11. P.D. Mayworm and A.M. Lago. The Costs of Transit Fare Prepayment Programs: A Parametric Cost Analysis. Research Report 125-7. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation; Ecosometrics, Inc., Bethesda, Md., Feb. 15, 1982.
12. Y. Peles. Rates of Amortization of Advertising Expenditures. Journal of Political Economy, Vol. 79, Sept. 1977.
13. National Urban Mass Transportation Statistics: First Annual Report, Section 15 Reporting System. Transportation Systems Center, U.S. Department of Transportation, Cambridge, Mass., May 1981.

Opinions expressed in this paper are those of the authors.

Performance Assessment Methods and Results for Transit Automatic Fare Collection Equipment

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ABSTRACT

Performance assessment methods and results for transit automatic fare collection (AFC) equipment are presented. The methods developed are based on the experience gained from a series of performance assessments conducted at eight U.S. and three foreign transit systems. The methods are intended to assist rail transit systems in their assessment of equipment, promote uniformity in applications, improve communications between companies, 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 Project, the overall goal of which 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. In this source document for assessment methodology key AFC terms and concepts are defined, and performance methods as well as the results of the systems assessments and industry AFC contract specifications are presented and discussed.

UMTA, U.S. Department of Transportation, initiated the Rail Transit Fare Collection (RTFC) Project in 1979 in response to a critical need by the U.S. transit industry for improved automatic fare collection (AFC) systems.

Currently there exists a clear lack of standardization in both performance measurement and specification of fare collection equipment. This has resulted in, among other things, increased procurement costs and the need to regularly "reinvent the wheel." In recognition of this, the RTFC Project was targeted at the development and application of uniform AFC performance assessment methods.

In this paper uniform performance assessment methods for AFC equipment are presented. In addition, the results of the systems assessments are summarized and discussed and compared with industry performance specifications.

AFC SYSTEMS AND EQUIPMENT

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

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 AFC equipment: Metropolitan Atlanta Rapid Transit Authority (MARTA); Washington Metropolitan Area Transit Authority (WMATA); Bay Area Rapid Transit (BART), San Francisco; Port Authority Transit Corporation (PATCO), Philadelphia and Camden; Illinois Central Gulf (ICG), Chicago; Chicago Transit Authority (CTA); Port Authority Trans-Hudson Corporation (PATH), New York and New Jersey; Massachusetts Bay Transportation Authority (MBTA), Boston; New York City Transit Authority (NYCTA); Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia; and Baltimore Metropolitan Transit Authority (BMTA). In addition to these, the Metro-Dade Transportation Administration (MDTA) system currently under construction in Miami will use AFC equipment.

In general, in the older transit systems (e.g., NYCTA, MBTA, CTA, PATH, SEPTA) the AFC systems consist primarily of gates that accept coins or tokens or both. In the relatively new transit systems (e.g., ICG, PATCO, MARTA, BART, WMATA, BMTA) the AFC systems consist of farecard vendors or farecard-accepting gates or both. In addition, equipment function and complexity vary from the simple (e.g., NYCTA, MBTA, and PATH gates) to the more complex microprocessor- or computer-controlled equipment (e.g., WMATA, BART, and MARTA gates).

Foreign transit systems also use AFC equipment. The RTFC Project investigated three that use state-of-the-art microprocessor-controlled equipment. The systems were Tyne and Wear Transport Executive (T&W), Stuttgarter Strassenbahnen (SSB), and Régie Autonome des Transports Parisiens (RATP). These systems operate in Newcastle, England; Stuttgart, West Germany; and Paris, France, respectively.

USES OF PERFORMANCE ASSESSMENT MEASURES

The performance measures generated from the methods presented are reliability, availability, and maintainability. These can be used for a variety of purposes. Three key uses are

1. To provide information for monitoring compliance with equipment procurement specifications (e.g., acceptance testing),
2. To provide operational data for management information systems (e.g., to monitor maintenance productivity), and
3. To generate baseline data for modification programs and aid in the development of a reliability data base similar to that which already exists for rail transit vehicles [the Transit Reliability Information Program (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. Two common measures used are mean transactions per failure (MTF) and mean time between failures (MTBF).

MTF = total transactions divided by total failures.

MTBF = total in-service time divided by 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 = total in-service time divided by 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.

ADT = total downtime divided by total failures.

MTTR indicates the average length of time required to respond to and repair a hard failure (described in the following) of AFC equipment.

MTTR = total downtime (hard failures only) divided by total number of hard failures.

