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U.S. Department
of Transportation

**Urban Mass
Transportation
Administration**

Performance Assessment Methods and Results for Transit Automatic Fare Collection Equipment

Input Output
Computer Services, Inc.
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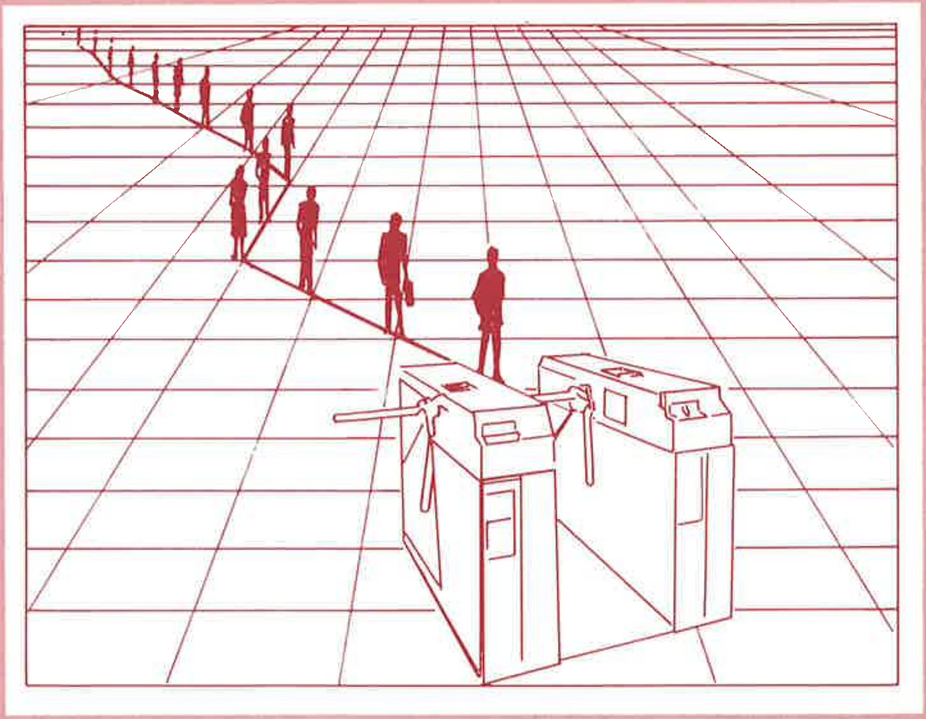
Final Report
October 1983



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16. Abstract

This report presents performance assessment methods for transit automatic fare collection (AFC) equipment. The methods developed are based on the experience gained from a series of performance assessments that have been undertaken at eight U.S., and three foreign transit systems. The report is intended to assist rail transit systems in their assessment of equipment, promote uniformity in applications, improve communications, and help achieve a better understanding of problems and issues.

The development effort has been conducted as part of the UMTA Rail Transit Fare Collection (RTFC) Project. The overall goal of the RTFC project is to aid in the development of improved AFC systems for rail transit. The expected benefits from the project include improved operating efficiency and reduced labor and maintenance costs at the transit systems. The report represents a source document for assessment methodology. It defines key AFC terms and concepts, describes rail transit AFC systems, presents and discusses performance methods, as well as the results of the systems assessments and industry AFC contract specifications. Also included in the report is a discussion of the requirements for interfacing AFC information with the UMTA Transit Reliability Information Program (TRIP).

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PREFACE

This study presents performance assessment methods for transit automatic fare collection (AFC) equipment. In addition, the report summarizes results of performance assessments at eight U.S., and three foreign transit systems.

The objective of this research is the development of methods that will promote uniformity in the assessment of AFC equipment. In addition, the work is intended to improve industry communication in the area of fare collection performance, and to help achieve a better understanding of problems and issues. The U.S. DOT Transportation Systems Center supported this study as part of continuing research in the area of automatic fare collection equipment performance and data base development. This report documents the findings of Input Output Computer Services, Inc. (IOCS) under contract number DOT-TSC-1669.

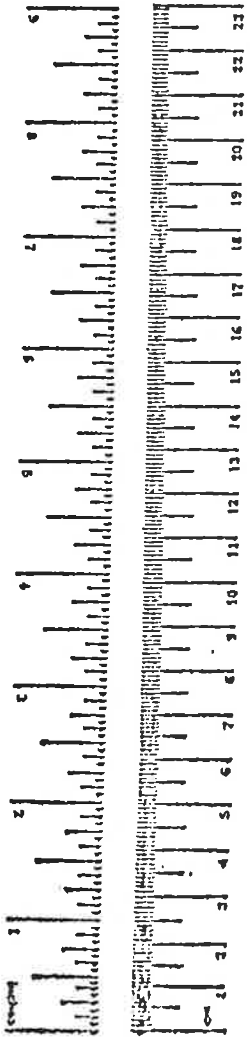
The research and documentation were performed and directed by Joseph Morrissey. Charles Erdrich, Program Manager - Analytical Services Group, provided technical and managerial support. Daniel Mesnick and Andreas Tzioumis were significant contributors to the study research. Joseph Koziol of TSC served as contract technical monitor and Nancy Cooney of Raytheon Service Company provided summary tables on contract practices and specifications.

This study also relied on the contributions of many people in the transit industry. Special thanks go to Albert Lock and Edward Gilcrease of MARTA, J.W. Vigrass of PATCO, Ralph Keeling of ICG, John O'Connor of CTA, Robert Peshel of BART, Robert Mutschler of PATH, Lloyd Johnson of WMATA, Tom Dunbar of MBTA, B.K. Kirkpatrick of BMTA, Harvey Becker of MDTA, Alexander Wahl of SSB, and Michael Rice of Tyne and Wear.

METRIC CONVERSION FACTORS

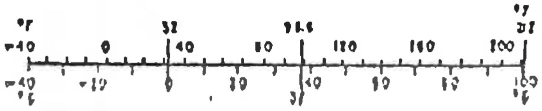
Approximate Conversions to Metric Measures

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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LIST OF ABBREVIATIONS

ADS	Advanced Data Systems
ADT	Average Downtime
AFC	Automatic Fare Collection
APTA	American Public Transit Association
ATO/ATC	Automatic Train Operation/Automatic Train Control
BART	Bay Area Rapid Transit (San Francisco)
BMTA	Baltimore Metropolitan Transit Authority
CTA	Chicago Transit Authority
CVEB	Change Vending Entrance Bill
CWD	Cubic Western Data
EDB	Experimental Data Bank
GIN	Generic Identification Number
GMAC	Generic Maintenance Action Code
GPN	Generic Part Number
GSN	Generic Serial Number
ICG	Illinois Central Gulf Railroad (Chicago)
IOCS	Input Output Computer Services, Inc.
LIRR	Long Island Railroad
MARTA	Metropolitan Atlanta Rapid Transit Authority
MBTA	Massachusetts Bay Transportation Authority (Boston)
MCBF	Mean Cycles Between Failures
MCBHF	Mean Cycles Between Hard Failures
MCBMA	Mean Cycles Between Maintenance Actions
MCBSF	Mean Cycles Between Soft Failures
MCBTJ	Mean Cycles Between Ticket Jams
MDTA	Metro-Dade Transportation Administration (Miami)
MMAX	Maximum Time to Repair
MOBF	Mean Operations Between Failures
MTBF	Mean Time Between Failures
MTF	Mean Transactions per Failure
MTTR	Mean Time to Repair
NDF	No Defect Found
NYCTA	New York City Transit Authority

LIST OF ABBREVIATIONS (CONT'D)

PAL	Passenger Assistance Link
PATCO	Port Authority Transit Corporation (PA, NJ)
PATH	Port Authority Trans-Hudson Corporation (NY, NJ)
PEP	Property Evaluation Plan
PM	Preventive Maintenance
RATP	Regie Autonome Des Transports Parisiens (Paris)
RCI	Remote Control Indicator
RER	Reseau Express Regional (Paris)
RRV	Rapid Rail Vehicle
RTFC	Rail Transit Fare Collection
SEPTA	Southeastern Pennsylvania Transportation Authority (Philadelphia)
SSB	Stuttgarter Strassenbahnen (Stuttgart, West Germany)
STARS	American Public Transit Association's Subsystem Technology Applications to Rail Systems Program
T&W	Tyne and Wear Metro (Newcastle, England)
TRIP	Transit Reliability Information Program
TSC	Transportation Systems Center
UCC	Universal Component Code
UMTA	Urban Mass Transportation Administration
WMATA	Washington Metropolitan Area Transit Authority

EXECUTIVE SUMMARY

BACKGROUND

The Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation initiated the Rail Transit Fare Collection (RTFC) project in 1979 in response to a critical need of the U.S. transit industry for improved automatic fare collection (AFC) systems. Expected benefits to be derived from improved fare collection systems include improved operating efficiency, enhanced control of receipts, increased passenger throughput rates, and reduced labor and maintenance costs.

The RTFC effort has been directed by the Transportation Systems Center with the assistance and input of representatives of U.S. rail rapid transit systems. The transit representatives comprise the American Public Transit Association's Subsystem Technology Applications to Rail Systems (STARS) Fare Collection Reliability Liaison Board.

In order to achieve the goals of the RTFC project, an extensive research and development program has been undertaken. Under this program, a key project area has been the development and application of performance assessment methods. The development of the methods has been undertaken with the overall goals of assisting transit systems in the assessment of equipment, promoting uniformity in applications, improving industry communication in the area of fare collection, and helping to achieve a better understanding of problems and issues. The development effort has taken an iterative approach that has included the assessment of 11 transit AFC systems using a preliminary assessment methodology that was formulated at the initiation of this effort, and industry input and consensus through the STARS Fare Collection Reliability Liaison Board.

PURPOSE AND OBJECTIVES

The purpose of this report is to promote and encourage the use of uniform AFC definitions, assessment methods and procedures by U.S. transit systems, and to present and discuss the results of system assessments. The report also outlines the requirements for incorporating AFC performance information into the UMTA Transit Reliability Improvement Program (TRIP).

Specifically, the objectives of this study are:

- To define AFC terms;
- To inventory existing systems, equipment and maintenance practices;
- To present and discuss methods for determining and assessing equipment performance;
- To summarize the results of systems assessments and compare these with industry contract specifications;
- To assess the information required in order to incorporate AFC information into the TRIP;
- To make recommendations on the potential application of the assessment methods within the transit industry.

APPROACH

The approach to the development of a set of performance assessment methods has included the following:

- An inventory of AFC equipment;

- The development of a preliminary assessment method, the IOCS Property Evaluation Plan (PEP);
- The application of the PEP to 11 transit systems, both domestic and foreign;
- A technology review of existing equipment;
- Review of performance results;
- Input and consensus of transit systems through the STARS Fare Collection Reliability Liaison Board.

Based on the previous system assessments, industry input, and the knowledge gained from the technology review, it was determined that the following steps were prerequisite to the development and implementation of a set of performance assessment methods:

- A determination of the uses of performance measures;
- Establishment of such measures;
- The definition of an AFC equipment failure;
- Establishment of a set of classifications for failures;
- Development of a set of failure causal factors;
- A determination of the chargeability of failures, i.e., what failures to use in generating the performance measures;
- Review and consensus by transit systems;
- Actual application of the methods.

It is expected that this approach will help achieve the overall goals of the development effort. As enumerated above, these are: (1) assisting transit systems in the assessment of equipment; (2) promoting uniformity in applications; (3) improving industry communications in the area of fare collection; and (4) helping to achieve a better understanding of problems and issues.

AFC SYSTEMS AND EQUIPMENT

An AFC machine is a device that provides a fare collection revenue service or function and that represents a complete unit to a patron. AFC machines include farecard/ticket vendors, automatic gates, addfares, transfer dispensers and change makers for bills and/or coins.

An AFC machine subsystem is a part or assembly of parts that accomplishes a specific revenue function or transaction service and can be considered, for the sake of maintenance, a discrete unit. Major subsystems of AFC machines include bill validators, coin acceptors, ticket transports, transfer dispensers, barrier mechanisms and control logic units.

Of the operating rapid rail and commuter rail systems in the United States, the following currently use automatic fare collection equipment:

MARTA - Metropolitan Atlanta Rapid Transit Authority
WMATA - Washington Metropolitan Area Transit Authority
BART - Bay Area Rapid Transit (San Francisco)
PATCO - Port Authority Transit Corporation (Philadelphia - Camden)
ICG - Illinois Central Gulf Railroad (Chicago)
CTA - Chicago Transit Authority

PATH - Port Authority Trans-Hudson Corporation (New York - New Jersey)
MBTA - Massachusetts Bay Transportation Authority (Boston)
NYCTA - New York City Transit Authority
SEPTA - Southeastern Pennsylvania Transportation Authority (Philadelphia)

In addition to these, two systems in the construction stages - The Baltimore Metropolitan Transit Authority (BMTA) and the Metro-Dade Transportation Administration (MDTA) in metropolitan Miami - will use AFC equipment. (BMTA expects to open in November 1983. MDTA has recently signed a contract to purchase AFC equipment for testing.) Another system, the Long Island Railroad, will be experimenting with four ticket vendors beginning in 1984.

At some systems - usually the older systems - (e.g., NYCTA, MBTA, CTA, PATH) the AFC system consists primarily of coin and/or token-accepting gates. At newer transit systems (e.g., ICG, PATCO, BART, WMATA) the AFC system consists of farecard vendors and farecard-accepting gates. (MARTA does not currently use vendors, but gates do accept encoded passes that are bought from ticket outlets.)

Equipment function and complexity, as can be expected, vary from the simple NYCTA, MBTA and PATH gates to the more complex, microprocessor- or computer-controlled WMATA, BART and MARTA equipment.

In addition to American transit systems, foreign transit systems have used AFC equipment for some time. Three that use state-of-the-art microprocessor-controlled equipment are Tyne and Wear Transport Executive (T&W), Stuttgarter Strassenbahnen (SSB) and Regie Autonome Des Transports Parisiens (RATP).

These systems operate in Newcastle, England; Stuttgart, West Germany; and Paris, France respectively. These three systems were included in the RTFC project because each had recently installed state-of-the-art equipment incorporating coin recyclers, failure diagnostics and needlepoint printers.

PERFORMANCE ASSESSMENT MEASURES AND METHODS

There exists a clear lack of standardization in transit fare collection equipment, including the area of performance measurement and specification. As part of the ongoing UMTA/APTA/TSC effort to improve the effectiveness of fare collection systems, this study is intended to promote uniform performance assessment methods for AFC equipment.

The performance measures generated from these procedures are reliability, availability and maintainability. These can be used for a variety of purposes. At a recent Fare Collection Reliability Liaison Board Meeting, representatives from the rapid rail and commuter rail systems identified five key uses:

1. To provide information for monitoring compliance with equipment procurement specifications (prototype testing, acceptance testing and system reliability testing);
2. To provide operational data for management information systems and for maintenance productivity monitoring;
3. To generate data as a baseline for modification programs;
4. To improve communication within the industry;
5. To aid in the development of a reliability data base similar to that which already exists for rail transit vehicles (i.e., TRIP).

DEFINITIONS OF PERFORMANCE MEASURES

Reliability - Reliability is a measure of equipment performance that indicates the rate at which a machine or a subsystem of a machine successfully accomplishes its functional task or mission. It can be expressed in a variety of ways. In this report, two common measures are used: mean transactions between failures (MTF) and mean time between failures (MTBF).

$$\text{MTF} = \frac{\text{Total Transactions}}{\text{Total Failures}}$$

$$\text{MTBF} = \frac{\text{Total In-Service Time}}{\text{Total Failures}}$$

Availability - Availability is defined as the probability that AFC equipment will be operating satisfactorily at any point in time. Availability is calculated by dividing the total in-service time by the total operating time and converting the result into a percentage.

$$A = \frac{\text{Total Operating Time - Total Downtime}}{\text{Total Operating Time}}$$

Maintainability - Maintainability is a measure of the amount of time it takes to repair a failure. It is commonly expressed as average downtime (ADT) and mean time to repair (MTTR). Average downtime indicates the average time AFC equipment can be expected to be out of service per failure. It is calculated as follows:

$$\text{ADT} = \frac{\text{Total Downtime}}{\text{Total Failures}}$$

Mean time to repair indicates the average length of time required to respond to and repair a hard failure (described below) of an AFC equipment.

$$\text{MTTR} = \frac{\text{Total Downtime (Hard Failures Only)}}{\text{Total Number of Hard Failures}}$$

FAILURE DEFINITIONS AND CLASSIFICATIONS

In this report, an AFC equipment failure is defined as any instance of malfunction that prevents a successful transaction or necessitates intervention by transit system personnel.

The classification scheme for AFC failures used in this report consists of three failure types: jams, and soft and hard failures. Note that these terms indicate the general nature and severity of failures. In a maintenance and/or performance reporting system, these should be complemented at least with an indication of the subsystem affected, and, preferably, with an indication of the component and/or subcomponent affected, a specific description of the problem (i.e., symptom), a causal factor, and, possibly, a weighting factor that would indicate severity more specifically. In addition, the reporting system should allow for instances where failures were reported but the technician or agent found no defects (NDFs). (This latter situation occurs enough to warrant a special category. For example, at ICG, NDFs represented 12 percent of vendor failures and 11 percent of gate failures. At SSB, NDFs comprised about 25 percent of equipment-related failures.)

Jams - A jam is defined as any instance in which a fare medium inserted by a patron, or a fare medium or other item (e.g., change) dispensed to a patron is stuck in the processing or dispensing path, precluding the completion of a successful transaction or rendering the machine or subsystem inoperative.

Soft Failures - A soft failure is any instance of malfunction of an AFC equipment, including jams not due to hard failures, that necessitates a minor adjustment, minor repair or a clearing or cleaning action. Adjustment refers to the resetting or rearranging of a subsystem, component or subcomponent that has changed its position (e.g., out of tolerance), rendering it malfunctioning. Repair refers to the fixing of a subsystem, component or subcomponent that has become damaged through use or abuse. Minor is defined in this report as requiring less than 20 minutes of total technician active repair time.

Hard Failures - A hard failure is any instance of malfunction of an AFC equipment that necessitates a major adjustment, major repair or replacement. It is important to note that jams are sometimes due to the failure of a subsystem, component or subcomponent that subsequently requires major repair or replacement. Major is defined as requiring more than 20 minutes total technician active repair time.

CAUSAL FACTORS

The failure classification set described above indicates the general nature and severity of the problem encountered by the maintenance technician or station agent. Jams, soft and hard failures do not necessarily indicate the cause of the failure - the "why". For the day-to-day administration and management of an AFC system, a set of six causal factors can be defined. These are:

1. Technical - A failure is considered a technical failure when it can be shown that the machine has malfunctioned on its own, i.e., as a result of normal operation and not as a result of the other causal factors listed here. This causal factor includes, among others, failures related to equipment and parts design and manufacture;

2. Operational - A failure due to oversight or error on

the part of maintenance personnel. This includes such diverse situations as operating equipment beyond life expectancy, faulty installations and faulty maintenance;

3. Environmental - A failure due to the operation of the equipment in adverse environmental conditions that exceed specifications;

4. Vandal - A failure resulting from damage due to vandalism;

5. Administrative - A failure due to oversight or error in non-technical functions of the machine. These failures include situations such as improper loading of ticket or transfer stock, out of tickets, etc.;

6. Patron-Induced - A failure caused by patrons improperly inserting fare media or interfering with the normal action of a machine. For example, at CTA during peak periods, some transfer jams occur because patrons in the paid area unwittingly interfere with the dispensing of the transfer through the transfer slot.

CHARGEABILITY OF FAILURES

In order to generate, report and use equipment performance measures, a determination must be made as to what failures to use. Chargeability refers to the concept of considering a particular failure as countable in the generation of such measures. Currently, differences exist among transit systems in terms of failures deemed chargeable. As can be expected, this had made it difficult to compare performance measures.

PROCEDURES FOR PERFORMANCE MEASUREMENT

Several ways exist to determine and monitor equipment performance. The results generated will vary depending on the failures deemed countable and the nature of the data. The former refers to whether all or a subset of all failures are used. As mentioned above, this depends on the intended use of the measures. The latter refers to whether data are obtained from dedicated in-service surveys or from transit system operational records.

Three procedures for computing reliability are described below. These measures are best used in conjunction with information on maintainability, availability, and failure distributions. Transit systems can select the procedures that best fit their needs.

Reliability Based on All Failures - An overview of equipment performance can be obtained by considering all failures as countable, regardless of cause. Thus, even if it is clear that a jam has occurred because a patron has inserted a damaged farecard into a ticket transport, the fact that the machine will not perform its mission is considered a failure.

As can be expected, when all failures are counted, reliability measures are at their lowest levels. This procedure was followed in the project systems assessments as a means to obtain a baseline of performance measures. It was also done because, in many cases, it was impossible to determine the origin of failure. For example, while failures due to bent coins are easily observed, farecard jams in gate ticket transports or bill jams in validators cannot always be clearly determined to be patron-induced.

This measure could be used in a number of ways. Similar to all the performance measures presented, tracking such a measure would be useful in spotting trends. (This would best be done in conjunction with a review of other performance measures and an assessment of failure distributions.) In addition, such a measure could provide an indication of the frequency of required patron assistance and of expected delay. These, in turn, could be used in station design and to determine the requirements for new equipment and manpower of both agents and technicians.

Reliability Based on Transit plus Technical Failures - Another procedure is to determine the reliability based on all failures less those caused by vandals and patrons (e.g., bent coins). These are defined in this report as transit plus technical failures. This procedure provides a performance measurement based on all failures over which the transit system, in theory, can exercise control and do something about. As a management tool, this measure can be used to monitor not only equipment performance, but also the productivity of those responsible for administrative functions such as vault pickups, and ticket and transfer stock refills. In order to make this measure a useful one, effort should be taken to carefully assess whether alleged patron-induced failures are indeed caused by torn bills, mutilated tickets, etc. In some cases, bills are torn and tickets mutilated by the equipment.

Reliabilities Based on Technical Failures - A third level of performance monitoring requires that only technical failures be counted in the determination of reliability. Such measurements could be generated for all soft and hard technical failures. These measurements could assist transit systems in monitoring performance of equipment under test or warranty, and also indicate to management specific technical problem areas as well as suggest the effectiveness of preventive maintenance (PM) procedures and policy (e.g., PM intervals).

These measures require that failures due to environmental causes, operational and administrative errors, as well as patron-induced and vandal failures, and NDFs not be counted. As mentioned above, it is often difficult to separate out operational failures, particularly those due to incorrect or inadequate corrective maintenance. One way to overcome this problem would be to track the reliabilities based on technical failures and operational problems alongside the reliabilities based only on assumed technical failures. This would minimize the problems inherent in assigning failures to improper maintenance techniques and, reviewed with the reliabilities based on assumed technical failures, would provide a better indication of problem trends.

