TRANSPORTATION RESEARCH RECORD 972

Trends in Transit Marketing and Fare Policy

TRB
TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1984

Transportation Research Record 972
Price $6.00
Editor: Naomi Kassabian
Compositor: Harlow A. Bickford
Layout: Betty L. Hawkins

mode
2 public transit

subject areas
11 administration
12 planning
13 forecasting
14 finance
15 socioeconomics
16 user needs

Transportation Research Board publications are available by ordering directly from TRB. They may also be obtained on a regular basis through organizational or individual affiliation with TRB; affiliates or library subscribers are eligible for substantial discounts. For further information, write to the Transportation Research Board, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

Printed in the United States of America

Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Trends in transit marketing and fare policy.

(Transportation research record; 972)
1. Local transit–United States–Congresses. 2. Local transit–United States–Fares–Congresses. I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 972 [HE4451] 380.5 s [388.4'042] 84-26746
ISBN 0-309-03754-9 ISSN 0361-1981

172

Contents

Addresses of Authors

Damm-Luhr, David L., Transportation Systems Center, U.S. Department of Transportation, Kendall Square, Cambridge, Mass. 02142
Diewald, Walter J., N. D. Lea and Associates, Inc., P.O. Box 17030, Washington, D.C. 20041
Lago, Armando M., Ecosometrics Incorporated, 4715 Cordell Avenue, Bethesda, Md. 20814
Mayworm, Patrick D., Ecosometrics Incorporated, 4715 Cordell Avenue, Bethesda, Md. 20814
Morrissey, Joseph M., Input Output Computer Services, Inc., 400 Totten Pond Road, Waltham, Mass. 02254

Assessment of a Transit Fare Increase: The Case of the Southeastern Michigan Transportation Authority

DAVID L. DAMM-LUHR

ABSTRACT

The results of a study of a 15-cent across-the-board increase in fares carried out in July 1981 by the Southeastern Michigan Transportation Authority (SEMTA) are detailed. Data from the same riders were gathered both before and after the fare increase; econometric methods tailored to these data were used. The results indicate that sensitivities to the fare increase vary noticeably across types of service. In particular, transit trip making in the off-peak period appears to be nearly twice as sensitive as that in the peak periods. Although fare increases appear to be virtually certain of raising revenues somewhat, differential pricing by time of day would appear to hold promise as a means of maximizing revenues. It is clear that a wide variety of factors influences the use of bus transit. Even if most transit-related factors other than fares (e.g., headways) are virtually constant during the period of study (as was true in the SEMTA system), many nontransit factors (e.g., whether a person works, location of job, location of home) change continually for enough riders to make a difference. Conclusions drawn about riders' sensitivities to fare increases that do not account for changes in nontransit factors are likely to be erroneous. The implications of the findings for pricing policies are presented. To show the possible uses of the results by SEMTA and other transit agencies, examples are given of how to aggregate up to the entire system of patrons and to predict the effects of future fare increases on levels of ridership and revenue. Highlights of the analyses are also given in terms of the relative importance of fares in the use of transit.

Public transit agencies are increasingly constrained by two factors in setting fares charged for services provided. First, costs for public transit outpace revenues in nearly all operations. Second, support for subsidies to transit agencies has lessened (1), particularly for federal operating assistance [based on Section 5 of the Urban Mass Transportation Act of 1964 (49 U.S.C. 1601 et seq.)]. In combination, these two factors have put enormous pressure on local service providers to seek out new sources of revenue. With a history during the 1970s of offering low fares, especially if calculated in real terms (i.e., accounting for inflation), operators have turned with growing frequency to the farebox (2). Within the transit industry, it has always been assumed that because the average rider is not sensitive to levels of fare, raising the price of service would, in nearly all cases, increase systemwide revenues. Conceived as a business decision, turning to the farebox to redress the imbalance between costs and revenues would appear to be both logical and prudent.

