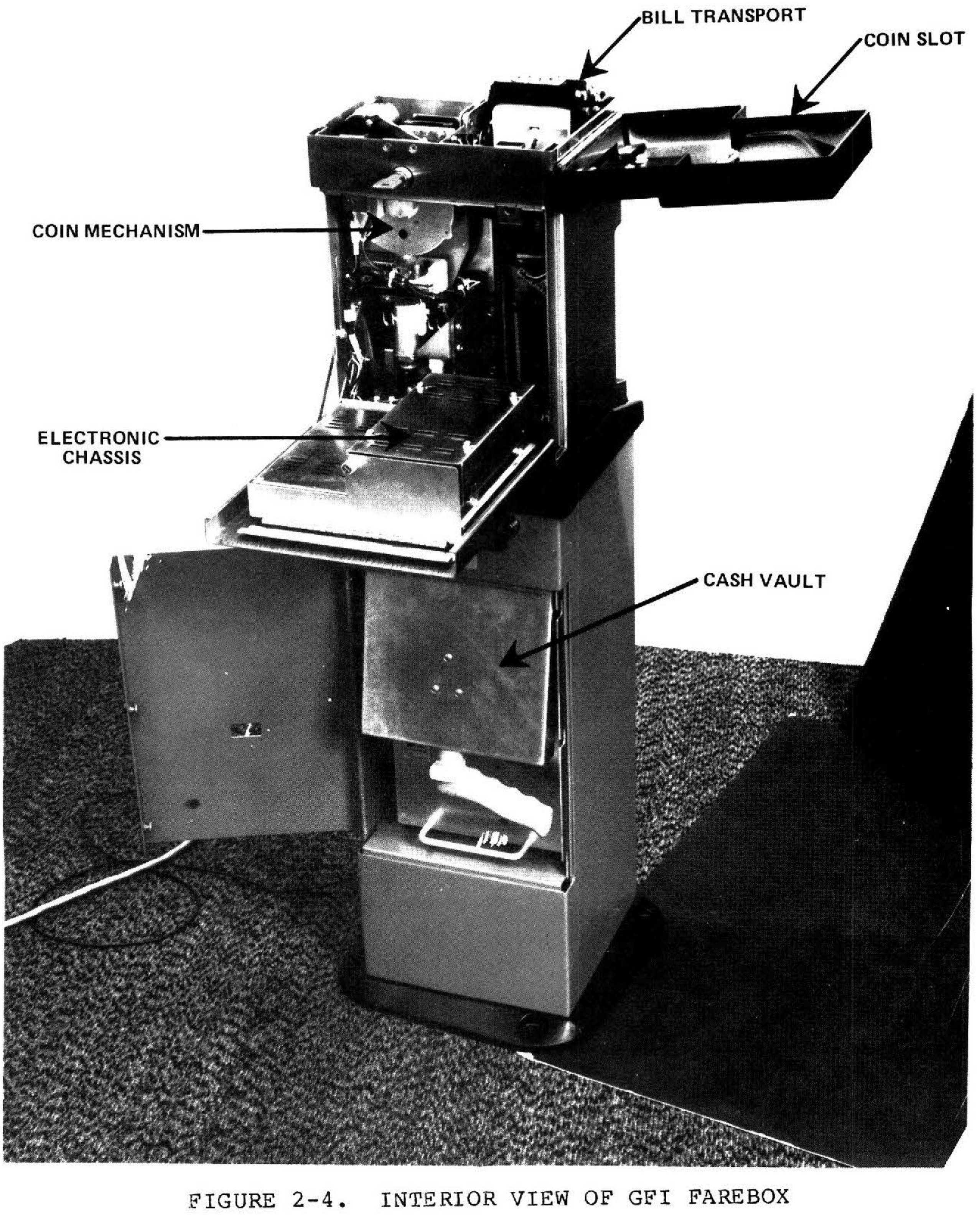

FIGURE 2-4. INTERIOR VIEW OF GFI FAREBOX

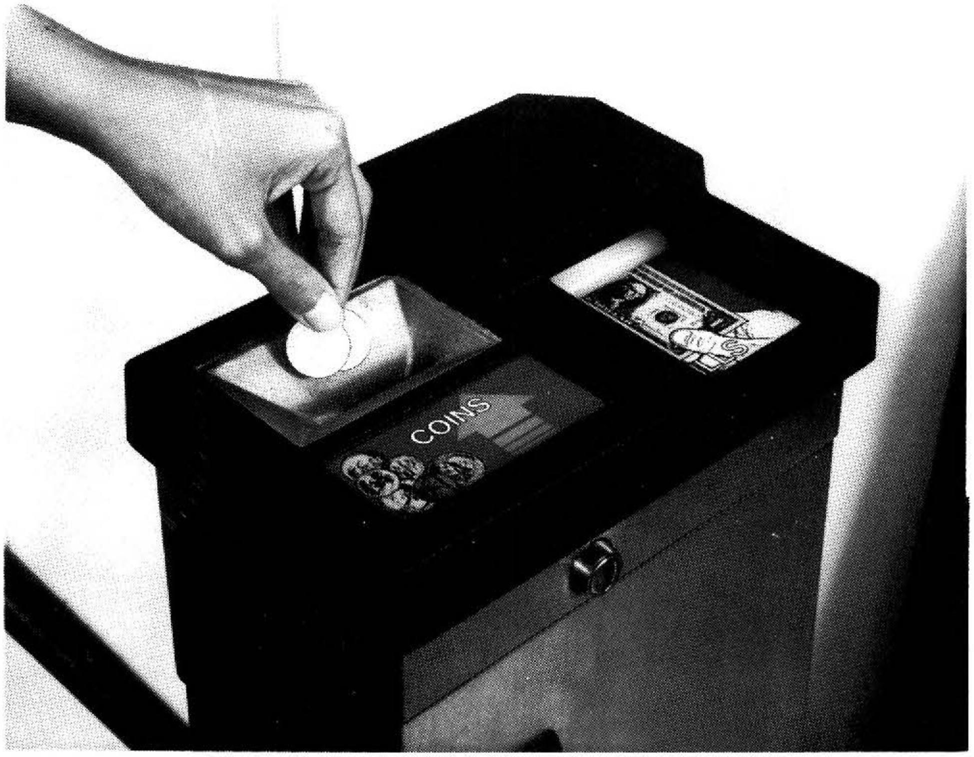

FIGURE 2-5. COIN SLOT ON GFI FAREBOX

FIGURE 2-6. BILL ACCEPTOR ON GFI FAREBOX

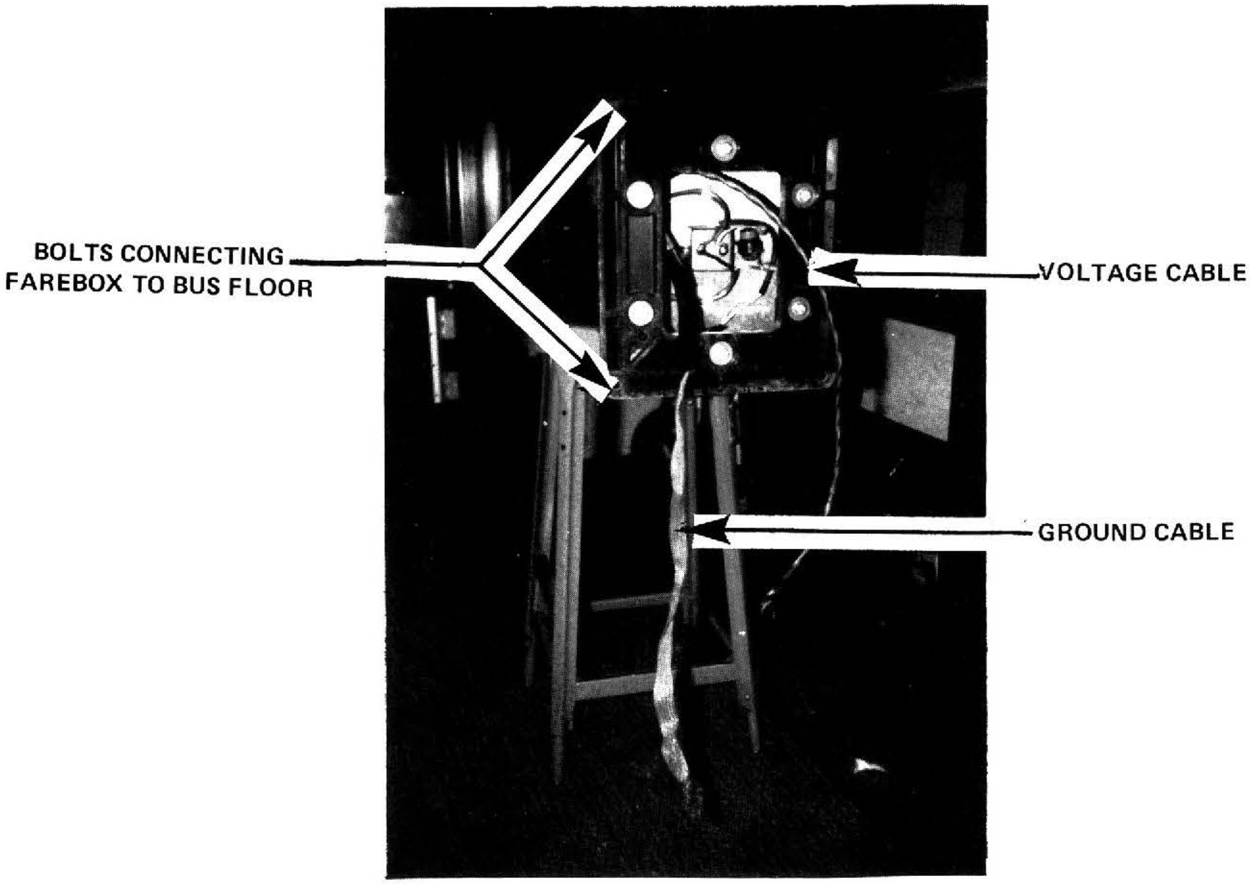

FIGURE 2-7. UNDERSIDE OF DUNCAN FAREBOX SHOWING CABLE CONNECTIONS

(3) Coin Mechanism

The coin mechanism detects the presence of a coin or token by the breaking of a light beam between a light-emitting diode (LED) and a phototransistor. The phototransistor transmits the direction signal to the control logic.

The Duncan coin mechanism uses a straight edge to guide the coins through the mechanism and past the photocell array. As each coin or token moves past the array, all photocells located a distance less than the diameter of the particular coin from the guiding edge are covered. The states of the photocells are transmitted to the control logic, which validates coins and tokens based on the maximum number of photocells covered as each coin passes through the detection area.

The GFI coin mechanism design permits the coins to drop between two rows of photocell arrays that are perpendicular to the coin drop. The vertical diameter of the coin is detected by the amount of time that passes from the bottom edge first passing the lower photocell array to the top edge passing the upper photocell array.

In both coin mechanism designs a permanent magnet motor drives a coin transport pad or grass wheel which separates the coins as they are dropped into the coin receiver and provides a steady coin velocity through the coin mechanism. A stream of coins is driven and funneled to the exit slot in the lower area of the mechanism. A photograph of the GFI coin mechanism is shown in Figure 2-8.

(4) Bill Transport

The bill transport accepts and registers dollar bills and/or tickets. The transport consists of a motor driven frictional belt mechanism which grasps the bill once it is inserted and moves it down the belt to the inspection area for driver verification.

Once inserted into the bill slot, the presence of the bill is detected by micro-switches in the Duncan farebox and a photocell array in the GFI farebox. The micro-switches or photocells measure the length and width of paper inserted to identify it either as a bill or a ticket. If the paper is approximately 6 inches long, the farebox will identify it as a dollar bill. The mechanism cannot distinguish between a $1, $2 or $5 bill; all will register as a $1 bill. The inserted paper is displayed on an illuminated plate for driver verification that the currency is a true dollar bill or true ticket.

A DC motor, similar to the motor used in the coin mechanism, is mounted at the bottom of the transport. The motor drives a gear belt which in turn transports the bill. The bill is transported to an illuminated plate inspection area where a time delay of the motor drive allows the bus driver to view the bill to detect the insertion of invalid currency. Then the motor starts automatically to drive the bill into the locked vault. The bill transport can be delayed if the driver wants to study the bill longer. Also, the driver can dump all fares into the locked vault before the automatic dump. Figure 2-9 shows a GFI bill transport.