Maintainability - Maintainability measures provide another indication of overall system effectiveness and the effectiveness of maintenance procedures, policies and techniques. Average downtime can be used to determine whether unacceptable delays are being placed upon patrons. Both ADT and MTTR could be used to indicate improving or declining performance of both the equipment and maintenance personnel.

Availability - Availability measures provide a basic indication of service provided to patrons. They can be used to determine the probability of delay, and as a general indication of the performance of equipment and maintenance efforts.

Failure Identification - Recording and monitoring of individual AFC equipment failures should be undertaken in conjunction with the generation and monitoring of performance measures. Tracking failure data can often indicate specific problem or improvement areas. In any case, interpretation of performance measures is complete only when failure distributions and trends have been investigated.

METHODS FOR OBTAINING DATA FOR PERFORMANCE MEASUREMENT

Two methods exist for obtaining data for performance measurement: in-service surveys and extraction of data from transit system records. The data requirements of each method are the same - failure, transaction, and operating time data.

The first two procedures presented for measuring reliability performance, i.e., reliability based on all failures, and reliability based on transit plus technical failures, require that in-service surveys be taken. Given the large percentage of jams that occur with ticket or cash systems, and the fact that few show up on a one-to-one basis in records at most transit systems, a survey must be performed to record such failures. In addition, a survey would have to be undertaken to determine reliabilities based on transit plus technical failures because of the need to collect data on patron-induced failures. For the computation of reliability based on technical failures, maintenance and transaction records should suffice since the assumption that every technical failure <u>eventually</u> generates a maintenance report seems to be valid throughout the industry. In this case, if records were not already segmented, a careful review of the data would have to be done to separate out technical failures. (Given the existing reporting systems, at some transit systems this is currently either impossible or very difficult to do.)

DATA ANALYSIS

There are three statistical areas of analysis that can be used for evaluating AFC performance measures: confidence intervals, t-tests of proportions, and the Chi-Square test.

Confidence intervals define the region within which it can be reasonable expected that the "true" performance value lies. A t-test is used to determine whether an AFC machine or subsystem exhibits a performance measure of a specified minimum value. A t-test can also be used to test whether retrofits improve equipment performance. The Chi-Square test determines whether variations in performance among equipment are due to chance or performance characteristics.

AFC TRIP

This report addresses the information requirements to include AFC performance information into the UMTA TRIP data bank. TRIP is a program designed to assist the transit industry in satisfying its need for timely reliability information. TRIP provides this assistance through the operation of a computerized national reliability data base. The TRIP data base system receives data from participating transit systems and outputs a series of reliability reports. The TRIP system currently reports only on transit vehicles. However, the system has been designed to incorporate the addition of wayside equipment such as automatic fare collection.

The performance assessments undertaken as part of the RTFC project have provided a limited amount of data on AFC equipment. In order to be useful, performance data need to be statistically sufficient and obtained on a continuous basis. Incorporating AFC equipment performance into TRIP would provide such an opportunity. The terms and concepts defined in this report represent a first step toward an AFC TRIP.

ASSESSMENT RESULTS

A key part of the approach to the establishment of uniform performance assessment methods has been a series of assessments on the performance of AFC equipment at 11 rail transit systems. Data for the assessments were gathered from in-service surveys and/or from transit system records. Where possible, the results are reported according to the three assessment methods described above. However, in some cases, data limitations made this impossible.

Tables 1 through 4 summarize the reliability results for vendors and gates. The results are reported separately for data from in-service surveys and for data from transit system records because in-service data include jams and patron-induced failures, while transit records, in general, do not. This fact accounts for the relative differences between reliabilities based on in-service data and those based on data from transit system records.

Vendors - Table 1 summarizes vendor reliability results based on in-service data. As can be seen from the table, vendor reliabilities based on all failures ranged from a low of 120 MTF to a high of 4,708 MTF. The higher performance measures were for the state-of-the-art microprocessor-controlled European vendors.

When vendor reliabilities were generated based only on hard failures, significant increases resulted. Computable reliabilities ranged from a low of 860 MTF (WMATA pre-retrofit) to 6,891 MTF (WMATA retrofit B). For the Tyne and Wear vendors, no hard failures occurred.

The reliabilities for coin acceptors, ticket transports and bill validators are also shown in Table 1, based on all failures. Coin acceptor reliability ranged from 844 MTF (WMATA pre-retrofit) to the reliability of ICG coin acceptors, which did not experience any failures over 3,698 transactions.

Ticket transport reliabilities ranged from 376 MTF (WMATA pre-retrofit) to 7,062 MTF (Tyne and Wear). Part of the differences in performance between the ICG and PATCO vendors versus the SSB and Tyne and Wear vendors is due to the age of the equipment and the design of the ticket delivery system.

TABLE 1. SUMMARY OF VENDOR RELIABILITIES BASED ON IN-SERVICE DATA

					MAJOR SUBSYSTEM RELIABILITIES (MTF) (ALL FAILURES)		
TRANSIT SYSTEM	NO. OF VENDORS	MACHINE MTF (ALL FAILURES)	MACHINE MTF (HARD FAILURES ONLY)	MACHINE MTBF (ALL FAILURES)	TICKET TRANSPORT	COIN ACCEPTOR	BILL VALIDATOR
ICG	9	167	2,510	5.6	717	3,698/0**	1,026
BART (All)	17	141	1,401	3.8	849	1,038***	338***
BART (IBM)	9	149	2,065	5.1	1,033	1,112***	321***
BART (Cubic)	8	133	1,043	2.5	714	969***	357***
WMATA-P*	40	120	860	2.0	376	844	358
WMATA-A*	14	133	2,293	1.7	573	1,058****	459****
WMATA-B*	6	265	6,891	2.8	3,455	1,027	572
T&W	19	4,708	14,123/0	71.7	7,062	N/D	N/A
SSB	10	1,821	5,464	45.3	N/A	N/D	N/A

*WMATA-P refers to pre-retrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.

**This notation indicates no failures.

***BART coin acceptor and bill validator reliabilities based on tickets sold, <u>not</u> coin or bill insertions.

****Subsystem not retrofit.

N/D = No Data

N/A = Not Applicable

TABLE 2. SUMMARY OF VENDOR RELIABILITIES BASED ON DATA FROM TRANSIT SYSTEM RECORDS

TRANSIT SYSTEM	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)			
				TICKET TRANSPORT	COIN ACCEPTOR	BILL VALIDATOR	NEEDLEPOINT PRINTER
ICG	92	103	118	439	N/D	N/D	N/A
PATCO	310*	310*	311	637*	8,681*	2,736*	N/A
T&W	3,284	6,908**	6,908**	14,227**	N/D	N/A	N/D
SSB	3,311	4,573	6,203	N/A	N/D	N/A	32,497

*Vandalism and patron-induced not cited in PATCO failure data.
**Tyne and Wear data did not cite patron-induced or NDFs.
ND = No Data
N/A = Not Applicable

TABLE 3. SUMMARY OF GATE RELIABILITIES BASED ON IN-SERVICE DATA

TRANSIT SYSTEM	NO. OF GATES	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (HARD FAILURES ONLY)	MACHINE MTBF (ALL FAILURES)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (ALL FAILURES)		
						TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER
MBTA	30	1,558	N/D	46,740	10.2	N/A	2,032	N/A
PATH	31	1,989	3,519	137,239	5.0	N/A	4,300	N/A
CTA	14	904	2,862	8,586	8.6	N/A	6,263	546
ICG	28	4,570	6,680	86,842/0	20.5	5,108	N/A	N/A
BART (All)	27	1,136	N/D	75,518	8.0	1,842	N/A	N/A
BART (IBM)	13	1,969	N/D	76,772/0	15.0	4,798	15,354*	N/A
BART (Cubic)	14	790	N/D	37,131	5.1	1,125	N/A	N/A
WMATA-P**	24	502	N/D	N/D	1.1	858	N/A	N/A
WMATA-A**	18	712	N/D	N/D	2.2	1,477	N/A	N/A
WMATA-B**	7	2,220	N/D	N/D	4.2	11,274	N/A	N/A
MARTA	26	1,740	N/D	12,015	6.1	5,340	3,266	2,874
T&W	16	10,299	10,299	20,597/0	91.1	10,299	N/A	N/A

*Reliability based on total entries, not coin insertions.

**WMATA-P refers to pre-retrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.

N/D = No Data

N/A = Not Applicable

TABLE 4. SUMMARY OF GATE RELIABILITIES BASED ON DATA FROM TRANSIT SYSTEM RECORDS

TRANSIT SYSTEM	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)			
				TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER	LOGIC
PATH	12,672	12,672**	12,672**	N/A	30,446	N/A	N/D
ICG	2,507	3,037	3,509	N/D	N/A	N/A	N/D
PATCO	5,907	5,907*	5,907	15,096	N/A	783	N/D
MARTA	3,225	3,225*	3,567***	N/D	24,225***	6,849***	21,742***

*Vandalism and patron-induced not cited in PATH, PATCO and MARTA failure data.
**PATH data did not include NDFs.
***Excluding administrative failures also.
N/D = No Data
N/A = Not Available

The ICG and PATCO machines use a ticket stacker system. Tyne and Wear uses a ticket unroller and SSB vendors use a sprocket feeder.

For bill validators, reliabilities ranged from 321 (BART IBM) to 1,026 MTF (ICG). Differences in the extent of bill checking that exist between the validators account for some of the differences.

Table 2 summarizes vendor reliabilities based on data from transit system records. Reliabilities based on all failures ranged from a low of 92 MTF (ICG) to 3,311 MTF for the SSB microprocessor-controlled machines.

When reliabilities were based on transit plus technical failures, the reliabilities of the European vendors rose dramatically, indicating the extent of the vandalism problems in Newcastle and Stuttgart.

When instances where failures were reported but no defects were found were excluded from transit and technical failures, the ICG reliability rose to 118 MTF, PATCO to 311 MTF, and the SSB reliability to 6,203 MTF.

Vendor subsystem reliabilities based on data from transit records are also shown in Table 2. These are based on all failures less vandalism, patron-induced and NDFs.

A review of failure distributions indicated that jams comprise the largest category of vendor failures based on in-service data. Bill jams were the largest category followed by farecard jams.

Gates - Table 3 summarizes reliability results based on in-service data. The gate reliabilities based on all failures ranged from 502 MTF (WMATA pre-retrofit) to 10,229 MTF (Tyne and Wear). The wide range reflects in part the differences in the design and complexity of the equipment and in the number of functions performed.

Reliabilities based on transit plus technical failures ranged from 2,862 MTF (CTA) to 10,299 (Tyne and Wear). For computable reliabilities based only on hard failures, the range was 8,586 MTF (CTA) to 137,239 MTF (PATH). Three sets of gates did not experience hard failures during in-serivce surveys - BART IBM, ICG and Tyne and Wear. The high PATH reliability reflects the simplicity of the equipment; PATH gates accept only nickels, dimes and quarters in separate slots. Most failures are coin jams that are quickly fixed.

Major subsystem reliabilities are also presented in Table 3 based on all in-service failures.. Ticket transport reliabilities ranged from 858 (WMATA pre-retrofit) to 11,274 MTF (WMATA retrofit B). For other gate subsystems, reliabilities ranged from 2,032 MTF to 15,354 MTF (coin acceptors), and from 546 MTF to 2,874 MTF (transfer dispensers).

Table 4 summarizes gate reliability results based on data from transit system records. Reliability based on all failures for ICG gates was 2,507 MTF. For PATH, reliability based on all failures was 12,672 MTF. For MARTA and PATCO, the figures were 3,225 MTF and 5,907 MTF respectively.

When transit plus technical failures were used, the ICG reliability increased to 3,037 MTF. When NDFs were also excluded, ICG reliability increased to 3,509 MTF. MARTA gate reliabilities increased to 3,567 MTF when both NDF and administrative failures were excluded. (The MARTA data allowed for the exclusion of administrative failures.)

Table 4 also presents gate subsystem reliabilities based on data from transit system records. The reliabilities, with the exception of PATCO transfer dispensers, are relatively high. However, in the case of coin acceptors, this is true because the overwhelming majority of jams are not included because they are cleared by agents.

For gates, as might be expected, the majority of failures were jams due to the medium inserted.

Addfares - Table 5 summarizes the reliability results for addfare machines based on all failures from in-service surveys. As can be seen, addfare reliabilities ranged from 84 MTF (WMATA pre-retrofit) to 232 MTF (BART IBM).

Subsystem reliabilities based on all failures were also generated for addfares. Ticket transport reliabilities ranged from 243 MTF (WMATA retrofit A) to 1,022 (BART Cubic). Coin acceptor reliabilities ranged from 510 MTF to 2,115 MTF. Bill validator reliabilities ranged from a low of 40 MTF (WMATA pre-retrofit) to 1,856 MTF (BART IBM).

SUMMARY OBSERVATIONS ON VENDOR AND GATE PERFORMANCE

Based on the results from the performance assessments, the following observations can be made on the performance of the equipment:

Vendors

1. The microprocessor-controlled European vendors performed significantly better than their American counterparts based on both in-service data and data from transit system records. The smaller size ticket, the method of ticket delivery and the absence of bill validators in the European machines may have had an impact;

TABLE 5. SUMMARY OF ADDFARE RELIABILITIES BASED ON IN-SERVICE DATA

TRANSIT SYSTEM	OVERALL MACHINE MTF	TICKET TRANSPORT MTF	COIN ACCEPTOR MTF	BILL VALIDATOR MTF
BART (All)	225	995	1,161*	1,393*
BART (IBM)	232	928	619*	1,856*
BART (Cubic)	222	1,022	1,703*	1,277*
WMATA-P**	96	552	2,115	40
WMATA-A**	84	243	510***	474***
WMATA-B**	174	872	1,039	454

*Reliability based on tickets sold, not coin or bill insertions.

**WMATA-P refers to pre-retrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.

***Subsystem not retrofit.

2. Based on in-service data, ticket transports of the American vendors tend to be less reliable than coin acceptors and slightly more reliable than bill validators;

3. Based on in-service data, bill jams comprised a slightly larger percentage of vendor failures than coin and farecard jams. However, other ticket transport failures accounted for the lower reliability of ticket transports compared to coin acceptors;

4. Based on the data from transit system records, transports of the American vendors are less reliable than both coin acceptors and bill validators. This is substantiated by the high percentage of ticket issuer failures for the ICG and PATCO vendors;

5. Vendor availability results were consistent with reliability results and maintenance policy. Where agents and technicians were in stations, and few complex failures occurred, availablities were relatively high (e.g., Tyne and Wear, SSB, WMATA-retrofit B). Where one or both of the situations were not true, availabilities suffered accordingly (e.g, ICG, WMATA pre-retrofit);

6. Vendor maintainability results, although data were limited, were consistent with the statements made in item number five. Both PATCO and ICG maintainability figures reflected large response times due to area coverage requirements by technicians (i.e., a technician has responsibility for equipment at more than one station).

Gates

1. Based on in-service data, the microprocessor-controlled Tyne and Wear gates performed significantly better than the other gates and turnstiles, including less complex gates such as those at MBTA and CTA;

2. Based on in-service data, farecard/ticket-accepting gates performed slightly better overall than coin/token-accepting gates because there was less jamming in the farecard/ticket-accepting machines;

3. For each transit system, based on both in-service data and data from transit system records, the largest category of gate failures were jams of the medium inserted;

4. Similar to the situation for vendors, gate availabilities reflected maintenance policy and incidence and severity of failures. Gate availabilities were generally higher than those for vendors because gates are, in general, less complex machines;

5. Gate maintainability measures were consistent with the factors presented in item number four.

PERFORMANCE RESULTS VERSUS SPECIFICATIONS

Of the eight American rapid rail transit systems surveyed, six have performance specifications for AFC equipment (PATCO, BART, ICG, CTA, MARTA and WMATA). In addition, two systems in the construction stage also have specifications (BMTA and MDTA). Among these eight systems, performance specifications for AFC equipment vary because of differences in failure definitions and chargeability of failures, as well as in equipment design, function and complexity. For example, the PATCO specification for farecard-accepting gates delivered in 1975-6 called for a reliability of 160,000 mean operations between failures (MOBF). A failure was defined as an event in which an element of the system failed to perform the function intended by the design, and thereby caused the unit in which it occurred to fail to meet specification (this did not include jams caused by external conditions). In order to be chargeable, such a failure had to be reproducible and witnessed by a maintenance technician.

In comparison, BART reliability specifications for its farecard-accepting gates were in three measures: 7,500 mean cycles between ticket jams (MCBTJ), 2,500 mean cycles between soft failures (MCBSF) and 15,000 mean cycles between hard failures (MCBHF). A soft failure was defined as any instance, including a ticket jam, in which an AFC equipment did not complete the transaction initiated and the equipment was returned to normal service without replacement, repair or adjustment of any part. A hard failure was defined as any incident rendering an AFC equipment inoperative, that required adjustment, repair or part replacement to restore the equipment to normal service.

Other differences in definition and chargeability exist. The MARTA specification for entry gate reliability was 34,000 mean cycles between failures (MCBF). WMATA set its reliability specification for gates at 720 (hours) MTBF. Under the MARTA specification, only "independent" failures were chargeable. A failure was independent when it was not caused by malfunction of other equipment, component abuse, incorrect maintenance procedures or errors. Errors included intermittent failures and ticket, bill and coin jams. Under the WMATA specification, an equipment failure occurred when any one or a multiple number of machine function modules within the equipment ceased to function and required repairs by a trained maintenance technician.

The two newest rapid rail systems in the U.S. - BMTA and MDTA - have also issued reliability specifications. Each uses the concepts of "relevant" and "non-relevant" failures. The BMTA specification defines relevant failures as all failures that can be expected to occur in revenue service operations. A non-relevant failure is caused by a condition external to the equipment and not expected to be encountered in field revenue service. MDTA has similar definitions. Reliability specification for BMTA gates is 70,000 MCBF; for MDTA gates, the reliability specification is 65,000 MCBF. Both specifications are based on relevant failures.

Comparisons were made between the performance results and specifications for vendors and gates. (Comparisons were difficult due to the differences in performance measures used and failures deemed chargeable.) Table 6 summarizes the results for vendors of those systems for which specifications existed (BART and WMATA). It is important to note that the vendors are quite similar in design and in the functions they provide. For BART, the survey overall machine reliability result of 141 MTF approximates the MCBSF specification of 200. However, 17 percent of the BART failures were ticket jams. This results in a (derived) MCBTJ of 824 (not shown in the table), well below the specification of 3,500 MCBTJ. In addition, the survey result of 1,401 MTF based on hard failures is below the 2,500 MCBHF which is based on a similar but more stringent hard failure definition. (The specification definition includes <u>all</u> adjustment, repair and replacement actions.)

For the WMATA specification, the 2.79 MTBF from the in-service survey pales in comparison to the specification MTBF of 920. (Retrofit B only is shown in the tables because it

TABLE 6. COMPARISON OF VENDOR RELIABILITY ASSESSMENT RESULTS AND SPECIFICATIONS

TRANSIT SYSTEM	SPECIFICATION	PERFORMANCE RESULTS (IN-SERVICE DATA)		
		MTF (ALL FAILURES)	MTF (HARD FAILURES ONLY)	MTBF**
BART	3,500 MCBTJ			3.75
	200 MCBSF	141		
	2,500 MCBHF		1,401	
WMATA*	920 MTBF**	265	6,891	2.79

*Retrofit B.
**MTBF in hours.

represented the best WMATA results.) This great difference is due in part to the many exceptions to the definition of a chargeable failure in the WMATA specifications. For example, not included as failures in the computation of the WMATA specification are damage due to vandalism, preventive maintenance operations and repair, malfunctions not related to component failure, <u>and/or those malfunctions that can be cleared by authorized personnel</u>. The latter exception covers quite a number of in-service situations that, for other systems, are chargeable failures, and that were used in the generation of MTBF measures from survey data.

Table 7 summarizes and compares gate reliability results and specifications. For BART gates, similar to the situation for vendors, the MTF based on all in-service failures is less than the MCBSF specification. However, in contrast to the situation for vendors, the performance of the gates based only on hard failures is five times the MCBHF specification of 15,000. (Recall that the specification definition is more stringent.) For WMATA, the situation for gates parallels that of vendors - an MTBF specification that is much greater than that measure based on survey data.

The MARTA specification of 34,000 MCBF is much greater than the reliability of 12,014 MTF based on hard failures. This difference is due in part to the extent of failures excluded from the MARTA failure definition (e.g., those failures "associated with equipment which senses fare media, or generates, stores, transfers, reads, or writes digital data.")

The CTA specification is close to the survey results based on hard failures. The CTA failure definition is simple and without a list of exceptions. It defines a malfunction as any failure to operate in a normal manner or allow passage because of inoperative mechanical or electrical components. Under this definition, jams due to media are not considered chargeable.

TABLE 7. COMPARISON OF GATE RELIABILITY ASSESSMENT RESULTS AND SPECIFICATIONS

		PERFORMANCE RESULTS			
		IN-SERVICE DATA			TRANSIT SYSTEM DATA
TRANSIT SYSTEM	SPECIFICATION	MTF (ALL FAILURES)	MTF (HARD FAILURES ONLY)	MTBF**	(ALL FAILURES)
PATCO	160,000 MOBF				5,907
BART	7,500 MCBTJ			8.0	
	2,500 MCBSF	1,136			
	15,000 MCBHF		75,518		
WMATA*	720 MTBF**	2,220	N/D	4.2	
MARTA	34,000 MCBF	1,740	12,014	6.1	3,225
CTA	10,000 MCBF	902	8,586	8.6	

*Retrofit B.
**MTBF in hours.
N/D = No Data.

This accounts for the large difference between the specification and the reliability based on all failures of 902 MTF.

SUMMARY AND RECOMMENDATIONS

As described above, there is currently a clear lack of standardization in the area of transit fare collection equipment performance measurement and specification. This report has addressed the performance measurement problem by presenting, delineating and categorizing terms, concepts, methods and procedures in order to aid transit systems in achieving more uniformity in equipment performance assessment and analysis.

A review of the performance results in Tables 1-4 reveals an absence of complete data. This situation indicates a need for more data to be collected and analyzed. However, before more data are collected, standardization criteria should be established. The difficulty in comparing performance results with equipment specifications underscores this need for uniformity in terms, concepts and performance methods and procedures.

Much has been done under the UMTA RTFC project to address these problems. A preliminary assessment method was developed and refined through its application to 11 AFC systems as well as through industry input into the development process by the APTA STARS Fare Collection Reliability Liaison Board. It is believed that implementation of the following recommendations represents a necessary step in the process of developing and applying uniform performance assessment methods for AFC equipment.

