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Department of Transportation
Urban Mass Transportation Administration

Assessment of a New Type of Coin Acceptor

Prepared by:
Transportation Systems Center

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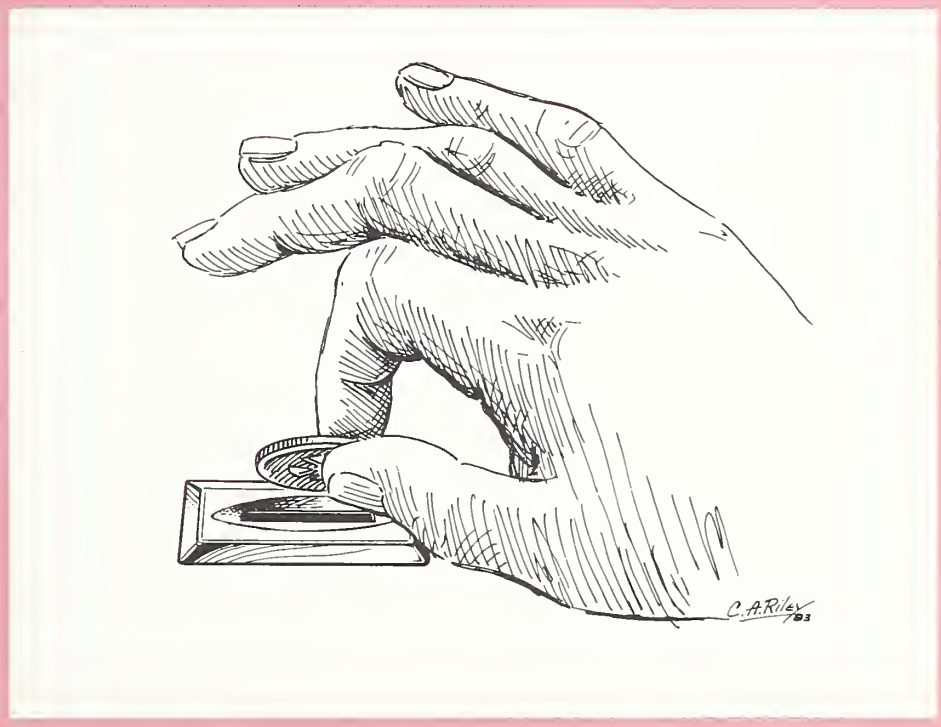

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U.S. Department
of Transportation

**Urban Mass
Transportation
Administration**

Assessment of a New Type of Coin Acceptor

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PREFACE

This study is part of the continuing research in the areas of automatic fare collection equipment performance and data base development supported by the Transportation Systems Center (TSC) and the Urban Mass Transit Administration (UMTA). Specifically, this report documents the performance of the Mars Money Systems, Inc. CD 540-1 electronic coin acceptor in use at the Port Authority Transit Corporation (PATCO).

The need for this study was determined by representatives from the rail transit properties in the United States. These representatives are members of the American Public Transit Association (APTA) Fare Collection Reliability Liaison Board for the fare collection project being conducted by the Transportation Systems Center. The objective of the project is to improve the effectiveness of fare collection systems that satisfy specific transit property needs. At project meetings, activities such as this study are identified and carried out as part of a comprehensive approach to meet the project's objective.

The following individuals were significant contributors to this assessment:

George C. Paxson - Port Authority Transit Corporation
David Heimann - Transportation Systems Center
Joseph S. Koziol - Transportation Systems Center

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SUMMARY

An assessment of Automatic Fare Collection (AFC) equipment, specifically the Mars Money Systems model CD 540-1 coin acceptor associated with farecard vendors, was conducted at the Port Authority Transit Corporation (PATCO). The assessment was based on data provided by PATCO for their second accounting period, a 28 day interval of time spanning January 24 through February 20, 1982.

Two basic types of data were considered: failure data and transaction data. Transaction data measures the usage of a coin acceptor in terms of the number of coins inserted. Failures due to a malfunction of the acceptor were included in this assessment. Those attributed to non-machine faults, i.e., bent coins, foreign objects, etc. were excluded.

During the time of the assessment, PATCO had four different coin acceptors in use with their 61 farecard vendors; 1,395,948 transactions and 82 failures were encountered by the coin acceptors as presented in the following table.

Coin Acceptor	No. In Service	% of Total Transactions	% of Total Failures
Mars CD 540-1	39	57	11
Mars Mark V	4	7	17
National Rejector	3	8	21
Sesko	15	28	51

Since fare collection equipment does not operate continuously and usage rates vary significantly, time is not the best measure of performance. Reliability and transactions per failure statistics are used as the primary measures. Performance measurements using time are included for completeness.

The reliability of the Mars CD 540-1 was measured at 88,562 MTF based on 797,064 transactions. MTBF was 2912.0 hours.

Availability data for the Mars CD 540-1 was based on the 28 day accounting period and was 99.96 percent.

Maintainability figures were computed for the accounting period for the CD 540-1. The average down time (ADT) was 46 minutes. The elements of ADT, active repair time and technician response time averaged out to be 16 and 30 minutes, respectively.

PATCO's experience with the Mars CD 540-1 coin acceptor indicates that the unit consistently outperforms the other coin acceptors in the farecard vendor system. Furthermore, the MTF measured for the CD 540-1 exceeded the average MTF measured for coin acceptors during a 1980 survey[1] conducted at PATCO by a factor of 10 (88,562 MTF vs. 8,681 MTF). Since preventative maintenance requirements for the MARS CD 540-1 are not greater than those for the other coin acceptors, the unit provides PATCO with a means for lowering operating costs while improving service to passengers.

The table below is a summary comparing the system's average performance with the MARS CD 540-1 performance. In all tests conducted, the CD 540-1 performance was substantially better than the system's average.

SUMMARY MARS CD 540-1 PERFORMANCE VS. SYSTEM AVERAGE PERFORMANCE
(January 24 - February 20, 1982)

	System Average	MARS CD 540-1
Number of Coin Acceptors	61	39
Number of Transactions	1,395,948	797,064
Reliability (R)	.99994	.99999
Mean Transactions per Failure (MTF)	17,023	88,562
Mean Time Between Failures (MTBF)	499.0	2912.0 Hours
Availability	99.83%	99.96%
Average Down Time (ADT)	49.2	48.3 Minutes
Failures per 100,000 Transactions	5.8	1.1

[1]"An Assessment of PATCO's Automatic Fare Collection Equipment". Interim Report; February, 1981.

1.0 INTRODUCTION

This report presents the findings of an assessment of reliability, availability and maintainability for coin acceptors associated with farecard vendors at the Port Authority Transit Corporation (PATCO).

1.1 Background

For many years there has been a trend by rail properties to increase automation in fare collection[1]. Automation was considered to be the solution to many problems, i.e.:

1) high costs due to the need for station attendants
2) fraud potential due to personnel handling revenue
3) inflexible pricing of fares
4) inefficient channeling of patrons through transit stations
5) unfair distribution of costs and revenues to local communities
6) poor passenger and revenue statistics

Unfortunately, transit properties have not experienced the optimum performance anticipated with the available automatic fare collection equipment. The reliability of the commercially available components including coin acceptors has been extremely low and has resulted in costly repairs and service disruptions due to the severe environmental conditions and service rates in transit systems. The available fare collection equipment, for the most part, has evolved from the merchandise vending industry where environmental conditions are less severe and volume lower than encountered in the transit industry. Since transit requirements are different and more critical in terms of impact on the patron, fare collection equipment should be designed and produced to meet the specific transit requirements.

[1] "Status Report on DOT's Fare Collection Project", Report No. UM-204-PP-82-5.

UMTA in an attempt to address issues and problems associated with rail transit fare collection systems has initiated a cooperative project with the transit industry. The objective of this project is to improve the effectiveness of fare collection systems that meet specific transit system needs, maximize revenues and minimize costs. The thrust of the project is to gather, generate and disseminate information to assist the transit properties in making investment decisions in regard to the selection of fare collection equipment that best meets their needs.

This report documents the performance of a new coin acceptor--a critical element in fare collection systems. Typically coin acceptors in transit applications have had low reliability as determined from past studies. The coin acceptor evaluated in this report had been recently deployed on the PATCO Hi-Speed line and is manufacturered by MARS.

1.2 Port Authority Transit Corporation

The Port Authority Transit Corporation (PATCO) Hi-Speed line began operations in 1969, servicing 13 stations (shown in Figure 1-1) on a 14.2 mile line that spans downtown Philadelphia, PA and Lindenwold, NJ.