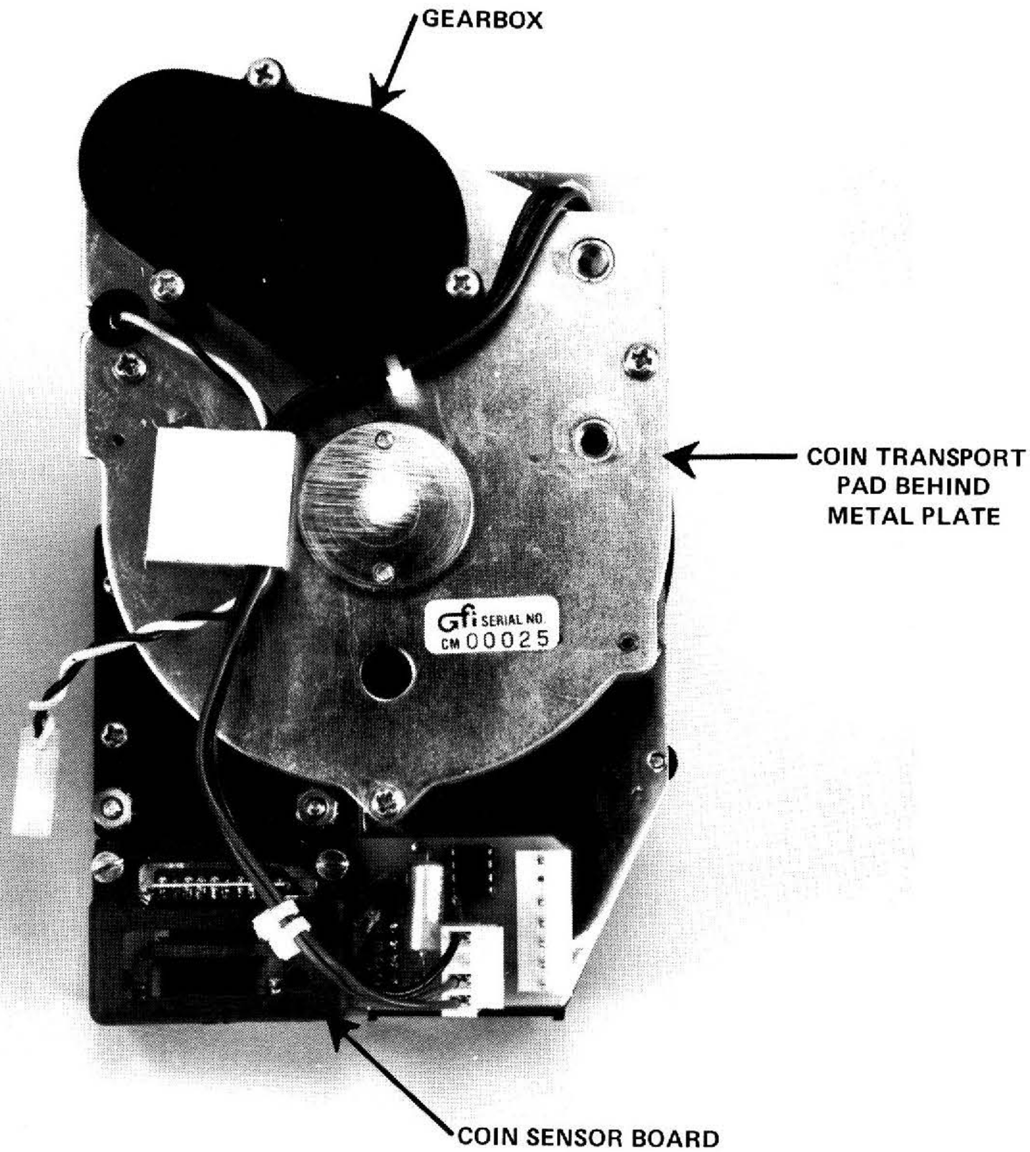

FIGURE 2-8. GFI COIN MECHANISM

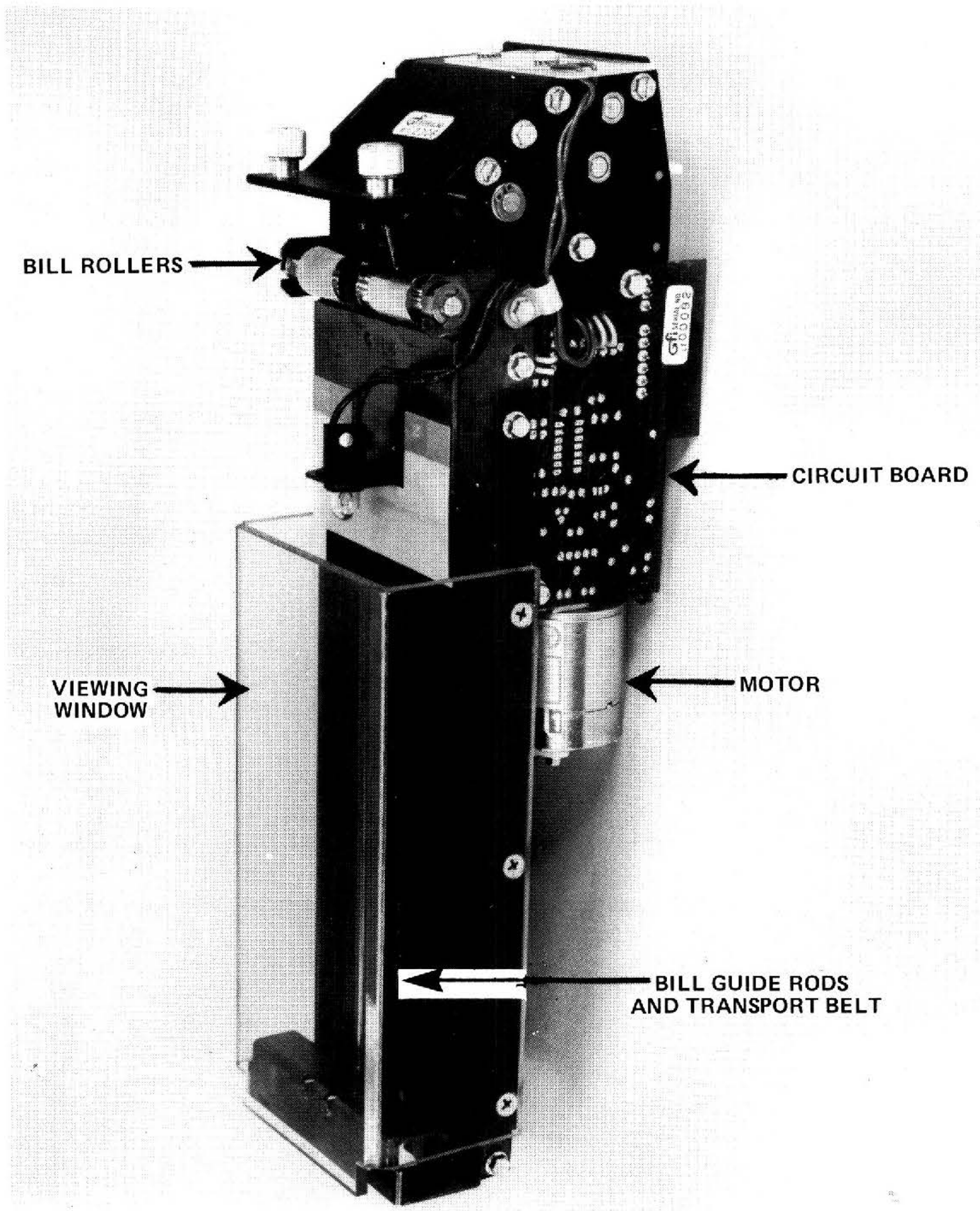

FIGURE 2-9. GFI BILL TRANSPORT

(5) Electronic Chassis

The farebox controls are contained in a central module called the electronic chassis. This chassis contains:

- All the logic circuitry for the coin mechanism, the bill transport and the driver's keypad
- The electronic data displays which exhibit the value of the fares deposited and the record of fare transactions
- Fare data storage
- The audio sound transducer
- A key switch for indexing the displays.

The chassis module may be easily removed from the farebox and replaced with a functioning spare to speed the repair cycle and return the bus to revenue service.

(6) Data Displays and Data Probe

An alphanumeric data display is incorporated into the chassis. The information viewed on this display is brought from the farebox computer memory and includes the various revenue totals and quantities of fares stored within this memory.

By pressing buttons on the keyboard, the bus driver can bring the displays into view in the display window. If the revenue data is not transmitted via an electronic data probe, then the driver must manually record the data from the displays.

The electronic data probe provides the most efficient transfer of revenue data at the end of each bus run. The probe connects to the farebox by means of a pronged connector in the Duncan farebox or by an infra-red photocell coupler in the housing of the GFI farebox. The latter probe design is shown in Figure 2-10.

(7) Driver Keyboard

On the driver's side of the farebox there are push button switches which perform specific functions relative to the operation of the farebox. The principal buttons are:

- Dump Button. When this button is depressed the coin inspection area back plate is released, and all of the coins and/or bills on the plates are dumped into the vault in the lower portion of the farebox.

- Fare Keyboard Buttons. The fare keyboard buttons are for specific preset fare values stored in the farebox computer. Each button may be depressed with the insertion of a fare, or to record the boarding of a passenger that displays a pass. Keyboard button use varies according to the requirements of the transit system. The buttons must be preprogrammed for each transit system.

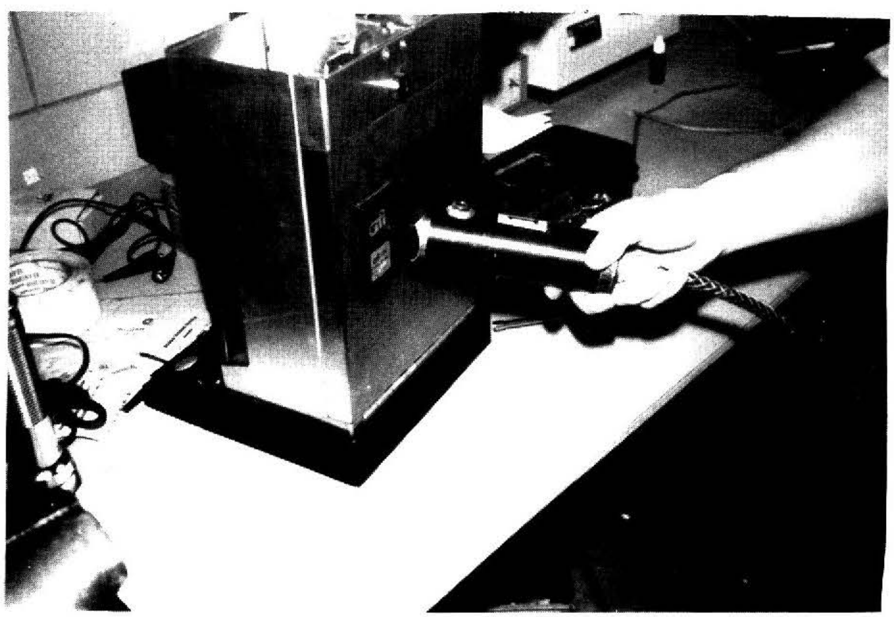

FIGURE 2-10. GFI ELECTRONIC DATA PROBE

(8) Cashbox

The cashbox or cash vault contains the collected revenue deposited in the farebox. All coins and/or bills and tickets inserted into the farebox will be collected in this container.

The cashbox is designed with a high level of security, requiring the presence of two security keys to allow the cashbox to be opened in an authorized manner. Only upon correct engagement with a rear lock and simultaneous rotation by a key or lever in the front lock is the container properly positioned in the farebox. This action "locks" the container into the farebox and opens the money apertures to permit entry of coins and bills into the container.

The Duncan Quantafare and GFI Dualport cashboxes have two separate compartments--one to hold coins and one to hold dollar bills. A dual chamber cashbox is shown in Figure 2-11. The Duncan Quantafare cashbox

FIGURE 2-11. DUNCAN QUANTAFARE CASHBOX

is designed to hold a maximum of 600 bills, assuming the bills are inserted correctly into the bill acceptor and they stack properly in the cashbox. The GFI Dualport cashbox is designed to hold a maximum of 400 bills. The stacked configuration of the bills is not preserved when the cashbox is emptied into a vault (cashbox) receiver. According to GFI, the bills typically fall into a heap when the cashbox is emptied. This heap of bills is then manually removed from the vault receiver, counted and re-stacked.

OVERVIEW OF REVENUE COLLECTION SYSTEMS

The four transit systems that participated in the evaluation have installed electronic registering fareboxes in the majority of their bus fleet. The fareboxes were installed as early as February 1979 at SEPTA and as late as December 1982 at Dallas. The number of fareboxes purchased ranges from 356 at Phoenix to 1,790 at SEPTA.

Phoenix and Dallas both use the electronic data transfer and the route/run data collection capabilities on the farebox. Table 2-1 summarizes the installation characteristics of revenue collection systems at each transit system.

The amount of total revenue collected through the fareboxes ranges from approximately $12,000 per day in Phoenix to $160,000 per day in SEPTA. The number of dollar bills collected daily ranges from 1,000 in Phoenix to 24,000 in SEPTA. Additional information on the revenues of each transit system are summarized in Table 2-2.

CHARACTERISTICS OF REVENUE COLLECTION AT EACH TRANSIT SYSTEM

Some of the principal features of revenue collection at each of the transit systems which participated in this study are described below.

- Metropolitan Suburban Bus Authority (MSBA). MSBA purchased 356 electronic registering fareboxes in March 1980, of which 39 are spares. The fareboxes are equipped with the Duncan Quantafare cashboxes which have separate compartments for bills and coins. The cashboxes are removed as the bus pulls into the service area for cleaning and refueling. Wall-mounted vault receivers are located at the bus lane, with one side of the receiver used to accept the cash vaults and the

TABLE 2-1. CHARACTERISTICS OF REVENUE COLLECTION SYSTEMS

	MSBA	Dallas	Phoenix	SEPTA
Type of Farebox	Duncan Faretronic Model 4	GFI CENTSaBill	Duncan Faretronic Model 4	Duncan Faretronic Model 4
Installation Date	January - March 1980	November - December 1982	June 1980	February - December 1979
Number Purchased Including Spares	356	600	343	1,790
Number of Operating Fareboxes	317	560	312	1,750
Number of Spare Fareboxes	39	40	31	40
Number of Fareboxes Typically in Use on a Weekday	263	439	242	1,200
Route/Run Data Collected	No	On 50 buses only	Yes	No
Electronic Data Transfer Capability	No	Yes	Yes	Yes**
Type of Cashbox*	Quantafare	Dualport	Quantafare	Secureafare
Vault Receiver	Wall Mounted	Mobile	Mobile	Panel Mounted

* The Quantafare and Dualport have separate chambers for coins and bills. The Secureafare has a single chamber.

** Electronic data transfer capability is not presently utilized.

TABLE 2-2. REVENUE CHARACTERISTICS OF TRANSIT SYSTEMS

Electronic Registering Farebox Revenues	MSBA	Dallas	Phoenix	SEPTA
Base Fare	$.75	Region 1- $.70 Region 2- 1.20 Region 3- 1.50	Phoenix- $.65 Scottsdale/ Tempe-.75	$.75
Average Daily* Cash Revenues	$56,000	$40,000	$12,000	$160,000
Average Number of Dollar Bills Collected Daily*	7,000	10,000	1,000	24,000
Average Number of Bills Per Farebox in Use**	27	23	4	20
Average Currency in Coins Per Farebox in Use**	186	91	45	113
Average Number of Tokens Collected Daily*	8,500	None	3,500	70,000
Average Number of Tickets Collected Daily*	None	2,000	6,000	200

* Monday through Friday

** Assumes 263 fareboxes in use at MSBA, 439 at Dallas, 1,200 at SEPTA and 242 at Phoenix during a typical weekday. Phoenix does not have many routes that require fares over a dollar.

other placed in the revenue counting room. The revenues are thus deposited directly into the counting room as soon as they are removed from the bus. MSBA operates an automated farebox defect reporting system. The system reports the frequency and cause of farebox defects, the consumption of spare parts and materials, the expenditures of labor hours on farebox repairs, and the location of each farebox. MSBA is considering installing computer terminals in the farebox maintenance rooms so that maintenance and repair data can be entered directly into the system.

- Dallas Transit System. The Dallas Transit System has an operating fleet of 560 buses, each equipped with a GFI electronic registering farebox. Approximately 50 of the fareboxes are equipped with route/run segmenters with the necessary memory to accumulate and store route/run data. The Dallas fareboxes have cash vaults with separate compartments for coins and bills. The receivers are located at shelters in the bus yard as shown in Figure 2-12. As each bus pulls into the yard, it stops at the vault receiver; a vault puller probes the farebox, removes and empties the cash vault, and returns the empty vault to the farebox. Dallas is planning to install an automated farebox maintenance reporting system.

- Phoenix Transit System. At Phoenix, electronic registering fareboxes were installed with the objective of improving routing information as an aid to transit system planning. The City of Phoenix purchased the fareboxes and the Phoenix Transit System operates them. Phoenix uses mobile vault receivers that are wheeled into the counting room nearby. The fareboxes are equipped with electronic data transfer probes, and the fare data is transferred to a microprocessor where daily revenue reports are generated. One unique aspect of the Phoenix system is that route supervisors are authorized to board a bus and attempt to remove jams that occur while the bus is in service. The service island at the Phoenix North facility where the farebox vaults are pulled and emptied is shown in Figure 2-13.