FAILURE

Definition and Classification

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 consists of three failure types: jams and soft and hard failures. As defined in the following, the concepts of soft and hard failures indicate the general nature and relative severity of failures. All failures are either soft or hard. The concept of jam, on the other hand, specifies the symptom of the failure. Jam is used as a failure type because jamming is a common (and often the most frequent) problem with AFC equipment. Like all failures, jams are also classified as either hard or soft failures.

Jams

A jam is defined as any instance in which something is stuck in the processing or dispensing path of an AFC machine preventing the completion of a successful transaction or rendering the machine or one of its subsystems inoperative.

Soft Failure

A soft failure is any instance of malfunction of AFC equipment 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 and thus is malfunctioning. Repair refers to the fixing of a subsystem, component, or subcomponent that has become damaged through use or abuse. Minor is defined as requiring less than 20 min of total technician active repair time.

Hard Failure

A hard failure is any instance of malfunction of AFC equipment that necessitates a major adjustment, major repair, or replacement. Major is defined as requiring more than 20 min total technician active repair time.

Causes

Jams and soft and hard failures indicate the general nature or severity of the problem encountered. Jams and soft and hard failures do not indicate the cause of the failure. For the day-to-day administration and management of an AFC system, eight failure causes are defined. These are as follows:

- Technical: A failure when it can be shown that the machine has malfunctioned on its own, that is, as a result of normal operation and not as a result of the other causes listed here, which includes, among others, failures related to equipment and parts design and manufacture and failures related to normal aging of the equipment.

- Operational: A failure due to oversight or error on the part of maintenance personnel, which includes such diverse situations as operating equipment beyond life expectancy, faulty installations, and faulty maintenance.
- Environmental: A failure due to the operation of the equipment in adverse environmental conditions that exceed specifications.
- Vandal: A failure resulting from damage or tampering by vandals.
- Administrative: A failure due to oversight or error in nontechnical functions of the machine, which includes situations such as improper loading of ticket or transfer stock, being out of tickets, and so on.
- Passenger-Induced: A failure caused by improper insertion of fare media or interference with the normal action of a machine by passengers.
- Media: A failure caused by fare media such as coins, tokens, or farecards, whether they are dirty or defective, which subsumes some passenger-induced failures but is a separate category because in many cases it is not clear that the passenger is responsible for the failure.
- No Defect Found (NDF): A common situation in which a machine has been put out of service by an agent suspecting a failure but when checked no defect is found; in some cases, transient or intermittent failures are the cause of the problem.

Chargeability

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 might be expected, this has made it difficult to compare performance measures.

PERFORMANCE ASSESSMENT METHODS

Several methods 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 failures or a subset (i.e., specific failure causes) of all failures is used. As mentioned earlier, 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 methods for assessing performance are described in the following. The reliabilities generated should be evaluated in conjunction with information on maintainability, availability, and failure distributions. Transit systems may select the methods 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. As might be expected, when all failures are counted, reliability measures are at their lowest levels. 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. In addition, such a measure could provide an indication of the frequency of passenger assistance required and of expected delay. These in turn could be used to determine the requirements for new equipment and manpower of both agents and technicians.

Reliability Based on Transit-Plus-Technical Failures

Another method is to determine the reliability based on all failures less those caused by vandals and passengers. These are defined as transit-plus-technical failures. This method provides a performance measurement based on all failures over which the transit system, in theory, can exercise control. 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.

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 or hard technical failures or both. These measurements could assist transit systems in monitoring performance of equipment under test or warranty and also indicate to management specific technical problems.

Maintainability

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

Availability

Availability measures provide a basic indication of service provided to passengers. They can be used to determine the probability of delay and as a general indication of maintenance response times.

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 problems or types of improvement. Interpretation of performance measures is complete only when failure distributions and trends have been investigated.

PROCEDURES FOR OBTAINING DATA FOR PERFORMANCE ASSESSMENT

Two procedures exist for obtaining data for performance assessment: 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 methods presented for measuring reliability performance require that in-service surveys be taken. Given the large percentage of jams that occur and the small amount that shows up 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 passenger-induced failures. For the computation of reliability based on technical failures, maintenance and transaction records should suffice because the assumption that every technical failure eventually generates a maintenance report seems to be valid throughout the industry.

DATA ANALYSIS

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

A confidence interval indicates the region within which there is a specified probability 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 determine whether retrofits improve equipment performance. The chi-square test determines whether variations in performance among equipment are due to chance or performance characteristics.