1. That the transit systems use the set of definitions, classifications, performance measures, causal factors, chargeability criteria, and assessment methods and

procedures for AFC equipment detailed in this report on a trial basis prior to a formal decision on whether to adopt them;

2. That transit systems schedule performance surveys on a regular basis, using data from both in-service surveys and from internal records. This implies that internal record keeping be such that data are useable for performance measurement;

3. That performance results and failure distribution information be generated on a regular basis and made available to other properties through a system such as TRIP;

4. That surveys and statistical analysis techniques as presented in this report be undertaken to measure and compare the performance of retrofit and non-retrofit equipment;

5. That based on the established definitions and an adequate amount of performance data, equipment specifications be set that reflect achievable and uniform criteria, as well as industry experience.

1. INTRODUCTION

The Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation initiated the Rail Transit Fare Collection (RTFC) project in 1979 in response to a critical need of the U.S. transit industry for improved automatic fare collection (AFC) systems. Expected benefits to be derived from improved fare collection systems include improved operating efficiency, enhanced control of receipts, increased passenger throughput rates, and reduced labor and maintenance costs.

The RTFC effort has been directed by the Transportation Systems Center with the assistance and input of representatives of U.S. rail rapid transit systems. The transit representatives comprise the American Public Transit Association's Subsystem Technology Applications to Rail Systems (STARS) Fare Collection Reliability Liaison Board.

In order to achieve the goals of the project, an extensive research and development program has been undertaken. Under this program, a key project area has been the development of uniform performance assessment methods. The development of the methods has been undertaken with the objectives of assisting transit systems in the assessment of equipment and promoting uniformity in applications. In addition, the effort is intended to improve industry communication in the area of fare collection, and help achieve a better understanding of problems and issues. The development effort has taken an iterative approach that has included the assessment of 11 transit AFC systems using a preliminary assessment methodology, and industry input and consensus through the STARS Fare Collection Reliability Liaison Board.

1.1 PURPOSE AND OBJECTIVES

The purpose of this report is to promote and encourage the use of uniform AFC definitions, assessment methods and procedures by U.S. transit systems, and to present and discuss the results of system assessments. In addition, the report outlines the requirements for incorporating AFC performance information into the UMTA Transit Reliability Improvement Program (TRIP).

Specifically, the objectives of this study are:

- To define AFC terms;
- To inventory existing systems, equipment and maintenance practices;
- To present and discuss methods for determining and assessing equipment performance;
- To summarize the results of systems assessments and compare these with industry contract specifications;
- To make recommendations on the potential application of the assessment methods within the transit industry.
- To assess the information required in order to incorporate AFC information into the TRIP;

1.2 APPROACH

The approach to the development of uniform definitions and performance assessment methods has included the following:

- An inventory of AFC equipment;

- The development of a preliminary assessment method, the IOCS Property Evaluation Plan (PEP);
- The application of the PEP to eleven transit systems, both domestic and foreign;
- A technology review of existing equipment;
- Review of performance results.
- Input and consensus of transit systems through the STARS Fare Collection Reliability Liaison Board;

Based on the previous system assessments, industry input, and the knowledge gained from the technology review, it was determined that the following steps were prerequisite to the development and implementation of a set of uniform performance assessment methods:

- A determination of the uses of performance measures;
- Establishment of such measures;
- The definition of AFC equipment failures;
- Establishment of a set of classifications for failures;
- Development of a set of failure causal factors;
- A determination of the chargeability of failures, (i.e., what failures to use in generating the performance measures);
- Review and consensus by transit systems;
- Actual application of the methods.

1.3 REPORT ORGANIZATION

An inventory and description of rail AFC equipment at U.S. rapid rail systems and at three foreign transit systems is presented first in Section 2.

Section 3 provides a presentation and discussion on procedures for assessing equipment performance, and the methods for obtaining and analyzing performance data. Included are definitions of the key terms and concepts used.

Section 4 presents selected results of the system assessments. These consist of performance measures and failure distributions. In addition, reliability results are compared with selected industry performance specifications. Section 5 presents recommendations on the potential application of the assessment methods within the transit industry.

The appendices to the report provide a glossary of terms, descriptions of AFC maintenance organizations, industry contract specifications and procurement testing procedures, a discussion on the integration of AFC performance information into the TRIP system, and a selected bibliography.

2. INVENTORY OF AFC SYSTEMS AND EQUIPMENT

2.1 DEFINITIONS OF AFC MACHINES AND MAJOR SUBSYSTEMS

2.1.1 AFC Machine

An AFC machine is a device that provides a fare collection revenue service and/or function, and that represents one complete unit to a patron. Examples of AFC machines are farecard/ticket vendors, automatic gates, addfares, transfer dispensers, token dispensers, and change makers.

2.1.2 AFC Machine Major Subsystem

An AFC Machine Major Subsystem is a part or an assembly of parts of an AFC machine that accomplishes a specific revenue function or transaction service and can be considered, for the sake of maintenance, a discrete unit. The major subsystems of AFC machines are: bill validators/verifiers/acceptors, coin (and/or token) selectors/acceptors, ticket transports/issuers, transfer dispensers, turnstile (barrier) mechanisms and control logic units. Table 2-1 presents a listing of AFC machines and their major subsystems.

2.2 AFC SYSTEM DESCRIPTIONS

Table 2-2 presents a summary of AFC equipment at 12 rapid rail transit systems in the U.S. and three foreign systems. Each system is also briefly described below. The descriptions provide the type, number, generation and mix of the equipment in-service. Descriptions of maintenance organizations are presented in Appendix B.

TABLE 2-1. LISTING OF AFC MACHINES AND MAJOR SUBSYSTEMS

MACHINE	MAJOR SUBSYSTEMS
Farecard/Ticket Vendor	Coin Acceptor Bill Verifier Ticket Transport Coin Recycler/Change Dispenser Printer Logic Unit
Addfare	Same as for vendor
Farecard/Ticket-Accepting Gate	Ticket Handler/Transport Coin Acceptor Transfer Dispenser Printer Barrier Logic Unit
Coin/Token-Actuated Gate (Turnstile)	Coin Acceptor Barrier Logic Unit Transfer Dispenser
Bill Changer	Bill Verifier Logic Unit Change Dispenser
Change Maker	Bill Verifier Coin Acceptor Logic Unit Coin Recycler/Change Dispenser
Transfer Dispenser	Logic Unit Transfer Dispenser

TABLE 2-2. SUMMARY OF AFC EQUIPMENT AT RAPID RAIL TRANSIT SYSTEMS

METROPOLITAN AREA/ TRANSIT SYSTEM	GATE	TURNSTILE	FARECARD VENDOR	ADDFARE	CHANGE MAKER	BILL CHANGER	TRANSFER DISPENSER
1. Atlanta (MARTA)	123[1]	-	-	-	-	-	-
2. Washington, D.C. (WMATA)	419	-	283	170	-	-	-
3. San Francisco (BART)	320	-	180	110	140	-	80
4. Lindenwold (PATCO)	85	-	72	-	42	-	19
5. Chicago (ICG)	169	-	112	-	-	-	-
6. Chicago (CTA)	-	240[2]	-	-	-	-	-
7. NY and NJ (PATH)	-	190	-	-	-	24[3]	-
8. Boston (MBTA)	-	325[4]	-	-	-	-	-
9. New York (NYCTA)	-	2747	-	-	-	-	19
10. Philadelphia (SEPTA)	-	140	-	-	-	-	-
11. Baltimore (BMTA)[5]	139	-	52	-	-	16	-
12. Miami (MDTA)[6]	114	-	32	-	-	30	22
13. Newcastle, England	89	-	65	-	-	-	-
14. Stuttgart, West Germany	-	-	485	-	-	-	-
15. Paris (Metro)	1700	-	-	-	-	-	-
16. Paris (RER)	540	-	370	-	-	-	-

1 - Gates accept coins and tickets and dispense transfers.
2 - Transfer dispenser incorporated into turnstile.
3 - Each bill changer tied to a turnstile.
4 - One hundred seventy-nine turnstiles are equipped with magnetic pass slide readers.
5 - The BMTA AFC system is expected to be operational in November 1983.
6 - The MDTA AFC system is expected to be operational in 1984.

The concept of generation refers to the characteristics of the logic units of the machines. First generation equipment either do not have electronics or rely on analog systems, using diodes, capacitors, etc., while second generation equipment, generally built after 1976, are microprocessor-controlled. Encoded media used at U.S. rapid rail transit systems are of the credit card size. These farecards include a variety of types. The most common are single-trip, round-trip, multi-trip, passes and permits. Two of the three European systems described use the Edmondson size ticket (1-3/16" x 2-5/8"). (The Baltimore Metropolitan Transit Authority (BMTA), scheduled to open in the fall of 1983, plans on using the Edmondson ticket.)

The fare structure used by each transit system is also provided in the descriptions. In general, all systems offer reduced fares to certain groups such as students, elderly and/or handicapped persons.

2.2.1 U.S. Transit Systems

2.2.1.1 MARTA - MARTA uses 123 Cubic Western Data (CWD) faregates in 13 stations. The system represents the newest operational AFC system for rapid rail in the country. It consists of entry gates, exit-only gates and fully accessible gates. The entry and fully accessible gates accept coins, tokens and encoded media (e.g., monthly and weekly passes), and dispense transfers. The fare structure is flat with reduced fares available.

The gates, built in 1977 and since modified, are microprocessor-controlled, provide failure diagnostics and are connected to a monitoring center. The entry and exit gates have tripod barriers. The fully accessible gates have a hinged service-type barrier. All tripod gates freewheel in the exit direction.

The coin acceptor is a single-slot unit that accepts quarters, dimes, nickels and MARTA tokens. Coins are checked for diameter and metal content. The belt-driven ticket transport reads, writes (passback information), and returns or captures farecards as necessary (e.g., bus-to-rail transfers are captured). The transfer dispenser issues transfers from paper roll stock. MARTA is currently experimenting with fanfold stock.

2.2.1.2 WMATA - The WMATA AFC system consists of 419 farecard-accepting gates, 283 farecard vendors and 170 addfare machines located in 37 stations. The fare structure is mileage-based during peak hours and flat during off-peak hours. The equipment was manufactured by Cubic Western Data and placed into operation beginning in 1977. AFC equipment in each mezzanine are connected to a computerized Data Acquisition Display System that monitors machine operation. A series of modifications has been undertaken since installation to improve equipment reliability.

The vendors accept coins, bills, and farecards with value remaining. They give coin change and dispense encoded farecards of up to $20 in value. The coin acceptor is a single-slot unit that accepts half-dollars, quarters, dimes and nickels. It checks for diameter, weight, perforations and metallic content. The bill validator accepts one and five dollar bills and scans them magnetically to check validity and denomination. The ticket transport automatically interfaces with a ticket stacker and writes and verifies encoded data and prints farecard values.

The gates control both entrance and exit, with some configured for one-way action. The ticket transports read, write and verify encoded data. Exit gates also print value remaining and capture farecards with no value remaining.

Addfare machines accept undervalued farecards, bills and coins, provide coin change, and dispense farecards for the exact fare needed for exit. The coin acceptor, bill validator, and ticket transport are the same as those in the vendor.*

2.2.1.3 BART - The BART AFC system consists of approximately 320 farecard-accepting gates, 180 farecard vendors, 110 addfares, and 140 change makers in 44 mezzanines located in 34 stations. Equipment for the system was manufactured first by IBM and then by Cubic Western Data. The fare structure is mileage-based.

Two hundred sixty gates were manufactured by IBM, the remainder by Cubic. IBM manufactured 120 vendors, Cubic built 60. Of the 110 addfares, 60 were built by Cubic, the rest by IBM, which also manufactured the change makers.

Both vendors accept coins, bills and farecards with value remaining. Both dispense farecards of up to $20 in value, but only the Cubic vendors provide (coin) change. The farecards are encoded at time of purchase. The coin acceptors of both are single-slot units that accept quarters, dimes and nickels. Similar to those in the WMATA vendors, they check for diameter, weight, perforations and metallic content. Both IBM and Cubic vendors incorporate bill verifiers that accept one and five dollar bills. Bills are scanned magnetically for validity and

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* For a fuller description of the WMATA AFC system, see "Automatic Fare Collection Equipment Reliability and Maintainability Plan for Urban Rail Transit Properties," U.S. DOT Report Number DOT-UMTA-MA-06-0025-81-1, March 1981.

For an assessment of WMATA AFC equipment performance, see "Assessment of WMATA's Automatic Fare Collection Equipment Performance," U.S. DOT Report Number UMTA-MA-06-0080-81-1, January 1981.

denomination. The IBM and Cubic ticket transports write and verify encoded data, and print farecard values.

IBM addfares accept coins and undervalued farecards, and dispense farecards for the exact value required for exit. They do not provide change. Cubic addfares accept coins, bills and undervalued farecards, and return (coin) change. For these machines, major subsystems function the same as for the vendors.

The gates control access in both directions, although some are configured for one-way action. The IBM gates allow for direct acceptance of coins for a minimum fare ticket. Similar to the WMATA gates, IBM and Cubic ticket transports read, write and verify encoded data. Exit gates also print value remaining and capture farecards with no value remaining.*

2.2.1.4 PATCO - The PATCO AFC system consists of 85 farecard-accepting gates, 72 farecard vendors, 42 bill changers, and 19 transfer dispensers in 13 stations. The fare structure is based on zones of travel. Vendors and gates are connected to a monitoring center.

The first generation farecard vendors were manufactured by Advanced Data Systems (ADS) and placed into operation in 1969. Since then, PATCO has modified the equipment to improve reliability. The vendors dispense pre-encoded single-ride and two-ride farecards. Forty-six of PATCO's 61 vendors accept coins only and give change. The other 15 vendors accept coins and one dollar bills and will not give change. (In fact, the machines can only accept one bill per transaction.)

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* For a fuller description and assessment of the BART AFC System, see "Automatic Fare Collection Equipment Reliability and Maintainability Plan for Urban Rail Transit Properties" U.S. DOT Report Number DOT-UMTA-MA-06-0025-81-1, March 1981.

PATCO uses two different types of coin acceptors. The vendors that accept only coins have electronic units, while the vendors that accept coins and bills have mechanical coin acceptors. Both acceptors are single slot units that accept Susan B. Anthony dollars, quarters, dimes and nickels. The electronic unit checks diameter, thickness and metal content. The mechanical unit checks only diameter and thickness.

Bill validators used in the vendors magnetically scan bills for validity and denomination. The ticket transport issues tickets from one of two stacks. Twenty-three vendors have an automatic ticket dispenser; the others have a manually powered ticket dispenser.

The gates were designed by Cubic Western Data and placed into operation in 1975. They incorporate tripod barriers and control both entrance and exit, with some configured for one-way action. The ticket transports read and write encoded data. Tickets with no rides remaining are captured.

The bill changers are used to provide passengers with enough change to insert in the farecard vendors. Thirty-eight machines will only accept one dollar bills. Six others have been modified to also accept five dollar bills. The machines use verifiers that optically scan bills for validity.

Each transfer dispenser incorporates a single-slot coin acceptor and delivers transfers from paper stock.

2.2.1.5 ICG - The ICG AFC system consists of 169 farecard-accepting gates and 110 farecard vendors in 59 mezzanines at 49 stations. The first generation equipment was manufactured by Cubic Western Data and placed into service between 1973 and 1976. Both the gates and vendors are connected to a central monitoring facility. The fare structure is based on zones of travel. Since installation, ICG has modified the equipment to improve performance.

The vendors accept coins and bills, dispense stored-ride farecards and return coin change only. Farecards are encoded at time of purchase. The coin acceptor accepts half-dollars, quarters, dimes and nickels in a single slot. The coins are mechanically checked for metal content and weight. The original bill validators accepted one and five dollar bills and verified bills using photo-electric sensors. Due to low reliability, ICG initiated a program in 1980 that replaced these with units that accept one and five dollar bills and magnetically check for denomination and validity. (At this time, approximately 80 percent of the vendors have been so equipped.) The ticket transport issues tickets from a single stack. The transport writes and verifies encoded data.

The gates have tripod barriers and control both entry and exit, with some configured for one-way action. Ticket transports read and write encoded data. Tickets with no rides remaining are captured upon exit.

2.2.1.6 <u>CTA</u> - The CTA uses approximately 240 coin-operated turnstiles in 178 mezzanines at 140 stations. (These are supplemented by agent-operated turnstiles.) The fare structure is flat with reduced fares available. The turnstiles were manufactured by Duncan Industries and installed in three sets - 1976, 1979 and 1981. They are microprocessor-controlled, dispense transfers and can register two fares simultaneously. (In other words, the machines can accept one patron's fare while another patron is still going through the barrier.) They have tripod barriers and control entry access and freewheel for exit.

Coin acceptors have a wide single slot that can accept more than one coin at a time. The unit accepts all coins except the

Susan B. Anthony dollar. Some turnstiles use a transfer dispenser that issues transfers from paper roll stock. Others use units that issue from fanfold stock.

2.2.1.7 PATH - The PATH AFC system consists of 190 Tiltman-Langley coin-operated turnstiles and 24 Hamilton-Scale Change Vending Entrance Bill (CVEB) machines in 13 stations. The fare structure is flat. The first generation turnstiles control entry and freewheel in the exit direction. The machines use a coin acceptor that accepts quarters, dimes and nickels in separate slots. The acceptor checks coins for size and weight. The CVEBs are electronically interfaced to turnstiles, and accept dollar bills and provide change less the payment of the fare. There is at least one CVEB at each station. The bill validators provide a magnetic check of bills inserted.

2.2.1.8 MBTA - The MBTA uses 325 token-accepting turnstiles, manufactured by Perey. Similar to CTA, these are supplemented with agent lanes. The fare structure is flat, with some zone fares. The first generation turnstiles have tripod barriers and control entry access and freewheel for exit. Eighty percent of the turnstiles are 30 years or older; the rest are about ten years old. The coin acceptor is a single slot mechanical unit that checks diameter, thickness and weight. A program was undertaken in November 1980 to incorporate magnetic pass slide readers on a subset of the turnstiles. Currently, one hundred seventy-nine turnstiles are so equipped.*

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* For a fuller description and analysis of the MBTA slide reader program, see "Description and Evaluation of the MBTA Magnetic Card Fare Collection System," U.S. DOT Report Number UMTA-MA-06-0025-81-2, DOT-TSC-UMTA-81-42, September, 1981.

2.2.1.9 NYCTA - The NYCTA AFC system consists of 2,747 token-accepting turnstiles, 83 agent-operated turnstiles, and 146 agent-operated pass gates. The fare structure is flat with reduced fares available for the elderly, handicapped and students. Of the token-accepting turnstiles, 2,546 are conventional low-entrance turnstiles and 201 are high-entrance turnstiles. The conventional turnstiles represent equipment from a variety of manufacturers. Some of the machines are as old as 60 years. The majority of the relatively new machines were manufactured by Perey. Each Perey gate has a single slot token acceptor, and tripod barrier, and controls access upon entry. Many, but not all, freewheel in the exit direction.

The Metropolitan Transportation Authority, the regional transportation agency that oversees the NYCTA, has included in its modernization plan for the region's transportation facilities a feasibility study of modernizing the NYCTA AFC system.

2.2.1.10 SEPTA - The SEPTA AFC system consists of three sets of turnstiles. There are 100 from Perey, 20 from Duncan and 20 from Tiltman-Langley. The fare structure is flat with reduced fares available. The turnstiles control access in the entry direction and freewheel for exit.

The first generation Perey machines, which accept only tokens in a single slot, were installed in the late 1950s. The Tiltman-Langley machines accept both coins and tokens in a single slot and rely on analog logic systems. These were installed in the early 1970s. The Duncan machines are microprocessor-controlled, and accept both coins and tokens in a single slot. Similar to the CTA machines, they can accept multiple coins and register two fares simultaneously. These machines were installed beginning in 1976.

2.2.1.11 BMTA - The BMTA has awarded a contract to Alta Technology for the procurement of AFC equipment for its system, scheduled to open in November 1983. The BMTA will have a zone fare structure. The AFC system is being installed in two phases. The second phase is expected to be operational by the end of 1986.

The Phase A system consists of 40 vendors, 115 gates (of which 21 are emergency/fully accessible gates) and 12 bill changers in nine stations. The equipment are linked to a central computer. When Phase B is completed, the AFC system will consist of 52 ticket vendors, 139 gates (of which 25 will be emergency/fully accessible gates) and 16 bill changers in 12 stations.

The vendors are microprocessor-controlled, accept coins only, provide change, and dispense individual and sets of two single-trip tickets of the Edmondson size. Tickets with or without transfer privileges can be purchased from the machines. The coin acceptor is a single-slot unit that accepts nickels, dimes, quarters, and Susan B. Anthony dollars. Coins are electro-mechanically checked for diameter, weight and metallic content. The ticket delivery system uses a double-roll feeding assembly (i.e., ticket unrollers) that delivers tickets into the ticket transport from a continuous strip. Ticket stock is fed and cut, and the tickets are encoded, verified and dispensed to the patron.

The gates have tripod barriers, and control both entrance and exit, with some configured for one-way action. Tickets are accepted in any of four directions (either side up or either end first). In addition to tickets sold by vending machines, the Baltimore MTA AFC system will use encoded monthly passes. Ticket data are read, written and verified. Monthly passes and tickets with transfer privileges are returned; single trip tickets without transfer privileges are captured.

2.2.1.12 MDTA - MDTA has recently entered into a contract with Cubic Western Data for AFC equipment. The proposed system calls for 74 entry gates, 40 exit gates, 32 vendors, 22 transfer dispensers, and 30 bill changers in 20 stations. The MDTA system is expected to open in 1984. At this time, only the gates have been approved for purchase. The transit system is still in the process of deciding whether to install in-station ticket vendors.

The CWD faregates are microprocessor-controlled and are similar to the MARTA gates. The entry gates accept coins and farecards. They control entry access, freewheel in the exit direction and will be connected to a monitoring center.

The coin acceptor is a single-slot unit designed to accept nickels, dimes, quarters, MDTA tokens and Susan B. Anthony dollars. Coins are checked for diameter and metal content. The ticket transport reads, writes, and returns or captures farecards.

2.2.1.13 LIRR - The Long Island Railroad presently does not use automatic fare collection equipment. All tickets are currently sold by agents and clerks at ticket outlets, and by conductors onboard trains. Tickets are inspected, punched, and collected onboard trains. The LIRR has a zone fare structure.

The Metropolitan Transportation Authority, the regional transportation agency that oversees the LIRR, has included in its modernization plan for the region's transportation facilities the implementation of an AFC system for the LIRR within five years.