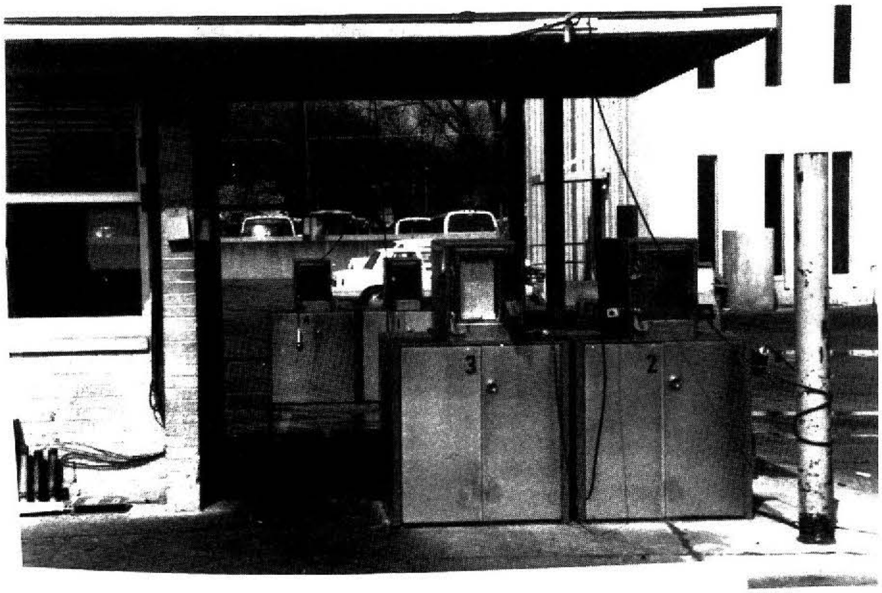

FIGURE 2-12. VAULT RECEIVERS AT DALLAS TRANSIT SYSTEM

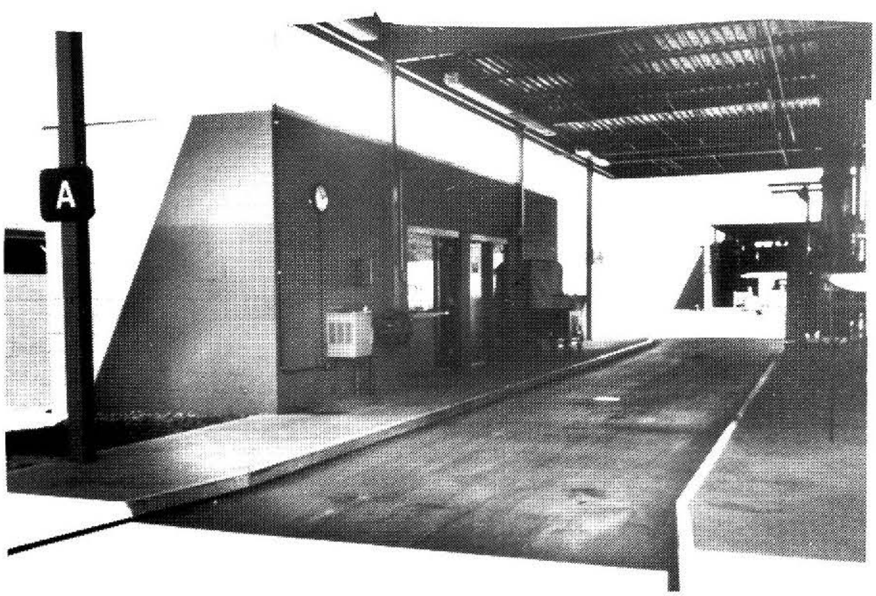

FIGURE 2-13. BUS AND FAREBOX SERVICE ISLAND AT PHOENIX

- Southeastern Pennsylvania Transit Authority (SEPTA). SEPTA has a decentralized farebox maintenance organization. Ten satellite maintenance offices perform preventive maintenance and mechanical repairs on the fareboxes. A central maintenance organization performs electronic chassis troubleshooting and repairs and complex repairs on other components. The SEPTA is the only one of the four transit system to use a single chamber cashbox in which the coins and bills are mixed in one chamber rather than being separated. Duncan revenue counting machines called Sort-a-Coin were purchased for use with the single chamber cashbox. The Sort-a-Coin can accept mixed bills and coins and separate them. The cashboxes are emptied into panel mounted receivers, which channel the cash into the Sort-a-Coin machine.

3. STAFFING AND FACILITY PROVISIONS

This chapter addresses the farebox management and organization plans, maintenance staff sizes, facility requirements, maintenance equipment, and information processing hardware found at the transit systems. Key issues that relate to staffing and facility provisions include the organizational approach to farebox management, the ratio of fareboxes to farebox maintenance staff, the types of electronic maintenance equipment, and the type of data processing system to be installed.

ORGANIZATION

Two different organizational approaches are used to manage revenue collection and farebox maintenance -- centralized and decentralized fare system management.

(1) Centralized Fare System Management

SEPTA AND MSBA have assigned total responsibility for revenue collection, farebox maintenance and fare system security to the financial or accounting manager. All activities related to the fare system, including farebox maintenance are managed by this one department, even though they may not be traditional financial activities. Tasks such as equipment maintenance, parts inventory and vault pulling are considered as important as revenue counting for maximizing revenue and maintaining fare system security. An organization chart, that is typical of a centralized revenue collection system, is shown in Figure 3-1.

(2) Decentralized Fare System Management

Under decentralized fare system management the responsibilities for the fare system are distributed among different transit departments such as accounting, equipment maintenance and spare parts inventory. This approach offers the disadvantage of having no single manager solely responsible for the fare collection system. Also, each department manager

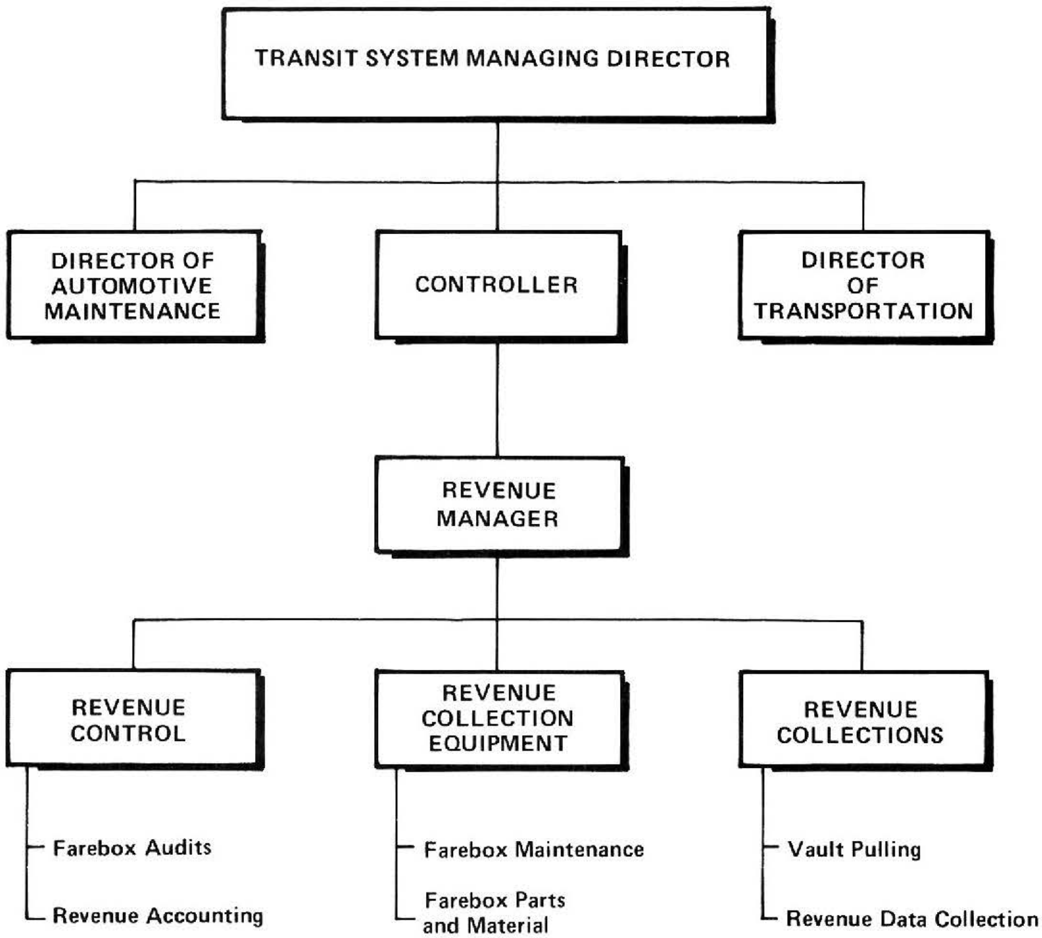

FIGURE 3-1. CENTRALIZED ORGANIZATION FOR FARE SYSTEM MANAGEMENT

has a job objective that may conflict with the goal of maximizing fare revenue. For example, the maintenance manager may be primarily concerned with seeing that the buses are maintained in operating condition and the required number of buses are available each morning. As long as the fareboxes can accept fares, the maintenance manager may not be too concerned about their accuracy. Close coordination among the department managers is required for the decentralized fare system management approach to work. A typical decentralized fare system management organization is shown in Figure 3-2.

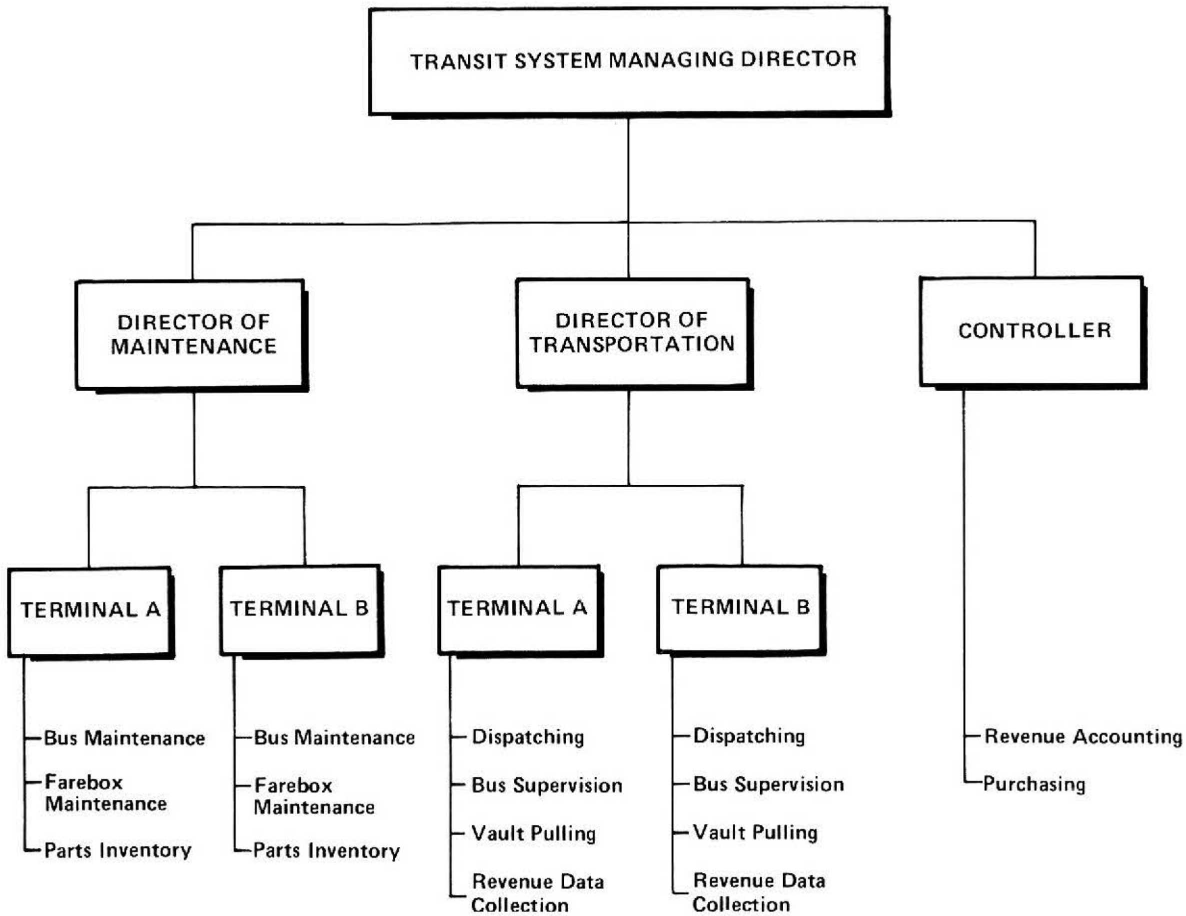

FIGURE 3-2. DECENTRALIZED ORGANIZATION FOR FARE SYSTEM MANAGEMENT

FAREBOX MAINTENANCE STAFF

The farebox maintenance staff includes electronic technicians who troubleshoot and diagnose failures of the chassis components. Technicians may be selected from the bus maintenance department and encouraged to enroll in electronics courses if they desire to continue working in farebox maintenance. The manufacturer's warranty will cover electronic repairs during a fixed period of time after installation; during this year, the transit system technicians can obtain electronics training.

Staff size may vary depending on the number of maintenance locations, the extent of repairs being performed by the manufacturer and the farebox maintenance philosophy of the transit system. For example, if the fareboxes have recently been procured and the warranty is still in effect, then the transit system farebox maintenance staff may only need to perform preventive maintenance and minor repairs; all major repairs may be the responsibility of the manufacturer. On the other hand, if the warranty has elapsed and the transit system is responsible for total farebox maintenance, then additional staff will be needed to handle the workload and the ratio of fareboxes to farebox maintenance staff will be lower.

Table 3-1 shows the ratio of fareboxes to farebox maintenance staff at the four transit systems. Farebox maintenance staff sizes range from 6 to 28 persons. The highest ratio of fareboxes to maintenance staff is at Dallas, where the full manufacturer's warranty is still in effect. SEPTA and MSBA perform all maintenance, including electronic repairs, on the fareboxes; and thus, have a lower ratio than Dallas. Phoenix performs mechanical farebox maintenance and depends on the manufacturer for many electronic repairs.

TABLE 3-1. FAREBOX MAINTENANCE STAFF SIZE

	Number of Maintenance Locations	Farebox Maintenance Staff Size*	Total Operating Fareboxes	Ratio of Fareboxes to Farebox Maintenance Staff
Dallas	1	6	560	93:1
Phoenix	2	4	312	78:1
SEPTA	10	28	1,750	63:1
MSBA	2	7	317	45:1

* Includes farebox mechanics and supervisers.

FACILITIES

A clean maintenance room separated from the bus maintenance area is required for farebox maintenance. From 1.7 to 2 square feet of maintenance space per farebox is provided by the transit systems that were studied. This area includes storage of spare parts, work benches and open working space. The rooms are insulated from much of the noise in the bus maintenance areas -- the ability to listen to modules such as the coin mechanism, bill transport and chassis are often necessary for accurate diagnosis of failures. Figures 3-3 and 3-4 show farebox maintenance facilities at SEPTA and Dallas.

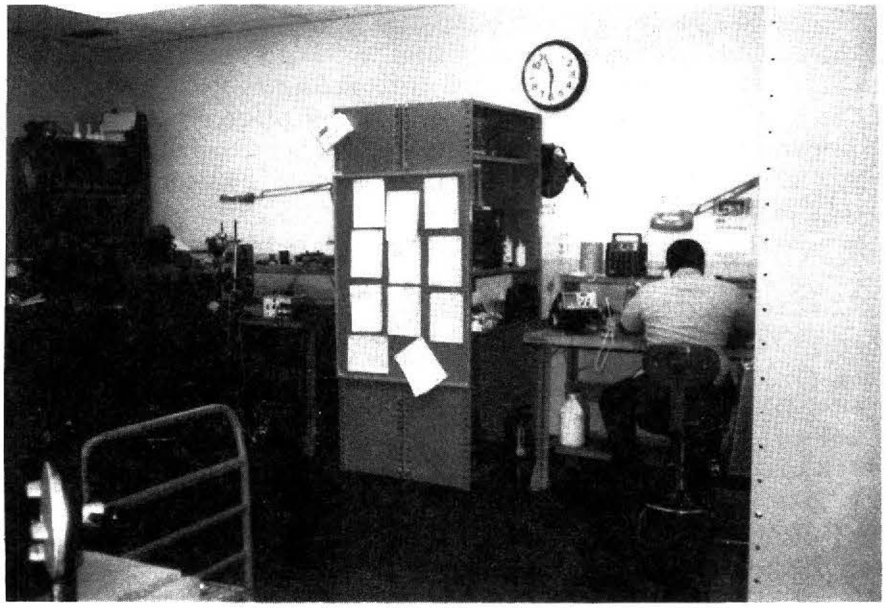

FIGURE 3-3. FAREBOX MAINTENANCE AREA AT SEPTA

FIGURE 3-4. DALLAS FAREBOX TECHNICIAN REPLACES A CIRCUIT BOARD

MAINTENANCE EQUIPMENT

Farebox maintenance requires the use of conventional hand tools such as screwdrivers and pliers; electrical tools such as variable power supplies, ammeters, voltmeters and multimeters; and electronic equipment such as soldering tools, oscilloscopes and electronic test benches. The types of electronic equipment used varies according to the extent of responsibility assumed by the transit system for electronic troubleshooting and repair.