PATCO is one of the most modern transit systems in the country. It was designed to operate with unmanned stations. Equipment had to be specified that did not require the services of a station attendant. The transit passenger had to be able to operate the equipment without any aid. PATCO's fare collection equipment consists of farecard ticket vendors, automatic gates, transfer dispensers, and dollar bill changers.

The ticket vendors were designed by Advanced Data Systems. Magnetically encoded tickets for one and two rides that correspond to established zone fares are dispensed by PATCO's 61 vendors. At the time of this study, four different coin acceptors were utilized in these 61 vendors: Mars Money Systems CD 540-1 units were used in 39 vendors; Mars Money Systems Mark V units were used in 4 vendors; National Rejector units were used in 3 vendors; and Sesko units were used in 15 vendors. All of the Mars CD540-1 acceptors are set-up to accept nickels, dimes, quarters and the Susan B Anthony dollar.

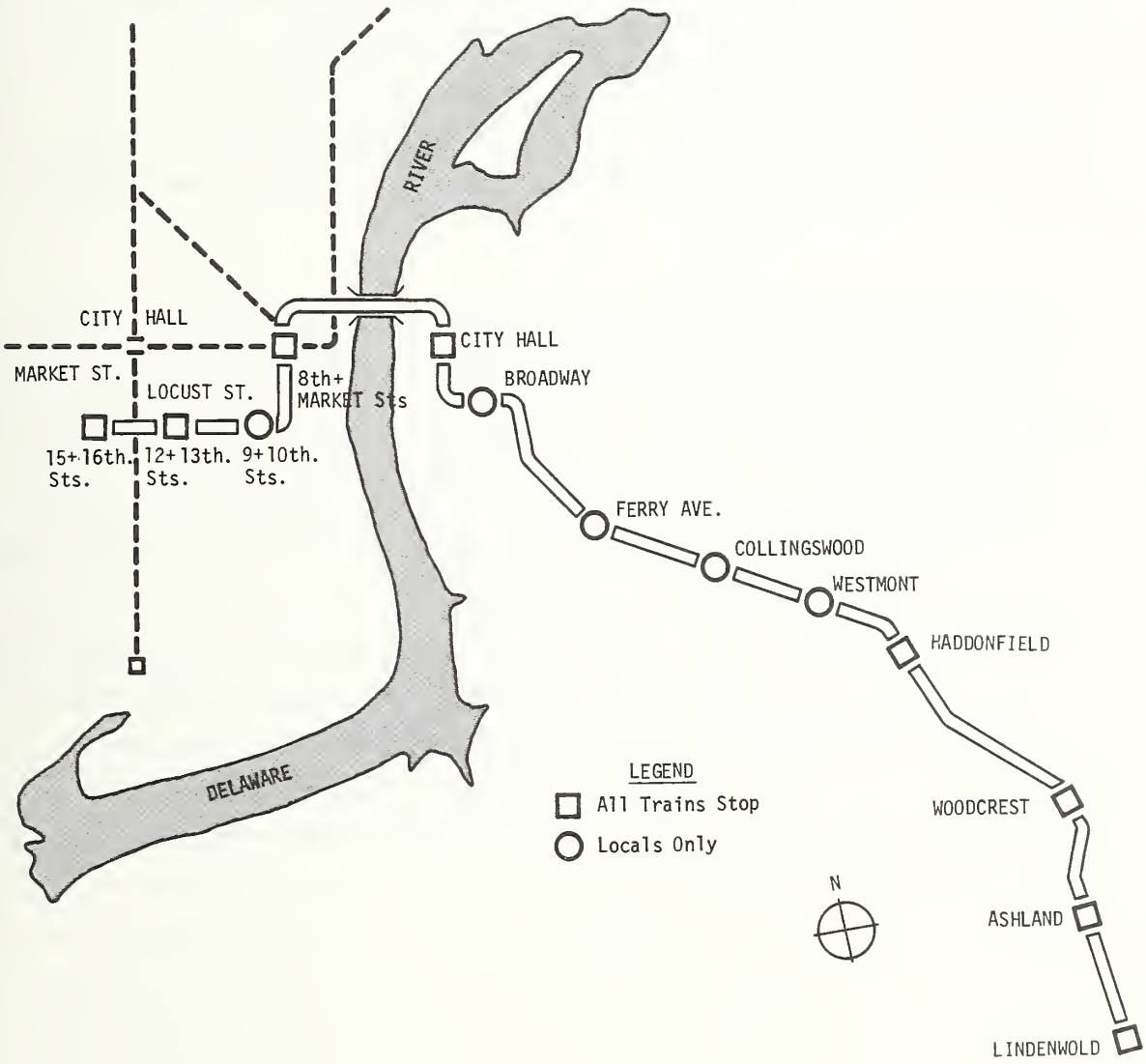

Figure 1-1. PATCO SYSTEM MAP

1.3 Coin Acceptors

Coin acceptors are found in ticket vendors and change makers and often are utilized in turnstiles.

Coin acceptors used in conjuction with turnstiles have speed of operation as a paramount requirement. A slug now and then is not considered to be a critical problem in the turnstile. In regard to change makers and ticket vendors, transit properties are very concerned with revenue losses. Therefore, the critical functional requirement of coin acceptors used for these purposes is high accuracy.

In coin changers which include escrow and change return functions, coin acceptors are an integral subcomponent. Many of the coin acceptors utilized in automatic fare collection systems are modified versions of those used in commercial vending equipment. Reliability/performance of coin acceptors in a variety of fare collection equipment has been less than satisfactory as determined by past studies for the fare collection project.

Table 1-1 presents reliability data, collected in 1979 and 1980, for coin acceptors used in conjunction with farecard vendors for three transit properties. PATCO experienced the greatest reliability with 8,681 mean transactions per failure. The increased use of farecard vendors--6 of the 14 transit authorities* make use of vendors,as portrayed in Table 1-2,--dictate a need for reliable coin acceptors.

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*Members of Fare Collection Reliability Liaison Board.

TABLE 1-1. COMPARISON OF COIN ACCEPTOR RELIABILITY FOR FARECARD VENDORS

Transit Property	Survey Date	Reliability (R)	Mean Transactions per Failure (MTF)
BART	1980	.9990	1,038(1)
PATCO	1980	.9999	8,681(2)
WMATA	1979	.9988	844(3)

(1) "Automatic Fare Collection Equipment Reliability and Maintainability Assessment Plan for Urban Rail Transit Properties" Report No. UMTA-MA-06-0025-81-1.

(2) "An Assessment of PATCO's Automatic Fare Collection Equipment" Interim Report; February 1981.

(3) "Assessment of WMATA's Automatic Fare Collection Equipment" Report No. UMTA-MA-0080-81-1.

TABLE 1-2. METHOD OF TICKET SALES[1]

AUTHORITY	STATION AGENT	VENDING MACHINES	OFF-STATION OUTLETS
MARTA			*
MBTA	*		*
CTA	*		*
GCRTA	*		*
NYCTA	*		
SEPTA	*		*
ICG	**	*	
PATCO	**	*	*
BART		*	*
WMATA		*	*
BALT		*	
LIRR	*		*
PATH	*		
MIAMI		*	

**Ticket agents at certain stations

[1]"Rail Transit Fare Collection Policy and Technology Assessment" Report No. UMTA-MA-06-0025-82-4.

2.0 EQUIPMENT DESCRIPTION

PATCO, at the time of this test, used four different coin acceptors in conjunction with farecard vendors, the National Rejector Model XL, a Sesko unit modified by PATCO and Mars models Mark V and CD 540-1.

2.1 National Rejector Coin (NRI) Acceptor

The NRI Model XL acceptor utilizes solid-state electronics; optical sensors replace most of the switches of earlier models. The model series 01-15, an all mechanical coin rejector, is used in conjunction with the model XL coin acceptor to route coins to the accepted or rejected coin chutes.

2.2 Sesko Coin Acceptor

The Sesko coin acceptor was manufactured by World Wide Engineering. The acceptor's price range is 5 cents to $1.95 maximum (exact change only), with two vend outputs. The method of reading coins is by coin sizing utilizing solid state logic which was designed by PATCO. Nixi tubes (lights) are used to display credit. The acceptor interfaces with a Rowe dollar bill verifier modified to hold a dollar bill in escrow - if sale is cancelled, the dollar bill is returned to the patron. Tickets are delivered by a rotary solenoid with a picker knife assembly. The coin escrow bucket is activated by a rotary solenoid.