If experiences in the transit industry are any indication, raising fares as such does not necessarily result in meeting performance-related objectives better. In addition to upsetting political constituencies within a service region, some types of fare increases could result in a worsened ratio of costs to revenues for some parts of a system. In their quest to control costs, transit professionals have realized as never before that operating expenses can vary considerably across type of service (e.g., express versus line haul), time of day (peak versus off peak), time of week (weekday versus weekend), and distance of trips, to name the most obvious dimensions. In parallel, attention given to performance and productivity of services has been growing (tying, for example, allocation of subsidies to measures of efficiency and effectiveness). Because riders are the consumers around whom services are designed and costs incurred, it is only logical for operators also to pay attention to how riders use or might use their services when priced at various levels. Just as costs vary, so do consumers' uses of transit. Unless there is an explicit and well-understood connection made between the two, turning to the farebox may produce mixed results.

Over the years, a number of transit agencies have grappled with various means of charging fares in closer relation to the cost of providing service. Zonal or distance-based fares as well as surcharges for express service, for example, have been tried in a range of settings, although sometimes dropped in favor of the administratively simpler flat-fare structure. Flat-fare systems, however, typically result in subsidizing longer trips at the expense of shorter trips (3) and, given our knowledge of the incomes of riders, also subsidizing richer patrons at the expense of the poorer. However, even if the flat fares are held at relatively low levels, it is not at all clear that poorer patrons' mobility is improved substantially (4). Besides simple concern over amount of revenue raised by charging a particular fare, transit operators, as public (and perhaps political) officials, are concerned with the distributional effects (or equity) of fare policies.

In this context reliable information about riders' responses to changes in transit fares has become a precious commodity. Without doubt, data on the use of transit ought to be disaggregated (i.e., at the level of the individual rider) as much as data on the cost of transit. It is consequently imperative for operators to develop a source of information that enables them to examine categories of trips and, if possible, of users and then estimate likely responses to various changes in fares (and implicitly the resulting systemwide ridership and revenues). If generated when preparing options for policy makers (e.g., a board of directors), such estimates could be invaluable in identifying those pricing strategies that are most likely to meet the objectives of both cost recovery and equity.

MOTIVATION

Most studies of either increases or decreases in transit fares have been conducted with aggregate, systemwide data (5) and have not controlled for the many known nontransit factors that influence the use of transit. The widespread acceptance in the transit industry of the Simpson-Curtin rule (6), the derivation of which is based on aggregate data and that states that a 10 percent fare increase means a 3 percent loss in ridership, has often meant that analysts in various agencies have given little attention to distinguishing the impacts of fare changes across service types or groups of riders (7). In addition, many prior analyses focused on a single percentage change in fares, implicitly assuming that riders' use of transit would vary in about the same way, whatever percentage of change occurred. In the case of the Southeastern Michigan Transportation Authority (SEMTA), a wide range of relative fare increases was experienced because of its zonal structure.

Among transit operators and analysts, there is growing acknowledgment that not all riders, types of trips, or percentage of changes in fares can be treated identically (8-12). Fare policies based on recognition of the range of possible responses are more likely to meet an agency's objectives than those simply applied uniformly. Policies can affect riders differently (e.g., distance-based or quality-based fares) and riders' responses may vary depending on their sociodemographic characteristics (e.g., income level). As a result, it is important for transit planners to understand how ridership and revenue can vary, in some cases considerably, when more businesslike approaches to pricing policy are used. As Kemp (13) points out, "Price and service quality should be adjusted as far as possible to improve those aspects known to influence most the travel choices of the people in a catchment area." By separating out nontransit factors, transit agencies will be in a better position to identify those aspects that can be controlled.

THE FARE POLICY AND ITS ENVIRONMENT

SEMTA serves the suburban portion of the Detroit metropolitan area. Its primary service region includes Macomb, Wayne, and Oakland counties. SEMTA's fare structure is zonal and in spring 1981 was represented by a base fare of 60 cents and 20 cents charged for each zonal boundary crossed. In addition, surcharges of 20 cents each were assessed for park-and-ride services and the use of limited-stop buses (e.g., express service). In July 1981 cash fares rose 15 cents uniformly over the system; that is, everyone's total fare increased by 15 cents. Ten-ride tickets rose in price correspondingly and maintained a discount rate of 10 percent. Monthly passes (SEMTA cards) were priced at the cost of 32 (versus the earlier 30) one-way cash trips. In addition, transfers cost 10 cents, whereas formerly they were free. Because fares are calculated on a zonal basis, the relative increase in fare that each rider experienced depended on the number of zones crossed and transfers made. For example, riders who usually traveled within one to two zones and made one or more transfers experienced a greater than 25 percent increase in fare, whereas users who crossed eight (the maximum) zones paid less than 10 percent more than before.