At Dallas where the farebox warranty started in January 1983, an oscilloscope is the principal electronic instrument used. At transit systems where the warranty is completed or near completion, electronic test benches have either been purchased or built by the technicians. Such benches allow the technicians to operate and test a farebox module outside of the farebox. Other equipment used at one or more of the transit systems includes an infra-red detector, used at Dallas to determine if a data probe is working correctly, a universal programmer to re-program the eraseable programmable read only memories (EPROMs), a PROM eraser, and custom built simulators to simulate specific farebox operations. Figures 3-5 through 3-7 show an electronic test bench, soldering equipment, and a universal programmer used in farebox maintenance.

The simulator shown in Figure 3-8 was built by a technician at SEPTA. It simulates coins being dropped through the coin mechanism and identifies the point when a failure in the coin mechanism occurs. Thus, an intermittent problem can be diagnosed without the technician having to physically insert coins into the coin mechanism. Another simulator, in use at SEPTA, single-steps the chassis microprocessor through each fare handling function, judges the condition of all the electronic chips, and determines whether an EPROM is bad or a component has failed. This simulator works as a signaturing analyzer--it finds the address in the software where the problem exists.

INFORMATION PROCESSING

The transit systems either have in place or are planning the installation of automated data processing systems to track farebox performance and revenue collections. The hardware elements of the information processing system at Dallas are illustrated in Figure 3-9. These elements include:

- The electronic data probe to collect the end of run or end of day farebox data

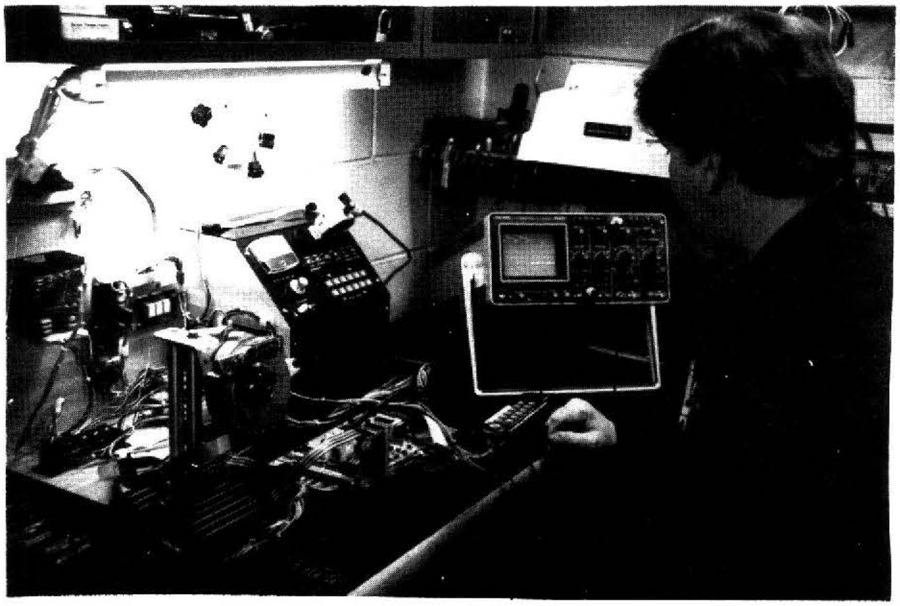

FIGURE 3-5. ELECTRONIC TEST BENCH
AT MSBA

FIGURE 3-6. SEPTA FAREBOX TECHNICIAN
SOLDERS CHASSIS CIRCUIT BOARD

FIGURE 3-7. UNIVERSAL PROM PROGRAMMER
AT MSBA

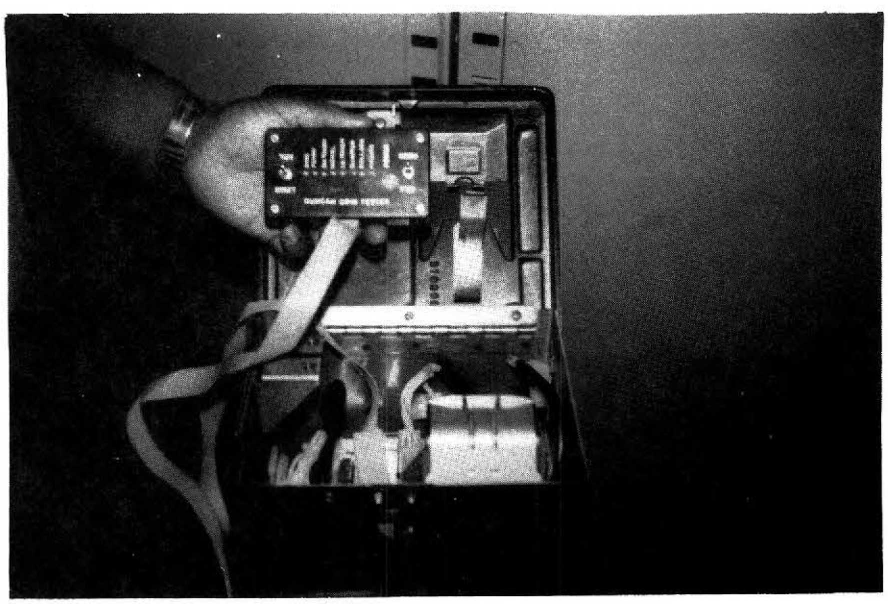

FIGURE 3-8. COIN MECHANISM TESTER
AT SEPTA

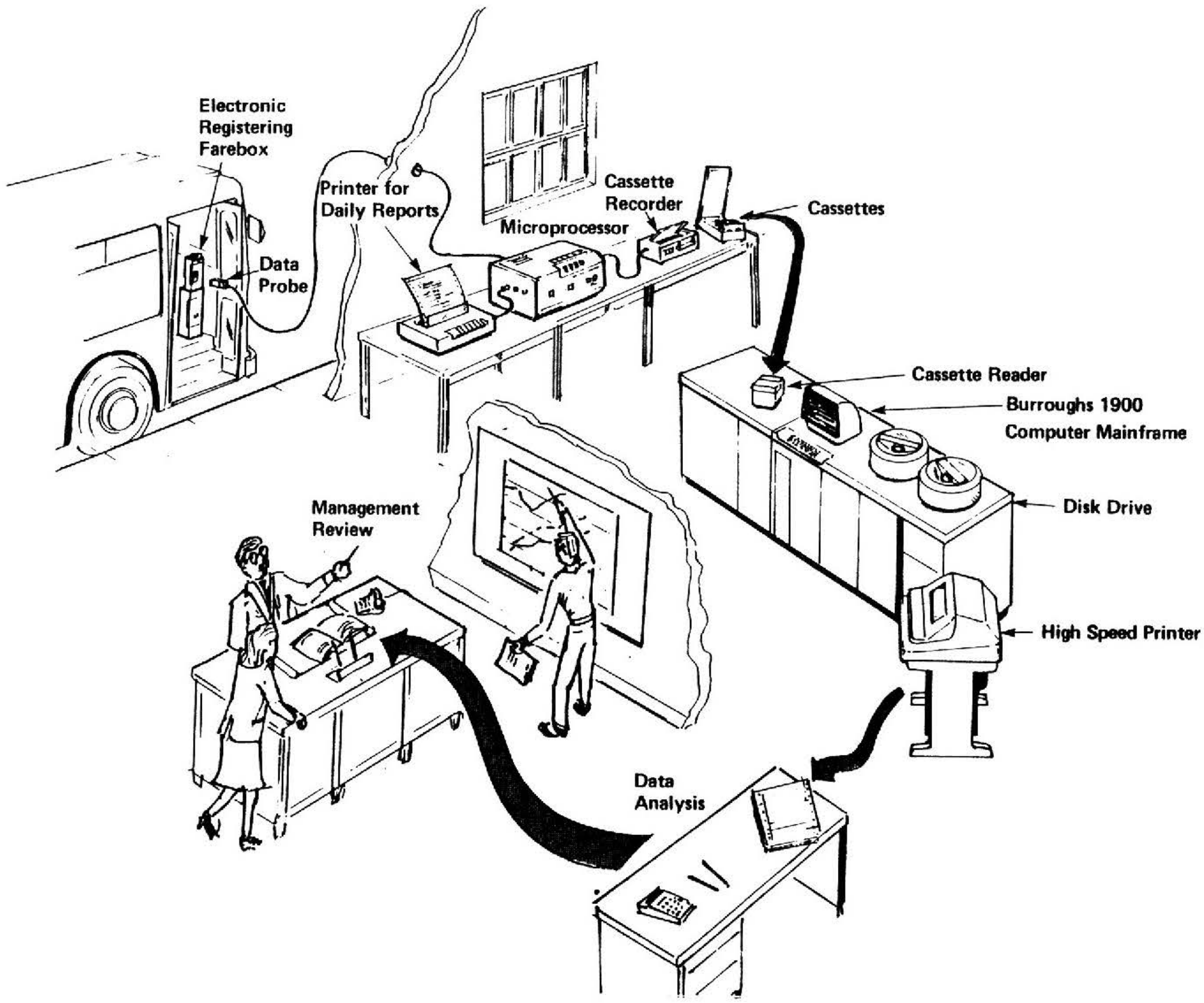

FIGURE 3-9. ILLUSTRATION OF HARDWARE FOR PROCESSING REVENUE DATA AT DALLAS TRANSIT SYSTEM

- A microprocessor and printer for generating immediate hard copies of the data

- A cassette recorder for transcribing the data onto a cassette tape

- Equipment for transcribing the data from cassette to disk so that it can be processed by the transit system's main computer.

At all of the transit systems, data on farebox maintenance and repairs is typically recorded by the technicians on manual forms and then keyed for entry into a computer. Programs to tabulate the farebox performance data and to print out management reports are developed by the transit system staff. The types of manual data collection forms for recording farebox problems and maintenance include:

- A daily farebox trouble report for bus drivers.

- A service report itemizing the trouble found and repairs performed by each maintenance technician.

- A preventive maintenance (PM) report for recording the dates and types of PM performed.

- Daily (or weekly) farebox audit report.

Examples of a maintenance report and a driver's farebox defect report are shown in Figures 3-10 and 3-11.

Form #1088
9/82

Dallas Transit System

ELECTRONIC FAREBOX MAINTENANCE REPORT

FAREBOX NO.__________ BUS NO.________ DATE REPORTED____________ TIME______ AM PM

FAILURE REPORT______________________________________

FAILED PART:	Serial # Removed	Serial # Installed	Re-pair	Re-place	Repair Time Hours	Mins.
1. Electronic Chassis						
2. Coin Mechanism						
3. Coin Escrow						
4. $ Bill Transport						
5. Driver's Panel, Push B., Pre S.B.						
6. Farebox Housing						
7. Cashbox						
8. Probe Assy.						
9. Data Microprocessor						
10. Printer/Cassette Rec						
11. Receiver/Vault						
12. Logic Board						
13. Power Board						
14. Display Board						
15. ±1% Count Vs. Reg. Variance						
DIAGNOSIS TIME						

REMARKS______________________________________

MECHANIC__________ DATE COMPLETED__________ TIME______ AM PM

SUPERVISOR________________

FIGURE 3-10. SAMPLE FAREBOX MAINTENANCE DATA COLLECTION FORM

PHOENIX TRANSIT SYSTEM

OPERATOR'S DAILY REPORT FAREBOX DEFECTS

Bus No.____________ **Date**____________

Operator________________________

Time Defect Reported________________

Chassis #____ **Vault #**____ **Farebox #**____

CHASSIS

- ☐ Will Not Power Up
- ☐ Powers Down Too Fast
- ☐ Driver Readout Wrong
- ☐ Beeps
- ☐ Key Switch

BILL TRANSPORT

- ☐ Doesn't Accept Bills
- ☐ Reading Not Shown On Digit Display

FAREBOX FRAME

- ☐ Top Cover
- ☐ Damaged

GLASS

- ☐ Coin
- ☐ Dollar
- ☐ Dirty
- ☐ Broken

DUMP DOOR

- ☐ Will Not Open
- ☐ Will Not Close

COIN MECHANISM

- ☐ Jammed Coins
- ☐ Coins Drop Through Too Slow
- ☐ Digital Display Wrong

VAULT

- ☐ Damaged
- ☐ Missing

PUSH BUTTON PANEL

- ☐ Not Working
- ☐ Not Beeping
- ☐ Clear Readings
- ☐ 30 Second Time Delay Not Working

DECALS	Missing	Dirty
☐ Insert Bills	☐	☐
☐ Insert Coins	☐	☐

AUXILIARY BOX

- ☐ Damaged
- ☐ Missing

OTHER:

____

____

____

____

FIGURE 3-11. SAMPLE FAREBOX DEFECT REPORT

4. FAREBOX ACCURACY

At the end of an operating day, total cash revenues may be compared with the total farebox meter readings as a revenue security measure. If the farebox is accurate and the cash count is lower than the registered revenues, then there is a possibility that the revenue collection system security has been breached. If the farebox is not accurate in registering revenues it cannot be used effectively to identify potential thefts or to monitor revenue collections. Thus, it is important to periodically evaluate the accuracy of each farebox. This chapter presents examples of the types of accuracy data which may be collected and the accuracy measures which can be applied.

ACCURACY OF TOTAL FAREBOXES SYSTEMWIDE

Most of the transit systems record the daily total revenues collected, the total farebox meter readings, and the difference between the two. This gives an indication of the accuracy of the fareboxes as a fare registering system.

Daily records on the total cash revenues collected compared with the total meter readings were available from the Dallas, Phoenix and MSBA transit systems; SEPTA data was not available. Representative data covering approximately a two-week period was collected from each of the three properties and is presented in Tables 4-1, 4-2, and 4-3. Three statistical measures are calculated from the data as follows:

$$\text{Mean Percent Absolute Deviation} = \frac{\sum_{i=1}^{n} \left| x_i - \bar{x} \right|}{n}$$

$$\text{Algebraic Mean Deviation} = \frac{\sum_{i=1}^{n} \left(x_i - \bar{x} \right)}{n}$$

$$\text{Standard Deviation} = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \bar{x} \right)^2}{n-1}}$$

where: x_i = the difference between farebox meter reading and cash

$\bar{x}$ = the mean percent difference between farebox meter reading and cash

n = the number of accuracy audits

TABLE 4-1. DIFFERENCE BETWEEN DAILY REGISTERED REVENUES AND CASH RECEIVED AT MSBA, MITCHELL FIELD LOCATION

Audit Date (1983)	Total Meter Readings ($)	Total Cash ($)	Cash Difference	Percent Difference
April 1	31,911.14	31,883.23	+27.91	+ .09
April 2	20,240.78	20,236.53	+4.25	+ .02
April 3	4,902.99	4,905.44	-2.45	- .05
April 4	37,105.99	37,252.76	-146.77	- .40
April 5	37,242.24	37,279.63	-37.39	- .10
April 6	34,870.27	34,910.61	-40.34	- .11
April 7	34,139.19	34,242.64	-103.45	- .30
April 8	34,094.64	34,163.31	-68.67	- .20
April 9	20,504.59	20,551.17	-46.58	- .23
April 10	4,438.60	4,564.87	-126.27	-2.77
April 11	36,579.42	36,554.07	+25.35	+ .07
April 12	36,194.05	36,138.22	+55.83	+ .15
April 13	36,188.58	36,243.92	-55.34	- .15
April 14	35,661.90	35,719.35	-57.45	- .16
Mean Percent Absolute Deviation				.34%
Algebraic Mean Deviation				-.3%
Standard Deviation				.71%

TABLE 4-2. DIFFERENCE BETWEEN DAILY REGISTERED REVENUES AND CASH RECEIVED AT DALLAS TRANSIT SYSTEM

Audit Date (1983)	Total Meter Readings ($)	Total Cash ($)	Cash Difference	Percent Difference
April 1	34,665.36	34,888.73	-223.37	- .64
April 2	15,713.39	16,044.41	-331.02	-2.06
April 3	4,412.84	4,395.04	-17.80	- .40
April 4	42,534.86	42,400.07	+134.79	+ .32
April 5	40,322.38	40,213.63	+108.75	+ .27
April 6	38,805.09	38,907.25	-102.16	- .26
April 7	39,175.95	38,107.68	+1,068.27	+2.80
April 8	39,069.24	39,171.05	-101.81	- .26
April 9	14,783.10	14,928.70	-145.60	- .98
April 10	4,803.27	4,805.22	-1.95	- .04
April 11	41,308.34	42,690.94	-1,382.60	+3.24
April 12	40,161.90	40,271.05	-109.15	- .27
April 13	37,330.44	37,102.88	+227.56	+ .61
April 14	38,885.12	40,167.60	-1,282.48	-3.19
Mean Percent Absolute Deviation				1.10%
Algebraic Mean Deviation				- .06%
Standard Deviation				1.18%

TABLE 4-3. DIFFERENCE BETWEEN TOTAL METER READINGS AND CASH AT PHOENIX TRANSIT SYSTEM*

Audit Date (1983)	Total Meter Readings ($)	Total Cash ($)	Difference	Percent Difference
February 1	12,671.93	12,964.79	-292.68	- 2.25
February 4	12,563.49	12,397.40	+166.09	+ 1.34
February 9	13,069.85	12,992.36	+77.49	+ 0.60
February 16	12,703.75	12,288.81	+414.94	+ 3.37
February 22	13,470.66	13,691.62	-220.96	- 1.61
March 3	9,996.45	12,105.49	-2,109.04	-17.42
March 9	12,517.64	13,192.59	-674.95	- 5.12
March 10	12,180.58	12,953.24	-772.66	- 5.96
March 11	12,917.16	13,160.24	-243.08	- 1.85
March 14	12,076.98	12,643.09	-566.11	- 4.48
March 15	13,864.92	13,469.70	+395.20	+ 2.93
March 17	18,942.86	17,870.25	+1,072.61	+ 6.00
March 31	11,173.37	11,371.81	-198.44	- 1.74
April 4	12,563.49	12,397.40	+166.09	+1.34
Mean Percent Absolute Deviation				4.00%
Algebraic Mean Deviation				-1.8%
Standard Deviation				4.25%

The mean percent absolute deviation for all three transit systems ranged from .34 percent to 4 percent. The algebraic mean deviation ranged from -.06 to -1.8 percent, with standard deviations from .71 to 4.25 percent. The accuracy of the total fareboxes systemwide appears to be more erratic in Phoenix than in Dallas or MSBA. Phoenix has experienced frequent malfunctions of the microprocessor which records the data collected from the farebox electronic data probes.