2.3 Mars Mark V Coin Acceptor

The Mars Mark V is one of the earlier coin acceptors built by Mars Money Systems Inc. In this unit coin diameter is measured optically and thickness is measured by magnetic field.

2.4 Mars CD 540-1 Coin Changer (See Figure 2.1)

The MARS CD 540-1 is an electronic coin changer that utilizes pot core sensors, which are inductive loops, to electronically validate coins and optical sensors to detect the presence of coins. Many mechanical parts have

been eliminated as a result of the solid state technology employed. Thirty dollars and fifty cents are stored in escrow ($3.75 in nickles, $9.50 in dimes and $17.25 in quarters).

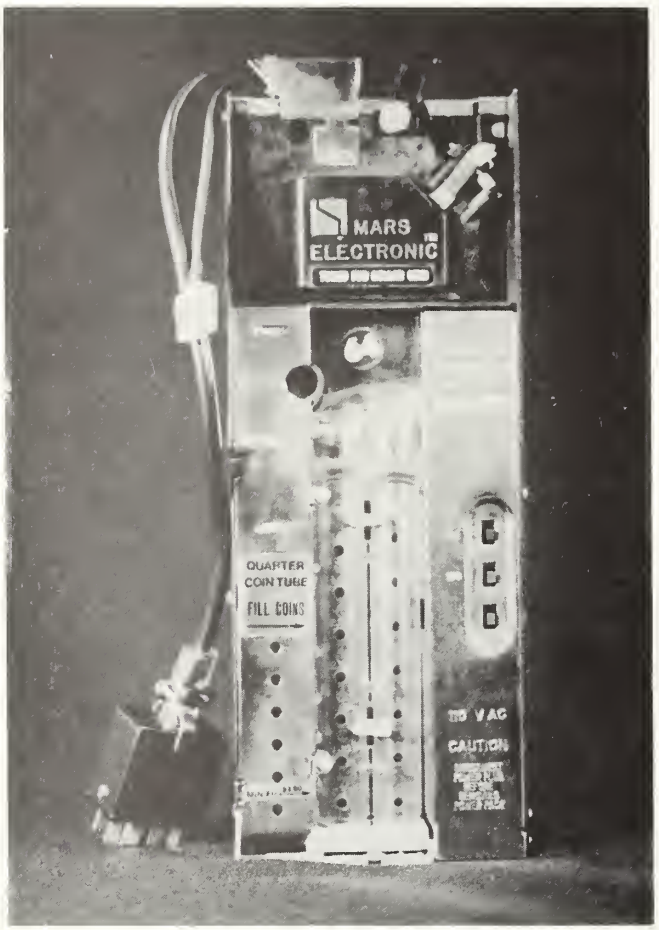

Figure 2.1. MARS CD 540-1

2.4.1 CD 540-1 Design

Modular construction has been used in the design of this changer. Each module has distinct functions that help simplify trouble shooting and repair. The five modules are:

1) Power Supply - provides electrical interface between vending machine and coin changer and source voltage required for changer operation.

2) Flight Deck - performs coin validation and recognition, pricing and credit accumulations. It contains a integrated circuit chip that provides all of the necessary control logic.

3) Cover Plate - contains two solenoid operated gates (the only two moving parts in the coin path) that separate coins for routing purposes. The "accept gate" accepts or rejects coins. The separator gate directs coins into coin tubes or cash box.

4) Coin Tube - stores coins for change (recycling). Separator windows sort coins by diameter. Low and high sensors monitor coin levels in the tubes.

5) Dispenser Assembly - pays out change. It pays back coins when exact change determination is made or when credit is cancelled.

2.4.2 CD 540-1 Operating principles (see Figure 2.2)

Coins inserted through the coin cup roll along a ramp that has three pot core sensors imbedded in the walls. Denomination and validity of a coin are verified by electronically testing the coins diameter, metal content and thickness.

A coin judged invalid by any of the sensors will not allow the "Accept Gate" to open and will be returned through the "Reject Chute". A coin judged to be valid by the sensor will allow the "Accept Gate" to open and the coin will enter into the separator section. The coins value is added to the accumulator section of the integrated circuit.

As the coin approaches the Separator Gate there are two possible paths to follow; direct to the cash box or to one of the coin tubes. The action of the "Separator Gate" is controlled by the coin levels in the coin tubes.

Once the vend price is reached or exceeded, a vend signal is sent to the vending machine and change will be paid out. At anytime, escrow return may be requested by depressing the coin return level. This lever sends a signal to the integrated circuit chip to cancel accumulated credit and return coin for coin escrow from the Dispenser Assembly.

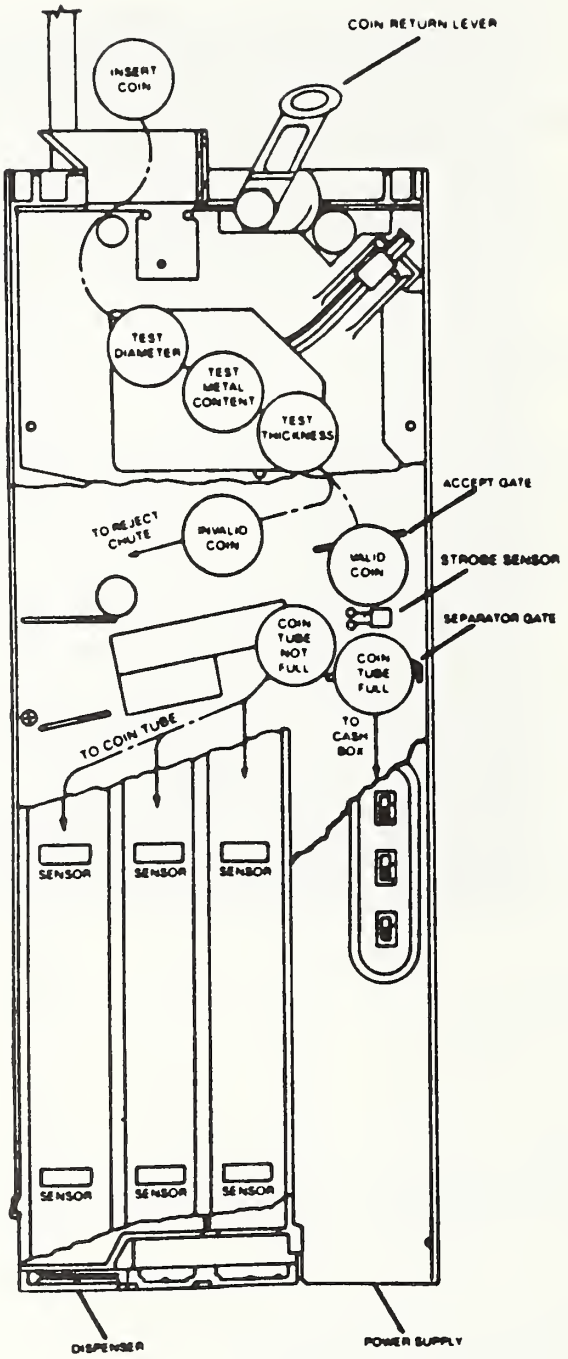

Figure 2-2. PICTORIAL OUTLINE CD 540-1

The coin tubes contain two sets of optical sensors monitoring the empty and full conditions for each denomination. The high (full) sensor directs the action of the Separator Gate: when the sensor is covered coins are directed to the cash box. The low (empty) sensor detects a correct change condition. The exact change light is never illuminated continuously. The changer will always accept coins. Vend price will be compared at the time of selection. If change can be paid with available coins, a vend will take place and change paid out. If change is not available the exact change light will illuminate for as long as a selection is maintained.

3.0 DATA COLLECTION

PATCO's business operations are based on 28 day accounting periods. The second accounting period of 1982 (January 24-February 20) was chosen for this assessment due to the fact that several Mars CD 540-1 coin acceptors were installed in mid-January. The second accounting period was the first in which all (39) Mars CD 540-1 units were installed and operational.

3.1 Transaction Data

Transaction data for all AFC equipment is collected daily by PATCO employees. The revenue department provided copies of their revenue collection work sheets. Appendix D contains sample revenue sheets for the second accounting period. Each work sheet is a daily tabulation of revenue at the machine (ticket vendor) level. Each farecard vendor has an alpha numeric code i.e., 621N, which in this case stands for vendor N, located at the 15th and 16th Street station.