As part of this modernization plan, the LIRR has recently entered into an agreement with Autelca for the delivery of four ticket vending machines. The machines will be used on an experimental basis and are expected to be delivered at the end of 1983. The vendors will accept coins and bills and sell tickets using four different types of paper stock. The machines only print (rather than print and encode) relevant data on the tickets. The vendors are similar to those currently in service in Stuttgart, West Germany. (See Section 2.2.2.2 below.)

2.2.2 Foreign Transit Systems

The three foreign systems described below were selected for inclusion in the RTFC project because each had recently installed automatic gates and/or self-service ticket vendors incorporating new technology - microprocessors, failure diagnostics, coin recycling, and needle printers. This provided an opportunity to assess the performance of such equipment and to compare results with the performance of equipment at American transit systems.*

2.2.2.1 Tyne and Wear Metro (T&W) - The Tyne and Wear Metro system in Newcastle, England, uses 65 Crouzet vendors and 89 Cubic- Tiltman-Langley-Crouzet ticket-accepting gates. The Metro system, which began operation in 1980, has a zonal fare structure with reduced fares available.

The vendors are microprocessor-controlled, accept coins only, provide change, and issue single-ride, magnetically encoded tickets of the Edmondson size. The machines incorporate new technology such as coin recycling, needle printers and failure diagnostics.

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* For a full description and assessment of these systems, see "An Assessment of Automatic Fare Collection Equipment at Three European Transit Properties," U.S. DOT Report Number UMTA-MA-06-0025-82-5, DOT-TSC-UMTA-82-36, December, 1982.

The coin acceptor is a single-slot unit that electromechanically checks for volume and metallic content. The ticket delivery system uses a double-roll feeding assembly (i.e., ticket unrollers) that delivers tickets into the ticket transport from a continous strip. Ticket stock is fed and cut, and the tickets are encoded, verified and dispensed to the patron.

The gates have four-section paddle barriers and Crouzet ticket transporters. The gates read and cancel only. They control access in the entry direction but are not available for exit. There are separate gates at each station that freewheel in the exit direction. The Tyne and Wear AFC equipment are connected to a central monitoring center.

2.2.2.2 Stuttgarter Strassenbahnen (SSB) - The SSB system is an integrated trolley and bus system in Stuttgart, West Germany that uses 485 Autelca vendors and on-board ticket cancellers. The SSB system has a zonal fare structure and a barrier-free system.

The vendors are microprocessor-controlled, accept coins only, provide change, and issue single- and multi-ride paper tickets. The tickets are not magnetically encoded. Data are printed on the tickets to indicate such items as fare paid, time of day, and zones of travel. The machines incorporate coin recycling, failure diagnostics and needle printers. The cancellers are available on vehicles for passengers who purchase multi-ride tickets.

The coin acceptor is a single-slot unit that can accept six types of coins. Coins are mechanically and electronically checked for size and material. The ticket delivery system is a sprocket feeder that moves ticket stock vertically into the printing subsystem. The ticket is then printed, cut and dropped into a delivery cup.

2.2.2.3 Regie Autonome Des Transports Parisiens (RATP) - The Paris Metro and Regional Express Rail System (RER) comprise the rail system of the RATP, an integrated rail and bus system. The Metro operates in the urban area and has a flat fare structure, while the RER is basically a commuter system, which relies on a zone fare structure.

The Metro uses agent-operated machines for ticketing, and about 1700 gates for access control. There are no exit gates; exit is through exit-only doors. The gates accept magnetically encoded tickets of the Edmonson size for entry, and freewheel in the exit direction. The gates read and cancel and are connected to a central computer for monitoring.

The RER uses about 370 first generation Crouzet vendors for ticketing and 540 ticket-accepting gates for both entry and exit. The vendors, which were built in the early 1970s, accept coins only, provide change, and dispense individual and sets of five encoded single-ride tickets of the Edmonson size. The vendors are expected to be replaced in 1984 by microprocessor equipment from Crouzet and Marcel Dassault. These are similar to the Tyne and Wear and SSB vendors respectively.

The gates used in the RER system consist of entry-only, exit-only and reversible gates. An RER passenger must insert his or her ticket in a gate for both entry and exit from the system. The gates that comprise the system include microprocessor-controlled equipment from Crouzet. They incorporate failure diagnostics, and perform read, write and verification functions. In addition, the equipment is linked to a station computer for monitoring.

3. PERFORMANCE ASSESSMENT METHODS

3.1 OVERVIEW

There is a clear lack of standardization in transit fare collection equipment, including the area of performance measurement and specification. Substantial disagreement, for example, exists within the transit industry as to what constitutes a countable failure for AFC machines. This has had serious consequences for transit systems. For example, several systems have had to work tenaciously with suppliers to ensure quality products and adherence to testing requirements. In some cases, higher costs have been the result of the lack of standardization. The problem has been summed up in a recent report from MITRE on standardization of equipment:

> "the lack of standardization has hindered the accumulation, analysis and transfer of performance and reliability data which could be used for the specification, design and production of improved systems and subsystems and their components. On the whole, the lack of standardization appears to result in higher costs, lower levels of performance and reliability and significant increases in the uncertainties and risks associated with procurement".*

As part of the ongoing UMTA/TSC/APTA effort to improve the effectiveness of fare collection systems, this study is intended to promote uniform performance assessment methods for AFC equipment. This section presents procedures for performance measurement, and the methods by which data can be obtained and analyzed.

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* Implementation Plan for Fare Collection Standardization, MITRE Corp., July 1981, p. 1.

The performance measurements generated from these procedures - reliability, maintainability and availability - can be used for a variety of purposes. At a recent Fare Collection Reliability Liaison Board Meeting, representatives from rapid rail and commuter rail systems identified five key uses:

1. To provide information for monitoring compliance with equipment procurement specifications (prototype testing, acceptance testing and system reliability testing);
2. To provide operational data for management information systems and for maintenance productivity monitoring. For example, such data could be used to determine manpower requirements for agents and technicians, as well as the effectiveness of preventive and corrective maintenance programs;
3. To generate data as a baseline for modification programs. For example, improvement goals could be established based on known performance;
4. To improve communication within the industry. For example, performance comparisons would make more sense if each transit system used the same assessment method;
5. To aid in the development of a reliability data base similar to that which already exists for transit vehicles (i.e., TRIP).

3.2 NOMENCLATURE

In this section key AFC terms and concepts are defined. In the case of failure definitions and classifications, it is important to note that many different definitions and classifications exist. In some cases, there is one set for specification documents and another set for operational use. The definitions and classifications presented here are based on experience gained from the systems assessments and on input from transit AFC managers and technical personnel. (AFC failure definitions and classifications from equipment specification documents are provided in Appendix C.)

3.2.1 Glossary of Terms

Appendix A presents a full list of specific terms and concepts used in automatic fare collection performance assessment. The subsections below describe in detail the key terms and concepts used in this report.

3.2.2 Performance Measures

The output of any system is the performance of a specified function. System effectiveness is a term used to describe the overall capability of a system to accomplish its intended function. Effectiveness encompasses system design, use, and maintenance as well as administrative and policy decisions that support system operation. Reliability, availability, and maintainability are quantitative measures of performance that refer to the operational readiness of a system. Each of these three concepts is defined below as it applies to an AFC system.

3.2.2.1 Reliability - Reliability is a measure of equipment performance that indicates the rate at which a machine or a major subsystem of a machine successfully accomplishes its functional task or mission. It can be expressed in a variety of ways. Two common measures used are:

1. Mean Transactions Per Failure (MTF) represents the average number of transactions that can be expected to be processed before a failure occurs. A transaction is defined as each instance in which a machine or major subsystem is called upon to perform its function.

   MTF is expressed as follows:

   $$\text{MTF} = \frac{\text{Total Transactions}}{\text{Total Failures}}$$

2. Mean Time Between Failures (MTBF) represents the average amount of time that a machine can be expected to remain operable before a failure occurs.

   MTBF is expressed as follows:

   $$\text{MTBF} = \frac{\text{Total In-Service Time}}{\text{Total Failures}}$$

Mean Cycles Between Failures (MCBF) is often used interchangeably with MTF. Other reliability measures used by transit systems for AFC equipment include Mean Cycles Between Maintenance Actions (MCBMA) and Mean Cycles Between Jams (MCBJ).

In addition, as will be discussed in the section on data analysis (Section 3.5), the probability measure R is required in order to perform statistical analysis on reliability measures. R represents the probability of a successful transaction and is expressed as follows:

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

It is worth noting that $\text{MTF} = \frac{1}{1-R}$.

3.2.2.2 Availability - Availability is defined as the probability that AFC equipment will be operating satisfactorily at any point in time. Availability is calculated by dividing the total in-service time by the total operating time and converting the result into a percentage. Total operating time is comprised of: (1) total in-service time (operating and available for service); and (2) total downtime (i.e., combined duration of all failures, including active repair time and response and logistic time). An example of logistic time is time spent going for parts. Availability is expressed as follows:

$$A = \frac{\text{Total Operating Time} - \text{Total Downtime}}{\text{Total Operating Time}}$$

3.2.2.3 Maintainability - Maintainability is a measure of the average length of time failures take to be repaired. It is commonly expressed as average downtime (ADT) and mean time to repair (MTTR). Average downtime indicates the average time AFC equipment can be expected to be out of service per failure. It is calculated as follows:

$$ADT = \frac{\text{Total Downtime}}{\text{Total Failures}}$$

Mean time to repair indicates the average length of time required to respond to and repair a "hard" failure of AFC equipment.

$$MTTR = \frac{\text{Total Downtime (Hard Failures Only)}}{\text{Total Number of Hard Failures}}$$

It is important to note that in the system assessments, MTTR figures were generated for hard failures only. These are described below.

3.2.3 Failure Definitions/Classifications

An AFC equipment failure is defined as any instance of malfunction that prevents a successful transaction or necessitates intervention by transit system personnel. Figure 3-1 provides a flowchart of an AFC failure and its eventual corrective maintenance action.

The classification scheme for AFC failures consists of three failure types: jams, and soft and hard failures. Note that these terms indicate the general nature and severity of failures. In a maintenance and/or performance reporting system, these should be complemented at least with an indication of the subsystem affected, and, preferably, with an indication of the component and/or subcomponent affected, a specific description of the problem (i.e, symptom), a causal factor, and, possibly, a weighting factor that would indicate severity more specifically. In addition, the reporting system should allow for instances where failures were reported but the technician or agent found no defects (NDFs). (This latter situation occurs enough to warrant a special category. For example, at ICG, NDFs represented 12 percent of vendor failures and 11 percent of gate failures. At SSB, NDFs comprised about 25 percent of equipment-related failures.)

3.2.3.1 Jams - A jam is defined as any instance in which a fare medium inserted by a patron, or a fare medium or other item (e.g., change) dispensed to a patron is stuck in the processing or dispensing path, precluding the completion of a successful transaction or rendering the machine or subsystem inoperative.

3.2.3.2 Soft Failures - A soft failure is any instance of malfunction of AFC equipment, including jams not due to hard

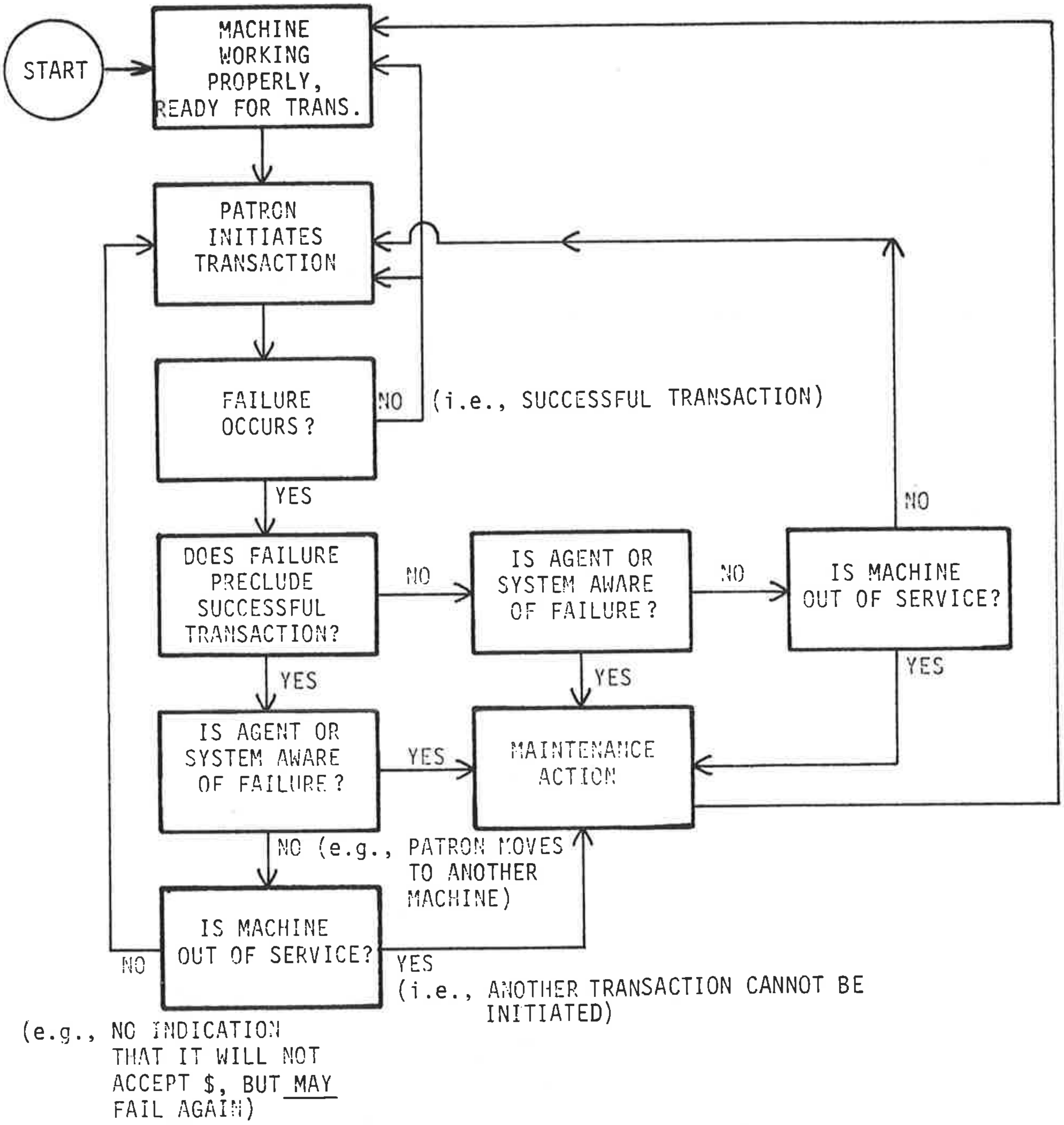

FIGURE 3-1. AFC EQUIPMENT FAILURE SCENARIO

failures (see below), that necessitates a minor adjustment, minor repair or a clearing or cleaning action. Adjustment refers to the resetting or rearranging of a subsystem, component or subcomponent that has changed its position (e.g., out of tolerance), rendering it malfunctioning. Repair refers to the fixing of a subsystem, component or subcomponent that has become damaged through use or abuse. Minor is defined in this report as requiring less than 20 minutes of total technician active repair time.

3.2.3.3 Hard Failures - A hard failure is any instance of malfunction of an AFC equipment that necessitates a major adjustment, major repair or replacement. It is important to note that jams are sometimes due to the failure of a subsystem, component or subcomponent that subsequently requires major repair or replacement. Major is defined as requiring more than 20 minutes total technician active repair time.

3.2.4 Causal Factors

The failure classification set described above indicates the general nature and severity of the problem encountered by the maintenance technician or station agent. Jams, soft and hard failures do not necessarily indicate the cause of the failure - the "why". In order to indicate the cause of a failure, a set of causal factors is defined. Note that these causal factors are, in some cases, difficult to assign (particularly operational problems). Nevertheless, segmenting failures into categories such as these already takes place at some transit systems, although, in most cases, the practice has not been formalized (i.e., the factors are not used officially). In discussions about failures with maintenance managers and technical personnel, these causal factors are the most often cited.

1. Technical - A failure is considered a technical failure when it can be shown that the machine has malfunctioned on its own, i.e., as a result of normal operation and not as a result of the other causal factors listed here. This causal factor includes, among others, failures related to equipment and parts design and manufacture;

2. Operational - A failure due to oversight or error on the part of maintenance personnel. This includes such diverse situations as operating equipment beyond life expectancy, faulty installations and faulty maintenance;

3. Environmental - A failure due to the operation of the equipment in adverse environmental conditions that exceed specifications;

4. Vandal - A failure resulting from damage done by vandals;

5. Administrative - A failure due to oversight or error in non-technical functions of the machine. These failures include situations such as improperly loaded ticket or transfer stock, out of tickets, etc.;

6. Patron-Induced - A failure caused by patrons improperly inserting fare media or interfering with the normal action of a machine. For example, at CTA during peak periods, some transfer jams occur because patrons in the paid area unwittingly interfere with the dispensing of the transfer through the transfer slot.

3.2.5 Chargeability of Failures

In order to generate, report and use equipment performance measures, a determination must be made as to what failures to use. Chargeability refers to the concept of considering a particular failure as countable in the generation of such measures.

Within the industry, differences exist depending on whether the performance measures are being used for procurement testing or for maintenance management. For example, Baltimore uses the concepts of relevant and non-relevant to determine reliability in procurement tests. Even among transit systems that generate reliability measures for management purposes, differences exist in terms of failures used. For example, some systems use technical failures only, while others use both technical and administrative failures. The specific failure to use as chargeable depends on the intended use of the performance measure.

3.2.6 Weighting

In addition to chargeability, a weighting system could be established that would indicate more specifically the severity of the failure encountered, or the importance of the part being adjusted, repaired, or replaced. For example, a major subsystem such as a coin acceptor that needs major adjustment could be assigned a weight of one (full weight), while components and subcomponents, such as printed circuit boards, springs, screws, etc., that need replacement, could be assigned a fraction less than one.

3.3 PROCEDURES FOR PERFORMANCE MEASUREMENT

This section describes procedures that can be used to determine and monitor equipment performance. The results generated will vary depending on the failures deemed countable and the nature of the data. The former refers to whether all or a subset of all failures are used. As mentioned above, this depends on the intended use of the measures. The latter refers to whether data are obtained from in-service surveys or from transit system records.

Three procedures for computing reliability are described below. These measures are best used in conjunction with information on maintainability, availability, and failure distributions. Transit systems may choose the methods that best fit their needs. Figure 3-2 presents a block diagram of the assessment process.

3.3.1 Reliability Based on All Failures

An overview of equipment performance can be obtained by considering all failures as countable, regardless of cause. Thus, even if it is clear that a jam has occurred because a patron has inserted a damaged farecard into a ticket transport, the fact that the machine will not perform its mission is considered a failure.

As can be expected, when all failures are counted, reliability measures are at their lowest levels. This procedure was followed in the previous systems assessments as a means to obtain a baseline of performance measures. It was also done because, in many cases, origin of failure was impossible to determine. For example, while failures due to bent coins are easily observed, farecard jams in gate ticket

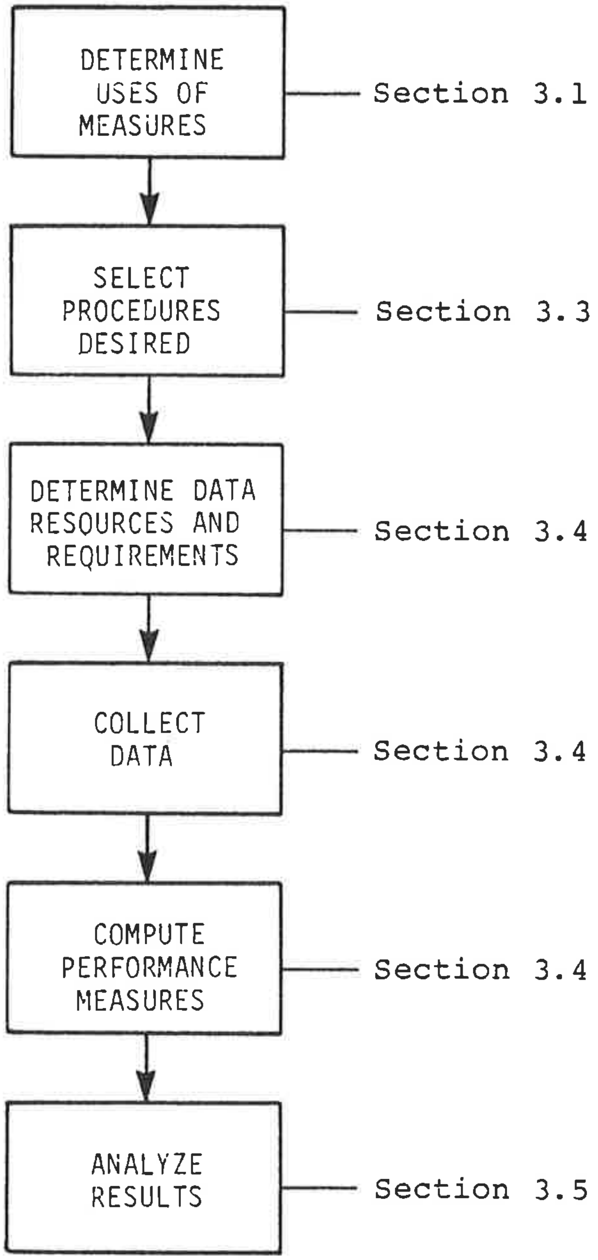

FIGURE 3-2. BLOCK DIAGRAM OF PERFORMANCE ASSESSMENT PROCESS

transports or bill jams in validators cannot always be clearly determined to be patron-induced.

This measure could be used in a number of ways. Similar to all the performance measures presented, tracking such a measure would be useful in spotting trends. (This would be done in conjunction with a review of other performance measures and an assessment of failure trends.) In addition, such a measure could provide an indication of the frequency of required patron assistance and of expected delay. These, in turn, could be used to determine the requirement for future equipment as well as manpower for both agents and technicians.

3.3.2 Reliability Based on Transit plus Technical Failures

This procedure determines the reliability based on all failures less those caused by vandals and patrons. The resultant set of failures is referred to as transit plus technical failures. This procedure provides a performance measurement based on all failures over which the transit system, in theory, can exercise control and do something about. As a management tool, this measure can be used to monitor not only equipment performance, but also the productivity of those responsible for administrative functions such as vault pickups, and ticket and transfer stock refills. In order to make this measure a useful one, effort should be taken to carefully assess whether alleged patron-induced failures are indeed caused by torn bills, mutilated tickets, etc. In some cases, bills are torn and tickets mutilated by the equipment.