DESIGN

General Considerations

To the extent possible, controls were developed for the many factors that influence riders' use of transit; also a frame of time was chosen in which as much of the variation in transit use over time as possible could be captured. The study was conceived around the same persons (i.e., a panel) to be contacted before and after SEMTA's fare increase. The primary concern was to eliminate as many competing explanations (i.e., not related to the change in fare) for why people did or did not change their use of transit. Five types of factors were considered as sources of these explanations:

1. Transit related (e.g., fare and service),
2. Locational (e.g., home and job) for rider,
3. Attributes of the rider (e.g., age and sex),
4. Attributes of the rider's household (e.g., availability of automobile), and
5. Survey specific (e.g., dates for which transit use was reported).

By collecting identical or comparable data twice from the same persons, it was possible to compute changes in many variables with little difficulty. Fixed factors (e.g., age and sex) served as controls for variation in transit use across riders. It is assumed that the 4-month period (July to October 1981) after the fare increase was not so long that measurements made after the increase would not uncover the effects of the change in fares. Further corrections were made for the possible bias of the final sample if those remaining in the panel had been significantly different from those dropping out. [A procedure similar to that of Hausman and Wise (14) was used.]

In order to capture variation in day-to-day use of transit, the primary unit of measurement (i.e., what would be compared before and after the fare increase) was defined as the number of weekly transit trips. Based on the expected responses to the fare increase, it was then possible to propose the sampling needed to detect whether a change actually occurred and judge the extent that the fare increase significantly influenced riders' use of transit.

Sampling

Prior information was used to stratify the population of SEMTA riders and thereby control for the variation associated with each dimension. Choosing samples within each of five categories (three types of service, each with peak and off-peak variations, except park and ride, which has only peak service) afforded a better chance of detecting variation in reaction to the fare increase with respect to unstratifiable dimensions (e.g., income and number of drivers per number of automobiles in a household). Given that SEMTA personnel produced good estimates of numbers of riders by service type and time of day, it presented no problem simply to make five sets of estimates of the sample sizes needed for analysis. Assumptions were made about the average response to the fare increase in each of the five categories, weighted by prior information on the proportion of riders experiencing various percentage increases. In addition, information on the diversity of types of riders in each category was used to judge the likely statistical spread of responses (i.e., variance). Based on reasonable criteria for statistical tests as well as corrections for expected losses of panel respondents (from the surveys either before or after the fare increase), sample sizes were computed by using formulas developed by Cochran (15). SEMTA staff and their contractors arranged to distribute surveys to patrons on each bus route as closely as possible in proportion to their shares of riders within each of the five categories of service type or time of day.

Surveys and Data

In spring 1981 patrons were contacted on board buses. To test the efficacy of the proposed instruments and procedures, SEMTA staff conducted a pretest during the week of May 11, 1981, followed by administration on May 20 and 21 of the revised survey of conditions before the increase. In the fall of 1981, SEMTA staff mailed a second questionnaire to everyone who provided a legible, usable name and address on the spring survey. In addition to repeating most of the first round of questions (to make comparisons), there were questions on the household's income and on change in occupational and locational conditions as well as reasons for any change in use of transit. No direct question was asked on the increase in fares, since prior studies (13) showed that there is a tendency to attribute changed use of transit to raised fares if such a connection is explicitly suggested. On October 27, 1981, the questionnaire about conditions after the increase was mailed out, followed on November 3 by a reminder postcard and on December 3 by a replacement survey form (the latter two mailed, of course, only to those whose form had not yet been received). [A detailed comparison of assumed and actual sample sizes is presented elsewhere (16).]

Before the findings are discussed, a caution should be stated. Inherent in sampling on board buses is the consequence that more frequent users receive questionnaires with greater likelihood than less frequent riders. Because frequency of travel may vary by other attributes of riders (e.g., age or sex), most analyses of transit use include appropriate statistical adjustments. Not to weight the observations may mean that results will be biased in the direction of attributes of more frequent riders.