A summary of the transactions for the second accounting period for all stations and vendors is as follows:

Revenue Distribution	Dollars	Transactions
Susan B. Anthony Dollars	$ 57,930.00	57,930
Quarters	183,172.00	732,688
Nickels	7,848.00	156,960
Dimes	41,877.30	418,773
Dollar Bills	29,597.00	29,597
	$329,424.00	1,395,948

All the dollar bills are obtained from the Sesko units which are interfaced with a Rowe dollar bill verifier.

Each coin or dollar bill is counted as a single transaction, bringing the total number of transactions for the test period to 1,395,948.

Transactions at the machine level may be found in Appendix A.

3.2 Failure Data

Failure data were provided by PATCO in the form of an automated report, from their "Maintenance Information System". See Appendix C for example. These data were compared with the maintenance technician's work report to assure completeness and proper interpretation. Only failures that were due to the malfunction of the revenue acceptor, e.g., coin jam, were included in this assessment. Failures due to bent coins, foreign objects, etc., (29 such failures) were not considered to be a machine problem and, therefore, were excluded.

4.0 COIN ACCEPTOR PERFORMANCE

The results of PATCO's coin acceptor performance is presented in this chapter. Reliability, availability and maintainability data for coin acceptors associated with ticket vendors are provided.

4.1 Reliability

Reliability is a primary measure of equipment performance that addresses the probability that specific equipment (coin acceptor in this case) will successfully accomplish the function it was designed for.

In general, more than one coin is required in the purchasing of a ticket. The number of coins inserted and accepted determines the number of successful transactions. The following formula may be used to estimate reliability based on transactions.

$$R = \frac{\text{Total Transactions - Total failures}}{\text{Total Transactions}}$$

Reliability may also be expressed as the mean transactions per failure or the mean time between failures.

$$\text{Mean transactions per failure} = \frac{1}{1-R}$$

$$\text{Mean time between failures} = \frac{\text{Total In-Service Time}}{\text{Total Failures}}$$

The above measures of reliability are used to assess the performance of PATCO's coin acceptors.

Overall system reliability as illustrated in Table 4-1 was calculated by summarizing the transactions and failures for each manufacturer. The average

Table 4-1

Comparison of Coin Acceptor Reliability by Manufacturer

Manufacturer	No. of Transactions	Reliability (R)	Mean Transactions per Failure (MTF)
Nation Rejector	104,791	.99984* (.999763, .999917)	6,164
Sesko	393,745	.99989* (.999657, .999923)	9,374
Mars Mark V	100,258	.99986* (.999786, .999933)	7,161
Mars CD 540-1	797,064	.99999** (.999988, .999997)	88,562
Average Reliability	1,395,948	.99994 (.999927, .999953)	17,023

Numbers enclosed in parentheses are 95% confidence intervals.

* Reliability significantly below system average at the 95% confidence level.

** Reliability significantly above system average at the 95% confidence level.

reliability is .99994 and the mean transactions per failure is 17,023. Figure 4-1 is a graphic presentation of MTF. The MARS CD 540-1 had an MTF of 88,562 which was significantly higher than all other manufacturers.

In order to determine if the reliability of the coin acceptors of the different manufacturers differed by chance or actually performed differently, a zI test was conducted. The test results indicate that the units of the various manufacturers do actually perform at different levels of reliability, i.e., some are significantly better than others.

A T-Test, was applied at the 95% confidence level to compare manufacturer performance with the system average. This test determines if a specified equipment is performing in an acceptable or unacceptable manner based on use and overall system reliability. The test results indicate that National Rejector, Sesko and the Mars Mark V acceptors had reliabilities significantly below the system average.

Table 4-2 presents mean time between failures (MTBF) for each manufacturer. MTBF ranged from a low of 118 to a high of 2912 with the system average of 499.0 hours. The average MTBF in this case is greatly influenced by the Mars CD 540-1 since it far exceeds the systems average. A T-Test was applied to this data, showing that the MTBF for the National Register, Sesko and Mars Mark V units were significantly below the system average at the 95% confidence level.

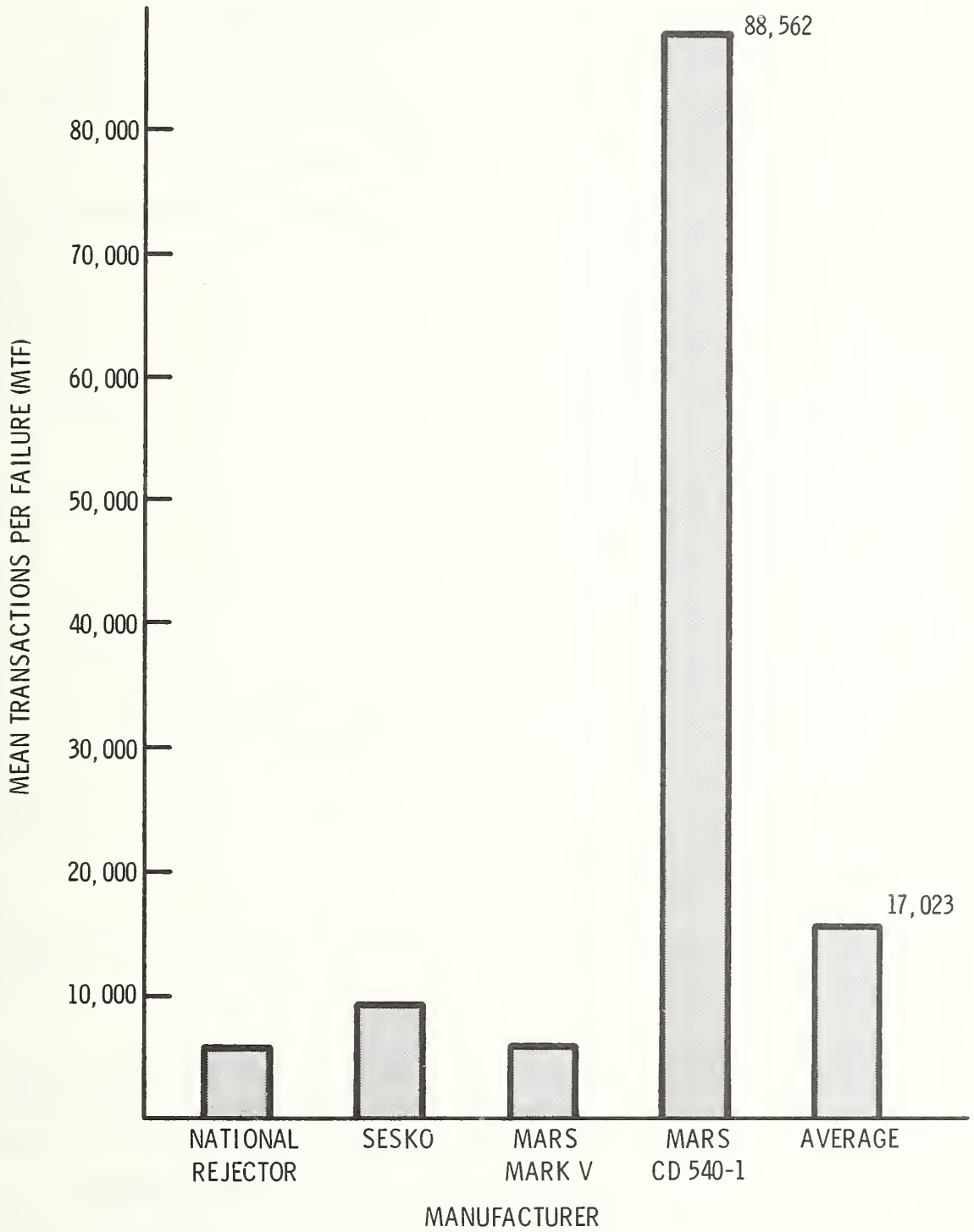

Figure 4-1. COMPARISON OF COIN ACCEPTOR RELIABILITY BY MANUFACTURER (DATA PERIOD JAN. 24 - FEB. 20, 1982)

Table 4-2. COMPARISON OF MEAN TIME BETWEEN FAILURES OF COIN ACCEPTORS BY MANUFACTURER

Manufacturer	Mean Time Between Failures MTBF (Hours)
National Rejector	118.59*
Sesko	240.0 *
Mars Mark V	192.0 *
Mars CD 540-1	2912.0 **
Average	499.0

* Significantly below average at the 95% confidence level

**Significantly above average at the 95% confidence level

4.1.1 Reliability - Mars CD 540-1

During the test period there were 39 Mars CD 540-1 coin acceptors in the PATCO farecard vendor system.