3.3.3 Reliabilities Based on Technical Failures

This procedure requires that only technical failures be counted in the determination of reliability. Such measurements could be generated for all soft and hard technical failures. These measurements could assist transit systems in monitoring performance of equipment under test or warranty, and also indicate to management specific technical problem areas as well as suggest the effectiveness of preventive maintenance (PM) procedures and policy (e.g., PM intervals).

These measures require that failures due to environmental causes, operational and administrative errors, as well as patron-induced failures, vandal failures, and NDFs not be counted. As mentioned above, it is often difficult to separate out operational failures, particularly those due to incorrect or inadequate preventive and/or corrective maintenance. One way to overcome this problem would be to track the reliabilities based on technical failures and operational problems alongside the reliabilities based only on assumed technical failures. This would minimize the problems inherent in assigning failures to improper maintenance techniques and, reviewed with reliabilities based on assumed technical failures, would provide a better indication of problem trends.

3.3.4 Maintainability

Maintainability measures provide another indication of overall system effectiveness and the effectiveness of maintenance procedures, policies and techniques. Average downtime can be used to determine whether unacceptable delays are being placed upon patrons. Both ADT and MTTR could be used to indicate improving or declining performance of both the equipment and maintenance personnel. Similar to the case of reliability, maintainability measures can be generated and assessed based on failures considered chargeable.

3.3.5 Availability

Availability measures provide a basic indication of service provided to patrons. They can be used to determine the probability of delay, and as a general indication of the performance of equipment and maintenance efforts.

3.3.6 Failure Identification

Recording and monitoring of individual AFC equipment failures should be undertaken in conjunction with the generation and monitoring of performance measures. Tracking failure data can often indicate specific problem or improvement areas. In any case, the interpretation of performance measures is complete only when failure distributions and trends have been investigated.

3.4 METHODS FOR OBTAINING DATA FOR PERFORMANCE MEASUREMENT

The first two procedures presented for measuring reliability performance, i.e., reliability based on all failures, and reliability based on transit plus technical failures, require that in-service surveys be taken. Given the large percentage of jams that occur with ticket or cash systems, and the fact that few show up on a one-to-one basis in records at most transit systems, a survey must be performed to obtain such failures. In addition, a survey would have to be undertaken in order to determine reliabilities based on transit plus technical failures because of the need to collect data on patron-induced failures. For the computation of reliability based on technical failures, maintenance and transaction records should suffice since the assumption that every technical failure <u>eventually</u> generates a maintenance report seems to be valid throughout the industry. In this case, if records were not already segmented, a careful review of the data would have to be done to separate out technical failures. (Given the existing reporting systems, at some transit systems this is currently either impossible or very difficult to do.)

For maintainability and availability, transit system records cannot currently be used effectively because downtime and repair times are often not included. Where they are, care should be taken that they are reported accurately. For both, in-service surveys would provide good baseline data. Failure identification could be based on either in-service surveys or transit system records. If jams were to be included in an assessment of failures, a survey would be the optimum method.

3.4.1 Transit System Records

Transit system records often provide good data for generating performance measures, particularly reliability. Generally, transaction data in the form of daily or weekly summaries are maintained for a continuous period that encompasses both peak and non-peak periods. For example, the transit system may take machine passenger counts and pick up receipts at approximately the same time daily. Maintenance data may be kept in the form of technician logs or repair calls from monitoring centers, and may, in some cases, be more completely kept as part of an on-going record for an individual machine. In addition, some transit systems (e.g., MARTA) maintain summaries of failures by type and major subsystem affected. Such summaries are excellent sources of failure data, particularly for technical failures. As mentioned above, operating time data indicating the extent of total downtime and time to repair are sometimes kept, but most often are not kept, limiting the generation of availability and maintainability measures.

3.4.2 In-Service Surveys

In-service surveys represent efforts to observe the equipment as the patrons experience it. The surveys can provide much more information on the day-to-day performance of the equipment than measures based on transit system records. The surveys can be conducted using a methodology such as that described in the next few sections.

3.4.2.1 Peak Hour Monitoring - A primary concern in the implementation of an in-service survey is to collect a sufficient amount of data to ensure a representative sample of transactions and failures for statistical validity. (This is usually not a problem with recorded data because of the extent of the data available.) The number of transactions and failures observed during the in-service survey can be maximized by restricting data collection activities to peak periods (about 7:00 AM to 9:00 AM and 4:00 PM to 6:00 PM) when passenger flows are usually three times greater than off-peak periods. While this approach would eliminate comparison to off-peak and weekend periods, it would ensure that sufficient data points are generated.

3.4.2.2 Sample Sizes - The amount of data (number of transactions and number of failures) that should be collected is based on the reliability of the equipment and the number of failures encountered. If mean transactions per failure has been established for the AFC equipment, then the minimum number of transactions observed should be several times the MTF for that type of equipment. If there is no established reliability, then the number of transactions required would have to encompass a survey period during which at least five (5) failures are observed. Five failures are required so that statistical validity of data can be ascertained at the 95 percent confidence level. If the analysis is being performed at the machine or subsystem level, then the minimum number of observations should be accomplished for the machine or subsystem.

The number of station entrances or mezzanines to be sampled should be representative of passenger boarding and alightings in terms of high, medium and low usage and the type of AFC equipment available at the mezzanine. In addition to sampling all types of AFC equipment, considerations should also be given to the ease at which a survey team can access the equipment, record observations and not disrupt the flow of passenger traffic.

A final aspect in determining the number of mezzanines sampled is the duration of the on-site survey period. Since this is dictated by sample size, a review of traffic statistics will ensure selection of mezzanines with adequate traffic volumes.

3.4.2.3 Data Collection - In-service survey activities would involve the recording and collecting of transaction, failure and operating time data. The initial task is to record the beginning transaction status data for each machine on the mezzanine. During the course of the survey period, depending on the size of the mezzanines, a one or two person survey team would record failure data. If two people were used, one team member would record the duration of the failure (downtime) while the other team member would observe the failure with the station attendant or technician to determine the classification and Wear vendors in a two-month period in 1981. During the first six months of 1981 at SSB, the average number of vandal related failures was 75.) When NDFs were excluded, the ICG vendor reliability rose to 118 MTF, the PATCO figure to 311 MTF, and the SSB figure to 6,203 MTF. Note that for Tyne and Wear, the data did not contain instances wherein no defects were found.

Vendor major subsystem reliabilities are also shown in Table 4-3. (Note that these figures do not include vandalism, patron-induced failures and NDFs.) The reliability of the ticket transports of the Tyne and Wear machines was 14,227 MTF. This is significantly greater than the ticket stacker/issuer system for both ICG (439 MTF) and PATCO (637 MTF). Other vendor subsystem reliabilities based on transit system data were for the PATCO coin acceptors (8,681 MTF) and bill validators (2,736 MTF), and the SSB needlepoint printers (32,497 MTF).

4.3.1.2 Vendor Failures - Table 4-4 summarizes the distribution of failures for the BART, WMATA and ICG vendors based on the in-service data. SSB and Tyne and Wear vendor failures are not provided because few failures occurred. Bill jams were the largest category for all but the WMATA pre-retrofit equipment. Farecard jams were the next largest category except in the case of WMATA retrofit B.

Vendor failures based on transit system records were assigned to major subsystem affected. Table 4-5 summarizes these data. PATCO vendors had roughly the same percentage of ticket issuer failures, but a higher percentage of coin acceptor failures than the Tyne and Wear and SSB vendors. ICG had a lower percentage of ticket issuer and coin acceptor failures, but had the highest "other" percentage at roughly 38 percent. The percentage of change dispenser failures was

TABLE 4-4. SUMMARY OF VENDOR FAILURE DISTRIBUTIONS BASED ON IN-SERVICE DATA (PERCENT)

TRANSIT SYSTEM	FARECARD JAMS	COIN JAMS	BILL JAMS	FAILURE TO VERIFY	OTHER SOFT FAILURES	HARD FAILURES	SAMPLE SIZE (NUMBER OF FAILURES)
ICG	28	31*	25	0	17	6**	36
WMATA-P	32	18	25	1	10	4	1,283
WMATA-A	23	23	24	0	24	6	155
WMATA-B	8	32	37	0	19	4	78
BART (All)	17	14	41	1	17	10	199
BART (IBM)	14	13	46	0	26	7	97
BART (Cubic)	19	14	37	2	28	13	102

*All of these failures occurred in the change dispenser. Coin jams for WMATA and BART are for the coin acceptors.

**Percentage totals may be greater than 100 because some jams were due to hard failures.

TABLE 4-5. SUMMARY OF VENDOR FAILURE DISTRIBUTIONS BASED ON DATA FROM TRANSIT SYSTEM RECORDS (PERCENT)

MAJOR SUBSYSTEM AFFECTED	TRANSIT SYSTEM			
	TYNE AND WEAR	SSB	ICG	PATCO
Ticket Issuer	48.8	39.2	25.6	49.8
Coin Recycling	22.6	29.4	N/A	N/A
Change Dispenser	N/A	N/A	27.8	N/D
Coin Acceptor	11.9	9.2	7.8	19.7
Logic	1.2	6.4	1.1	N/D
Other (Includes both Soft and Hard)	15.5	15.8	37.7	30.5

N/D = No Data
N/A = Not Applicable

similar to those for the coin recycling subsystems of the European vendors.

For PATCO and ICG, the ticket issuer failures were considered jams while jamming occurred less frequently in the European equipment. The difference is partially due to the lack of detail in the failure reports for the American equipment, since, in some cases, jams were assumed for lack of detail.

4.3.1.3 Vendor Maintainability - Maintainability measures were generated for both vendors and gates based only on in-service data, with the exception of PATCO. These figures are shown in Table 4-6. The low ADT for the Tyne and Wear vendors reflects the minor nature of the failures and the presence of technicians at key stations during peak hours. On the other hand, both the ICG and PATCO figures reflect a maintenance organization that does not employ station agents in all stations and relies on area coverage, i.e., a technician must cover more than one station. In the case of ICG, this is further compounded by the fact that, for security reasons, a technician must be accompanied by an ICG policeman to open a vendor. The MTTR figures for ICG also reflect time awaiting parts. However, the maintenance action required in both cases of hard failures during the survey were replacements, with the faulty equipment being taken to a shop for repair. In any case, the average active repair or replacement time was about five minutes.

For PATCO vendors, about 46 minutes of both the 65 minute ADT and the 96 minute MTTR represented the technician response time. The long response times result from the fact that PATCO maintenance policy requires technicians to maximize machine availability during the peak hours. Since the PATCO maintainability data are for both peak and off-peak hours,

TABLE 4-6. SUMMARY OF AFC EQUIPMENT MAINTAINABILITIES (ALL, EXCEPT PATCO, BASED ON IN-SERVICE DATA)

TRANSIT SYSTEM	VENDORS		GATES	
	(ALL FIGURES IN MINUTES)			
	ADT	MTTR	ADT	MTTR
MBTA	N/A	N/A	28	N/D
CTA	N/A	N/A	15	69
ICG	37	42	20	N/D
MARTA	N/A	N/A	14	19
TYNE & WEAR	13	N/D	13	N/D
PATCO	65*	96	65	83

N/D = No Data
N/A = Not Applicable
*PATCO policy is that technicians ensure maximum machine operation during the peak hours. The high maintainabilty figures result, in part, from long down times in the off-peak periods due to this policy.

average response time is relatively higher based on these data than that based only on peak hour data.

The average active repair time for vendors was 50 minutes. This long repair time results from the age and complexity of the equipment and the fact that PATCO policy calls for attending the vendors on a repair basis only (i.e., there is no preventive maintenance for vendors).

4.3.1.4 Vendor Availability - Availability measures for AFC equipment were calculated based on in-service data, again with the exception of PATCO. Table 4-7 summarizes the availablity results.

As can be expected from the reliability and maintainability figures, the Tyne and Wear and SSB equipment displayed the greatest availability. This is due to two factors: (1) fewer failures; and (2) low downtime for those failures that did occur.

The low availability of the WMATA pre-retrofit equipment is consistent with its low performance. In addition, the improved availabilities due to both retrofits A and B parallel their improved reliability. The relatively low reliability of the retrofit B vendors (265 MTF) and the high availability (97.6 percent) resulted because, although failures were frequent, they were mostly bill and coin jams quickly cleared by station agents.

On the other hand, the relatively low availability of the ICG vendors was due primarily to the requirement that all vendor failures, including jams, must be attended by technicians in the presence of a security officer.

TABLE 4-7. SUMMARY OF AFC EQUIPMENT AVAILABILITIES (ALL, EXCEPT PATCO, BASED ON IN-SERVICE DATA)

TRANSIT SYSTEM	VENDOR AVAILABILITY	GATE AVAILABILITY	OTHER
MBTA	N/A	95.6	N/A
PATH	N/A	97.2	98.4*
CTA	N/A	98.6	N/A
ICG	90.1	98.4	N/A
PATCO	96.7	99.1	N/D
BART (All)	93.0	88.6	99.3**
BART (IBM)	95.8	94.3	99.9**
BART (Cubic)	87.8	85.2	99.0**
WMATA-P	84.1	92.7	96.2**
WMATA-A	91.6	95.5	93.3**
WMATA-B	97.6	95.4	98.7**
MARTA	N/A	96.4	N/A
T&W	99.6	99.8	N/A
SSB	99.9	N/A	N/A
RATP	88.5	N/D	N/A

*CVEBs
**Addfares
N/D = No Data
N/A = Not Applicable

4.3.2 Automatic Gates

4.3.2.1 Reliability

In-Service Data

Table 4-8 summarizes overall machine reliabilities for gates based on in-service data. These reliabilities ranged from 502 MTF (WMATA pre-retrofit) to 10,229 MTF (Tyne and Wear). ICG gates had the second highest reliability at 4,570 MTF. MTBF figures are also presented. These ranged from a low of 1.1 hours (WMATA pre-retrofits) to a high 91.1 hours for the Tyne and Wear equipment.

Reliabilities based on transit and technical failures are also shown in Table 4-8. (Recall that no vandalism failures occurred during the surveys.) For BART, MARTA and WMATA gates, patron-induced failures were not assigned. For PATH, it was estimated from the data that half of the jams were due to bent coins. The range based on the exclusion of patron-induced failures was 2,862 MTF (CTA) to 10,299 MTF (Tyne and Wear). When only hard failures were used in the reliability computation, the range was 8,506 MTF (CTA) to 137,239 MTF (PATH). In addition, the Tyne and Wear gates did not experience a hard failure over 20,597 transactions, the ICG gates did not experience a hard failure over 86,842 transactions and the BART IBM gates did not experience a hard failure over 76,772 transactions.

Table 4-8 also presents gate major subsystem reliabilities based on in-service data. Ticket transport reliabilities ranged from 858 (WMATA pre-retrofit) to 11,274 (WMATA Retrofit B). For other gate major subsystems, reliabilities ranged from 2,032 MTF to 15,354 MTF (coin acceptors) and 546 MTF to 2,874 MTF (transfer dispensers). The large coin acceptor reliability was for BART IBM equipment.

TABLE 4-8. SUMMARY OF GATE RELIABILITIES BASED ON IN-SERVICE DATA

TRANSIT SYSTEM	NO. OF GATES	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (HARD FAILURES ONLY)	MACHINE MTBF (ALL FAILURES)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (ALL FAILURES)		
						TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER
MBTA	30	1,558	N/D	46,740	10.2	N/A	2,032	N/A
PATH	31	1,989	3,519	137,239	5.0	N/A	4,300	N/A
CTA	14	904	2,862	8,586	8.6	N/A	6,263	546
ICG	28	4,570	6,680	86,842/0	20.5	5,108	N/A	N/A
BART (All)	27	1,136	N/D	75,518	8.0	1,842	N/A	N/A
BART (IBM)	13	1,969	N/D	76,772/0	15.0	4,798	15,354*	N/A
BART (Cubic)	14	790	N/D	37,131	5.1	1,125	N/A	N/A
WMATA-P**	24	502	N/D	N/D	1.1	858	N/A	N/A
WMATA-A**	18	712	N/D	N/D	2.2	1,477	N/A	N/A
WMATA-B**	7	2,220	N/D	N/D	4.2	11,274	N/A	N/A
MARTA	26	1,740	N/D	12,015	6.1	5,340	3,266	2,874
T&W	16	10,299	10,299	20,597/0	91.1	10,299	N/A	N/A

*Reliability based on total entries, not coin insertions.
**WMATA-P refers to pre-retrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.
N/D = No Data
N/A = Not Applicable

Data from Transit System Records

Table 4-9 summarizes gate reliabilities based on data collected from transit system records. It should be noted that only ICG records included vandalism reports. In addition, no defect found (NDF) information was not part of the PATH data.

The overall reliability for the ICG gates was 2,507 MTF. This increased to 3,037 MTF when the vandalism and patron-induced failures were excluded. The PATH reliability was highest at 12,672 MTF, partially due to the fact that the majority of jams are not included in system records. When NDFs were also excluded, ICG reliability increased to 3,509 MTF. MARTA gate reliabilities increased to 3,567 MTF when both NDF and administrative failures were excluded.

Table 4-9 also presents gate major subsystem reliabilities based on transit system data. (Recall that these figures do not reflect vandalism, patron-induced and NDF type failures. In addition, the MARTA data also do not include failures due to administrative errors.) The reliabilities, with the exception of the PATCO transfer dispenser, are relatively high. However, in the case of coin acceptors, this is true because the overwhelming majority of jams are not included because these are cleared by agents.

4.3.2.2 Gate Failures - Gate failure distributions based on in-service data were generated for several of the transit systems as shown in Table 4-10. Note that the Tyne and Wear gates are not included due to the low number of failures observed. In addition, the WMATA data did not indicate the type of gate failures. For each system shown in the table, the greatest majority of failures for gates were jams due to the medium inserted.

TABLE 4-9. SUMMARY OF GATE RELIABILITIES BASED ON DATA FROM TRANSIT SYSTEM RECORDS

TRANSIT SYSTEM	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)			
				TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER	LOGIC
PATH	12,672	12,672**	12,672**	N/A	30,446	N/A	N/D
ICG	2,507	3,037	3,509	N/D	N/A	N/A	N/D
PATCO	5,907	5,907*	5,907	15,096	N/A	783	N/D
MARTA	3,225	3,225*	3,567***	N/D	24,225***	6,849***	21,742***

*Vandalism and patron-induced not cited in PATH, PATCO and MARTA failure data.
**PATH data did not include NDFs.
***Excluding administrative failures also.
N/D = No Data
N/A = Not Available

TABLE 4-10. SUMMARY OF GATE FAILURE DISTRIBUTIONS BASED ON IN-SERVICE DATA (PERCENT)

TRANSIT SYSTEM	FARECARD JAMS	COIN/TOKEN JAMS	TRANSFER JAMS	OTHER SOFT FAILURES	OUT OF SERVICE AND/OR NDF	HARD FAILURES	LOGIC FAILURES	SAMPLE SIZE (NUMBER OF FAILURES)
MBTA	N/A	73	N/A	10	14	3	N/D	30
ICG	75	N/A	N/A	0	25	0	0	20
CTA	N/A	68	16	0	5	0	11	19
PATH	N/A	89	N/A	10	0	1	0	69

N/D = No Data
N/A = Not Applicable

Failure distributions for gates based on data from transit system records were generated for PATH, MARTA and ICG. Because of the differences in reporting techniques, a comparative table was based on major subsystem affected for the farecard-accepting MARTA and ICG gates (Table 4-11). In addition, the MARTA data were based on summaries of maintenance reports filed while the ICG data were the raw technician trouble logs. As a result, some of the failures in the ICG data were not specifically assigned to a subsystem. These have been placed in the "other" category. In addition, the ICG data reflects all instances of jams whereas the MARTA data do not. (MARTA agents can clear ticket jams.) This accounts for the low percentage of ticket transport failures for the MARTA gates (Table 4-11).

4.3.2.3 Gate Maintainability - Table 4-6 (page 4-15) summarizes the maintainability measures for automatic gates and turnstiles. The relatively low ADTs for the Tyne and Wear, MARTA and CTA equipment reflect the high percentage of minor failures (mostly jams) and the presence in the stations of technicians or agents. The high MTTR for the CTA equipment was due to the fact that in the two instances of hard failures, replacement logic boards had to be obtained from the shop. Average active repair time for these was about 45 minutes, 10 minutes of which was diagnosis.

The ADTs for MTBA and ICG consist mostly of response time. Average repair time for ICG and MBTA gates was about three minutes. For PATCO, the large MTTR is due to long response and repair times. Average response time was about 46 minutes. Average active repair time was about 36 minutes. (No hard failures occurred at ICG gates and only one occurred at MBTA gates during the survey.) (See Table 4-10.)

TABLE 4-11. SUMMARY OF GATE FAILURE DISTRIBUTIONS BASED ON DATA FROM TRANSIT SYSTEM RECORDS (PERCENT)

TRANSIT SYSTEM	SUBSYSTEM AFFECTED					
	TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER	TURNSTILE	LOGIC	OTHER
ICG	67	N/A	N/A	7	5	21
MARTA	18	17	26	N/D	19	20

N/D = No Data
N/A = Not Applicable

4.3.2.4 Gate Availability - Table 4-7 (page 4-17) summarizes the availability measures for gates and turnstiles. In general, gate availabilities are usually higher than those for vendors because they are less complicated machines, and they can often be cleared by agents rather than by technicians.

As previously discussed, maintenance organization and policy influence availability. MBTA gate availability is influenced by the response times of technicians. This is also true of ICG and PATCO. During the ICG survey, however, a high availability of gates was maintained in part because technicians could open machines without security personnel present. In addition, the availability reflects the high percentage of minor failures, particularly farecard jams (75 percent).

The WMATA availabilities parallel their respective reliabilities. The similar availabilities between retrofits A and B contrast with their differences in reliability. This suggests that failures for retrofit B had longer downtimes (e.g., were more complex).

The MARTA gate availability also parallels its reliability and the low ADTs per failure.

4.3.3 Other AFC Equipment

Other AFC machines for which performance measures were generated were WMATA and BART addfares, PATH CVEBs (bill acceptors/changers) and PATCO bill changers. Table 4-12 presents the addfare reliabilities based on all failures that occurred during the surveys. (Recall that the data were not segmented into failure categories.) Addfare overall reliabilities based on survey data ranged from 84 MTF (WMATA pre-retrofit) to 232 MTF (BART IBM).

TABLE 4-12. SUMMARY OF ADDFARE RELIABILITIES BASED ON IN-SERVICE DATA

TRANSIT SYSTEM	OVERALL MACHINE MTF	TICKET TRANSPORT MTF	COIN ACCEPTOR MTF	BILL VALIDATOR MTF
BART (All)	225	995	1,161	1,393
BART (IBM)	232	928	619	1,856
BART (Cubic)	222	1,022	1,703	1,277
WMATA-P	96	552	2,115	40
WMATA-A	84	243	510**	474**
WMATA-B	174	872	1,039	454

* Reliability based on tickets sold, not coin or bill insertions.
** Subsystem not retrofit.

and Wear vendors in a two-month period in 1981. During the first six months of 1981 at SSB, the average number of vandal related failures was 75.) When NDFs were excluded, the ICG vendor reliability rose to 118 MTF, the PATCO figure to 311 MTF, and the SSB figure to 6,203 MTF. Note that for Tyne and Wear, the data did not contain instances wherein no defects were found.