In this case, the design of the study did not lead to single-period data to be analyzed using conventional trip-generation methods. Having two periods of data on the same persons permitted focus on transit use after the fare increase as the prime variable of interest. Consequently, a case has been made that by using prior transit use as an explanatory variable, the sampling could be considered exogenous. That is, even though more frequent riders may be overrepresented, the numbers of trips made can be given a coefficient and effectively controlled statistically. In this way, prior transit use can be held to one side as the effects of other variables on subsequent transit use are interpreted.

Model of Transit Use

Needed in making the connection between the expectations (the model) and the data collected is an appropriate econometric structure. Because the dependent variable (i.e., what was to be explained) was the number of trips made after the fare increase (having prior trips as an explanatory variable), the use of ordinary-least-squares (OLS) regression was questioned. Because there is a bunching of some observations at zero (those who no longer use transit necessarily have zero trips per week), the assumptions of normality of OLS are violated. Further, if observations with zero values were simply ignored, the resulting estimators would be inefficient (i.e., not have the smallest variance among all unbiased estimators) if it was attempted to explain the probability of observing both zero as well as positive values.

As an alternative, Tobin (17) proposed a limited dependent variable model, that is, a regression that allows truncation at either lower or upper limits or at both. Using his model, the effect of the hypothesized explanatory variables on the probability of observing both zero and nonzero values for the number of transit trips after SEMTA's fare increase was accounted for. Tobin's model (which was estimated using maximum-likelihood techniques) can be represented approximately as follows:

$$\begin{aligned} t &= XB + E \quad \text{if } XB + E > 0 \\ t &= 0 \quad \text{if } XB + E \leq 0 \end{aligned} \qquad (1)$$

where

X = set of explanatory variables,
B = vector of coefficients, and
E = vector of random disturbances or unexplained variation.

The dependent variable, t (number of weekly transit trips), takes a value of zero if the person no longer used transit in October.

RELATIVE IMPORTANCE OF FARE FOR TRANSIT USE

Transit operators can gain insight into the weight and diversity of non-fare-related factors, which often blur the effects of changes in fares and hence conclusions about the merits of various policies. The complexity of the environment of most fare changes should become evident. In addition, transit operators may also derive ideas for other factors that should be controlled when fares are increased (e.g., service levels). Analysts will find some of the details of the specifications and statistical analyses useful in future work. Many of the factors for which data were collected and variables created are addressed for the first time here.

Exploration of Data

Transit Use

As reflected in the structure of the econometric model, the prime interest here (and the dependent variable) was patrons' use of transit. Since "use" was defined in terms of weekly transit trip making, it was possible to explore it by means of histograms (Figure 1) and begin to identify patterns. Even if the special nature of the raw data (i.e., skewed by frequency of transit use) is kept in mind, these results make clear a point that recurred throughout the analyses: A much wider range of behaviors is indicated than was originally conceived. A sizable proportion of riders in all categories took more trips after the fare increase of July 1981, a finding that indicates the involvement of factors other than fare. In addition, it becomes apparent that those who do alter their number of weekly transit trips do not do so uniformly in either an absolute or a relative sense.

Transit Fare

Having changes in relative trip frequency that were spread over a wide range and that included those who actually increased their use of the bus led to the suspicion that relative change in fares paid might also vary beyond original expectations. When average values for selected variables within the subsample of line-haul and peak service were compared, this suspicion was indeed confirmed. It is evident that analysis within separate groups is appropriate.

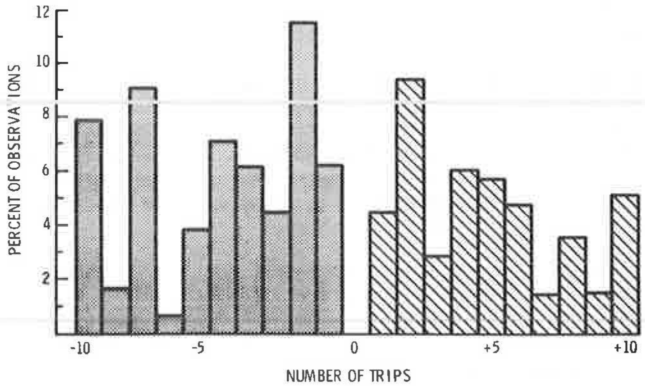

FIGURE 1 Changes in weekly SEMTA trip making (line-haul off-peak, weekday, work-school).