Table 4-3 presents reliability data by station. Seven of the eleven stations that use the CD540-1 acceptor experienced no failures. The station with the lowest reliability was 12th and 13th Streets, with a MTF of 24,995. A T-Test was applied at the 95% confidence level to examine differences between stations. The results indicated that the coin acceptor reliabilities at the individual stations do not differ significantly. The reason for this may be explained by the fact that there were over 797 thousand transactions for the Mars CD 540-1 coin acceptors and only 9 machine related failures were observed (1 each on 9 different vendors). Figure 4-2 is a graphical presentation of MTF's for the CD 540-1 units by station.

TABLE 4-3. COMPARISON OF MARS CD 540-1
COIN ACCEPTOR RELIABILITY BY STATION-OVERALL RELIABILITY

STATION	RELIABILITY (R)	MEAN TRANSACTION'S PER FAILURE (MTF)
15th & 16th Streets	1.00000	181,610/0*
12th & 13th Streets	.99996	24,995
9th & 10th Streets	1.00000	10,322/0*
8th & Market	.99997	37,504
City Hall	No CD 540-1 Units	
Broadway	No CD 540-1 Units	
Ferry	1.00000	37,274/0*
Collingswood	1.00000	60,438/0*
Westmont	1.00000	55,493/0*
Haddonfield	1.00000	79,199/0*
Woodcrest	.99997	35,706
Ashland	1.00000	48,191/0*
Lindenwold	.99999	76,318
Average	.99999	88,562

* No failures occurred at these stations.

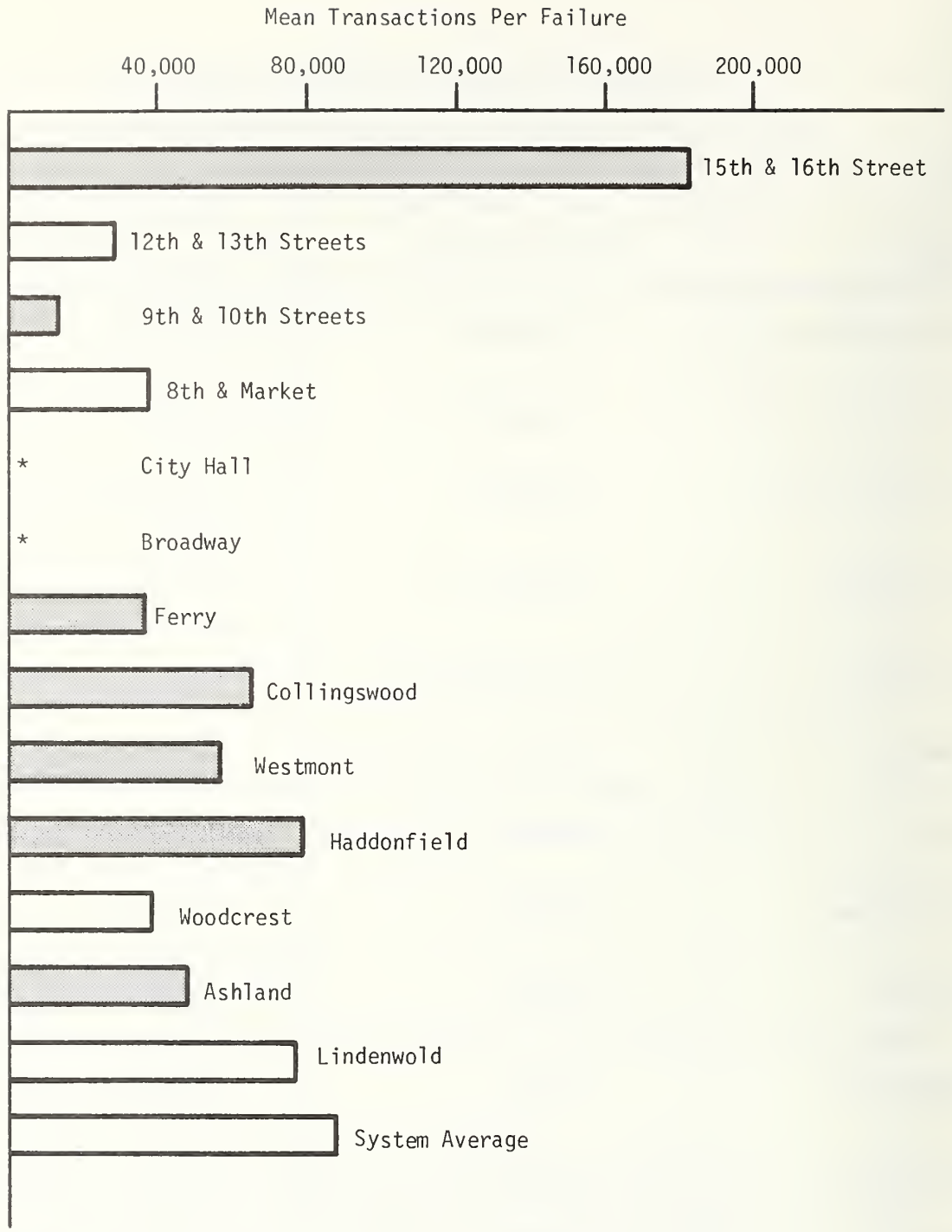

Figure 4-2. COMPARISON OF MARS CD 540-1 RELIABILITY BY STATION

4.2 Availability

Availability is the probability that a piece of equipment (coin acceptor in this study) will be operating satisfactory at any point in time. Availability is expressed in terms of percent as follows:

$$\text{Availability} = \frac{\text{Total Operating Time - Total Down Time}}{\text{Total Operating Time}} \times 100$$

Table 4-4 presents availability for the PATCO coin acceptors by manufacturer. The average availability is 99.91 percent. All coin acceptors except the Mars CD 540-1 are below the average at the 95% confidence level, however all manufacturers are also above 99 percent availability level.

4.3 Maintainability

Maintainability is defined as the length of time it takes to repair a failure and may be expressed as average down time (ADT) or mean time to repair (MTTR). Average down time (ADT) is defined as follows:

$$\text{ADT} = \frac{\text{Active Repair Time + Technician Response Time}}{\text{Number of Failures}}$$

Average down time (ADT) for all coin acceptors is presented by manufacturer in Table 4-5. The ADT is 48.3 minutes. The elements of ADT, active repair time and technician response time averaged out to be 19.28 and 30 minutes respectively. According to PATCO the lower ADT for the National Rejector coin acceptors is due to the proximity of the repair shop which is located at City Hall Station. The MARS CD 540-1 coin acceptor had an ADT of 46 minutes.

Table 4-4. COMPARISON OF AVAILABILITY FOR COIN ACCEPTORS BY MANUFACTURER

Manufacturer	Availability (%)
National Rejector	99.25* (.990466, .994634)
Sesko	99.64* (.994968, .997988)
Mars Mark V	99.55* (.992295, .998851)
Mars CD 540-1	99.96 (.999532, .999782)
Systems Average	99.83 (.997722, .999024)

Numbers in parenthesis are 95% confidence intervals.

*Manufacturers with availability significantly below the system average at the 95% confidence level.

Table 4-5. AVERAGE DOWN TIME -- COIN ACCEPTORS BY MANUFACTURER

Manufacturer	Average Down Time (Minutes)
National Rejector	45.6
Sesko	50.7
Mars Mark V	51.0
Mars CD 540-1	46.0
Average	48.3

4.3.1 Analysis of Failures

Most of the failures encountered during the test period were of the coin jam variety. There were also a few related to improper adjustment or broken/damaged parts. Table 4-6 compares manufacturer's performance in terms of failures/100,000 transactions. This method normalizes the performance of individual manufacturers. Results show that the Mars CD 540-1 had only 1.1 failure per 100,000 transactions. This compares to a high of 16.2 failures per 100,000 transactions for another manufacturer.

A further review of failures recorded at three downtown stations is presented in Table 4-7 which covers seven accounting periods (10/03/81 - 4/17/82). A dramatic decrease in the number of failures can be seen during the latter part of the first accounting period, at which time the Mars CD 540-1 acceptors were installed. It should be noted that data were available for the 15 farecard vendors listed, but not for the entire system. These data represent actual

number of failures and not normalized failures based on the number of transactions. Figure 4-3 is a graphic presentation of the data. Analysis of the chart (accounting period 1) shows that failures for the pre Mars CD 540-1 were somewhat on the increase. (The 52 failures, listed for the accounting period beginning 12/25 were for a 19 day period). It should be noted that Mars CD 540-1 units that were installed as early as May of 1981 are performing equally as well as those analyzed in this report.