Vendor major subsystem reliabilities are also shown in Table 4-3. (Note that these figures do not include vandalism, patron-induced failures and NDFs.) The reliability of the ticket transports of the Tyne and Wear machines was 14,227 MTF. This is significantly greater than the ticket stacker/issuer system for both ICG (439 MTF) and PATCO (637 MTF). Other vendor subsystem reliabilities based on transit system data were for the PATCO coin acceptors (8,681 MTF) and bill validators (2,736 MTF), and the SSB needlepoint printers (32,497 MTF).

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Vendor failures based on transit system records were assigned to major subsystem affected. Table 4-5 summarizes these data. PATCO vendors had roughly the same percentage of ticket issuer failures, but a higher percentage of coin acceptor failures than the Tyne and Wear and SSB vendors. ICG had a lower percentage of ticket issuer and coin acceptor failures, but had the highest "other" percentage at roughly 38 percent. The percentage of change dispenser failures was

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BART (All)	17	14	41	1	17	10	199
BART (IBM)	14	13	46	0	26	7	97
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*All of these failures occurred in the change dispenser. Coin jams for WMATA and BART are for the coin acceptors.

**Percentage totals may be greater than 100 because some jams were due to hard failures.

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MAJOR SUBSYSTEM AFFECTED	TRANSIT SYSTEM			
	TYNE AND WEAR	SSB	ICG	PATCO
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Coin Recycling	22.6	29.4	N/A	N/A
Change Dispenser	N/A	N/A	27.8	N/D
Coin Acceptor	11.9	9.2	7.8	19.7
Logic	1.2	6.4	1.1	N/D
Other (Includes both Soft and Hard)	15.5	15.8	37.7	30.5

N/D = No Data
N/A = Not Applicable

similar to those for the coin recycling subsystems of the European vendors.

For PATCO and ICG, the ticket issuer failures were considered jams while jamming occurred less frequently in the European equipment. The difference is partially due to the lack of detail in the failure reports for the American equipment, since, in some cases, jams were assumed for lack of detail.

4.3.1.3 Vendor Maintainability - Maintainability measures were generated for both vendors and gates based only on in-service data, with the exception of PATCO. These figures are shown in Table 4-6. The low ADT for the Tyne and Wear vendors reflects the minor nature of the failures and the presence of technicians at key stations during peak hours. On the other hand, both the ICG and PATCO figures reflect a maintenance organization that does not employ station agents in all stations and relies on area coverage, i.e., a technician must cover more than one station. In the case of ICG, this is further compounded by the fact that, for security reasons, a technician must be accompanied by an ICG policeman to open a vendor. The MTTR figures for ICG also reflect time awaiting parts. However, the maintenance action required in both cases of hard failures during the survey were replacements, with the faulty equipment being taken to a shop for repair. In any case, the average active repair or replacement time was about five minutes.

For PATCO vendors, about 46 minutes of both the 65 minute ADT and the 96 minute MTTR represented the technician response time. The long response times result from the fact that PATCO maintenance policy requires technicians to maximize machine availability during the peak hours. Since the PATCO maintainability data are for both peak and off-peak hours,

TABLE 4-6. SUMMARY OF AFC EQUIPMENT MAINTAINABILITIES (ALL, EXCEPT PATCO, BASED ON IN-SERVICE DATA)

TRANSIT SYSTEM	VENDORS		GATES	
	(ALL FIGURES IN MINUTES)			
	ADT	MTTR	ADT	MTTR
MBTA	N/A	N/A	28	N/D
CTA	N/A	N/A	15	69
ICG	37	42	20	N/D
MARTA	N/A	N/A	14	19
TYNE & WEAR	13	N/D	13	N/D
PATCO	65*	96	65	83

N/D = No Data
N/A = Not Applicable
*PATCO policy is that technicians ensure maximum machine operation during the peak hours. The high maintainabilty figures result, in part, from long down times in the off-peak periods due to this policy.

average response time is relatively higher based on these data than that based only on peak hour data.

The average active repair time for vendors was 50 minutes. This long repair time results from the age and complexity of the equipment and the fact that PATCO policy calls for attending the vendors on a repair basis only (i.e., there is no preventive maintenance for vendors).

4.3.1.4 Vendor Availability - Availability measures for AFC equipment were calculated based on in-service data, again with the exception of PATCO. Table 4-7 summarizes the availablity results.

As can be expected from the reliability and maintainability figures, the Tyne and Wear and SSB equipment displayed the greatest availability. This is due to two factors: (1) fewer failures; and (2) low downtime for those failures that did occur.

The low availability of the WMATA pre-retrofit equipment is consistent with its low performance. In addition, the improved availabilities due to both retrofits A and B parallel their improved reliability. The relatively low reliability of the retrofit B vendors (265 MTF) and the high availability (97.6 percent) resulted because, although failures were frequent, they were mostly bill and coin jams quickly cleared by station agents.

On the other hand, the relatively low availability of the ICG vendors was due primarily to the requirement that all vendor failures, including jams, must be attended by technicians in the presence of a security officer.

TABLE 4-7. SUMMARY OF AFC EQUIPMENT AVAILABILITIES (ALL, EXCEPT PATCO, BASED ON IN-SERVICE DATA)

TRANSIT SYSTEM	VENDOR AVAILABILITY	GATE AVAILABILITY	OTHER
MBTA	N/A	95.6	N/A
PATH	N/A	97.2	98.4*
CTA	N/A	98.6	N/A
ICG	90.1	98.4	N/A
PATCO	96.7	99.1	N/D
BART (All)	93.0	88.6	99.3**
BART (IBM)	95.8	94.3	99.9**
BART (Cubic)	87.8	85.2	99.0**
WMATA-P	84.1	92.7	96.2**
WMATA-A	91.6	95.5	93.3**
WMATA-B	97.6	95.4	98.7**
MARTA	N/A	96.4	N/A
T&W	99.6	99.8	N/A
SSB	99.9	N/A	N/A
RATP	88.5	N/D	N/A

*CVEBs
**Addfares
N/D = No Data
N/A = Not Applicable

4.3.2 Automatic Gates

4.3.2.1 Reliability

In-Service Data

Table 4-8 summarizes overall machine reliabilities for gates based on in-service data. These reliabilities ranged from 502 MTF (WMATA pre-retrofit) to 10,229 MTF (Tyne and Wear). ICG gates had the second highest reliability at 4,570 MTF. MTBF figures are also presented. These ranged from a low of 1.1 hours (WMATA pre-retrofits) to a high 91.1 hours for the Tyne and Wear equipment.

Reliabilities based on transit and technical failures are also shown in Table 4-8. (Recall that no vandalism failures occurred during the surveys.) For BART, MARTA and WMATA gates, patron-induced failures were not assigned. For PATH, it was estimated from the data that half of the jams were due to bent coins. The range based on the exclusion of patron-induced failures was 2,862 MTF (CTA) to 10,299 MTF (Tyne and Wear). When only hard failures were used in the reliability computation, the range was 8,506 MTF (CTA) to 137,239 MTF (PATH). In addition, the Tyne and Wear gates did not experience a hard failure over 20,597 transactions, the ICG gates did not experience a hard failure over 86,842 transactions and the BART IBM gates did not experience a hard failure over 76,772 transactions.

Table 4-8 also presents gate major subsystem reliabilities based on in-service data. Ticket transport reliabilities ranged from 858 (WMATA pre-retrofit) to 11,274 (WMATA Retrofit B). For other gate major subsystems, reliabilities ranged from 2,032 MTF to 15,354 MTF (coin acceptors) and 546 MTF to 2,874 MTF (transfer dispensers). The large coin acceptor reliability was for BART IBM equipment.

TABLE 4-8. SUMMARY OF GATE RELIABILITIES BASED ON IN-SERVICE DATA

TRANSIT SYSTEM	NO. OF GATES	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (HARD FAILURES ONLY)	MACHINE MTBF (ALL FAILURES)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (ALL FAILURES)		
						TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER
MBTA	30	1,558	N/D	46,740	10.2	N/A	2,032	N/A
PATH	31	1,989	3,519	137,239	5.0	N/A	4,300	N/A
CTA	14	904	2,862	8,586	8.6	N/A	6,263	546
ICG	28	4,570	6,680	86,842/0	20.5	5,108	N/A	N/A
BART (All)	27	1,136	N/D	75,518	8.0	1,842	N/A	N/A
BART (IBM)	13	1,969	N/D	76,772/0	15.0	4,798	15,354*	N/A
BART (Cubic)	14	790	N/D	37,131	5.1	1,125	N/A	N/A
WMATA-P**	24	502	N/D	N/D	1.1	858	N/A	N/A
WMATA-A**	18	712	N/D	N/D	2.2	1,477	N/A	N/A
WMATA-B**	7	2,220	N/D	N/D	4.2	11,274	N/A	N/A
MARTA	26	1,740	N/D	12,015	6.1	5,340	3,266	2,874
T&W	16	10,299	10,299	20,597/0	91.1	10,299	N/A	N/A

*Reliability based on total entries, not coin insertions.
**WMATA-P refers to pre-retrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.
N/D = No Data
N/A = Not Applicable

Data from Transit System Records

Table 4-9 summarizes gate reliabilities based on data collected from transit system records. It should be noted that only ICG records included vandalism reports. In addition, no defect found (NDF) information was not part of the PATH data.

The overall reliability for the ICG gates was 2,507 MTF. This increased to 3,037 MTF when the vandalism and patron-induced failures were excluded. The PATH reliability was highest at 12,672 MTF, partially due to the fact that the majority of jams are not included in system records. When NDFs were also excluded, ICG reliability increased to 3,509 MTF. MARTA gate reliabilities increased to 3,567 MTF when both NDF and administrative failures were excluded.

Table 4-9 also presents gate major subsystem reliabilities based on transit system data. (Recall that these figures do not reflect vandalism, patron-induced and NDF type failures. In addition, the MARTA data also do not include failures due to administrative errors.) The reliabilities, with the exception of the PATCO transfer dispenser, are relatively high. However, in the case of coin acceptors, this is true because the overwhelming majority of jams are not included because these are cleared by agents.

4.3.2.2 Gate Failures - Gate failure distributions based on in-service data were generated for several of the transit systems as shown in Table 4-10. Note that the Tyne and Wear gates are not included due to the low number of failures observed. In addition, the WMATA data did not indicate the type of gate failures. For each system shown in the table, the greatest majority of failures for gates were jams due to the medium inserted.

TABLE 4-9. SUMMARY OF GATE RELIABILITIES BASED ON DATA FROM TRANSIT SYSTEM RECORDS

TRANSIT SYSTEM	MACHINE MTF (ALL FAILURES)	MACHINE MTF (TRANSIT AND TECHNICAL FAILURES)	MACHINE MTF (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)	MAJOR SUBSYSTEM RELIABILITIES (MTF) (EXCLUDING VANDALISM, PATRON-INDUCED AND NDF)			
				TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER	LOGIC
PATH	12,672	12,672**	12,672**	N/A	30,446	N/A	N/D
ICG	2,507	3,037	3,509	N/D	N/A	N/A	N/D
PATCO	5,907	5,907*	5,907	15,096	N/A	783	N/D
MARTA	3,225	3,225*	3,567***	N/D	24,225***	6,849***	21,742***

*Vandalism and patron-induced not cited in PATH, PATCO and MARTA failure data.

**PATH data did not include NDFs.

***Excluding administrative failures also.

N/D = No Data

N/A = Not Available

TABLE 4-10. SUMMARY OF GATE FAILURE DISTRIBUTIONS BASED ON IN-SERVICE DATA (PERCENT)

TRANSIT SYSTEM	FARECARD JAMS	COIN/TOKEN JAMS	TRANSFER JAMS	OTHER SOFT FAILURES	OUT OF SERVICE AND/OR NDF	HARD FAILURES	LOGIC FAILURES	SAMPLE SIZE (NUMBER OF FAILURES)
MBTA	N/A	73	N/A	10	14	3	N/D	30
ICG	75	N/A	N/A	0	25	0	0	20
CTA	N/A	68	16	0	5	0	11	19
PATH	N/A	89	N/A	10	0	1	0	69

N/D = No Data
N/A = Not Applicable

Failure distributions for gates based on data from transit system records were generated for PATH, MARTA and ICG. Because of the differences in reporting techniques, a comparative table was based on major subsystem affected for the farecard-accepting MARTA and ICG gates (Table 4-11). In addition, the MARTA data were based on summaries of maintenance reports filed while the ICG data were the raw technician trouble logs. As a result, some of the failures in the ICG data were not specifically assigned to a subsystem. These have been placed in the "other" category. In addition, the ICG data reflects all instances of jams whereas the MARTA data do not. (MARTA agents can clear ticket jams.) This accounts for the low percentage of ticket transport failures for the MARTA gates (Table 4-11).

4.3.2.3 Gate Maintainability - Table 4-6 (page 4-15) summarizes the maintainability measures for automatic gates and turnstiles. The relatively low ADTs for the Tyne and Wear, MARTA and CTA equipment reflect the high percentage of minor failures (mostly jams) and the presence in the stations of technicians or agents. The high MTTR for the CTA equipment was due to the fact that in the two instances of hard failures, replacement logic boards had to be obtained from the shop. Average active repair time for these was about 45 minutes, 10 minutes of which was diagnosis.

The ADTs for MTBA and ICG consist mostly of response time. Average repair time for ICG and MBTA gates was about three minutes. For PATCO, the large MTTR is due to long response and repair times. Average response time was about 46 minutes. Average active repair time was about 36 minutes. (No hard failures occurred at ICG gates and only one occurred at MBTA gates during the survey.) (See Table 4-10.)

TABLE 4-11. SUMMARY OF GATE FAILURE DISTRIBUTIONS BASED ON DATA FROM TRANSIT SYSTEM RECORDS (PERCENT)

TRANSIT SYSTEM	SUBSYSTEM AFFECTED					
	TICKET TRANSPORT	COIN ACCEPTOR	TRANSFER DISPENSER	TURNSTILE	LOGIC	OTHER
ICG	67	N/A	N/A	7	5	21
MARTA	18	17	26	N/D	19	20

N/D = No Data
N/A = Not Applicable

4.3.2.4 Gate Availability - Table 4-7 (page 4-17) summarizes the availability measures for gates and turnstiles. In general, gate availabilities are usually higher than those for vendors because they are less complicated machines, and they can often be cleared by agents rather than by technicians.

As previously discussed, maintenance organization and policy influence availability. MBTA gate availability is influenced by the response times of technicians. This is also true of ICG and PATCO. During the ICG survey, however, a high availability of gates was maintained in part because technicians could open machines without security personnel present. In addition, the availability reflects the high percentage of minor failures, particularly farecard jams (75 percent).

The WMATA availabilities parallel their respective reliabilities. The similar availabilities between retrofits A and B contrast with their differences in reliability. This suggests that failures for retrofit B had longer downtimes (e.g., were more complex).

The MARTA gate availability also parallels its reliability and the low ADTs per failure.

4.3.3 Other AFC Equipment

Other AFC machines for which performance measures were generated were WMATA and BART addfares, PATH CVEBs (bill acceptors/changers) and PATCO bill changers. Table 4-12 presents the addfare reliabilities based on all failures that occurred during the surveys. (Recall that the data were not segmented into failure categories.) Addfare overall reliabilities based on survey data ranged from 84 MTF (WMATA pre-retrofit) to 232 MTF (BART IBM).

TABLE 4-12. SUMMARY OF ADDFARE RELIABILITIES BASED ON IN-SERVICE DATA

TRANSIT SYSTEM	OVERALL MACHINE MTF	TICKET TRANSPORT MTF	COIN ACCEPTOR MTF	BILL VALIDATOR MTF
BART (All)	225	995	1,161	1,393
BART (IBM)	232	928	619	1,856
BART (Cubic)	222	1,022	1,703	1,277
WMATA-P	96	552	2,115	40
WMATA-A	84	243	510**	474**
WMATA-B	174	872	1,039	454

* Reliability based on tickets sold, not coin or bill insertions.
** Subsystem not retrofit.

Ticket transport, coin acceptor and bill validator reliabilities were also generated based on all failures. Ticket transport reliabilities ranged from 243 (WMATA retrofit A) to 995 MTF (BART). Coin acceptor reliability ranged from 510 MTF (WMATA retrofit A) to 2,115 MTF (WMATA pre-retrofit); and bill validator reliabilities ranged from a low of 40 MTF (WMATA pre-retrofit) to 1,856 MTF (BART IBM).

Availablities for the addfares are shown in Table 4-7 (page 4-17). BART and WMATA retrofit B machines had relatively high availabilities. The relatively low availabilities of the pre-retrofit and retrofit A machines parallel their low reliabilities.

A comparison of addfare availability and reliability to that of BART and WMATA vendors can be made because the machines incorporate many of the same subsystems and perform many of the same functions. As can be seen in Table 4-7 (page 4-17), addfare availability was higher in each case (e.g., retrofit A) than vendor availability. However, a comparison of the results from Tables 4-12 and 4-2 (page 4-7) indicates that overall addfare reliabilities were higher than vendors for BART equipment, and lower than vendors for WMATA equipment. These contrasting results make it difficult to determine the specific reasons for the relatively higher availability of the addfares. One possible reason is that, during the surveys, these machines were used less often than vendors, and thus experienced less total failures, resulting in less total downtime than the vendors.

For the PATH CVEB machine, overall reliability and bill validator reliability, based on all failures that occurred during the survey, were 1,119 MTF and 2,015 MTF respectively. The corresponding figures based on data from transit system records were 4,609 MTF and 8,923 MTF respectively. Note that these data did not contain vandalism failures, patron-induced failures or NDFs. The availability of the CVEBs was computed at 98.4 percent. This resulted from the low number of failures that occurred during the survey, and the quick response of PATH technicians in clearing the bill jams.

For the PATCO bill changers, the reliability of the machines based on data from transit system records was 1,187 MTF and 120.0 MTBF. Availability measures were unable to be generated from the data.

4.4 SUMMARY OBSERVATIONS ON VENDOR AND GATE PERFORMANCE

Based on the results presented above, the following observations can be made on the performance of the equipment.

Vendors

1. The microprocessor-controlled European vendors performed significantly better than their American counterparts based on in-service survey data and data from transit system records. The smaller size ticket, the method of ticket delivery and the absence of bill validators in the European machines may have had an impact;

2. Based on in-service data, ticket transports of the American vendors tend to be less reliable than coin acceptors and slightly more reliable than bill validators;

3. Based on in-service data, bill jams comprised a slightly larger percentage of vendor failures than coin and farecard jams. However, other ticket transport failures accounted for the lower reliability of ticket transports compared to coin acceptors;

4. Based on the data from transit system records, transports of the American vendors are less reliable than both coin acceptors and bill validators. This is substantiated by the high percentage of ticket issuer failures for the ICG and PATCO vendors;

5. Vendor availability results were consistent with reliability results and maintenance policy. Where agents and technicians were in stations, and few complex failures occurred, availablities were relatively high (Tyne and Wear, SSB, WMATA-retrofit B). Where one or both of the situations were not true, availabilities suffered accordingly (ICG, WMATA pre-retrofit);

6. Vendor maintainability results, although data were limited, were consistent with the statements made in item number five. Both PATCO and ICG maintainability figures reflected large response times due to area coverage requirements by technicians (i.e., a technician has responsibility for equipment at more than one station).

Gates

1. Based on in-service data, the microprocessor-controlled Tyne and Wear gates performed significantly better than the other gates and turnstiles, including less complex gates such as those at MBTA and CTA;

2. Based on in-service data, farecard/ticket-accepting gates performed slightly better overall than coin/token-accepting gates because there was less jamming in the farecard/ticket-accepting machines;

3. For each transit system, based on both in-service data and data from transit system records, the largest category of gate failures were jams of the medium inserted;

4. Similar to the situation for vendors, gate availabilities reflected maintenance policy and incidence and severity of failures. In general, gate availabilities were higher than those for vendors because they are less complex machines;

5. Gate maintainability measures were consistent with the factors presented in item number four.

4.5 PERFORMANCE RESULTS VERSUS SPECIFICATIONS

4.5.1 Overview

Of the eight American rapid rail transit systems surveyed, six have performance specifications for AFC equipment (PATCO, BART, ICG, CTA, MARTA and WMATA). In addition, two systems in the construction stage also have specifications (BMTA and MDTA). Among these eight systems, performance specifications for AFC equipment vary because of differences in failure definitions and chargeability of failures as well as in equipment design function and complexity. For example, the PATCO specification for farecard-accepting gates delivered in 1975-6 called for a reliability of 160,000 mean operations between failures (MOBF). A failure was defined as an event in which an element of the system failed to perform the function intended by the design, and thereby caused the unit in which it occurred to fail to meet specification (this did not include jams caused by external conditions). In order to be chargeable, such a failure had to be reproducible and witnessed by a maintenance technician.

In comparison, BART reliability specifications for its farecard-accepting gates were in three measures: 7,500 mean cycles between ticket jams (MCBTJ), 2,500 mean cycles between soft failures (MCBSF) and 15,000 mean cycles between hard failures (MCBHF). A soft failure was defined as any instance, including a ticket jam, in which an AFC equipment did not complete the transaction initiated and the equipment was returned to normal service without replacement, repair or adjustment of any part. A hard failure was defined as any incident rendering an AFC equipment inoperative, that required adjustment, repair or part replacement to restore the equipment to normal service.

Other differences in definition and chargeability exist. The MARTA specification for entry gate reliability was 34,000 MCBF. WMATA set its reliability specification for gates at 720 (hours) MTBF. Under the MARTA specification, only "independent" failures were chargeable. A failure was independent when it was not caused by malfunction of other equipment, component abuse, incorrect maintenance procedures or errors. Errors included intermittent failures and ticket, bill and coin jams. Under the WMATA specification, an equipment failure occurred when any one or a multiple number of machine function modules within the equipment ceased to function and required repairs by a trained maintenance technician.

The two newest rapid rail systems in the U.S. - BMTA and MDTA - have also issued reliability specifications. Each uses the concepts of "relevant" and "non-relevant" failures. The BMTA specification defines relevant failures as all failures that can be expected to occur in revenue service operations. A non-relevant failure is caused by a condition external to the equipment and not expected to be encountered in field revenue service. MDTA has similar definitions. Reliability specification for BMTA gates is 70,000 MCBF; for MDTA gates, the reliability specification is 65,000 MCBF. Both specifications are based on relevant failures.