Because transit fare was the central policy variable, considerable effort was spent in trying to understand its place in explaining (statistically) variation in use of transit after the fare increase. Because a range of relative fare changes sizably larger than that expected was found, it was decided to create separate variables, depending on the patron's position in the range. It was assumed that at least three separate categories exist: decrease in fares, high increase in fares, and moderate increase in fares. At the same time, it was theorized that within each category, substantial differences would be found if those experiencing a change in some time-space constraint (i.e., location or timing of an important activity like work) were separated from those without such a change. [Detailed exploration of the effects of these constraints on travel has been presented elsewhere (18,19).] Especially for the two extremes (decrease and high increase), changes in time-space constraints were thought to be responsible for the unusual values.

Definition of Variables for a Model

Based on a priori hypotheses about the use of transit plus results from the exploratory analyses described previously, variables for estimation of statistical models were defined. The dependent variable was the number of weekly transit trips taken after SEMTA's fare increase. In this way the number of prior trips could be estimated as an explanatory factor and not have its coefficient effectively constrained to a value of 1. On the explanatory side, five groups of variables were set up. First and obviously, transit-oriented factors were defined:

1. Relative change in fare (May 1981 as the base relative to October 1981),
2. Decrease in level of service (0/1 value depending on whether the person's route was affected), and
3. Service variation by garage of the person's bus (0/1 by garage).

Second, prior use of transit and method of paying for fares constituted another set of variables. Third, dummy variables were created to reflect changes in temporal-spatial constraints (such as occupational status, location of job or home, and length of trips). Fourth, person-specific factors were recognized as potentially important explainers of variation across transit users. Besides the usual variables of age and sex, data were gathered and used on whether it was reported that the day surveyed was typical (or, for example, that the person was on vacation or had a disabled car). Finally, survey-specific variables were created in the realization that the week's transit use being reported after the fare increase might not be comparable across respondents. After the possible periods of response were divided into early, expected, and late, two dummy variables were set up.

Statistical Estimations

By examining the results of statistical estimations across the four service types (see Tables 1 and 2), a number of insights valuable for designing fare policies can be obtained. Besides the regularities observed within classes of variables, more general points of note emerged. These are as follows:

1. The degree of explanation of behaviors ranged clearly from the most homogeneous group (park and ride) to the most heterogeneous group (crosstown);
2. A sharp break exists between peak and off-peak periods in terms of degree of explanation, magnitude of coefficients, and statistical significance; and
3. Patrons in all categories altered their use of transit because of many different changed conditions (between May and October 1981), only one of which was SEMTA's fare increase.

It has also become evident that patrons can adjust to fare changes in many different ways. These include changes in frequency of transit travel, type of service used (proportions), type of payment, and location of boarding and alighting. A detailed discussion of the results of the statistical estimations has been presented by Damm-Luhr (16).

Fare and Service

With a few exceptions, only fare variables in the normal range (increases of 0 to 40 percent) had significant coefficients. Tests indicated, as one expects, that patrons in the crosstown and line-haul off-peak (LHOP) groups were more sensitive than patrons in the line-haul peak (LHP) and park and ride (P&R) groups. Because nearly 27 percent of all riders actually experienced either a fare decrease or a fare increase above expectation (40 or 30 percent in the case of the crosstown group), it becomes clear that inferences drawn on a single change-in-fare variable will be inaccurate or even wrong.