Table 4-6. FAILURES PER 100,000 TRANSACTIONS BY MANUFACTURER

Manufacturer	Failures/100,000
National Rejector	16.2
Sesko	10.6
Mars Mark V	13.9
Mars CD 540-1	1.1
Average	5.8

Table 4-7. COIN ACCEPTOR FAILURES BEFORE AND AFTER THE INSTALLATION OF MARS CD 540-1

STATION	VENDOR	FAILURES/ACCOUNTING PERIOD							
		10/03 10/30	10/31 11/27	11/28 12/25	12/27 1/12	1/13* 1/23	1/24 2/20	2/21 3/20	3/21 4/17
15th & 16th Streets									
	621J	2	4	2	1	1	--	--	--
	621K	1	--	4	2	--	--	1	--
	621M	4	3	2	3	--	--	1	--
	621N	3	5	8	9	--	--	--	--
	621S	3	2	5	5	--	--	--	--
	621T	3	3	3	3	--	--	--	--
	621U	6	8	6	1	--	--	--	--
12th & 13th Streets									
	622A	2	2	3	2	--	1	--	--
	622B	2	3	4	2	--	--	--	--
	622C	8	2	--	1	1	1	1	--
	622D	5	4	4	2	--	1	--	--
	622J	8	7	7	10	--	1	1	--
	622K	3	--	1	3	1	--	1	--
9th & 10th Streets									
	623A	2	4	5	10	--	--	--	--
	623B	--	1	3	1	--	--	--	--
TOTAL FAILURES		52	48	57	52	3	4	5	0

*MARS Date (1/13/82) CD 540-1 Coin Acceptors Installed

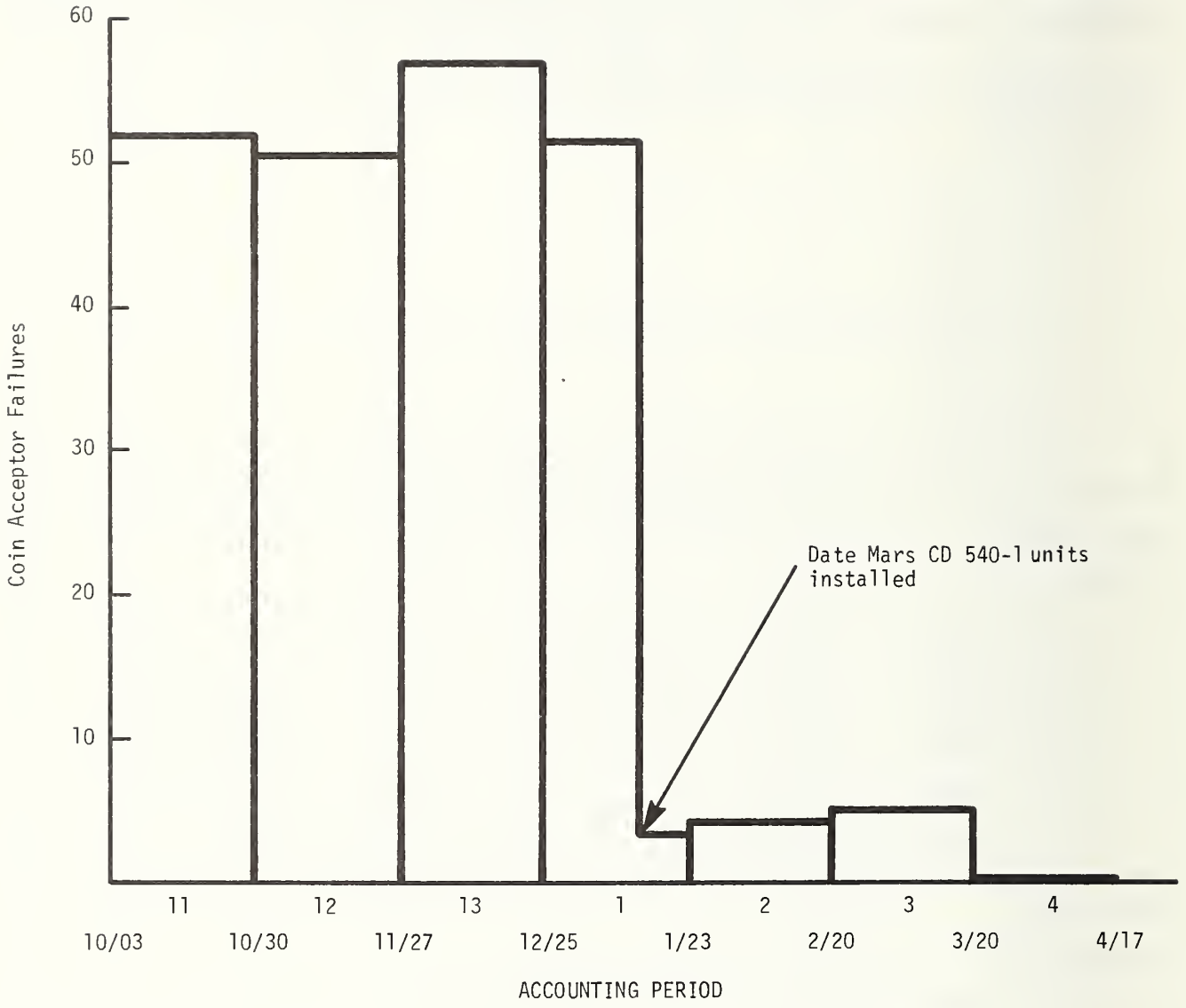

Figure 4-3. FAILURES VS. ACCOUNTING PERIOD

5.0 MAINTENANCE

PATCO has a fare collection equipment maintenance shop that is located at City Hall station. The shop is staffed with eight electro-mechanical technicians, a machinist and a shop manager. Repairs/maintenance are accomplished in the shop and on-site.

Most of the coin acceptor repair and preventative maintenance is performed by PATCO.

Preventative maintenance requirements and schedules are established as a result of experience gained with specific equipments. The NRI coin acceptor must be removed from the farecard vendor and brought to the shop for a thorough cleaning at 6-month intervals. The Sesko coin acceptor requires a re-soldering of the coin tubes and a complete testing of the electronics every 2 years. The MARS Mark V requires frequent cleaning due to the many mechanical parts.

There has not been sufficient experience gained with the Mars CD 540-1 coin acceptor to fully establish preventative maintenance requirements or schedules. The only maintenance requirement that has surfaced to date is that the flight path must be cleaned with a mild detergent (at 9-month intervals). This is accomplished with the coin acceptor in place in the farecard vendor. PATCO estimates that farecard vendor maintenance requirements for coin acceptors has been reduced by approximately 40% since the installation of the MARS CD 540-1 unit.

6.0 FINDINGS AND CONCLUDING REMARKS

The performance of the MARS CD 540-1 coin acceptor has been found to be far superior compared to other coin acceptors in the PATCO system as well as compared to coin acceptors used at other transit properties. The unit during the PATCO test period had a reliability of 88,562 mean transactions per failure.

PATCO installed their first CD 540-1 coin acceptor in May of 1981. Additional units were phased in through January of 1982, at which time 39 units existed in the farecard vendor system.

The CD 540-1 coin acceptor is an operationally flexible unit that may be installed in a variety of different farecard vendors. AC line voltage (110) is the only external power requirement.

All of the CD 540-1 acceptors at PATCO are set-up to operate with nickels, dimes, quarters and the Susan B. Anthony dollar. They may also be adjusted to accept a token (the value of the token may be set for a vend up to $3.15) in place of the dollar coin. The unit can, thus, meet many transit property requirements for coin acceptors.

It is recommended that other transit properties experiment with this unit to determine if the reliability results are repeatable under a variety of conditions. Furthermore, it is recommended that, as further experience is gained with the CD 540-1, the preventative maintenance requirements be fully developed and documented.