4.5.2 Results Versus Specifications

In this section, comparisons are made between the performance results and specifications for vendors and gates. (Comparisons were difficult due to the differences in performance measures used and failures deemed chargeable.) Table 4-13 summarizes the results for vendors of those systems for which specifications existed (BART and WMATA). It is important to note that the vendors are quite similar in the functions they provide. For BART, the survey overall machine reliability result of 141 MTF approximates the MCBSF specification of 200. However, 17 percent of the BART failures were ticket jams. This results in a (derived) MCBTJ of 824 (not shown in the table), well below the specification of 3,500 MCBTJ. In addition, the survey result of 1,401 MTF based on hard failures is below the 2,500 MCBHF which is based on a similar but more stringent hard failure definition. (The specification definition includes all adjustment, repair and replacement actions.)

For the WMATA specification, the 2.79 MTBF from the in-service survey pales in comparison to the specification MTBF of 920. (Retrofit B only is shown in the tables because it represented the best WMATA results.) This great difference is due in part to the many exceptions to the definition of a chargeable failure in the WMATA specifications. For example, not included as failures in the computation of the WMATA specification are damage due to vandalism, preventive maintenance operations and repair, malfunctions not related to component failure, and/or those malfunctions that can be cleared by authorized personnel. The latter exception covers quite a number of in-service situations that, for other systems, are chargeable failures, and that were used in the generation of MTBF measures from survey data.

Table 4-14 summarizes and compares gate reliability results

TABLE 4-13. COMPARISON OF VENDOR RELIABILITY ASSESSMENT RESULTS AND SPECIFICATIONS

TRANSIT SYSTEM	SPECIFICATION	PERFORMANCE RESULTS (IN-SERVICE DATA)		
		MTF (ALL FAILURES)	MTF (HARD FAILURES ONLY)	MTBF**
BART	3,500 MCBTJ			3.75
	200 MCBSF	141		
	2,500 MCBHF		1,401	
WMATA*	920 MTBF**	265	6,891	2.79

* Retrofit B.
** MTBF in hours.

TABLE 4-14. COMPARISON OF GATE RELIABILITY ASSESSMENT RESULTS AND SPECIFICATIONS

		PERFORMANCE RESULTS			
		IN-SERVICE DATA			TRANSIT SYSTEM DATA
TRANSIT SYSTEM	SPECIFICATION	MTF (ALL FAILURES)	MTF (HARD FAILURES ONLY)	MTFB**	(ALL FAILURES)
PATCO	160,000 MOBF				5,907
BART	7,500 MCBTJ			8.0	
	2,500 MCBSF	1,136			
	15,000 MCBHF		75,518		
WMATA*	720 MTBF**	2,220	N/D	4.2	
MARTA	34,000 MCBF	1,740	12,014	6.1	3,225
CTA	10,000 MCBF	902	8,586	8.6	

* Retrofit B.
** MTBF in hours.

and specifications. For BART gates, similar to the situation for vendors, the MTF based on all in-service failures is less than the MCBSF specification. However, in contrast to the situation for vendors, the performance of the gates based only on hard failures is five times the MCBHF specification of 15,000. (Recall that the specification definition is more stringent.) For WMATA, the situation for gates parallels that of vendors - an MTBF specification that is much greater than that measure based on survey data.

The MARTA specification of 34,000 MCBF is much greater than the reliability of 12,014 MTF based on hard failures. This difference is due in part to the extent of failures excluded from the MARTA failure definition (e.g., those failures "associated with equipment which senses fare media, or generates, stores, transfers, reads, or writes digital data.")

The CTA specification is close to the survey results based on hard failures. The CTA failure definition is simple and without a list of exceptions. It defines a malfunction as any failure to operate in a normal manner or allow passage because of inoperative mechanical or electrical components. Under this definition, jams due to media are not considered chargeable. This accounts for the large difference between the specification and the reliability based on all failures of 902 MTF.

5. SUMMARY AND RECOMMENDATIONS

As discussed in Section 3, there is currently a clear lack of standardization in the area of transit fare collection equipment performance measurement and specification. This report has addressed the performance measurement problem by presenting, delineating and categorizing terms, concepts, methods and procedures in order to aid transit systems in achieving more uniformity in equipment performance assessment and analysis.

A review of the performance results presented in the previous section reveals an absence of complete data. This situation indicates a need for more data to be collected and analyzed. However, before more data are collected, standardization criteria should be established. The difficulty in comparing performance results with equipment specifications underscores this need for uniformity in terms, concepts and performance methods and procedures.

Much has already been done under the UMTA RTFC project to address these problems. A preliminary assessment method was developed and refined through its application to 11 AFC systems as well as through industry input into the development process by the APTA STARS Fare Collection Reliability Liaison Board. It is believed that implementation of the following recommendations represents a necessary step in the process of developing and applying uniform performance assessment methods for AFC equipment.

1. That the transit systems use the set of definitions, classifications, performance measures, causal factors, chargeability criteria, and assessment methods and procedures for AFC equipment detailed in this report on a trial basis prior to a formal decision on whether to adopt them;

2. That transit systems schedule performance surveys on a regular basis, using data from both in-service surveys and from internal records. This implies that internal record keeping be such that data are useable for performance measurement;

3. That performance results and failure distribution information be generated on a regular basis and made available to other properties through a system such as TRIP;

4. That surveys and statistical analysis techniques as presented in this report be undertaken to measure and compare the performance of retrofit and non-retrofit equipment;

5. That based on the established definitions and an adequate amount of performance data, equipment specifications be set that reflect achievable and uniform criteria, as well as industry experience.

APPENDIX A
GLOSSARY OF TERMS

Acceptance Test -	A test performed to determine whether or not delivered items of hardware satisfy predetermined standards or specifications.
Active Repair Time -	(See Time, Active Repair).
Addfare -	An AFC machine that allows a patron who has insufficient value or rides remaining on the fare medium to purchase any remaining fare required to exit.
Automatic Fare Collection -	The means of accepting patron fares, dispensing fare media and controlling entry and exit through the use of unattended machinery operated by patrons.
Availability -	A performance measure of AFC equipment indicating the percentage of revenue service time that a machine is fully ready for use by a patron.
Average Downtime (ADT) -	The mean amount of time that an AFC machine or subsystem is out of service.

Barrier	The subsystem of an automatic gate that prevents invalid passage into and/or out of a transit system. Barriers come in a variety of designs (e.g., vertically rotating tripod and quadripod arms, horizontally rotating paddles, hydraulically operated retracting leaves, etc.)
Bill Changer	An AFC machine that provides coins as change for bills inserted.
Bill Verifier	A major subsystem of an AFC machine designed to accept and verify bills inserted by patrons. Also referred to as a bill acceptor and a bill validator.
Causal Factor	A descriptive term indicating the general cause of a machine failure. Causal factors used in this document have been identified as vandal, patron-induced, operational, or administrative and technical.
Change Maker	An AFC machine that returns coins as change for bills or coins inserted.
Change Vending Entrance Bill (CVEB)	A specific bill changer that accepts dollar bills, subtracts the value of one fare, sends an unlocking signal to a gate to which it is connected, and returns change less the amount of the fare. It is used in the PATH system.

Coin Acceptor	-	A major subsystem of an AFC machine designed to accept and verify coins inserted by patrons. Also referred to as a coin selector.
Component	-	A part or an assembly of parts in an AFC machine.
Confidence Interval	-	In statistics, the region which can be reasonably expected to contain the "true" value of an estimated parameter.
Confidence Level	-	A statement of assurance of the accuracy of a statistical statement. For example, if it is asserted that a population parameter is indeed within the computed confidence interval at the 95 percent confidence level , this means that the risk of error is 5 percent.
Confidence Limit	-	A boundary of the confidence interval, usually referred to as lower and upper confidence limits.
Corrective Maintenance	-	(See Maintenance, Corrective).
Downtime	-	The amount of time that a machine or subsystem is not available for service.
Failure	-	Any instance of malfunction in a machine that necessitates either human or mechanical intervention. For types of failures, see jams, soft failures, hard failures, relevant and nonrelevant failures.

Gate, Automatic	-	An AFC machine that controls patron entry to and/or exit from a transit system and is operated directly by the patron. Automatic gates can be designed to accept a variety of fare media (e.g., farecards, coins) and to perform a variety of services (e.g., dispense transfers, capture used tickets, etc.) The gates that accept coins or tokens and have rotating barriers are often called turnstiles.
Hard Failure	-	A failure category. A hard failure is any instance of malfunction that requires a major adjustment, major repair or replacement. Major is defined as requiring more than 20 minutes total technician active repair time.
In-Service Data	-	Performance data collected by surveyors out in the field observing AFC equipment in operation.
In-Service Time	-	(See Time, In-Service).
Jam	-	A failure category. A jam is any instance in which a fare medium or any other item (e.g., change) inserted by or dispensed to a patron is stuck in the processing or dispensing path.
Logic Unit	-	A major subsystem of an AFC machine that provides the "brains" or overall control of the machine.

Logistic Time	A subset of downtime. It is that part of downtime during which a repair person is going for or awaiting parts.
Machine	A device that provides a fare collection revenue service and/or function and represents one complete unit to a patron. AFC machines include farecard vendors, addfares, automatic gates, bill changers, change makers and transfer dispensers.
Maintainability	A performance measure of AFC equipment indicating how long a failure has taken (or is expected to take) to be repaired. It is usually expressed as average downtime (ADT) or mean time to repair (MTTR).
Maintenance, Corrective	The action taken to restore a failed item of equipment to an operable state.
Maintenance, Preventive	The actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection and prevention of incipient failure.
Maintenance, Scheduled	Programmed preventive maintenance.
Maintenance, Unscheduled	Maintenance action initiated by the malfunction of equipment.

Malfunction	-	Any instance wherein a machine, subsystem or component fails to function as intended. Synonymous with failure.
Mean Cycles Between Failures (MCBF)	-	A measure of reliability often used interchangeably with MTF. It represents the arithmetic mean of the number of cycles between successive failures.
Mean Time Between Failures (MTBF)	-	A measure of reliability that represents the arithmetic mean of the time between successive failures.
Mean Time to Repair (MTTR)	-	A maintainability measure that represents the arithmetic mean of active repair time for hard failures.
Mean Transaction Per Failure (MTF)	-	A measure of reliability that represents the arithmetic mean of the number of transactions between successive failures.
Nonrelevant Failure	-	A failure category used in transit AFC contract specifications. The complement of relevant failure. It is defined as a failure caused by a condition external to the equipment and not expected to be encountered in field revenue service.
Operating Time	-	The time that AFC equipment is in service.

Peak Period	-	The time of day during which an AFC system is most in use. Although it varies, it generally runs between 6:30-9:00 AM and 3:30-6:00 PM.
Power Supply	-	A major subsystem of an AFC machine that provides the electrical power. The battery.
Preventive Maintenance	-	(See Maintenance, Preventive.)
Relevant Failure	-	A failure category currently used in transit AFC contract specifications. It refers to all failures that can be expected to occur in revenue service operations.
Reliability	-	A measure of performance that indicates the rate at which a machine or subsystem successfully accomplishes its mission or function.
Repair	-	The maintenance activity which restores a failed item to an operable state.
Scheduled Maintenance	-	(See Maintenance, Scheduled).
Soft Failure	-	A failure category. A soft failure is any instance of malfunction that necessitates a minor adjustment, minor repair or clearing or cleaning action. Minor is defined as requiring less than 20 minutes total technician active repair time.

Subsystem - A part or an assembly or parts of an AFC machine that accomplishes a specific revenue function or transaction service and can be considered to be, for the sake of maintenance, a discrete unit.

Ticket Transport - A major subsystem of an AFC machine that moves tickets while functions such as read, write, verify and print are performed. Gate ticket transports are also called ticket handlers.

Time, Active Repair - That portion of downtime during which one or more repairmen are working on failed equipment.

Time, In-Service - The time during which an AFC machine or subsystem is operating satisfactorily.

Transfer Dispenser - A major subsystem of an AFC machine that dispenses transfers. In some cases, transfer dispensers are stand-alone units.

Transit System Records - Records maintained by the transit system that provide performance data. These are usually in the form of revenue receipts, passenger counts and maintenance records. They can be obtained by manual or automatic processes.

Turnstile - (See Gate, Automatic).

Unscheduled Maintenance - (See Maintenance, Unscheduled).

Vendor, Farecard - An AFC machine that dispenses tickets or farecards directly to a patron in return for payment.

APPENDIX B

TRANSIT SYSTEM AFC MAINTENANCE PRACTICES

This appendix presents summary descriptions of transit system maintenance organizations and practices.

ICG

The ICG AFC maintenance organization consists of 29 persons, two of whom are supervisors. This number includes a group of six field electronic technicians responsible for the upkeep of the PAL (Passenger Assistance Line) equipment. (The PAL is a central monitoring facility providing patron assistance, closed circuit television and public address system.) Another group of four electronic technicians work at the central workshop and do equipment rebuilding, redesign and modification under a research and development program.

The remaining personnel provide repair and preventive maintenance of vendors and gates, and are assigned into one of four coverage areas, each with its own small shop.

On weekdays during daytime hours (including both morning and evening peak periods), there are either one or two electronic technicians covering each area. These workers are contacted by PAL operators who inform them of equipment problems. After each repair, the technicians fill out Trouble Logs indicating the type of failure repaired. If not working on a repair, the technicians are doing preventive maintainance on the equipment. (Gates and vendors are preventively maintained about once a week.) In rare instances where a bench is required, the technicians will bring a part back to a shop for repair.

At the central maintenance facility there are three electronic technicians assigned to do simple electrical and mechanical repairs. Sometimes these workers are dispatched to the field to handle additional workload.

PATCO

The PACTO AFC maintenance organization consists of ten people: a foreman, eight electronic technicians and one repairman. On weekdays during the daytime hours (including both morning and evening peak periods), there are two technicians in the field responding to calls for repair from an operator in a central monitoring facility. One technician covers the Pennsylvania side, the other the New Jersey side of the system. The operator receives patron complaints and information concerning AFC equipment problems and contacts the appropriate technician. The technicians do repair work only. When finished with a job, they call the operator to let it be known that the repair has been done, and to inquire about another job. In some cases, these technicians will find and repair unreported failures.

In addition to the field technicians, the foreman, two electronic technicians and the repairman work at a central repair shop. One of the technicians and the repairman do preventive maintenance and overhaul. The second technician does subsystem and component repair, primarily on electronics and coin acceptors.

At PATCO, vendors are not preventively maintained but are attended on a repair basis. Gates, on the other hand, are preventively maintained on a fixed schedule by subsystem. For example, the ticket handler is maintained once per year.

CTA

Turnstile maintenance at CTA is performed by electrical construction technicians, the majority of whom are electricians. Equipment failures are usually reported by station agents to their supervisor who in turn informs the CTA Power Supervisor. The technicians, each of whom is assigned to cover an area of several stations, receive their assignments from a foreman who has been informed of the problems by the Power Supervisor. In addition to handling the coin turnstiles, the technicians also cover the equipment at the agent lanes. At some busy downtown stations, technicians are present up to 75 percent of the PM peak period to ensure maximum equipment availability.

Since CTA does not have a standardized maintenance policy for the turnstiles, procedures used by technicians have evolved from their field experience. Preventive maintenance is conducted by each technician at his own discretion. In addition, periodic inspection of each turnstile is performed but intervals between inspections vary due to station traffic and technician availability.

MARTA

The MARTA Rail Maintenance Group is responsible for all AFC shop maintenance, retrofit programs, and field operations. The group consists of a foreman, six journeymen electronics technicians, and six apprentice technicians, who alternate between work and electronics school. (Three are working while the other three are in school.) The technicians split their time between shop and field assignments. During peak periods, there are five maintainers in the field. When technicians are out in the field, they may be contacted through a monitoring center operator over a public address system. In turn, technicians may contact the operator by utilizing a Passenger Aid telephone.

For preventive maintenance, each gate receives a five-minute check daily to ensure that the major subsystems are properly functioning. Technicians are assigned specific stations to monitor. There is a full preventive maintenance action conducted on each gate once a month. The average time spent per gate is about one hour and twenty minutes.

AFC technicians are assigned a daily list of gate failures to repair by the shop foreman. Minor failures are repaired in the field. For major repairs, the component or subsystem is replaced and brought back to the shop for repair. A log of maintenance actions is kept by each technician.

WMATA

WMATA maintenance consists of 49 technicians and 22 support supervisory personnel, including a superintendant of AFC maintenance. During a normal shift, there are eight technicians in the field doing preventive maintenance, seven technicians out in the field doing repairs, and seven technicians in the shop doing repairs and modifications. If a WMATA agent, who has access to the machines, cannot fix a problem, he or she calls one of three central controllers. The controller will then inform a maintenance man of the problem.

WMATA maintenance repair policy stresses modular replacement. Complex problems are dealt with by replacing the unit and bringing it back to the shop for repair. Spares are centrally dispatched.

PATH

At PATH, a general maintenance group is responsible for the proper operation of various mechanical and electrical systems not related to rolling stock. Out of this group, there are eight technicians who work on AFC maintenance. One does full-time shop work while the others split their time between shop work, coverage of assigned stations during rush hours, and repair work in the field. At PATH, there is a central AFC shop facility and several smaller shops.

For preventive maintenance, a daily on-site spot check is performed on all turnstiles and CVEBs. It consists of a visual check and clearing of jams. More exhaustive preventive maintenance actions are performed on each unit on a monthly and quarterly basis.

At high volume stations during peak periods, agents will attempt to clear coin jams using a special metal probe. Other minor turnstile failures will be attended by a technician. Technicians will attempt to clear bill jams by pushing bills through with a plastic device. If the jam cannot be cleared, a technician must wait for a coin box operator and a PATH police officer to open the machine.

Major repairs, especially those involving the machine logic, are undertaken in the shop. A replacement subsystem or component is installed during this time to keep the machine operable.

MBTA

The MBTA AFC maintenance staff consists of ten electricians, who are also responsible for other equipment at stations (e.g., lights). There are three technicians in the field doing preventive maintenance during the day (two shifts). If a station agent or starter, who does not have access to the internal workings of the equipment, cannot fix a problem, he or she notifies a dispatcher who informs one of the three field technicians. When the repair is completed and, if another repair is not required, the technician returns to do preventive maintenance.

BART

AFC maintenance at BART consists of field technicians and repair shop personnel. The maintenance effort is divided into primary maintenance and secondary repair. Primary maintenance entails adjustment, preventive maintenance and subassembly replacement. The primary maintenance staff consists of 30 people (two shifts). Technicians are permanently assigned to one of four lines. If a station agent, who has access to the equipment, cannot handle a problem, he or she calls a central facility which contacts a line technician. Field maintenance encompasses adjustment, cleaning, clearing and replacement. If repair is required, the subsystem or component is replaced and returned to the shop. Parts are deliverd by a line foreman or travelling technician. (BART uses a system of satellite supply sites for spares.)

Secondary repair encompasses repair of all equipment at subassembly and assembly level. Of the 20 technicians at the central shop, two are assigned to AFC repair and overhaul. Details of repairs are input into a computer data base for historical failure analysis.

TYNE AND WEAR

At Tyne and Wear maintenance for both the vendors and the gates is provided by a subcontractor. As part of the original contract with Crouzet, Tyne and Wear was provided a one-year equipment warranty. Crouzet subcontracted Balfour-Kilpatrick Inc. to provide the maintenance/warranty service.

The AFC maintenance organization comprises six electronic technicians, two engineers, i.e., senior technicians, and a supervisor. Under a program initiated by Tyne and Wear, three of the technicians are Metro employees, who are being trained to repair equipment coming out of warranty.

Maintenance is divided into two levels. The first is on-site correction and routine preventive maintenance. The latter is carried out on gates and vendors about every six weeks, in accordance with an extensive checklist of items to be attended. The second level consists of repairs and overhauls in the workshop.

When a gate or vendor goes out of service, a control center is automatically notified via a computerized Remote Control Indicator (RCI) system. The message sent to the center indicates whether the out-of-service condition is due to a technical failure, a full vault, or ticket stock. If due to a technical failure, a supervisor at the center informs a maintenance technician in the field by a two-way radio.

The technician can utilize failure diagnostics in the machines to determine the problem. When the repair is completed, the technician fills out a form indicating the nature of the problem and repairs made. A copy of each form is kept in the machine while the original is filed at the maintenance shop. When the machine is put back into service, it is indicated automatically on the RCI system. When they are not attending to on-site failures, Tyne and Wear AFC technicians are either doing preventive maintenance or repairing or overhauling AFC equipment in the workshop.

STUTTGART STRASSENBAHNEN (SSB)

The SSB AFC maintenance organization consists of 25 technical and maintenance support personnel located at a central workshop. During the day, there is a team of two technicians in the field who are in radio contact with the central facility. Since the machines are not monitored electronically, patrons and drivers are relied upon for information on out-of-service vendors.

In the field, the technicians make necessary minor adjustments, e.g., clearing paper jams in the printer or removing bent coins. In addition, for preventive maintenance and major repair, the technicians replace subsystems and/or components and bring them back to the central workshop where more highly skilled personnel attend to the equipment. Several of the major subsystems, such as the printer, coin acceptor, and coin recycler, are replaced and preventively maintained about once a year. However, machines that experience extensive use usually have the printer replaced every six months.

After each minor repair or replacement, the field technician files a failure report that is kept at the central facility. In addition to these, permanent maintenance records for the machine as a whole and each major subsystem are kept on file by SSB administrative staff.

RATP

At RATP, each rail system, (i.e., Metro and RER), has its own AFC maintenance organization. The Metro has a centralized organization based around a main workshop, while RER has a decentralized organization comprised of small workshops located at various stations.

The Metro AFC maintenance organization consists of about 45 technicians and their supervisors. There are separate groups for preventive maintenance and equipment repair. These groups are futher subdivided by equipment type. Preventive maintenance is carried out on the gates about once every 4-5 weeks.

For failures that are not able to be fixed by a station agent, a technician is contacted via two-way radio by a central dispatcher. Major repairs are, if possible, done on-site, with workshop technicians primarily used for overhaul of major subsystems and components as part of the preventive maintenance program.

The RER AFC maintenance organization consists of about 40 technicians and their supervisors. The technicians each cover an assigned area of two to three stations. RER AFC technicians can do preventive maintenance and repair on all types of AFC equipment. When a failure occurs that a station agent cannot fix, the station master contacts the appropriate maintenance workshop, and a technician is dispatched.

Gates in the RER are preventively maintained once every 7-8 weeks. For vendors, the period is 3-12 weeks depending on ticket volume. The experimental vendors have been preventively maintained on a 6-8 week basis.