Prior Transit Use and Form of Payment

The split in behavior between peak and off-peak riders is clearly shown in this category. A higher proportion of off-peak travel seems to be explained by habit (i.e., as indicated by transit use before the fare increase for off-peak patrons). Especially if the LHP and LHOP groups are contrasted, there is a sharp difference between payment with cash and with a monthly pass. Evaluated with average values (i.e., coefficient from Table 1 times the average value for all riders in the category), LHP is 25 percent of LHOP for the cash users, whereas LHP is 50 percent larger than LHOP for card users. The contrast again becomes apparent in the variable for whether a person switched the form of paying fares (e.g., cash to monthly pass). This variable was much more important (relatively) for off-peak users than for peak users. Apparently, among those who change the form of payment, there is a tendency for off-

TABLE 1 Summary of Equations of Transit Use by Service Type

Variable[a]	P&R (N = 476) Value	P&R t-Statistic	LHP (N = 608) Value	LHP t-Statistic	LHOP (N = 284) Value	LHOP t-Statistic	Crosstown (all times) (N = 241) Value	Crosstown t-Statistic
Dependent (constant): no. of weekly transit trips	-2.14	-1.73	-0.26	-0.29	0.98	0.99	-5.03	-3.29
Independent								
Transit specific								
Fare decrease and time-space change	-	-	-4.24	-1.81	-	-	-	-
Fare decrease and no time-space change	2.72	1.76	-	-	-	-	-	-
Fare increase 0 to 40 percent and time-space change	-4.73	-1.44	-4.95	-2.98	-7.93	-2.47	-9.47	-3.00[b]
Fare increase 0 to 40 percent and no time-space change	-3.65	-1.39	-	-	-14.8	-4.41	-9.22	-2.40[b]
Decrease in level of service	-1.44	-1.94	-2.96	-4.50	-	-	-	-
Bus in Wayne Division	-	-	0.46	1.48	-	-	-	-
Bus in Macomb Division	-	-	-	-	-	-	3.29	2.91
Prior transit use and form of payment								
No. of prior trips	0.22	3.15	0.34	7.87	0.48	8.46	0.39	6.58
Cash paid after fare increase	-	-	1.61	3.49	2.05	2.66	4.01	4.77
SEMTA card used after fare increase	0.98	3.20	2.61	7.46	4.18	4.49	7.76	6.71
Change in form of payment	1.11	2.77	1.00	2.49	2.41	2.53	2.94	2.94
Change in riders' time-space constraints								
Shift of job	-1.85	-2.21	1.48	2.15	-	-	-	-
Employment status	-	-	-1.27	-2.01	-2.63	-2.71	-	-
Job location	-	-	-2.64	-3.13	-2.89	-1.85	-	-
Perceived location	-1.85	-3.61	-2.74	-5.58	-2.23	-2.41	-	-
Trip length	-	-	1.20	2.40	-	-	-	-
Transfer frequency	-	-	2.30	4.79	-	-	-	-
Driver's license status	-	-	3.11	2.09	-9.19	-3.11	-	-
Person specific								
Age	-0.03	-2.05	-	-	-	-	0.06	3.46
Sex	7.47	11.94	-	-	-	-	-	-
Employed (yes/no)	0.97	1.64	1.69[c]	3.41	-	-	-	-
Unemployed	-4.30	-2.40	-	-	-	-	-	-
Typical weekday	1.67	4.05	1.25	3.09	2.07	2.74	2.55	3.44
Likelihood of staying on panel	-	-	-1.83	-1.81	-	-	-	-
Survey specific								
Returned post-fare-change form more than 5 weeks after receipt	-0.71	-1.87	-	-	-	-	-	-
Prior-survey form received during peak	NA	NA	NA	NA	NA	NA	1.67	2.32

Note: NA = not applicable; P&R = park and ride; LHP = line-haul peak; LHOP = line-haul off peak.

[a] Except those for which strong a priori or theoretical arguments could be made, variables were included if they both met the statistical criterion (t-statistic of |1.64|) and could be interpreted reasonably; dashes indicate data did not meet statistical criterion.

[b] Fare increase of 0 to 30 percent.

[c] Defined as "employed or student."

peak patrons to make greater use of transit than those riding in the peak. With the realization that most trips in the peak cannot be postponed or cancelled, one can imagine that shifts in the form of payment would be more likely to stabilize one's current use of transit (e.g., discourage a switch to another mode for obligatory work trips). In the off peak, many trips are discretionary, so that switches to another form of payment could well encourage increased trip making.