APPENDIX A

COIN ACCEPTOR RELIABILITY
AT THE MACHINE LEVEL

COIN ACCEPTOR RELIABILITY BY MANUFACTURER AND STATION

Station	Vendor	No. of Transactions	Reliability (R)	Mean Transactions Per Failure (MTF)
15th & 16th Streets	621J	25,091	1.00000	25,091/0
	621K	29,675	1.00000	29,675/0
	621M	25,532	1.00000	25,532/0
	621N	26,846	1.00000	26,846/0
	621S	25,956	1.00000	25,956/0
	621T	17,764	1.00000	17,764/0
	621U	30,746	1.00000	30,746/0
Station Total		181,610	1.00000	181,610/0
12th & 13th Streets	622A	17,934	.99994	17,934
	622B	12,844	1.00000	12,844/0
	622C	14,069	.99993	14,069
	622D	8,729	.99989	8,729
	622J	24,790	.99996	24,790
	622K	21,614	1.00000	21,614/0
Station Total		99,980	.99996	24,995
9th & 10th Streets	623A	5,748	1.00000	5,748/0
	623B	4,574	1.00000	4,574/0
Station Total		10,322	1.00000	10,322/0
8th & Market	624A	9,179	.99989	9,179
	624B	4,211	1.00000	4,211/0
	624C	8,279	1.00000	8,279/0
	624D	8,268	1.00000	8,268/0
	624E	10,099	1.00000	10,099/0
	624F	24,654	.99996	24,654
	624N	9,018	.99989	9,018
	624P	4,868	1.00000	4,868/0
	624Q	22,082	.99995	22,081
	624R	11,856	1.00000	11,856/0
Station Total		112,514	.99997	37,504
City Hall	No CD-540 units			
Broadway	No CD-540 units			
Ferry	628B	37,274	1.00000	37,274/0
Station Total		37,274	1.00000	37,274/0
Collingswood	629A	43,344	1.00000	43,344/0
	629D	17,094	1.00000	17,094/0
Station Total		60,438	1.00000	60,438/0

Station	Vendor	No. of Transactions	Reliability (R)	Mean Transactions Per Failure (MTF)
Westmont	630A	24,037	1.00000	24,037/0
	630C	31,456	1.00000	31,456/0
Station Total		55,493	1.00000	55,493/0
Haddonfield	631A	51,145	1.00000	51,145/0
	631F	28,054	1.00000	28,054/0
Station Total		79,199	1.00000	79,199/0
Woodcrest	632B	25,830	1.00000	25,830/0
	632C	9,895	.99990	9,895
Station Total		35,725	.99997	35,725
Ashland	633A	18,502	1.00000	18,502/0
	633B	29,689	1.00000	29,689/0
Station Total		48,191	1.00000	48,191/0
Lindenwold	634A	29,915	1.00000	29,915/0
	634C	25,560	.99996	25,560
	634E	20,843	1.00000	20,843/0
Station Total		76,318	.99999	76,318
TOTAL FOR MARS CD-540-1		797,064	.99999	88,562
	Mars - Mark V			
City Hall	626A	30,547	.99984	6,109
	626B	23,946	.99992	11,972
Broadway	627C	18,895	.99979	4,723
	627D	26,870	.99989	8,956
TOTAL MARS MARK V		100,258	.99986	7,161
	NRI			
City Hall	626C	28,517	.99972	3,564
Broadway	627A	34,575	.99997	34,575
	627B	41,699	.99981	5,212
TOTAL NRI		104,791	.99984	6,164
	Sesko			
Ferry	628A	55,071	.99998	55,071
	628C	47,088	.99981	5,231
	628D	40,025	.99995	20,012

Station	Vendor	No. of Transactions	Reliability (R)	Mean Transactions Per Failure (MTF)
Collingswood	629B	24,449	1.00000	24,449/0
	629C	11,108	1.00000	11,108/0
Westmont	630B	16,988	.99994	16,988
	630D	17,462	.99989	8,731
Haddonfield	631B	25,570	.99988	8,523
	631D	20,886	.99981	5,221
	631E	20,332	1.00000	20,322/0
Woodcrest	632A	18,447	1.00000	18,447/0
Ashland	633C	21,772	.99995	21,772/0
	633D	18,007	.99989	9,003
Lindenwold	634B	29,892	.99946	1,868
	634D	26,648	.99992	13,324
TOTAL SESKO		393,745	.99989	9,374
OVERALL COIN ACCEPTOR TOTAL		1,395,948	.99994	17,023

APPENDIX B

FORMULAE FOR SIGNIFICANCE TESTING

Confidence Intervals

Confidence intervals are established in order to provide assurance that specified regions will contain true reliability/transactions per failure data. Reliability is estimated using Normal probability distribution.

R_i = reliability of the i^{th} coin acceptor

n_i = number of transactions

k = 1.96 (Normal Distribution, 95% confidence level)

Confidence intervals for reliability may be calculated using the following formula:

$$R_i + 1.96 \sqrt{\frac{R_i\ (1-R_i)}{n}}$$

The extreme points of the confidence interval may be converted to transactions per failure in the following manner:

$$\text{transactions per failure} = \frac{1}{1-R_i}$$

T-Test

The T-Test of Proportions is applied to determine if a specified equipment is performing in an acceptable or unacceptable manner with respect to reliability. In this report a T-Test was conducted to determine if performance was significantly above or below the system average.

The formula below is used to derive a minimum acceptable reliability.

R = overall system reliability

R_i = reliability of the i^{th} coin acceptor

n_i = number of transactions by the i^{th} coin acceptor

R_i is acceptable at the 95% confidence level if:

$$R_i \geq R - 1.645 \sqrt{\frac{R_i\ (1-R_i)}{n_i}}$$

zI Test

A zI test was applied to determine if the different reliabilities happened by chance or that the coin acceptors manufactured by the various companies did in fact perform at different levels.

In order to use the zI test the following criteria must be observed:

1) the number of failures must be 40 or greater
2) there must be two random samples, and the smaller sample must be 10% or more of the combined pair.

Data Required:

x = failures in the smaller sample

y = failures in the larger sample

$n = x + y$

P_x = fractional proportion of the x sample to the whole

$P_y = 1 - P_x$

E = expected number of failures for sample of size observed

$E = (Px)\ (n)$

$$Z = \frac{|E - x| - c}{\sqrt{(E)\ (P_y)}}$$

c = correction factor .5

Application

CD 540-1 transactions = 797,064
All other transactions = 598,884
Total transactions = 1,395,948

x = 73 (failures all other) $\qquad$ n = 82 (all failures)

y = 9 (failures CD 540-1)

$$P_x = \frac{598,884}{1,395,948} = .43$$

$P_y = 1 - .43 = .57$

$E = (P_x)\ (n)$

$(.43)\ (82) = 35.26$

$$z = \frac{|35.26 - 73| - .5}{\sqrt{(35.26)\ (.57)}}$$

$$= \frac{37.24}{4.48} = 8.31$$

Looking up the value (8.31) on a z table the probability of no significant difference between E and x far exceeds 0.2%. We thus conclude that the observed difference could be expected to occur by chance almost twice in 1000 times, which is significantly remote, therefore, the coin acceptor did perform at different levels.

APPENDIX C

EXAMPLES OF

PATCO'S MAINTENANCE INFORMATION REPORT

SEQUENCE			DATE	V	FAC.	SERIAL	PURPOSE	LOC	DEF	REP	IR NO	EMPL	
	1-FACILITY	* INDIVIDUAL											
	2-PURPOSE	*	2-				7						
	3-DATE	* SELECTION	3-										* FROM- 012382
	4-	*	4-										
	5-	* CRITERIA	5-										* TO - 021982
	6-	*	6-										