The algebraic mean deviation for all three transit systems is negative, i.e. the total cash exceeds the registered revenues on the average. This suggests that the fareboxes are undercounting the revenue or are not recording excess fares deposited by passengers. According to the Director of Accounting at the Dallas Transit System, the negative 3.19 percent error on April 14 in Table 4-2 is the result of several buses pulling into the maintenance yard from road calls without having their fareboxes probed for fare data. The cause of the positive errors on April 7 and 11 has not been determined.

ACCURACY OF INDIVIDUAL FAREBOXES

A more detailed measure of farebox accuracy is a comparison of the revenues collected and the fares recorded by each farebox. To evaluate individual farebox counting accuracy, the cash contents of each farebox must be segregated and individually counted. The frequency of such accuracy checks ranges from daily to monthly.

At Dallas, a daily audit check is performed on a sample of 20 to 30 boxes. At the MSBA, one day a week is devoted to an individual audit of every farebox in use that day. The SEPTA performs accuracy audits on approximately 40 to 50 fareboxes a day for four days out of each month. Phoenix does not perform periodic farebox audits.

Consistent documentation of the accuracy audit results can aid in substantiating claims against the manufacturer's warranty, particularly if the serial numbers of major modules such as the chassis and coin mechanism are recorded at the time of the accuracy check.

Tables 4-4 and 4-5 present the results of repeated accuracy audits of fareboxes on individual buses at Dallas and MSBA. The audits were conducted as the buses pulled into the maintenance yard; thus, the fareboxes are identified by bus number rather than farebox number. It should be recognized that the farebox is designed as a modular unit; components may be replaced periodically as

TABLE 4-4. RESULTS OF REPEATED ACCURACY CHECKS ON THREE DALLAS FAREBOXES

Bus Number	Audit Date	Meter Reading ($)	Total Cash ($)	Difference Amount ($)	Difference Percent
308	4/14/83	32.84	32.84	.00	--
	4/15/83	27.85	27.95	-.10	- .36
	4/20/83	28.00	27.70	+.30	+1.08
	4/21/83	27.35	27.25	+.10	+ .37
311	4/11/83	61.87	61.84	+.03	- .05
	4/14/83	35.60	35.60	.00	--
	4/20/83	21.65	21.65	.00	--
	4/21/83	20.15	20.15	.00	--
837	4/11/83	173.24	172.78	+.46	+ .27
	4/15/83	164.56	163.86	+.70	+ .43
	4/19/83	164.64	168.54	-4.00	-2.37
	4/20/83	11.53	11.95	-.42	-3.51
	4/21/83	163.87	164.07	-.20	- .12
Mean Percent Absolute Deviation					.66%
Algebraic Mean Deviation					-.57%
Standard Deviation					1.08%

TABLE 4-5. RESULTS OF REPEATED ACCURACY CHECKS ON FIVE MSBA FAREBOXES

Bus Number	Audit Date	Meter Reading ($)	Total Cash ($)	Difference Amount ($)	Difference Percent
689	03/09/82	63.40	63.15	+ .25	+ .40
	04/27/82	73.75	73.50	+ .25	+ .34
	05/26/82	8.85	8.85	--	--
	11/16/82	44.36	44.45	- .09	- .20
	02/09/83	80.40	80.30	+ .10	+ .12
777	03/09/82	172.85	172.75	+ .10	+ .06
	04/27/82	76.81	84.00	-7.19	-8.56
	05/11/82	96.24	96.59	- .35	- .36
	05/26/82	197.02	197.30	- .28	- .14
	06/08/82	92.97	94.41	-1.44	-1.52
	10/06/82	117.92	118.37	- .45	- .38
	11/16/82	187.41	186.92	+ .49	+ .26
	02/09/83	142.66	143.06	- .40	- .28
779	03/09/82	188.90	188.79	+ .11	+ .06
	05/11/82	147.94	147.94	--	--
	05/26/82	152.75	153.65	- .90	- .58
	06/08/82	168.95	168.89	+ .06	+ .04
	09/21/82	99.30	99.95	- .65	- .65
	10/06/82	102.15	102.50	- .35	- .98
	11/16/82	106.45	106.35	+ .10	+ .94
	02/09/83	161.48	160.94	+ .54	+ .62
800	05/11/82	38.30	38.40	- .10	-2.60
	05/26/82	120.90	120.65	+ .25	+ .21
	06/08/82	45.81	44.81	+1.00	+2.23
	09/21/82	79.90	79.40	+ .50	+ .63
	10/06/82	59.20	58.70	+ .50	+ .85
	11/16/82	26.05	26.15	- .10	- .38
	02/09/83	66.98	66.73	+ .25	+1.50
801	03/09/82	50.70	50.70	--	--
	04/27/82	68.75	69.70	- .95	-1.36
	05/11/82	73.20	79.95	-6.75	-8.44
	06/08/82	74.60	74.60	--	--
	09/21/82	83.06	82.96	+ .10	+ .12
	10/06/82	49.10	49.40	- .30	-2.02
	11/16/82	181.24	180.78	+ .46	+ .55
	02/09/83	100.15	100.25	- .10	-1.00
Mean Percent Absolute Deviation					1.07%
Algebraic Mean Deviation					-.32%
Standard Deviation					1.94%

part of preventive maintenance or repair procedures between accuracy checks. The bus numbers selected for this analysis were those that received the largest number of accuracy audits and provided the most data.

For the audit dates shown, the mean percent absolute deviation between the counted revenues and the farebox registered fares at both transit systems ranged from 0 to 8.56 percent. The mean percent absolute deviation for the fareboxes from both transit systems over all audit dates shown in Tables 4-4 and 4-5 is .96 percent, which is equivalent to an accuracy of 99.04 percent. The standard deviation for the data from both transit systems is 1.75.

MSBA attributes the farebox reading errors of 8.56 percent in bus number 777 on April 27, 1982 and 8.44 percent in bus number 801 on May 11, 1982 to possible problems with the coin sensor or the bill transport. If the coin sensor were out of adjustment, it could have repeatedly misread high value coins as lower value coins. Or if the bill transport were seriously out of adjustment, a bill could have been accepted but not recorded by the farebox.

ACCURACY IN COUNTING TOKENS

Data on the accuracy of the fareboxes in counting specific denominations of coins or dollar bills was not available from the transit systems. The work, which would be required to segregate quarters, dimes or dollar bills from each farebox, individually count and record the total, and compare the sum with the metered amount for each denomination, is considered too time-consuming by the transit systems for the benefits that may result.

Data on the accuracy of the fareboxes in counting tokens was available from SEPTA.* SEPTA collects approximately 70,000 tokens daily through its electronic registering fareboxes. The number of tokens collected in each farebox is recorded separately; the farebox does not calculate the value of each token or add the value to the total revenue count.

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* Dallas Transit does not use tokens. Phoenix does not perform periodic farebox audits. In MSBA's weekly audits, the value of tokens collected in the farebox is combined with the value of cash revenues. A separate count of the number of tokens collected is not recorded.

Tables 4-6 and 4-7 present data on the number of convenience and student tokens registered by fareboxes in 26 buses on April 5 and 29 buses on April 6, 1983. The metered number of tokens is compared with the actual token count.

The accuracy of the individual fareboxes in counting tokens ranges from 100 percent accuracy to a large error of 73 convenience tokens on bus #8022 on April 5. The algebraic mean deviation over the two days is an error of +3.6 convenience tokens and -1.2 student tokens or a percent mean deviation of + 20 percent and - 2 percent. The farebox errors in counting the .900-inch diameter convenience tokens are almost consistently positive, while the errors in counting the .650-inch diameter student tokens are mixed. Both tokens are the same width. Convenience tokens could be misregistering as nickels, while student tokens could possibly be misregistering as dimes. This type of problem needs further data collection and analysis to discover the exact cause of the inaccuracy in counting.

TABLE 4-6. ACCURACY OF FAREBOX IN COUNTING TOKENS AT SEPTA APRIL 5, 1983

	Convenience Token Size			Student Token Size		
Bus Number	Metered Tokens	Token Count	Difference	Metered Tokens	Token Count	Difference
6452	5	5	0	17	17	0
6455	6	6	0	21	21	0
8026	13	13	0	9	9	0
8002	5	5	0	24	24	0
1254	3	3	0	12	12	0
8025	9	7	+ 2	24	25	-1
6457	1	1	0	32	32	0
8006	14	14	0	10	10	0
6457	1	1	0	63	62	+1
8055	36	22	+14	10	13	-3
8047	46	44	+ 2	31	33	-2
8022	113	40	+73	16	20	-4
6417	3	3	0	1	1	0
8060	14	13	+ 1	1	1	0
6452	25	18	+ 7	89	95	-6
6426	11	11	0	52	52	0
8102	79	68	+11	30	30	0
8003	21	21	0	31	31	0
8018	25	24	+ 1	26	28	-2
8009	57	55	+ 2	30	33	-3
6062	19	8	+11	14	16	-2
8048	41	39	+ 2	0	0	0
6363	0	0	0	0	0	0
8091	11	6	+ 5	1	1	0
8099	28	22	+ 6	0	0	0
8007	20	18	+ 2	2	2	0
Mean Absolute Deviation			5.3			.9
Algebraic Mean Deviation			+5.3			-.8
Mean Percent Absolute Deviation			23.6%			2.7%
Algebraic Mean Percent Deviation			+23.6%			-2.6%
Standard Deviation			45.7%			5.4%

TABLE 4-7. ACCURACY OF FAREBOX IN COUNTING TOKENS AT SEPTA APRIL 6, 1983

	Convenience Token Size			Student Token Size		
Bus Number	Metered Tokens	Token Count	Difference	Metered Tokens	Token Count	Difference
1252	0	0	0	53	53	0
8042	10	10	0	9	9	0
6319	0	1	- 1	0	46	-46
6342	5	5	0	45	45	0
6418	8	8	0	14	0	+14
6541	1	1	0	2	2	0
1256	10	10	0	42	42	0
8069	6	5	+ 1	16	20	- 4
6541	1	1	0	53	53	0
1268	1	1	0	1	1	0
8072	34	34	0	24	24	0
8080	25	20	+ 5	8	9	- 1
8050	35	28	+ 7	73	82	- 9
6063	24	12	+12	26	32	- 6
8037	12	7	+ 5	16	16	0
6449	9	4	+ 5	22	23	- 1
6461	3	2	+ 1	2	3	- 1
8039	43	43	0	37	37	0
8089	35	35	0	37	36	+ 1
8095	31	33	- 2	25	23	+ 2
8061	3	2	+ 1	4	3	+ 1
8026	58	58	0	38	37	+ 1
1158	8	6	+ 2	10	11	- 1
8043	69	62	+ 7	37	35	+ 2
8079	83	82	+ 1	25	24	+ 1
8097	17	14	+ 3	10	10	0
8006	32	32	0	5	5	0
8038	10	10	0	1	1	0
8057	36	23	+13	0	0	0
Mean Absolute Deviation			2.3			4.3
Algebraic Mean Deviation			+ 2.1			-1.6
Mean Percent Absolute Deviation			24.0%			12.6%
Algebraic Mean Percent Deviation			+16.7%			-1.7%
Standard Deviation			34.4%			25.9%

5. FAREBOX RELIABILITY

Measures of farebox reliability include the types and frequency of farebox failures, the causes of farebox failures, mean time between failures and mean transactions between failures.

MAJOR TYPES AND FREQUENCY OF FAREBOX FAILURES

The average number of farebox component failures per week for three of the four transit systems is shown in Table 5-1. The most frequent failures occur in the electronic chassis and coin mechanism, followed by the bill transport and a category called "other" which, depending on each transit system's definition, may include farebox failures such as power downs, the farebox going into the bypass mode, the cash vault being stuck, or a condition where a failure is reported but no trouble is found by the technicians. Only a few failures each week are attributed to the driver keyboard, the farebox housing and baseplate, the driver display and the cash vault.

TABLE 5-1. AVERAGE WEEKLY FAREBOX FAILURES AT THREE TRANSIT SYSTEMS

Module	MSBA[1]		Dallas Transit[2]		SEPTA[3]	
	Number	Rank	Number	Rank	Number	Rank
Coin Mechanism	26	2	20	2	94	2
Bill Transport	8	3	33	1	41	4
Electronic Chassis	30	1	15	4	163	1
Keyboard	5	5	10	5	6	6
Driver Display	0		-		1	8
Farebox & Baseplate	2	7	-		30	5
Cash Vault	7	4	-		5	7
Other Farebox	3	6	17	3	45	3
Total Module Failures Per Week	81		95		385	

The module failure data shown here should not be rigorously compared since a uniform definition of failure is not shared or applied by the three transit systems.

1 Average weekly failures based on total defect reports for 1982.

2 Based on farebox performance reports for February through August 1983.

3 Based on maintenance statistics reports for week of February 27 and March 13 through April 2, 1983.

Each transit system has its own system for recording failures. No uniform definition of a failure has been adopted by the transit systems or applied here. The data is based on each transit system's failure records. Phoenix failure data is not categorized or tabulated by farebox module and is not included.

Table 5-2 shows the average farebox failures per week per operating farebox for MSBA, Dallas and SEPTA. The number of failures range from .16 to .26 weekly failures per operating farebox. The table disregards differences in farebox utilization, especially on weekends, at the three transit systems.