Changes in Time-Space Constraints

Off-peak riders tend to be more vulnerable to occupational shifts (e.g., losing or switching jobs) than peak users and hence have a greater likelihood of using transit less if job-related changes occur. The results for the LHP and LHOP groups for the variable representing whether one's driver's license status changes contrast strongly. Because both positive and negative changes in status are reflected in this variable, it can be inferred that sufficient numbers of people in the LHOP group obtained licenses and that this change led to fewer transit trips.

Person-Specific Variables

In the person-specific variables the most noteworthy finding is that so few variables showed up as significantly different from zero in the LHOP and crosstown groups. This is perhaps an indicator of the degree of heterogeneity present among these users. Being the most work-oriented of the service

TABLE 2 Summary Statistics for Table 1

Statistic	P&R (N = 476) Value	P&R t-Statistic	LHP (N = 608) Value	LHP t-Statistic	LHOP (N = 284) Value	LHOP t-Statistic	Crosstown (all times) (N = 241) Value	Crosstown t-Statistic
Sigma	3.01	28.75	3.47	32.73	4.87	21.2	4.70	20.09
Log likelihood (LL) of full model [L * (U)]	-1,094.75	-	-1,538.31	-	-750.87	-	-647.93	-
LL of model with constant only [L * (R)]	-1,288.46	-	-1,700.09	-	-832.95	-	-709.18	-
LL ratio - 2[L * (R) - L * (U)]	387.42	-	323.56	-	164.16	-	102.50	-

types, it is not surprising that analyses of the park-and-ride group indicated significance of both employment variables. Further, both age and sex emerged as good explainers of variation in the park-and-ride group, unlike all other service types. In all cases, whether the day a questionnaire was received was typical was of great relevance, indicating that a good deal of observed use of transit may well be virtually unpredictable and certainly not controllable.

USING THE MODEL TO ANALYZE POLICIES

Determining Sensitivity to Fare Changes

Estimated coefficients may be thought of as numbers representing the relative contributions of the important variables. Because the values of each variable are known for each person on the panel, the coefficients can be used to compute the number of weekly transit trips each traveler is likely to make when the fare changes by a given amount or proportion. Because the equations were developed with data from a panel (that is, over a period before and after SEMTA's fare increase), a do-nothing situation is actually represented by an estimated equation without the fare-related variables. (This assumes that the marginal contributions of the remaining variables stay unaltered when fare levels do not change.) By multiplying the new value of each fare variable by its estimated coefficient and inserting the results in the equation for the number of weekly transit trips, a revised estimate of these trips can be obtained to be compared with the do-nothing case (i.e., without the fare-related variables).

Elasticities for each service type were computed by altering the relative change in transit fares by 1 percent. This number can be thought of as an index for the proportion of transit trips likely to be lost with each 1 percent increase in fares. The effects of a possible range of fare levels for each of the service types are also estimated. Development of the do-nothing cases and of forecasts for each service type proceeds from the level of the individual on the panel up to the entire SEMTA system. First the appropriately modified equation is used to compute the best estimates of the revised number of weekly transit trips for each person. Because the bus route is known on which each person received the survey of prior conditions, these best estimates can be grouped accordingly. Assuming that the estimates are representative of the trip making of everyone on a route, a factor for estimates up to the route level can be created. If the average number of trips per day by users in each service type is known, the number for average daily load (i.e., numbers of boardings) can be adapted to get the approximate number of persons using each route daily. Once the number of users per route is known, it is simple to multiply the estimated number of weekly transit trips by the ratio of users per route to users in the panel. Summing over all routes produces the number of weekly trips for the service type given a particular policy. Comparing the aggregated result with that for the do-nothing case provides the forecasted effect of a policy (i.e., expected change in both number of weekly trips and revenues).

A caution, however, needs to be made. The estimation procedure did not include an explicit weighting scheme to control for the higher probability that higher-frequency riders would appear in the sample than lower-frequency riders. Instead, it was assumed that by having the number of transit trips taken before the fare increase as an explanatory variable, bias was sufficiently minimized to produce acceptable results. It is possible that there could be as yet undeveloped procedures that account for the bias that may still exist. If this were true, using the current models to evaluate policies may produce different outcomes than that with an improved procedure. Nevertheless, it is suspected that even if the numerical results were different, the relative results across service types would still be quite similar. In this context, attention should not be overly focused on the absolute values of the results from various tests of policies.