DATE	V	FAC.	PURP. CODE	SERIAL	PURPOSE	LC	DEFECT	REPAIR	QTY	HRS	EMPL	IR NO
021582		621U	706B	B STACK			JAM (TICKET)	JAM CLEARED	1	.5		
021682		621U	706B	B STACK			JAM (TICKET)	TICKET (BAD) REMOV		.3		
013082		622A	706A	A STACK			JAM (TICKET)	TICKET (BAD) REMOV		.7		
020182		622A	706A	A STACK			JAM (TICKET)	JAM CLEARED	1	.3		
021182		622A	706A	A STACK			JAM (TICKET)	JAM CLEARED		.3		
020882		622B	705D	CLU			MISCELLANEOUS DEFE	MISCELLANEOUS REPA		.3		
021682		622B	706	TICKET VENDORS			NEED TESTING	TESTED - NDF		.4		
012882		622C	706	TICKET VENDORS			NEED TESTING	TESTED - NDF	1	.2		
013182		622C	706	TICKET VENDORS			NEED TESTING	TESTED - NDF		.2		
021282		622C	706	TICKET VENDORS			NEED TESTING	TESTED - NDF		.3		
021282		622C	706	TICKET VENDORS			AWAITING AUDIT	...LABOR NOT AVAIL		.3		
020582		622C	706A	A STACK			ADJUSTMENT IMPROPE	ADJUSTED	1	.3		
020882		622C	706A	A STACK			MISCELLANEOUS DEFE	MISCELLANEOUS REPA		.1		
020882		622C	706A	A STACK			JAM (TICKET)	JAM CLEARED		.3		
012382		622C	706B	B STACK			JAM (TICKET)	JAM CLEARED		.3		
012882		622C	706B	B STACK			JAM (TICKET)	JAM CLEARED	1	.3		
021282		622C	706C	COIN ACCEPTOR			JACKPOTTING	REMOVED AND REPLAC		.5		
012582		622D	706	TICKET VENDORS			NEED TESTING	...NO DEFECT FOUND		.3		
021882		622D	706A	A STACK			JAM (TICKET)	JAM CLEARED		.3		
020382		622D	706B	B STACK			JAM (TICKET)	JAM CLEARED	1	.3		
021782		622D	706B	B STACK			JAM (TICKET)	JAM CLEARED		.3		
012582		622D	706C	COIN ACCEPTOR			MISSING	REPLACED		.5		
012582		622D	706C	COIN ACCEPTOR			WILL NOT OPERATE	...NO MATERIAL		.4		
021582		622J	706	TICKET VENDORS			NEED TESTING	TESTED - NDF	1	.3		
020482		622J	706A	A STACK			JAM (TICKET)	JAM CLEARED	1	.3		
020982		622J	706C	COIN ACCEPTOR			NEED TESTING	TESTED - NDF		.3		
020882		622K	706	TICKET VENDORS			ADJUSTMENT IMPROPE	ADJUSTED		.2		
020882		622K	706	TICKET VENDORS			NEED TESTING	REMOVED AND REPLAC		.4		
020482		622K	706A	A STACK			JAM (TICKET)	JAM CLEARED	1	.3		
020182		622K	706B	B STACK			MISCELLANEOUS DEFE	REMOVED AND REPLAC		.7		
020882		622K	706B	B STACK			JAM (TICKET)	JAM CLEARED		.3		
020882		622K	706B	B STACK			WILL NOT OPERATE	TROUBLE SHOOTING		.3		
020882		622K	706B	B STACK			STACK DEFECTIVE	REMOVED AND REPLAC		.3		
020982		622K	706B	B STACK			JAM (TICKET)	TICKET (BAD) REMOV		.3		
021482		622K	706B	B STACK			JAM (TICKET)	TICKET (BAD) REMOV		.3		

				DATE	V	FAC.	SERIAL	PURPOSE	LOC	DEF	REP	IR NO	EMPL	
SEQUENCE	1-FACILITY	* INDIVIDUAL												
	2-PURPOSE	*	2-											
	3-DATE	* SELECTION	3-											* FROM- 012382
	4-	*	4-											
	5-	* CRITERIA	5-											* TO - 021982
	6-	*	6-											

DATE	V	FAC.	PURP. CODE	SERIAL	PURPOSE	LC	DEFECT	REPAIR	QTY	HRS	EMPL	IR NO
021682		622K	706B		B STACK		JAM (TICKET)	TICKET (BAD) REMOV		.3		
021682		623A	706A		A STACK		JAM (TICKET)	JAM CLEARED		.3		
021782		623A	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
020282		623B	706B		B STACK		CONNECTION (NONE)	CONNECTED	1	.5		
020882		623B	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
021282		623B	706B		B STACK		JAM (TICKET)	TICKET (BAD) REMOV		.3		
012682		624A	706C		COIN ACCEPTOR		PROGRAMMED MAINTEN	INSPECTED		.2		
020182		624A	706C		COIN ACCEPTOR		MISCELLANEOUS DEFE	MISCELLANEOUS REPA	1	.3		
012782		624B	706A		A STACK		BINDING,JAMMED LOC	COIN (BAD) REMOVED		.3		
012782		624B	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
020582		624B	706B		B STACK		JAM (TICKET)	JAM CLEARED	1	.3		
020782		624B	706B		B STACK		JAM (TICKET)	TICKET (BAD) REMOV		.3		
020882		624B	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
021682		624B	706B		B STACK		JAM (TICKET)	TICKET (BAD) REMOV		.3		
012682		624B	706C		COIN ACCEPTOR		PROGRAMMED MAINTEN	INSPECTED		.2		
021682		624B	706C		COIN ACCEPTOR		WILL NOT OPERATE	...NO DEFECT FOUND		.2		
012982		624C	706		TICKET VENDORS		NEED TESTING	TESTED - NDF	1	.3		
021182		624C	706		TICKET VENDORS		NEED TESTING	TESTED - NDF		.3		
021982		624C	706A		A STACK		JAM (TICKET)	JAM CLEARED	1	.3		
012682		624C	706C		COIN ACCEPTOR		PROGRAMMED MAINTEN	INSPECTED		.2		
021682		624C	706C		COIN ACCEPTOR		WILL NOT OPERATE	...NO DEFECT FOUND		.2		
020982		624D	706		TICKET VENDORS		NEED TESTING	TESTED - NDF		.3		
021682		624D	706		TICKET VENDORS		NEED TESTING	TESTED - NDF		.2		
021382		624D	706A		A STACK		JAM (TICKET)	TICKET (BAD) REMOV	1	.5		
012582		624D	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
021582		624D	706B		B STACK		JAM (TICKET)	JAM CLEARED	1	.3		
021782		624D	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
012682		624D	706C		COIN ACCEPTOR		PROGRAMMED MAINTEN	INSPECTED		.2		
012882		624E	706		TICKET VENDORS		NEED TESTING	TESTED - NDF		.3		
020982		624E	706		TICKET VENDORS		NEED TESTING	TESTED - NDF		.3		
021282		624E	706B		B STACK		TICKET IN BACKWARD	ADJUSTED		.1		
021282		624E	706B		B STACK		JAM (TICKET)	JAM CLEARED		.3		
012682		624E	706C		COIN ACCEPTOR		PROGRAMMED MAINTEN	INSPECTED		.2		
020782		624F	706		TICKET VENDORS		JAM (TICKET)	JAM CLEARED		.2		
021182		624F	706		TICKET VENDORS		JAM (COIN)	COIN (BAD) REMOVED		.3		

APPENDIX D

EXAMPLES OF

PATCO'S REVENUE COLLECTION WORKSHEET

Form Patco 112, Rev. (8-80)

PORT AUTHORITY TRANSIT CORPORATION
REVENUE COLLECTION WORK SHEET

DATE 1/25/82

HADD (STATION) IN 620 OUT ______ GUARD [illegible]

TICKET VENDORS	A	B	D	E	F			
DOLLARS								85605
~~[illegible]~~ 8	7600	1100	2500	1400	1080			53230
QUARTERS	64650	25400	12975	18850	29150			41380
NICKELS	3005	1410	1235	1415	1585			41505
DIMES	10350	8220	5470	5140	6200			47035
SUB TOTAL		36130	22180	26805				
CURRENCY		17100	19200	14700				
TOTAL	85605	53230	41380	41505	47035			#1 2687 55
PARKING GATES					22	00		
QUARTERS					1510	25		
NICKELS					86	50		
DIMES					353	80		
			268655		2276	55		
TOTAL			268655		510	00		#2
TRANSFERS	A1		B					
QUARTERS	15475		8850		243	25		20040
NICKELS	415		250		6	65		9950
DIMES	1650		850		25	00		
	2500				25	00		
TOTAL	20040		9950		299	90		#3 299.90
CALL FOR AID								
QUARTERS	400							
NICKELS	25							
DIMES	50							
TOTAL	475							#4 475
OVERAGE							METERS	
CHANGERS							QUARTERS	
QUARTERS	50025						NICKELS	
NICKELS	38000						DIMES	
DIMES	1000							
SUB TOTAL	90025						TOTAL	#5
CURRENCY	100000							
TOTAL	190025							#6 #30

199600
5

180.00 EX

B [illegible] for May

#7 299250

TOTAL DEPOSIT

TOTAL CURRENCY $ 247400

TOTAL COIN 51850

TOTAL $ 299250 (same as #7)

NO. OF REV. BAGS 2

COINS PURCHASED FOR CHANGERS		
CURRENCY		
QUARTERS		14900
NICKELS		100
DIMES		400
TOTAL		[illegible] 15400

OTHER EXCHANGE
27200
24650
51850
247400
299250

SENT TO BANK	27200
QUARTERS	24650
NICKELS	
DIMES	
CURRENCY	247400
TOTAL	2992.50

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