TABLE 5-2. AVERAGE FAILURES PER WEEK PER OPERATING FAREBOX

Transit System	Failures Per Week	Total Operating Fareboxes	Failures Per Week Per Operating Farebox
MSBA	81	317	.26
Dallas	95	600	.16
SEPTA	385	1,750	.22

CAUSES OF FAREBOX FAILURES

Frequent causes of farebox failures, according to the farebox maintenance managers and technicians, are chassis power downs, coin mechanism and bill transport jams, worn vault locks, and dirt and dust in transistor photocells, and LED displays. Principal causes of failures are summarized in Table 5-3.

Passengers contribute to many farebox problems. Table 5-4 shows data collected by Dallas on the types and frequency of passenger-induced farebox failures during July 1983. The failures primarily consist of coin mechanism jams such as the dropping of foil, nails, rivets and other pocket debris into the coin slot.

TABLE 5-3. FREQUENT CAUSES OF FAREBOX FAILURES

Module	Frequent Causes of Farebox Failures	Location			
		MSBA	Dallas	Phoenix	SEPTA
Coin Mechanism	Dirt and dust get into the photocells of the coin reader board and cause coins to register incorrectly.	X	X	X	X
	Patrons drop paper and other small debris from their pockets into the coin slot and jam the coin mechanisms.	X	X	X	X
	Brass tokens wear out, lose diameter and are misread as nickels or pennies.	X			
	The gate in the escrow assembly may bend and get stuck, preventing coins from being dumped.				X
Electronic Chassis	Chassis power downs frequently follow voltage spikes.	X		X	
	Vibrations of the bus loosen chassis connections.	X		X	X
	If the interior temperature of the bus increases beyond 130°F while the bus is in the bus yard, the heat can cause malfunctions of the chassis.			X	
Bill Transport	Bills crumple when they hit the bill transport rail if the rail height or transport belt tension are not adjusted correctly.		X		
Cash Vault	The cashbox cracks at the weldment on the corner seam.	X			
	The tumblers in the vault lock become worn and cause the lock to malfunction.	X		X	X
	Vault keys wear out and have to be replaced.	X			X

TABLE 5-3. CONTINUED

Module	Frequent Causes of Farebox Failures	Location: MSBA	Location: Dallas	Location: Phoenix	Location: SEPTA
Data Transmission Probe	Bad contacts on the probe connector cause incorrect data transfer.			X	
	The female plug on the chassis becomes filled with dust and causes problems with data transfer.		X		
	Extreme heat can cause the receiving microprocessor to overheat and shut down, causing the data transmission probe to fail.		X		
	Water seeps into the transmission probe through bolt holes and causes the probe to malfunction.		X		
Farebox Exterior	The notch for the bypass lever is not deep enough; a sudden jolt of the bus can cause the farebox to go into or out of the bypass mode.		X		
	The topframe may fit poorly on the base, causing vibration. The connecting seatings must be ground down to make the upper stanchion sit more squarely on the base.	X			

TABLE 5-4. PASSENGER INDUCED FAREBOX FAILURES AT DALLAS DURING JULY

Bus Number	Date Use	Trouble
637	7/5/83	Dollar in coin mechanism
834	7/5/83	Dollar in coin mechanism
126	7/5/83	Sticky coin in coin mechanism
922	7/5/83	3 pennies glued together
816	7/6/83	Dollar in coin mechanism
740	7/6/83	Piece of foil in coin mechanism
835	7/8/83	Chewing gum in coins in coin mechanism
664	7/8/83	Bent coin in coin mechanism
811	7/8/83	Dollar in coin mechanism
972	7/13/83	Paper in top of bill transport
702	7/15/83	Bent quarter in coin mechanism
902	7/18/83	Folded bill in bill transport
731	7/19/83	Pill in coin mechanism
481	7/20/83	Dollar in coin mechanism
674	7/21/83	Bent quarter in coin mechanism
632	7/27/83	Dollar in coin mechanism
721	7/27/83	Dollar in coin mechanism
970	7/27/83	Nail in coin mechanism
725	7/28/83	Dollar in coin mechanism
655	7/29/83	Dollar in coin mechanism
982	7/29/83	String in bill transport
965	7/29/83	Bent quarter in coin mechanism
930	7/29/83	Rivet in coin mechanism

MEAN TIME BETWEEN FAILURES

Mean time between farebox failures is estimated as follows:

$$\text{Mean Time Between Farebox Failures} = \frac{\text{Number Fareboxes in Use x Operating Days}}{\text{Number of Failures}}$$

As shown in Table 5-5, the number of fareboxes typically in use at each transit system during Monday through Friday, Saturday and Sunday was summed to obtain the total operating farebox days per week. This sum was divided by the average number of failures per week (from Table 5-1) to obtain the mean time (farebox days) between failures (MTBF). The estimated MTBF is somewhat consistent among the three transit systems - it ranges from 19.22 to 23.98 mean farebox days between failures.

TABLE 5-5. MEAN TIME BETWEEN FAREBOX FAILURES

	MSBA	Dallas	SEPTA
No. of Fareboxes in Use* Monday - Friday	263	439	1,200
No. of Fareboxes in Use Saturday	174	83	800
No. of Fareboxes in Use Sunday	85	0	600
Total Operating Farebox Days Per Week	1,574	2,278	7,400
Total Farebox Failures Per Week	81	95	385
Mean Farebox Days Between Failures	19.43	23.98	19.22

* Estimates of daily fareboxes in use were provided by the transit systems.

MEAN TRANSACTIONS BETWEEN FAILURES

An alternative measure of farebox failure frequency is the mean number of transactions between failures. The mean transactions between failures can be estimated by dividing the average number of farebox transactions per week by the total farebox failures per week. Table 5-6 shows the mean total transactions between module failures based on estimates of the total cash transactions per week provided by each transit system.

The estimated mean transactions involving only the bill transport or the coin mechanism between module failures are shown in Table 5-7. The comparatively low transactions between bill transport failures in Dallas are due to a problem in the transport belt which is being corrected.

When the principal causes of farebox failures provided by the transit system maintenance managers (Table 5-2) are considered, it is reasonable to conclude that the volume of transactions is not a leading measure of farebox reliability. Time in service is a more likely measure since many of the causes of failures are not related to transactions, but are related to time and exposure such as dirt and dust entering the coin mechanism; variations in bus voltage causing chassis power downs; bus vibrations causing loose connectors, and cashbox lock tumblers failing due to wear.

TABLE 5-6. MEAN FAREBOX TRANSACTIONS BETWEEN FAREBOX MODULE FAILURES

Farebox Module	MSBA Mean Weekly Transactions Per Module Failure[1]	Dallas Mean Weekly Transactions Per Module Failure[2]	SEPTA Mean Weekly Transactions Per Module Failure[3]
Coin Mechanism	15,810	16,500	123,297
Bill Transport	51,384	10,000	42,101
Electronic Chassis	13,702	22,000	10,590
Keyboard	82,214	33,000	287,692
Driver Display	No Failures	--	1,726,156
Farebox and Baseplate	205,535	--	57,539
Cash Vault	58,724	--	345,231
Other Farebox	137,023	19,412	38,359
All Failures	5,075	3,474	4,483

The mean transactions between module failures shown here should not be rigorously compared since a uniform definition of failure is not shared or applied by the three transit systems.

1 Assumes 411,070 total cash fare transactions per week.
2 Assumes 330,000 total cash fare transactions per week.
3 Assumes 1,726,156 total cash fare transactions per week.

TABLE 5-7. ESTIMATED NUMBER OF CURRENCY TRANSACTIONS PER MODULE FAILURE

	MSBA[1]	Dallas[2]	SEPTA[3]
Bill/Transport Transactions Per Week	44,000	65,150	142,250
Bill Transport Failures Per Week	8	33	41
Number of Bill or Ticket Transactions Between Bill Transport Failures	5,500	1,974	3,470
Coin/Token Transactions Per Week	367,070	264,850	1,583,906
Coin Mechanism Failures Per Week	26	20	94
Number of Coin or Token Transactions Between Coin Mechanism Failures	14,118	13,242	16,850

1 MSBA revenues include: Saturday-4,000 bills and 3,000 tokens, Sunday-5,000 bills and 2,000 tokens. Weekday average revenues are listed in Table 2-2. MSBA does not collect tickets through the farebox.

2 Dallas revenues include: Saturday-3,900 bills, Sunday-1,250 bills. No tickets are collected on Saturday and Sunday. See Table 2-2 for weekday revenues. Dallas is in the process of installing a design improvement in the bill transport which will reduce the bill transport failure rate.

3 SEPTA revenues include: Saturday and Sunday combined-20,000 bills and 1,250 tokens. See Table 2-2 for weekday revenues.

6. FAREBOX MAINTAINABILITY

This chapter addresses the accessibility of the farebox components, equipment repair and preventive maintenance procedures and spare parts and materials requirements. Evaluation measures relating to farebox maintainability include: the mean time to access each component, the estimated time to perform preventive maintenance, the mean time to repair each component and the number of initial spares purchases.

ACCESSIBILITY OF FAREBOX COMPONENTS

Maintenance technicians at all four transit systems consider all of the farebox modules to be easily accessible. When asked what module is most inaccessible, most technicians mentioned the bill transport, since both the coin mechanism and the electronic chassis have to be removed before the bill transport can be accessed. Figure 6-1 shows a technician removing a bill transport for preventive maintenance.

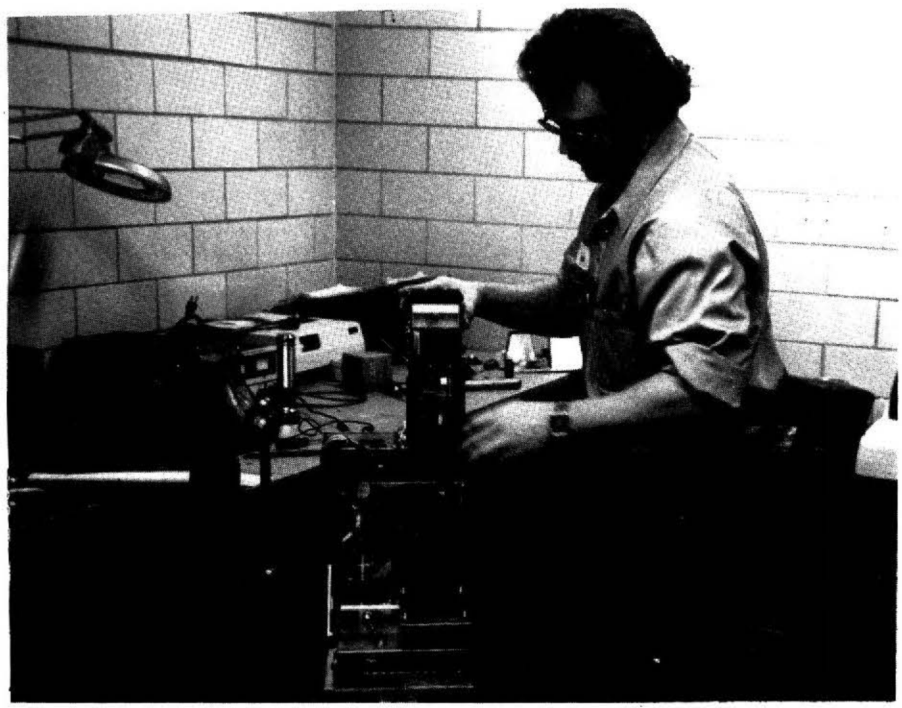

FIGURE 6-1. BILL TRANSPORT BEING REMOVED FOR PREVENTIVE MAINTENANCE AT DALLAS TRANSIT SYSTEM

Maintenance technicians were asked for estimates of the time required to gain access to each of the major farebox components. These times, and the time to replace each component in the farebox after it is repaired, are shown in Table 6-1. As shown, the bill transport and the driver keypad are each estimated to require approximately 7 minutes for the technician to gain access to and replace them following repair.

TABLE 6-1. ESTIMATED ACCESS AND REPLACEMENT TIMES FOR MAJOR FAREBOX MODULES

	Estimated Mean Minutes to Gain Access*				Estimated Mean Minutes to Replace After Repair*			
	Dallas	MSBA	SEPTA	Average	Dallas	MSBA	SEPTA	Average
Coin Mechanism	2	2	2	2	2	4	2	3
Electronic Chassis	4	3	3	3	4	3	3	3
Bill Transport	4	7	10	7	4	7	10	7
Driver Keypad	3	4	15	7	3	4	15	7
Vault	Negligible	Negligible	1/2	1/4	Negligible	2	1/2	3/4

* Estimates provided by maintenance technicians. Times are estimated for parts removal on-board the bus.

The steps required to gain access to each major component are summarized in Table A-1 in the appendix. The steps listed in the appendix are typical of the actions required at the transit systems studied.

FAREBOX PREVENTIVE MAINTENANCE PROCEDURES

Farebox manufacturers provide a recommended preventive maintenance schedule upon delivery of the equipment, but three out of four of the transit systems studied have developed their own schedules. Preventive maintenance is typically performed on-board the bus.

Most of the transit systems' maintenance managers attribute good farebox operation to a stringent preventive maintenance program. The maintenance managers report that the fareboxes collect a large amount of dirt, dust and grime, and frequent preventive maintenance is needed to remove this dirt from the gears, displays, push buttons and other farebox components to prevent potential jams or failures. Periodic lubrication of gears, push buttons and mechanical parts is also helpful in preventing failures.

The estimated mean minutes to perform preventive maintenance on each module, and the scheduled months between maintenance procedures are shown in Table 6-2. The time to perform preventive maintenance ranges from 2 minutes to check and lubricate a cash vault to 30 minutes to clean, lube and check the operation of a bill transport. Each property has its own preventive maintenance routine; differences in the estimated times are due to differences in the maintenance activities performed or in the design of the farebox. Preventive maintenance on the farebox is performed approximately every 3 months.

TABLE 6-2. TIME TO PERFORM AND FREQUENCY OF PREVENTIVE MAINTENANCE PROCEDURES

Component	Estimated Minutes to Perform Preventive Maintenance			Scheduled Months Between Maintenance Procedures		
	Dallas	MSBA	SEPTA	Dallas	MSBA	SEPTA
Coin Mechanism	10	30	30	2	2	3
Electronic Chassis	10	45	5	2	As Needed	3
Bill Transport	20	30	15	2	3	3
Driver's Keypad	3	15	10	2	3	3
Cash Vault	2	15	3	2	3	12
Farebox Exterior	2	30	6	2	3	3

A summary of preventive maintenance procedures that are representative of the types of procedures used by the transit systems studied are presented in Table A-2 in the appendix.

EQUIPMENT REPAIR PROCEDURES

The repair procedures that are followed when a failure is discovered in a coin mechanism, bill transport, chassis, keypad, or vault may range from removing a single jam to rebuilding an entire assembly. Most repairs involve initial diagnosis and troubleshooting.

According to the maintenance managers at MSBA and SEPTA, the most time consuming repairs involve the cash vault and the electronic chassis. The locks in the cash vaults have to be rebuilt or replaced approximately every three months due to daily wear by the vault keys. The cash vault housings are susceptible to cracks along weldments. Repairs on the electronic chassis range from tightening connections and resoldering circuit board wires to replacing EPROMS and installing new circuit boards.

Several maintenance managers interviewed stated that the coin mechanism may require time consuming repair procedures such as verifying the operation of the LED's and photo transistors and repairing or replacing these as necessary. Repairs of the bill transport typically involve removing jams and adjusting or repairing the microswitches, transport belt and/or motor. The pushbutton assembly of the keypad generally needs to be cleaned or replaced, a repair that requires one-quarter hour.

Table 6-3 summarizes the estimated mean minutes to perform repairs other than removing jams from each of the principal farebox components. A list of the most typical repairs performed on each farebox component is presented in Table A-3 in the appendix.

TABLE 6-3. ESTIMATED MEAN MINUTES TO REPAIR FAREBOX COMPONENTS

Farebox Component	Mean Minutes to Repair*
Coin Mechanism	30 - 60
Bill Transport	30
Electronic Chassis	30 - 60
Driver Keypad	15
Cash Vault	15 - 90

* Estimates provided by farebox maintenance technicians for repairs other than removing jams.