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, from transit system records, or from both. Where possible, the results are reported according to the three assessment methods described earlier. However, in some cases, data limitations made this impossible.

In Tables 1 through 4 the reliability results for vendors and gates are summarized. 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 passenger-induced failures, whereas transit records, in general, do not. This accounts for the relative differences between reliabilities based on in-service data and those based on data from transit system records.

Vendors

Vendor reliability results based on in-service data are summarized in Table 1. 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 preretrofit) to 6,891 MTF (WMATA retrofit B). For the T&W vendors, no hard failures occurred.

The reliabilities for coin acceptors, ticket

TABLE 1 Summary of Vendor Reliability Based on In-Service Data

		Machine Reliability			Major Subsystem Reliability (MTF) (all failures)		
Transit System	No. of Vendors	MTF (all failures)	MTF (hard failures only)	MTBF (all failures) (hr)	Ticket Transport	Coin Acceptor	Bill Validator
ICG	9	167	2,510	5.6	717	3,698/0[a]	1,026
BART (all)	17	141	1,401	3.8	849	1,038[b]	338[b]
BART (IBM)	9	149	2,065	5.1	1,033	1,112[b]	321[b]
BART (cubic)	8	133	1,043	2.5	714	969[b]	357[b]
WMATA-P[c]	40	120	860	2.0	376	844	358
WMATA-A[c]	14	133	2,293	1.7	573	1,058[d]	459[d]
WMATA-B[c]	6	265	6,891	2.8	3,455	1,027	572
T&W	19	4,708	14,123/0	71.7	7,062	ND	NA
SSB	10	1,821	5,464	45.3	NA	ND	NA

Note: ND = no data; NA = not applicable; MTF = mean transactions per failure; MTBF = mean time between failures.

[a] This notation indicates no failures.
[b] BART coin acceptor and bill validator reliabilities based on tickets sold, not coin or bill insertions.
[c] WMATA-P refers to preretrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.
[d] Subsystem not retrofit.

TABLE 2 Summary of Vendor Reliability Based on Data from Transit System Records

	Machine Reliability (MTF)			Major Subsystem Reliability (MTF) (excluding vandalism, patron-induced, and NDF)			
Transit System	All Failures	Transit-Plus-Technical Failures	Excluding Vandalism, Patron-Induced, and NDF	Ticket Transport	Coin Acceptor	Bill Validator	Needlepoint Printer
ICG	92	103	118	439	ND	ND	NA
PATCO	310[a]	310[a]	311	637[a]	8,681[a]	2,736[a]	NA
T&W	3,284	6,908[b]	6,908[b]	14,227[b]	ND	NA	ND
SSB	3,311	4,573	6,203	NA	ND	NA	32,497

Note: ND = no data; NA = not applicable; MTF = mean transactions per failure; NDF = no defect found.

[a] Vandalism and patron-induced not cited in PATCO failure data.
[b] T&W data did not cite patron-induced or NDF.

TABLE 3 Summary of Gate Reliability Based on In-Service Data

		Machine Reliability				Major Subsystem Reliability (MTF) (all failures)		
Transit System	No. of Gates	MTF (all failures)	MTF (transit-plus-technical failures)	MTF (hard failures only)	MTBF (all failures) (hr)	Ticket Transport	Coin Acceptor	Transfer Dispenser
MBTA	30	1,558	ND	46,740	10.2	NA	2,032	NA
PATH	31	1,989	3,519	137,239	5.0	NA	4,300	NA
CTA	14	904	2,862	8,586	8.6	NA	6,263	546
ICG	28	4,570	6,680	86,842/0	20.5	5,108	NA	NA
BART (all)	27	1,136	ND	75,518	8.0	1,842	NA	NA
BART (IBM)	13	1,969	ND	76,772/0	15.0	4,798	15,354[a]	NA
BART (cubic)	14	790	ND	37,131	5.1	1,125	NA	NA
WMATA-P[b]	24	502	ND	ND	1.1	858	NA	NA
WMATA-A[b]	18	712	ND	ND	2.2	1,477	NA	NA
WMATA-B[b]	7	2,220	ND	ND	4.2	11,274	NA	NA
MARTA	26	1,740	ND	12,015	6.1	5,340	3,266	2,874
T&W	16	10,299	10,299	20,597/0	91.1	10,299	NA	NA

Note: ND = no data; NA = not applicable; MTF = mean transactions per failure; MTBF = mean time between failures.

[a] Reliability based on total entries, not coin insertions.