APPENDIX C

SELECTED AFC CONTRACT SPECIFICATIONS AND PROCUREMENT PROCEDURES

This appendix summarizes the failure definitions, classifications and performance criteria that have been used in contract specifications documents at selected U.S. rapid rail transit systems. In addition, it presents summary tables indicating the implementation and testing procedures used as part of the purchase and acceptance of new AFC equipment.

As pointed out in Section 4.5 above, the reliability and maintainability specifications used in contract specification documents are quite different not only from the results obtained from both survey data and data from transit systems records, but also from each other. This is due to the differences in failure definition and chargeability, as well as in equipment design, function and complexity.

PATCO

The PATCO gate specification covered gates delivered in 1975-6 by Cubic Western Data. It called for a reliability of 160,000 mean operations between failures (MOBF). Note that the MOBF is interchangeable with mean cycles between failures (MCBF). The definition of failure used in the contract was an event in which an element of the system fails to perform the function intended by the design, and thereby causes the unit in which it occurs to fail to meet specification. However, the specification stated that in order to be chargeable, such a failure must be reproducible and witnessed by a maintenance technician. In addition, jams caused by external conditions were not chargeable.

PATCO also promulgated reliabilities for various subsystems of the gate equipment. Some are in terms of MOBF, while the others are in terms of MTBF. These are shown in Table C-1.

Maintainability was specified in terms of preventive maintenance performance times. For example, it was specified that the maximum time allowed to replace a drive belt is ten minutes.

BART

The most recent BART specification, written in 1981 for gates, vendors and addfares, detailed three types of reliability: mean cycles between ticket jams (MCBTJ), mean cycles between soft failures (MCBSF) and mean cycles between hard failures (MCBHF). These are shown in Table C-2 for vendors, gates and addfares.

The categories of jams, soft failures and hard failures are defined as follows:

1. Ticket Jam - Any instance in which a ticket is not completely processed through an AFC equipment, rendering the equipment inoperative, and where removal of the ticket will restore the equipment to normal service without replacement, repair, or adjustment of any item;

2. Soft Failure - Any instance, including a ticket jam, in which an AFC equipment does not complete the transaction initiated, and the equipment is returned to normal revenue service without replacement, repair or adjustment of any part;

3. Hard Failure - Any incident rendering an AFC equipment inoperative that does require adjustment, repair or

TABLE C-1. SUMMARY OF PATCO GATE RELIABILITY SPECIFICATIONS

SUBSYSTEM	MOBF	MTBF
Magnetic Heads	1,000,000	
Logic		26 weeks
Power Supply		52 weeks
Indicators (Lamps)		13 weeks
Ticket Transport	1,000,000	
Turnstile Mechanism	1,000,000	
Indicators (Solid State)		52 weeks

TABLE C-2. SUMMARY OF BART RELIABILITY SPECIFICATIONS

MACHINE	MCBTJ	MCBSF	MCBHF
Vendor	3,500	200	2,500
Gate	7,500	2,500	15,000
Addfare	5,000	275	5,000

part replacement to restore the equipment to normal service.

ICG

ICG does not have specifications for equipment reliability, but does have maintainability specifications for gates. These were written in the early 1970s and are in terms of subsystem and component replacement times. For example, the anticipated replacement time for the ticket transport with electronics was ten minutes.

CTA

CTA included a reliability specification of 10,000 transactions per unit malfunction in its 1978 specification document for gates. CTA defined the concept of unit malfunction as any failure to operate in a normal manner or allow passage because of inoperative mechanical or electrical components.

MARTA

MARTA wrote performance specifications in 1977 for each of the four types of gates in its system (entry gate, exit only gate, fully-accessible gate and dummy gate (stanchion) (Table C-3). Reliability for the first three machines are specified in terms of MCBF while the dummy is specified in terms of MTBF.

In its original contract with Cubic Western, MARTA defined independent failures as countable failures. The definition of an independent failure was any malfunction of the equipment which prevented a unit from performing its intended function. A failure was independent when it was not caused by malfunction of other equipment, component abuse, incorrect maintenance procedures or errors.

TABLE C-3. SUMMARY OF MARTA PERFORMANCE SPECIFICATIONS

MACHINE	MCBF	MTBF	MTTR (HOURS)	MMAX (HOURS)
Entry Gate	34,000		1.5	3.32
Exit Gate	1,000,000		1.0	2.21
Fully Accessible Gate	22,000		1.0	2.21
Dummy Gate		25,000	2.0	4.42

Errors, in turn, were defined as having the following characteristics:

1. Failure cannot be isolated to a component;
2. Failure is random and non-repetitive. In such a case, three errors recurring consecutively constitute an independent failure;
3. Frequency of failure is < 5,000 cycles;
4. Failure is associated with equipment which senses fare media or generates, stores, transfers, reads, or writes digital data.

Due to problems with the supplier over what failures were indeed independent, MARTA promulgated an in-house specification of 11,333 MCBMA (mean cycle between maintenance action) for the entry gate. This was designed so that the nature of the problem would not be the determining factor in monitoring performance.

Maintainability specifications were also promulgated in the specification document. These are in terms of MTTR and maximum time to repair (MMAX). MMTR was defined as the mean elapsed time required to perform the test, remove and replace, and checkout tasks due to a failure. It is calculated as the sum of all corrective maintenance action elapsed times divided by the sum of all maintenance actions. MMAX is defined as the maximum amount of time required to perform 90 percent of all corrective maintenance actions.

<u>WMATA</u>

The WMATA specification document provides MTBF and MTTR criteria for WMATA AFC equipment. These are shown in Table C-4

TABLE C-4. SUMMARY OF WMATA PERFORMANCE SPECIFICATIONS

MACHINE	MTBF (HOURS)	MTTR (HOURS)
Vendor	920	0.5
Gate	720	0.5
Addfare	744	0.5

for gates, addfares and vendors. According to the WMATA 1975 specifications, equipment failures occur when any one or a multiple number of machine function modules within the equipment cease to function and require repair by a trained maintenance technician. Not included as failures are damage due to vandalism, preventive maintenance operations and repair, malfunctions not related to component failure, and/or those malfunctions that can be cleared by authorized personnel.

BMTA

The BMTA 1980 specification provides reliability and maintainability criteria. These are shown in Table C-5 for gates, vendors, and bill changers. Reliability specifications are in terms of MCBF and MTBF. Note that these specifications are based on relevant failures only.

Maintainability specifications are in terms of MTTR for relevant failures and maximum time to repair (MMAX). In the BMTA document, MMAX is defined as an established maximum time limit within which 90 percent of all failed equipment should be returned to service.

Relevant failures refer to all failures that can be expected to occur in revenue service operations. These include:

1. Intermittent failures, i.e., failures that occur randomly;
2. Unverified failures which cannot be duplicated or are still under investigation, or for which no cause can be determined;
3. Verified failures not otherwise excluded under nonrelevant failure types;

TABLE C-5. SUMMARY OF BMTA PERFORMANCE SPECIFICATIONS

MACHINE	MCBF	MTBF (HOURS)	MTTR (HOURS)	MMAX (HOURS)
Vendor	40,000	2,000	0.6	1.3
Gate	70,000	390	0.4	0.9
Bill Changer	100,000	6,000	0.3	0.7

4. Independent failures related to equipment design, equipment manufacture, parts design, software errors, and contractor-furnished operating, maintenance or repair procedures that cause equipment failure.

The BMTA AFC contract specification states that a nonrelevant failure is one caused by a condition external to the equipment under test which is not a test requirement and not expected to be encountered in field revenue service. Nonrelevant failures include:

1. Installation damage;

2. Accident or mishandling;

3. Failures of the test facility or test instrumentation;

4. Equipment failures caused by an externally applied overstress condition in excess of the approved test requirements;

5. Normal operating adjustments (non-failures) as prescribed in the approved equipment operating and maintenance manuals;

6. Dependent failures counted with the independent failure that caused them;

7. Failures of items having a specified life expectancy, when operated beyond the defined replacement time of that item;

8. Failures caused by incorrect operating, maintenance or repair procedures;

9. Failures due to media.

MDTA - MDTA promulgated specifications in 1982 for gates, vendors, transfer dispensers and addfares. These are shown in Table C-6. Similar to BMTA, the MDTA specifications are based on relevant failures. These are defined as follows:

1. Relevant Failure - Any malfunction that prevents an AFC equipment from performing its designated function or fails to meets its performance criteria when operated under the environmental and operational conditions defined in the specifications. Relevant failures are related to:

    a. Equipment design;

    b. Equipment manufacture;

    c. Parts design or manufacture;

    d. Software errors;

    e. Contractor-furnished operating, maintenance or repair procedures that cause equipment failure.

2. Nonrelevant failures include:

    a. Installation damage;

    b. Accident or mishandling;

    c. Failures of the test facility or test instrumentation;

    d. Failures caused by externally applied overstress conditions in excess of specification requirements (e.g., bent coins, mutilated tickets, worn bills);

TABLE C-6. SUMMARY OF MDTA PERFORMANCE SPECIFICATIONS

MACHINE	MCBF	MTTR (HOURS)	MMAX (HOURS)
Entry Gate	65,000	0.6	1.3
Vendor	35,000	0.5	1.2
Transfer Dispenser	50,000	0.4	0.9
Bill Changer	45,000	0.3	0.7

e. Normal operating adjustments;

f. Dependent failures;

g. Failure of a part due to lack of scheduled replacement;

h. Failures caused by incorrect operation, maintenance, or repair procedures;

i. Failures, such as jams, that can be resolved by an agent in less than 120 seconds of active maintenance time.

Summary Tables

Tables C-7 and C-8 present summary tables for industry reliability specifications for vendors and gates respectively. As can be readily seen, the specifications are not only measured in different terms, but when they are in similar terms, they vary considerably due to differences in machine function and complexity, as well as failure definition and chargeability.

Industry Implementation and Testing Procedures

Tables C-9 through C-11 summarize AFC equipment specified, and implementation and testing procedures from industry AFC contract specifications. They indicate the differences in approach to equipment specification and acceptance testing procedures.

TABLE C-7. SUMMARY OF VENDOR PERFORMANCE SPECIFICATIONS

TRANSIT SYSTEM	RELIABILITY					MAINTAINABILITY	
	MCBF	MTBF	MCBTJ	MCBSF	MCBHF	MTTR (HOURS)	MMAX (HOURS)
BART			3,500	200	2,500		
WMATA		920				0.5	
BMTA	40,000	2,000				0.6	1.3
MDTA	35,000					0.5	1.2

TABLE C-8. SUMMARY OF GATE PERFORMANCE SPECIFICATIONS

TRANSIT SYSTEM	RELIABILITY					MAINTAINABILITY	
	MCBF	MCBTJ	MCBSF	MCBHF	MTBF	MTTR (HOURS)	MMAX (HOURS)
PATCO	160,000*						
BART		7,500	2,500	15,000			
CTA	10,000						
WMATA					720	0.5	
MARTA	34,000					1.5	3.32
BMTA	70,000				390	0.4	0.9
MDTA	65,000					0.6	1.3

*Actually in terms of mean operations between failures.

TABLE C-9. SUMMARY OF EQUIPMENT SPECIFIED

TRANSIT SYSTEM	FARECARD/ TICKET VENDOR	TRANSFER DISPENSER	PASSENGER GATE	TICKET ENCODER	BILL CHANGER	ADDFARE MACHINE	TICKET READER	FARE MEDIA	MONITOR/ CONTROL SYSTEM
BMTA	X		X	X	X			X	X
WMATA	X		X	X		X	X		X
MARTA		X	X	X				X	
BART	X		X			X	X	X	
MDTA	X	X	X	X	X			X	X

TABLE C-10. SUMMARY OF IMPLEMENTATION PROCEDURES

TRANSIT SYSTEM	SYSTEMS ASSURANCE PROGRAMS					MANAGEMENT SYSTEMS PROGRAM(3)	QUALITY ASSURANCE PROGRAMS(4)
	FAILURE DEFINED	RELIABILITY CRITERIA	MAINTAINABILITY CRITERIA(1)	AVAILABILITY CRITERIA	WARRANTY GIVEN(2)		
BMTA	X	X	X		X	X	X
WMATA	X	X	X				
MARTA	X	X	X	X	X	X	X
BART	X	X					
MDTA	X	X	X			X	X

(1) MTTR (Mean Time To Repair) and/or MMAX (Maximum Time To Repair) given for each type of equipment.

(2) The BMTA and MARTA warranties, in addition to overall guarantees, contain provisions that if a component fails with a certain frequency, all such components must be replaced or redesigned by the Contractor at no expense to the authority.

(3) Program which specifies how the particulars of the contractor will be carried out over time.

(4) Program which assures an acceptable level of quality for the equipment supplied.

TABLE C-11. SUMMARY OF TESTING PROCEDURES

TRANSIT SYSTEM	PROTOTYPE TESTING			ACCEPTANCE TESTING(4)	SYSTEM RELIABILITY TESTING(5)
	PERFORMANCE(1)	ENVIRONMENTAL(2)	OPERATIONAL(3)		
BMTA	X	X	X	X	X
WMATA	X				
MARTA	X	X	X	X	
BART	X	X	X		
MDTA	X	X	X	X	X

(1) Each type of equipment required to perform many functions repeatedly to simulate transit operations.

(2) Each type of equipment to be operated under extreme variations in temperature and humidity.

(3) Entire array of fare collection equipment to be operated in a transit-like environment for a significant period of time.

(4) Tests to be conducted after installation and prior to revenue service to ensure proper functioning.

(5) Tests during revenue service involving monitoring of equipment performance to ensure that reliability and maintainability measures specified are met. For MDTA, maintainability tests are performed at First Article Inspections.

APPENDIX D
TRIP INTERFACE REQUIREMENTS

D.1 BACKGROUND

The UMTA Transit Reliability Information Program (TRIP) is designed to assist the transit industry in satisfying its need for timely reliability information. TRIP provides this assistance through the operation of a computerized national reliability data base.* The TRIP project has been segmented into three phases. Phase I consists of definition and scoping of the functional requirements of the TRIP Data Bank, and design, implementation, operation, and enhancement of a Rail Rapid Vehicle (RRV) Experimental Data Bank (EDB) for the purposes of evaluating, on a prototype scale, the design concepts of the full-scale TRIP Data Bank.

Phase II consists of expanding the scope of the data bank to include all aspects of the vehicles involved. Phase III calls for the expansion of the TRIP Data Bank to include other classes of equipment such as automatic fare collection equipment.

The project is currently in the implementation stage of Phase I with the operation of the RRV EDB. Within this, five vehicle systems are being monitored: doors and door controls, propulsion, friction brakes, carborne Automatic Train Operation/Automatic Train Control (ATO/ATC), and auxiliary electric.

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* Much of the description of TRIP in this section has been excerpted from TRIP Participants Guidelines, Dynamics Research Corporation, Final Report 9/80.

This section presents a description of the current TRIP system and an outline for incorporating AFC data into TRIP.

D.2 THE TRIP SYSTEM

D.2.1 Overview

The TRIP data bank uses information provided by transit systems and outputs a series of reports which provide information on the reliability and associated utilization of transit equipment and systems being monitored. The functional steps that are required for the operation of the system are basic to any good information storage and reporting system: data preparation, input, verification, organization, storage, retrieval, manipulation, analysis and reporting.

Two types of data are required in the TRIP EDB on vehicles: dynamic and reference data. The dynamic data include transit vehicle operating and maintenance data and are used for the production of reliability information such as maintenance rates and inspection intervals. Sources of such data from the industry include reports on revenue service incidents, periodic inspections, and unscheduled maintenance.

Reference data are used for initializing the data base for a particular transit system, and for interpreting the reliability information. Reference data for initialization are obtained from operator and maintenance manuals, maintenance code books and data collection forms such as maintenance correction forms. Reference data used for interpretation consist of information that describes the operating characteristics, and environment of the equipment as well as maintenance policies and procedures. All of these are factors that effect the reliability of the equipment. Sources of these data are operating rules and procedures manuals, maintenance procedures manuals, operating schedules, inspection schedules, equipment specifications, parts catalogs and transit system route maps.

The TRIP system software consists of three major subsystems: input programs, a data base management system, and output programs. The TRIP input programs convert the incoming data from the various formats used by transit systems to the standard format of the Data Bank. The input programs provide the functions of data entry, data extraction, data editing and generic mapping. The mapping process converts the data entry record into the data base input record format by cross-referencing selected elements to "generic," i.e., standardized, assigned TRIP codes or IDs.

The data base management system provides the function of data editing, compaction, updating and accessing. The system relies on "key" or indexing elements in the typical data base record to retrieve information. The keys, which are discussed below, are assigned by the input programs.

The TRIP output programs provide for the specific information needs of TRIP users. The programs provide for output preprocessing, routine report production, and special request report production. Output preprocessing is a function that assesses the quality, integrity and validity of the data being used for output report production.

D.2.2 Generic Mapping and Key Elements

The data provided by the transit systems are input into the TRIP data bank in two stages. The first is data extraction and conversion from the transit system format into a standard entry format. The second stage is the generic mapping and reformatting of the data record into the data base input format.

Twenty-five unique record formats have been defined in the TRIP EDB. Three of these are for dynamic data, 22 are for reference data. (The first six data elements are key elements and are common to all data base records.) Each format is classified by RECORD TYPE and SEQUENCE keys. The SEQUENCE key is used to identify variations of RECORD TYPE. The combination of RECORD TYPE and SEQUENCE defines a unique record format.

The mapping process is accomplished in three steps, using three sets of reference tables. The steps are (1) construction of the generic serial number (GSN), (2) assignment of the generic identification number (GIN), and (3) assignment of generic maintenance action codes (GMACs). The GSN and GIN are key elements that are used for all records, while the GMAC is not a key element and is used only for maintenance records.

The GSN is constructed by determining the transit system ID and Car Number from the input data, and using these, obtaining a Vehicle Series ID from reference Fleet Tables. The Vehicle Series ID is added to the transit system ID and Car Number elements to make up the GSN.

The GIN is a code used to provide a common, computer-recognizable name for components of similar function. It consists of three parts: the Generic Part Number (GPN), the Universal Component Code (UCC), and the Type Code. Of the three codes that comprise the GIN, the GPN is the main one.

The GPN provides for a functional hierarchy of systems, subsystems, assemblies, components, etc. It is the basic reference through which assemblies are categorized by function. The GPN does not provide a description of the actual components but defines the functional breakdown of a vehicle to five levels: vehicle type, functional system (e.g., propulsion system), functional subsystem (e.g., manual controls), functional assembly (e.g., master control), and functional subassembly.

The functional hierarchy is the basic frame of reference through which components are categorized by function for subsequent identification by the other two parts of the GIN: the UCC and Type Code. The UCC and Type Codes capture component-specific information so that comparisons of specific hardware can be made. The UCC designates a particular hardware unit or part. The Type Code relates to a modifier of the UCC and is used when necessary to further describe the component depicted by the UCC. The UCC and Type Codes developed for TRIP encompass all vehicle systems.

The GMACs are assigned based on information in Maintenance Code reference tables. The tables provide cross-references to transit system maintenance codes versus GMACs. The transit system ID element of the GSN is used to get the appropriate table. The GMACs describe the four basic steps in the maintenance process: symptoms, defects, repairs and tests. Symptom codes are broken down into 12 categories corresponding to the 12 functional systems. Defect codes are segmented into nine categories with subcategories, most of which identify the nature of the defect (a few identify parts). The repair codes come in 12 categories, indicating the nature of the maintenance action (e.g., adjustment, removal/replacement, repair/correction). Test codes have yet to be assigned.

When the generic mapping process has been completed, the reformatted data are input into the data base management system, and are ready to be used for generating reliability information. This is accomplished through the use of the output programs.

D.3 AFC TRIP

The performance assessments undertaken as part of the Rail Transit Fare Collection project have provided only a limited amount of performance data on AFC equipment. In order to be useful, performance data need to be statistically sufficient and obtained on a continuous basis. Incorporating AFC equipment performance data into TRIP would provide such an opportunity. In practice, the operation of an AFC TRIP would require that transit systems submit raw data to the custodian of the data bank who, in turn, would provide processed reliability information to the transit systems.

The terms and concepts defined in this document represent a first step toward an AFC TRIP. In addition, the incorporation of AFC information into TRIP requires a determination of the dynamic and reference data necessary for preparing and interpreting performance information. The subsections presented below outline the dynamic and reference data requirements for an AFC TRIP.

D.3.1 Dynamic Data

At a minimum, the transaction, failure, operating time, and maintenance data required to generate the performance measures defined in this report should be included in an AFC TRIP data bank. Machine type, number of transactions, number of failures, type of failure, subsystem affected, total downtime, response time, actual repair time, total technician repair time, and logistic time would be used for developing and reporting reliability, availability and maintainability measures.

D.3.2 Reference Data

Similar to that of vehicles, a reference system must be established in order to provide identifying and interpretive information. Identifying information required could include transit system ID, machine type, machine ID, model, year built, manufacturer, location, major subsystems, subsystem type, subsystem function and subsystem ID.*

Interpretive data required could include station environmental data, passenger rates of usage, presence of agent, equipment specifications and maintenance activity and history.

Reference tables for an AFC TRIP could be established along lines similar to the current system. A GSN could be established that is based on transit system ID and machine ID and machine type (e.g., vendor). This information would be used to reference a table similar to the fleet tables. The AFC reference table would, however, identify the year built and model number of the machine and provide a list of major subsystems (both standard and optional) that comprise the machine. The year built and model number could then be used to retrieve information that would build the generic identification number for the subsystem or component being reported on.

The GPN for AFC equipment record could contain: machine type, functional major subsystem (e.g., coin acceptor, etc.)

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* MDTA has recently drafted an identification numbering system for its vehicles and wayside equipment. The ID is a seven digit number. The first digit identifies the major system (e.g., vehicles, train control, AFC). The next two digits label the type or category of equipment (e.g., entry gates). The last four digits allow for the numbering of up to 9,999 items.

and major subassembly (e.g., electronics of a coin acceptor). Similar to that used for vehicles, the GPN could be used for identification down to the subassembly level. The Universal Component Code and Type Code could then be used to get down to the component or subcomponent level.

In addition to GSN and GPN, maintenance action information could be standardized through the use of tables similar to the generic maintenance codes used for the EDB.

APPENDIX E

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APPENDIX F

REPORT OF NEW TECHNOLOGY

This report has presented performance assessment methods, procedures and results for transit automatic fare colletion equipment. It describes a refined methodology for assessing AFC equipment performance, and also presents the results of 11 AFC system assessments. It is expected that the methodology and results described in this report will help the transit industry address current problems in the area of standardization in fare collection performance assessment methods and specifications. The work performed under this contract leads to no new technology.

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