EXPERIENCE WITH SPARES AND MATERIALS CONSUMPTION

At the time of initial purchase, the transit systems ordered spare fareboxes equivalent to 7 to 11 percent of the total fareboxes procured. In addition, the transit systems purchased spare modules including vaults, chassis, bill transports, coin mechanisms, keyboards and logic boards. These initial spare parts have been sufficient for service requirements; no new procurements of spare modules have been made at any of the transit systems. The number of spares purchased by the Dallas Transit System and MSBA are shown in Table 6-4.

TABLE 6-4. INITIAL SPARES PURCHASES

Type of Spare	Dallas Transit System		MSBA	
	Number	Percent of Total Fareboxes	Number	Percent of Total Fareboxes
Complete Farebox	40	6.7	39	10.9
Coin Mechanism	30	5.0	8	2.2
Bill Transport	30	5.0	8	2.2
Logic Board	20	3.3		
Keyboard	20	3.3	4	1.1
Chassis			8	2.2
Three Digit Display			8	2.2
Cash Vaults			20	5.6

Parts and materials are consumed and purchased regularly by the farebox maintenance organizations. Parts and materials frequently used in farebox maintenance include coin separator (grass) wheels, cleaning fluids, lubricating materials, washers, screws, printed stickers for the fareboxes, connectors, and miscellaneous small hardware.

7. FAREBOX SECURITY

Measures of farebox security, the transit systems' recent experience with security, and the types of farebox security methods in use at the transit systems are discussed in this chapter.

TRANSIT SYSTEM EXPERIENCE WITH FAREBOX SECURITY

All four of the transit systems studied believed fare system security to be enhanced by the installation of electronic registering fareboxes. The reasons for the improved security include improved designs for the cashbox and the ability of the farebox to detect when a passenger deposits an insufficient fare.

Two measures of farebox security include:

- The number of incidences of vandalism or theft that occur before and after electronic farebox installation
- Changes in farebox revenues after installation of the farebox.

Estimates of the number of incidences of vandalism or theft were available for the time since farebox installation, but not before. As shown in Table 7-1, the incidence of theft/vandalism is low at all of the transit systems. The fareboxes at Dallas have only been installed for 6 months, and no vandalism has occurred in that time. SEPTA has from 3 to 5 times as many fareboxes as the other transit systems, and the number of incidences of vandalism are also higher. Although the data in Table 7-1 are interesting, to be really meaningful the data should be compared for the periods before and after farebox installation.

Any change in revenues after installation of the farebox should also be measured. Three of the four transit systems estimate that no increase in revenue has occurred as a result of the farebox installation. SEPTA estimates that a small percentage increase in revenue occurred. None of the transit systems have performed detailed analyses to support these estimates. A summary of the responses is presented in Table 7-2.

TABLE 7-1. NUMBER OF INCIDENCES OF VANDALISM OR THEFT SINCE INSTALLATION OF ELECTRONIC REGISTERING FAREBOXES

Transit System	Farebox Installation Date	Estimated Incidences of Farebox Vandalism or Theft Since Farebox Installation	Comments
MSBA	3/81	2 Incidents	In one incident a farebox key was missing and later found on the property. In another incident a vandal tried to pry open the farebox.
Dallas	12/82	None	
Phoenix	6/80	2 Incidents of Vandalism	Vandal chiseled between vault and frame, but was unable to reach cashbox. Both attempts were unsuccessful.
SEPTA	12/79	Approximately 10 per year	Vandals attempt to pry open the farebox door to gain access to the cashbox.

TABLE 7-2. ESTIMATED CHANGE IN FAREBOX REVENUES FOLLOWING ELECTRONIC FAREBOX INSTALLATION

Transit System	Effect of Electronic Registering Farebox on Fare Revenues	Transit System Comments
MSBA	No Apparent Change	MSBA has always maintained tight farebox security.
Dallas	No Apparent Change	There has been an increase in the use of bills and an offsetting decrease in coin usage, but no net change in revenue.
Phoenix	No Apparent Change	Fares were increased and service was expanded when the fareboxes were installed. Any changes in revenue are attributed to these factors and not to the farebox.
SEPTA	Small Increase	A small change in revenues is attributed to the greater security of the farebox.

OTHER METHODS TO IMPROVE FAREBOX SECURITY

Other farebox security methods enforced by the transit systems studied include security on-board the bus, security during vault pulling, and security during farebox maintenance.

- Security On the Bus. The tamperproof design of the electronic registering farebox provides the primary on-board security. Other measures used include the following:

  - Buses are not permitted to stand idle in the bus yard with a farebox vault that has not been emptied.

  - Only authorized supervisors may attempt to remove farebox jams while the bus is in service. Bus operators are not permitted to attempt to clear farebox jams.

  - If a farebox jam occurs while the bus is in service, the bus is either returned to the maintenance garage or is permitted to continue in service without collecting passenger fares until the run is completed. The dispatcher/superviser makes this determination.

- Security During Vault Pulling. Security measures during vault pulling include:

  - Authorized vault pullers only are permitted to empty the vaults and restore empty vaults to the farebox.

  - Any fare revenues found in the vault pulling area, no matter how small the amount, must be reported to the accounting department. A weekly or monthly accounting of this revenue is performed.

  - The serial number of each bus and vault that is emptied, and in some cases the total revenue for each run, is recorded.

- Security During Farebox Maintenance. Security measures during farebox maintenance include:

  - The farebox maintenance room is kept locked and only authorized technicians are given keys.

  - A chart showing the location of all fareboxes and vaults is kept continuously updated to prevent the loss of spare vaults.

8. FAREBOX INSTALLATION AND OPERATING COSTS

Examples of initial farebox procurement costs are presented in this chapter. A transit system should also be able to measure its costs to maintain the fareboxes including labor, parts and materials. Some examples of the types and amounts of farebox maintenance costs are presented.

EQUIPMENT PROCUREMENT AND INSTALLATION COSTS

The initial costs for installing the electronic registering fareboxes include the cost of:

- Fareboxes
- Installation on-board the buses
- Receiving units for fare revenues
- Data processing equipment
- Spare parts.

The cost of the farebox may vary depending on whether the specification includes accessories such as a data transfer plug, on-board diagnostics, or the capability to register revenue plus passenger category data. The farebox and related equipment costs incurred by three of the transit systems discussed in this report are presented in Table 8-1.

TABLE 8-1. EQUIPMENT PROCUREMENT COSTS

	Dallas	Phoenix	MSBA
Date of Purchase	12/82	6/80	3/81
Cost per Farebox	$3,114	$3,056	1,956
Number of Fareboxes	600	343	356
Installation Cost per Farebox	*	*	67
Vault Receiver Unit	9,250	9,315	4,500
Number of Receiver Units	8	4	4
Data Processing System (Probe and micro-processor)	60,000	16,404	NA
Data Printers (s)	1,900	8,091	NA
Farebox Audit Units	25,600	7,800	NA
Diagnostic Test Set	NA	9,700	NA
Addition of Route/Run Capability	NA	115,140	131,580
Extended Warranty	NA	--	38,500
Total Cost	$2,029,900	$1,242,603	$907,018

* Included in the cost of the farebox

NA Not applicable

Detailed SEPTA costs were not available for the 1979 farebox procurement.

EQUIPMENT OPERATING AND MAINTENANCE COSTS

Equipment operating and maintenance costs include the salary and fringe benefits for the farebox maintenance technicians and supervisors, and the materials needed to repair the fareboxes. This section presents operating and maintenance cost data for two properties to illustrate the range in costs that may be incurred. Table 8-2 shows the average farebox maintenance labor costs incurred in early 1983 by MSBA; on the average the costs amounted to $15.33 per farebox per week. Table 8-3 shows the maintenance labor costs at SEPTA, approximately $8.22 per week per farebox.

TABLE 8-2. MSBA FAREBOX MAINTENANCE LABOR COSTS

Labor Category	Weekly Salary ($)	Number of Positions	Total Weekly Salaries ($)	Salaries Plus Fringe* ($)
Supervisor	536	1	536	726.00
Lead Mechanic	519	3	1,557	2,102.00
Technician	507	1	507	686.00
Class I	497	2	994	1,346.00
Total Weekly Labor Cost				4,860.00
Number of Operating Fareboxes				317
Average Weekly Maintenance Labor Cost Per Farebox				15.33

* Fringe benefits are 35.4 percent of salaries. Labor costs are based on 1983 salaries paid to maintenance staff. The fareboxes are under the manufacturer's warranty; warranty labor costs are not included in these costs. The weekly salary includes base salary plus overtime.

TABLE 8-3. SEPTA FAREBOX MAINTENANCE LABOR COSTS

Labor Category	Weekly Salary ($)	Number of Positions	Total Weekly Salaries ($)	Salaries Plus Fringe* ($)
Foreman	461	3	1,383	$1,867
Specialist	422	3	1,266	1,709
Maintainer	364	22	8,008	10,811
Total Weekly Labor Cost				14,387
Number of Operating Fareboxes				1,750
Average Weekly Maintenance Labor Cost Per Farebox				8.22

* Labor costs are based on 1983 salaries paid to maintenance staff. Fringe benefits are estimated at 35 percent of salaries. The weekly salary for Maintainers includes overtime of 10 hours per week.

Table 8-4 summarizes the materials costs of farebox maintenance incurred at SEPTA, where the warranty has expired. On a per farebox basis, these costs amount to approximately $1.80 per farebox per week. At MSBA, the manufacturer's warranty is still in effect, and material costs are lower per farebox. Table 8-5 shows the average weekly materials costs per farebox at MSBA.

TABLE 8-4. SEPTA FAREBOX MAINTENANCE MATERIALS COSTS (1983 DOLLARS)

	Average Weekly Cost
Weekly Stock Materials* Cost	$ 180.00
Weekly Non-Stock Materials Consumed	2,962.00
Total Weekly Materials Cost	$3,142.00
Number of Operating Fareboxes	1,750
Weekly Materials Cost Per Farebox	$1.80

* Stock materials include materials normally stocked by the transit system. Non-stock materials are parts, components and materials required only for the electronic registering fareboxes.

TABLE 8-5. MSBA FAREBOX MAINTENANCE MATERIALS COSTS (1983 DOLLARS)

	Average Weekly Cost*
Shop Supplies, Parts, Hardware, Solder Wire, and All Other Materials Used in Farebox Maintenance	$212.00
Number of Operating Fareboxes	317
Average Weekly Materials Cost Per Farebox	$0.67

* Weekly costs represent an average over the first five months of 1983. Equipment is under manufacturer's warranty; warranty work is not included in these costs.

Table 8-6 shows the estimated weekly farebox maintenance costs including parts and materials, for both transit systems.

TABLE 8-6. ESTIMATED WEEKLY FAREBOX MAINTENANCE COSTS WHILE EQUIPMENT IS UNDER THE MANUFACTURER'S WARRANTY (1983 DOLLARS)

Item	SEPTA	MSBA
Maintenance Labor Per Farebox	$8.22	$15.33
Parts and Materials Per Farebox	1.80	.67
Average Weekly Maintenance Cost Per Farebox	$10.02	$16.00

9. RECOMMENDATIONS

This chapter presents recommendations for improvements in farebox procurement, design and operations that have been made by transit system operators managers, maintenance supervisors and bus drivers. A recommended farebox evaluation methodology is also presented.

RECOMMENDATIONS FROM TRANSIT SYSTEM MANAGERS FOR FAREBOX PROCUREMENT AND MANAGEMENT

Throughout interviews for this study, the transit system managers made a number of recommendations for the successful management of electronic fareboxes. Three revenue collecting managers commented that all aspects of farebox operations should be contained within one organization or department so that farebox problems will receive adequate attention and monitoring. All of the transit systems acknowledge the importance of inculcating electronics training and skills into the farebox maintenance staff. Other key recommendations made by the transit system managers are the following:

- Provide Adequate Top Management Attention. The purchase and operation of electronic registering fareboxes should be well integrated into the transit system's entire operation. The top management should be extensively involved, as well as the financial, operations, administration, purchasing and maintenance managers.

- Monitor Production Quality. The transit system should send electronics supervisors or technicians to monitor the farebox quality assurance testing and to observe or work on the farebox production assembly line. This will allow the transit system to oversee the production quality as well as familiarize the staff with the farebox design.

- Maintain Sufficient Spare Parts. To keep the fareboxes operating, a sufficient supply of spare parts should be provided; particularly, coin mechanisms, coin separator (grass) wheels, photo transistors, LED's, bill transport belts, switches and cashbox keys.

- Provide Good Working Space. Farebox technicians need a quiet, well-lighted, clean and secure area for maintenance activities and parts storage. Electronics test benches and other necessary tools should be provided if needed.

- Install Detailed Farebox Reporting System. A good data reporting system should be provided to monitor farebox failures and maintenance actions to the component level. Warranty claims can thus be supported and management can track the effectiveness of farebox repairs and maintenance.

- Provide Key Security. Good security should be maintained for cash vaults and receiver keys. The key inventory can be computerized.

- Second Source Spare Parts. Farebox maintenance managers generally agree that spare parts and materials can be obtained more cheaply from independent suppliers than from manufacturers. They recommend that parts such as integrated circuit chips, connectors, pins, and as many mechanical parts as possible be sourced from alternate suppliers.

FAREBOX DESIGN IMPROVEMENTS RECOMMENDED BY TRANSIT MAINTENANCE MANAGERS AND DRIVERS

The farebox maintenance managers and supervisors have considerable experience in troubleshooting farebox failures. Many have requested modifications to the farebox based on their experience with failures and diagnostic tests. This section summarizes the principal recommendations that were made by maintenance managers and bus drivers at the transit systems.

- Recommendations from Maintenance Managers. The maintenance managers are mainly concerned with reducing the frequency of failures in the coin mechanism and the electronic chassis, and improving the security of the farebox housing. Their recommendations are summarized in Table 9-1. The recommendations include providing more clearance for the bent coin release lever, eliminating problems in the chassis software which cause farebox power downs, and relocating the chassis power distribution board outside the chassis to reduce heat build-up. Suggestions regarding the farebox housing include building the farebox base out of steel rather than fiberglass, providing a tighter fit between the farebox lid and the

TABLE 9-1. RECOMMENDATIONS FROM TRANSIT SYSTEM MAINTENANCE MANAGERS FOR IMPROVING FAREBOX OPERATION

Component	Recommendations
Coin Mechanism	. Provide stronger connectors on the coin mechanism. The existing connectors are too short and break off easily. . Improve the life of the battery in the coin mechanism. Provide more clearance for the bent coin release lever. The current clearance is insufficient for effective coin release.
Electronic Chassis	. Improve the fuse design on the power module. The fuse should be glass and encased in a sturdy connector housing. . Change the chassis software to reduce farebox power downs when fluctuating voltage spikes occur. . Relocate the chassis power distribution board outside the chassis to reduce heat buildup in the chassis. . Improve the accuracy of data transmission through the data transfer probe.
Bill Transport	. Redesign the bill deflector chute to prevent bills from collecting in the top of the farebox outside of the cash vault.
Driver Keypad	. Improve the design of the push button assembly to reduce corrosion. The corrosion currently develops around the copper prongs between the connector and the push button assembly. . Provide an improved keypad design that is impervious to coffee spills, dirt and dust.
Farebox Housing	. Reseat the screw mounts in the base of the farebox. These screw mounts may be stripped when removing the bolts after they have been frozen and corroded with salt and water. . Build the farebox base out of steel rather than fiberglass so the farebox can't be torn or cut out of the bus. . Relocate the tone alerting device housing inside the farebox to protect it from dents and breakage by passengers. . Provide a tighter fit with less tolerance between the farebox lid and the coin mechanism. The lid is made of a soft metal and the screw holes can strip out. . Deepen the notch on the coin register bypass spring. The spring can jump off the notch when the bus experiences a strong jolt or drives over a pothole.

coin mechanism and deepening the notch on the coin register bypass spring.