[b] WMATA-P refers to preretrofit equipment. WMATA-A and B refer to retrofits A and B, respectively.

TABLE 4 Summary of Gate Reliability Based on Data from Transit System Records

	Machine Reliability (MTF)			Major Subsystem Reliability (MTF) (excluding vandalism, patron-induced, and NDF)			
Transit System	All Failures	Transit-Plus-Technical Failures	Excluding Vandalism, Patron-Induced, and NDF	Ticket Transport	Coin Acceptor	Transfer Dispenser	Logic
PATH	12,672	12,672[a]	12,672[a]	NA	30,446	NA	ND
ICG	2,507	3,037	3,509	ND	NA	NA	ND
PATCO	5,907	5,907[b]	5,907	15,096	NA	783	ND
MARTA	3,225	3,225[b]	3,567[c]	ND	24,225[c]	6,849[c]	21,742[c]

Note: ND = no data; NA = not available; MTF = mean transactions per failure; NDF = no defect found.

[a] PATH data did not include NDF.

[b] Vandalism and patron-induced not cited in PATH, PATCO, and MARTA failure data.

[c] Excluding administrative failures also.

transports, and bill validators are also shown in Table 1, based on all failures. Coin acceptor reliability ranged from 844 MTF (WMATA preretrofit) to the reliability of ICG coin acceptors, which did not experience any failures during 3,698 transactions. Ticket transport reliabilities ranged from 376 MTF (WMATA preretrofit) to 7,062 MTF (T&W). Part of the difference in performance between the ICG and PATCO vendors and the SSB and T&W vendors is due to the age of the equipment and the design of the ticket delivery system. The ICG and PATCO machines use a ticket stacker system. T&W machines use a ticket unroller, and SSB vendors use a sprocket feeder. For bill validators, reliabilities ranged from 321 MTF (BART IBM) to 1,026 MTF (ICG). The extent of bill checking that exists between the validators accounts for some of the differences.

Vendor reliability based on data from transit system records is summarized in Table 2. 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-plus-technical failures, the ICG reliability rose to 118 MTF, that of PATCO to 311 MTF, and that of SSB 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, passenger-induced, and NDF.

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

Gates

Reliability results based on in-service data are given in Table 3. The gate reliabilities based on all failures ranged from 502 MTF (WMATA preretrofit) to 10,299 MTF (T&W). 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 MTF (T&W). 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-service surveys: BART IBM, ICG, and T&W. The high PATH reliability reflects the simplicity of the equipment; PATH gates accept only nickels, dimes, and quarters in separate slots.

Major subsystem reliabilities are also presented in Table 3 based on all in-service failures. Ticket transport reliabilities ranged from 858 MTF (WMATA preretrofit) 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).

Gate reliability results based on data from transit system records are summarized in Table 4. 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 although 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.

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

Observations on vendor performance are as follows:

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. A smaller ticket, the method of ticket delivery, and the absence of bill validators in the European machines appear to 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 made up 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 with 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, availabilities were relatively high (e.g., T&W, SSB, WMATA retrofit B). Where one or both of the situations were not true, availabilities suffered accordingly (e.g., ICG, WMATA preretrofit).
6. Vendor maintainability results, although data were limited, were consistent with the statements made in item 5. 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

Observations on gate performance are as follows:

1. Based on in-service data, the microprocessor-controlled T&W 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- or ticket-accepting gates performed slightly better overall than coin- or token-accepting gates because there was less jamming in the latter.
3. For each transit system, based on both in-service data and data from transit system records, the largest category of gate failures was jams from 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 4.

PERFORMANCE RESULTS VERSUS SPECIFICATIONS

Of the eight American rapid rail transit systems surveyed, all have performance specifications for AFC equipment. 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 1975-1976 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 specifications (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 based on 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 the 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 that rendered the AFC equipment inoperative or 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 hr 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 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 United States--BMTA and MDTA--have also issued reliability specifications. Each uses the concepts of relevant and nonrelevant failures. The BMTA specification defines relevant failures as all failures that can be expected to occur in revenue service operations. A nonrelevant failure is caused by a condition external to the equipment and not expected to be encountered in field revenue service. MDTA has similar

TABLE 5 Comparison of Vendor Reliability Assessment Results and Specifications

		Performance Results (in-service data)		
Transit System	Specification	MTF (all failures)	MTF (hard failures only)	MTBF[a]
BART	3,500 MCBTJ			3.75
	200 MCBSF	141		
	2,500 MCBHF		1,401	
WMATA[b]	920 MTBF[a]	265	6,891	2.79

Note: MTF = mean transactions per failure; MTBF = mean time between failures; MCBTJ = mean cycles between ticket jams; MCBSF = mean cycles between soft failures; MCBHF = mean cycles between hard failures.