- Recommendations from Bus Drivers. The principal comment from the bus drivers was the need for a larger coin insert area that will permit the deposit of several coins at once without sticking in the throat of the coin receiver. Other recommendations included providing a backspace on the keypad to allow the correction of data entry errors, changing the tone of the audible beep (some say it is too high pitched, others say it is too loud), and moving the data display so the driver can record the readings without leaving the driver's seat. The driver's recommendations are listed in Table 9-2.

RECOMMENDED FAREBOX EVALUATION METHODOLOGY

A farebox evaluation is often performed prior to the final farebox procurement and the monitoring of farebox performance also continues after the fareboxes are installed and operating.* One approach to farebox evaluation involves defining an evaluation plan and detailed performance criteria, conducting farebox performance tests, and collecting data on farebox performance. Specific activities to be accomplished as part of a farebox evaluation are described in the paragraphs that follow. The methodology may be used for farebox evaluations conducted both before and after the equipment procurement.

- Develop a Plan and Schedule for Conducting the Testing. The farebox evaluation and test plan should specify the organizational responsibilities for performing and managing the tests, including accounting, operations, public awareness, planning and maintenance functions. The plan should set forth the test objectives and schedule. It should define the test and evaluation procedures to be used, the equipment/material requirements and personnel requirements for as many as four types of evaluation tests:

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* Pre-procurement testing has been performed by some transit systems to determine whether the selected farebox could provide the reliability needed for revenue service. If a supplier manufactures a farebox with demonstrated and proven reliability, then this step of pre-procurement testing may not be necessary. Such testing is costly to both the transit system and the farebox manufacturer.

TABLE 9-2. RECOMMENDATIONS FROM TRANSIT BUS DRIVERS FOR IMPROVING FAREBOX OPERATION

Component	Recommendations
Coin Mechanism	• Provide a larger coin insert with a large chute to permit the deposit of several coins at once without them being stuck in the coin mechanism. Provide a gradual slide through the mechanism so that coins that are stuck together will separate. • Improve the bent coin unjamming mechanism - the current lever often does not work. • Coins can get stuck horizontally in the throat of the coin receiver - the unjamming mechanism should be modified to remove this type of jam.
Electronic Chassis	• Provide a better seal between the glass and the data readout to prevent dust from accumulating and obscuring the displays. • Speed up the end-of-run summary displays -- they take too much time.
Bill Transport	• Provide a bill transport control to enable the operator to hold the conveyor or back it up before the bill is moved down into the vault. This would prevent wrinkled bills from jamming the bill transport. • Make the bill entry slot wider.
Driver Keypad	• Provide a backspace on the keypad for correcting data entry errors.
Farebox Housing	• Change the tone of the audible beep -- the current tone is too high. • Provide a volume adjustment for this beep. • Move the data readout display to the driver's side of the farebox so the driver can record the readings without leaving the driver's seat. • Provide a display of the deposited fare in public view so that social pressure will motivate passengers to pay the correct fare.

- Installation and checkout tests

- Acceptance tests

- In-service tests (2 to 3 month testing of fareboxes in revenue service)

- On-going monitoring after fareboxes are installed.

• Establish a Set of Farebox Performance Measures and Criteria by Which the Farebox Can Be Evaluated. Farebox evaluation measures should be established to assess farebox data transmission reliability and accuracy, component reliability, revenue counting accuracy and overall farebox maintainability, security, and productivity. Examples of comprehensive evaluation measures are presented in Table B-1 in the appendix. The feasibility of adopting a specific measure will depend upon the availability of accurate data. The list in Table B-1 is too broad for one farebox evaluation study; those measures that are most relevant to the objectives of the transit system in selecting electronic fareboxes should be adopted for use in the evaluation methodology. If possible, the evaluation measures and any related performance criteria should be published in the farebox equipment specification.

• Develop Test Data Forms to Document the Test and Evaluation Results. Structured data collection forms such as those shown in Figures B-1 through B-5 in the appendix should be developed for use during the farebox evaluation. The more detailed the data that is collected, the clearer the evaluation results will be.

• Conduct the Tests and Collect and Analyze the Evaluation Data. Conducting the evaluation will involve monitoring the farebox installation, acceptance and in-service tests and collecting as much detailed data as possible on farebox performance during the tests. Re-tests following manufacturer adjustment of equipment may be permitted in selected cases. Supervisors should periodically inspect the operation of all fare system equipment including the vault receivers, data plugs, printers, cassette recorders and revenue bins. Observers should be assigned to occasionally travel bus routes to observe farebox performance and record any passenger difficulties in using the system. Notes on all observations should be recorded in test logs. Driver trouble reports and maintenance action reports should be checked approximately twice a week to ensure that consistent data reporting quality is maintained. Summary tabulations of the farebox performance and accuracy data should be prepared weekly to identify trends or problems with equipment operation/maintenance or counting accuracy. Mean time to repair and mean time between failure measures should be updated weekly and placed on trend charts for monitoring equipment performance throughout the test period.

APPENDIX A

FAREBOX MAINTENANCE AND REPAIR PROCEDURES

TABLE A-1. STEPS TO GAIN ACCESS TO MAJOR FAREBOX COMPONENTS

Farebox Component	Steps Required to Gain Access to Each Component*	Mean Minutes to Gain Access
Coin Mechanism	1. Open top of farebox with key. 2. Remove the 2 screws from the coin mechanism bracket. 3. Unplug the driver's display. 4. Unplug the 2 wires to the motor. 5. Lift out the coin mechanism and motor. 6. Unplug the ribbon harness.	5
Electronic Chassis	1. Open top of farebox with key. 2. Remove the P-2 plug to the power harness (only in cases where the power harness is exterior to the electronic chassis). 3. Remove the 2 plugs for the card reader harness (only if a card harness is provided). 4. Remove the harness plug for the motors. 5. Slide chassis up and out of farebox frame. 6. Disconnect power cord at bottom of chassis.	10
Bill Transport	1. Open top of farebox. 2. Remove coin mechanism (see steps above). 3. Remove chassis (see steps above). 4. Remove the top cover lock. 5. Remove the 3 screws holding the bill transport and loosen the 3 nuts. 6. Disconnect the motor connects from the harness. 7. Unplug the harness to the microswitch on the bill transport.	20

* See footnote on page A-4.

TABLE A-1. CONTINUED

Farebox Component	Steps Required to Gain Access to Each Component*	Mean Minutes to Gain Access
Driver Keypad	1. Remove the 4 security screws attaching the keypad to the farebox. 2. Lift out the keypad and disconnect the interconnecting plug.	15
Cash Vault	1. Place vault key in lock. 2. Open farebox lower stanchion door. 3. Remove cash vault.	1/2

* These steps are required to gain access to the farebox components at the Metropolitan Suburban Bus Authority (MSBA) in East Meadow, New York. Steps to gain access to other fareboxes are similar.

TABLE A-2. FAREBOX PREVENTIVE MAINTENANCE PROCEDURES

Component	Farebox Preventive Maintenance Procedures
Coin Mechanism	Remove the coin mechanism. Check the grass wheel, hub, sensor area, coin reader and ribbon wire. Clean or replace the grass wheel. Blow out the coin mechanism with compressed air, relube the gear, check the wire solder joints and reassemble.
Electronic Chassis	Remove chassis from farebox. Clean the face plate and data display, check for loose hardware, tighten connections, check battery voltage, check all software operations.
Bill Transport	Remove the bill transport. Remove the plexiglass cover. Check the microswitches and transport belt for adjustment and wear. Clean and check all gears. Lube the gears. Clean the display window, dump door and glass. Inspect bill receiver for alignment and clearance. Check the motor. Check bill transport operation.
Driver's Keypad	Remove keypad and blow buttons out with compressed air. Check for damaged or binding buttons, clean and lubricate the console and replace assembly.
Cash Vault	Remove vault. Check lock. Examine tumblers for damage or wear. Check bottom plate to see that it slides in and out without binding. Check for cracks in housing. Make adjustments or lubricate as required.
Farebox Housing	Clean the exterior with a gentle polishing fluid and a nylon pad. Use glass cleaner to clean the glass or plexiglass windows. Check the top cover for fit and replace screws if necessary.

TABLE A-3. TYPICAL FAREBOX COMPONENT REPAIRS

Farebox Component	Typical Repair Steps	Mean Minutes to Repair
Coin Mechanism	1. Disassemble the coin mechanism. 2. Blow out coin mechanism, clean the grass wheel, check circuit board wires at the solder joint, relubricate the gears. 3. Check motor operation. If faulty, replace the motor. 4. Use a test bench to check counting accuracy. If not counting properly, check the L.E.D.'s and phototransistor. Make replacements as necessary. 5. Check interconnecting cables. Replace as necessary.	30 - 60
Bill Transport	1. Remove bill transport from farebox. If there is a paper jam under the plexiglass, remove the plexiglass and take out the jam. 2. Check microswitches. Adjust. Replace as necessary. 3. Check and adjust belt. 4. Check motor. 5. Test the bill transport on a test stand to verify that all components work.	30

TABLE A-3. CONTINUED

Farebox Component	Typical Repair Steps	Mean Minutes to Repair
Electronic Chassis	1. Remove chassis from farebox. 2. Go through trouble-shooting procedures with test stand or microprocessor. 3. Replace EPROM, circuit board or connectors as required.	30 - 60
Driver Keypad	1. Remove keypad from farebox. 2. Remove and replace the push button panel.	15
Cash Vault	1. Rebuild or replace the lock assembly. 2. For a jam inside the vault, remove the locking rod and send to manufacturer for straightening and repair. 3. Repair cracks in vault housing.	30 - 90

APPENDIX B

FAREBOX PERFORMANCE MEASURES AND DATA COLLECTION FORMS

TABLE B-1. PERFORMANCE MEASURES FOR ELECTRONIC REGISTERING FAREBOXES

Performance Area	Measure	Data Source
Accuracy	Accuracy and repeatability of farebox in revenue operation: • Accepts and counts coins • Accepts and counts small and large tokens • Accepts and records bills • Displays correct value of fare paid • Signals payment of full fare • Records and displays passenger count, date, time, location, route, run, other required information	Transit system records on farebox accuracy
	Accuracy and repeatability of farebox in performance tests: • Accepts and counts coins • Accepts and records bills • Displays value of fare paid • Signals payment of full fare • Records and displays passenger count, date, time, location, route, run, other required information	Performance test results, route observations
	Accuracy of equipment in transferring data electronically from farebox to a central collecting point	Observations of data transfer, transit system treasurer
	Rate of consumer complaints about inaccurate fare registering	Complaint records
	Accuracy of the revenue sums (total coins and paper collected)	Transit system records, on-site observations

TABLE B-1. CONTINUED

Performance Area	Measure	Data Source
Maintainability	Ratio of fareboxes to farebox maintenance technicians	Maintenance manager and records
	Farebox maintenance technicians as percent of total maintenance technicians	Maintenance manager and records
	Frequency of failures that are repairable by Level 1 (fingertip) maintenance	Maintenance manager, performance tests
	Frequency of failures that are repairable by Level 2 (replacement or adjustment of components) maintenance	Maintenance manager, performance tests, maintenance records
	Mean time to repair	Maintenance records, performance test results
	Number and frequency of warranty repairs	Warranty records
	Number and frequency of repairs after warranty is exhausted	Maintenance records
	Number of hours of additional training needed per farebox maintenance technician	Training records
	Accessibility to circuit boards and other replacement parts	Maintenance manager, farebox repair manual
	Cost per farebox of special facilities, tools, spares needed for maintenance	Maintenance cost records
	Total maintenance cost per farebox	Maintenance cost records

TABLE B-1. CONTINUED

Performance Area	Measure	Data Source
Security	Number and types of security controls in use	Security manager
	Estimated revenue loss due to pilfering	Transit system treasurer
	Number of incidents of attempted thefts and skimming by transit employees	Transit system records
	Number of farebox burglaries/break-ins	Transit system records
	Number of feasible ways to intentionally jam the farebox	Maintenance technician interviews, performance tests
	Number of unauthorized ways to extract money from the farebox or vault	Security manager
	Number of labor hours per farebox expended in farebox security	Maintenance labor records
	Total security cost per farebox	Security cost records
	Effectiveness of farebox in signalling driver when underpayment occurs	Security cost records, on-site observations

TABLE B-1. CONTINUED

Performance Area	Measure	Data Source
Reliability	Mean total transactions* between farebox failures: • Mean transactions between vault emptying jams • Mean transactions between bill entry jams • Mean transactions between L.E.D. display failures • Mean transactions between coin jams • Mean transactions between incorrect coin counts • Mean transactions between failures of the keyboard and related electronics	Farebox maintenance records
	Age of farebox versus mean transactions between failure	Farebox maintenance records
	Number of road calls for farebox failures (if performed)	Coach service records
	Number of transactions per farebox maintenance action	Farebox maintenance records
	Rate of torn or mutilated bills	Fare collection records; mutilated bills as a percent of daily revenues

* Transactions include the following types of fare collections: single zone fare, multiple zone fare, transfer, coins only, coins and tokens, coins and paper (bill or transfer), bill(s) only, tokens only.

TABLE B-1. CONTINUED

Performance Area	Measure	Data Source
Productivity	Time required for fare to be counted and registered on farebox	Performance test results
	Dwell time per boarding passenger/average dwell time per stop	Performance test results or transit system records
	Average waiting time per bus for farebox vault collections	Transit system records or on-site observations
	Amount of improvement in transit system fare accounting productivity due to electronic registering fareboxes	Transit system comptroller

Data Source: ____________

Date: ____________

1 Date of Accuracy Audit	2 Serial Number of Farebox Checked for Counting Accuracy	3 Total Revenues Registered In Farebox	4 Manually Counted Revenues	5 Revenue Amount Transmitted to Printer	6 Counting Accuracy (Difference Between Columns 3 & 4)	7 Transmission Accuracy (Difference Between Columns 4 & 5)

FIGURE B-1. FAREBOX ACCURACY IN REVENUE COUNTING AND TRANSMISSION DATA COLLECTION FORM

Data Source: ______________

Date: ______________

Farebox Serial Number	Failure Description	Date	Mean Total Transactions Before Failure	Operating Days Before Failure	Number of Occurrences of Each Type of Failure To Date

FIGURE B-2. FREQUENCY OF FAREBOX FAILURES DATA COLLECTION FORM

Data Source: ______________

Date: ______________

Farebox Module	Number of Module Failures Since Farebox Installation	Total Farebox Transactions Since Farebox Installation	Mean Transactions Between Module Failures	Number of Days for Which Farebox Performance Data is Available	Mean Operating Days Between Module Failures
Coin counter					
Bill transporter					
Electronics					
Upper frame (LED, Dump & Shift Buttons)					
Keyboard					
Stanchion/cash box					
Base plate					

FIGURE B-3. FREQUENCY OF FAREBOX MODULE FAILURES DATA COLLECTION FORM

Data Source: ______________

Date: ______________

1 Maintenance Staff Category	2 Total Number of Maintenance Staff	3 Total Number of Farebox Maintenance Staff	4 Total Fareboxes	5 Ratio of Fareboxes to Farebox Maintenance Staff	6 Farebox Maintenance Staff as Percent of Total Equipment Maintenance Staff	7 Comments
Maintenance supervisors						
Mechanics						

FIGURE B-4. FAREBOX MAINTENANCE STAFF DATA COLLECTION FORM

720 copies

Data Source: ____________

Date: ____________

Preventive Maintenance Procedures and Costs

Preventive Maintenance Procedure	Mean Hours to Perform Each Procedure	Preventive Maintenance Labor Grade	Total Labor Hours per Labor Grade	Parts and Materials Required for Each Maintenance Action	Parts and Materials Costs

FIGURE B-5. PREVENTIVE MAINTENANCE PROCEDURES AND COSTS DATA COLLECTION FORM

Evaluation of electronic registering fareboxes

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