[a] MTBF in hours.
[b] Retrofit B.

definitions. The 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 because of the differences in performance measures used and failures deemed chargeable.) The results for vendors of those systems for which specifications existed (BART and WMATA) are summarized in Table 5. 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 all adjustment, repair, and replacement actions.)

For the WMATA specification, the 2.79 MTBF from the in-service survey pales in comparison with the specification MTBF of 920. (Only retrofit B 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 last 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.

In Table 6 gate reliability results and specifications are summarized and compared. 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 that 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.

SUMMARY AND RECOMMENDATIONS

As described earlier, there is currently a clear lack of standardization in transit fare collection equipment performance measurement and specification. In this paper the performance measurement problem has been addressed by presenting uniform performance assessment methods and procedures.

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

TABLE 6 Comparison of Gate Reliability Assessment Results and Specifications

		Performance Results			
		In-Service Data			
Transit System	Specification	MTF (all failures)	MTF (hard failures only)	MTBF[a]	Transit System Data (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[b]	720 MTBF[a]	2,220	ND	4.2	
MARTA	34,000 MCBF	1,740	12,014	6.1	3,225
CTA	10,000 MCBF	902	8,586	8.6	

Note: ND = no data; MTF = mean transactions per failure; MTBF = mean time between failures; MOBF = mean operations between failures; MCBTJ = mean cycles between ticket jams; MCBSF = mean cycles between soft failures; MCBHF = mean cycles between hard failures; MCBF = mean cycles between failures.

[a] MTBF in hours.
[b] Retrofit B.

input into the development process. It is believed that implementation of the following recommendations would represent a final step in the process of developing and applying uniform performance assessment methods for AFC equipment. It is recommended

1. That transit systems use the set of uniform definitions, classifications, performance measures, causal factors, chargeability criteria, and assessment methods and procedures for AFC equipment detailed in this paper;
2. That transit systems schedule performance surveys on a regular basis, using data from both in-service surveys and from internal records;
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 paper be undertaken to measure and compare the performance of retrofit and nonretrofit equipment; and
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.

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An Examination of Transit Telephone Information Systems

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ABSTRACT

Some of the findings are reported of an examination of transit passenger information systems with particular emphasis on their technology-related subsystems and of an independent survey of the U.S. transit systems regarding telephone information systems currently in place. The first study examined the telephone information systems at three transit authorities, representing three categories: (a) a simple labor-intensive manual telephone system (Nashville--Davidson County Metropolitan Transit Authority), (b) a computer-assisted manual system (Washington Metropolitan Area Transit Authority), and (c) an automated system (Hamburg, West Germany). Each of these systems is designed to provide transit users with answers to their inquiries regarding transit system schedules, routes, and itineraries. A description of each of these systems as well as other components of passenger information systems is presented. The survey was carried out as part of a corporate-sponsored effort designed to provide new information about the type of telephone information system in place on transit authorities of various sizes in the United States. Information about planned changes and improvements is also provided.

In this paper some of the findings are reported of an examination of transit passenger information systems with particular emphasis on their technology-related subsystems and of an independent survey of U.S. transit systems regarding the type of telephone information system (TIS) currently in place. The former was conducted as a part of the project entitled Assessment of Transit Technologies carried out within the New Systems Alternatives Program for UMTA; the latter was carried out as part of a corporate-sponsored effort.

PASSENGER INFORMATION SYSTEMS

Passenger information systems are generally part of a broader transit marketing effort that includes everything involved with making a transit system attractive for the transit users in a region. Because passenger information systems in general, and the TIS in particular, are part of the overall transit marketing effort, it is important to keep in mind that although the information system performs an important service function, it is also an important marketing activity. In recent years it has become widely accepted that transit, like any other industry, is in the business of selling a service to its customers. The marketing activities of a transit agency are aimed at tailoring services to potential customers and meeting their transportation needs. Serving the transit consumer is at the heart of the transit business. Market research and planning studies are used to identify the various segments of the market defined by travel characteristics and ability to pay. The purpose of advertising is to inform the public, to stimulate demand, and to change attitudes toward the product advertised. Advertising is used to bring information about the system and its services to the public's attention.

Passenger information consists primarily of maps, schedules, and signs. It is used to educate the potential rider on the use of the transit system and