Effects of Policies on Ridership and Revenues

Tables 3 and 4 contain the primary results of tests of various policies. Using the do-nothing figures in the second column, successive variations in relative fares are compared. The third column shows the elasticities or the percentage of change in weekly transit trips with a 1 percent change in fares. In marked contrast to conventional thinking about systemwide effects in the transit industry, these percentages of change vary noticeably across service types. (Recall the Simpson-Curtin rule of -0.33.) Although the peak-oriented types (P&R and LHP) are close (-0.38 and -0.41) and not too different from aggregate values for elasticities computed elsewhere, their values are quite separate from those of the off-peak-oriented types. In all service types, the elasticities are negative and less than 1, which indicates an increase in revenues in spite of a loss in number of boardings per week. That is, an increase in fare will be met by a less-than-proportional decrease in use of transit, although the specific proportion depends on the type of service. Examination of Table 4 confirms this expectation. The lower the elasticity of trip making, the higher the proportional increase in revenues. For example, P&R has the lowest elasticity of trip making (-0.38) but the highest proportional increase (+0.64) in revenues after a 1 percent fare hike. Assuming that riders who began using SEMTA service after the fare increase are not systematically different from current riders, the elasticities and policy tests should not be affected by the way the panel was drawn.

The other policies should be viewed in the context of SEMTA's zonal structure. This means that the values of the relative change in fares vary from person to person depending on the number of zones crossed. When the base fare is increased, everyone's fare changes (although at different rates). When the zonal charge is altered, only those riders crossing three or more zones experience a change. Increasing the base fare is a common practice for most agencies implementing a fare increase. However, a growing number have considered or are considering selective increases (or decreases) geared to maximizing total fare-based revenues. For example, increasing the base fare only for peak riders probably makes sense when those patrons seem to be likely to reduce fewer trips than off-peak patrons. In the case of SEMTA, a 25-cent base increase for peak service only results in a lower level of loss than a 15-cent base increase across the board. Moreover, expected revenues from the 25-cent peak-only increase would be about 2 percent more (relative to the do-nothing case). Tinkering with changes in the zonal charges could be associated with the costs that an agency incurs for an average revenue mile and its desire to peg the price of service to the distances over which patrons travel. Increasing the zonal charge 25 cents, for example, clearly makes longer-distance trips more expensive and will tend to reduce transit travel for such distances. A variety of incentives to particu-

TABLE 3 Summary of Ridership Forecasts Using SEMTA Fare Change Model Across Service Types

No. of Weekly Transit Trips by Policy

Service Type	Do Nothing	1 Percent Fare Increase		Increase Base 10 ¢		Increase Base 15 ¢		Increase Base 25 ¢, Peak Only		Increase Zonal Charge 25 ¢		Decrease Zonal Charge 5 ¢		Decrease Youth Fare One-Half		Half Fare, Off Peak Only		Flat 50 ¢ Fare, Off Peak Only	
		Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)
P&R	26,993	26,893	-0.38	26,154	-3.1	25,680	-4.9	24,931	-7.6	25,064	-2.4	27,383	+1.5	26,993	0	26,993	-	26,993	-
LHP	82,237	81,902	-0.41	79,541	-3.3	76,199	-7.3	72,719	-11.6	74,346	-9.6	84,248	+2.4	82,280	0	82,237	-	82,237	-
LHOP	44,546	44,247	-0.67	39,836	-10.6	38,447	-13.7	44,546	-	40,473	-9.1	45,499	+2.1	45,670	+2.5	60,044	+34.8	50,674	+13.8
Crosstown (peak and off peak)	15,539	15,457	-0.53	14,103	-9.2	13,754	-11.5	14,607	-6.0	15,289	-1.6	15,604	+0.4	16,428	+5.7	18,518	+19.2	15,891	+2.3
Systemwide	169,315	168,499	-0.48	159,634	-5.7	154,080	-9.0	156,803	-7.3	155,173	-8.4	172,735	+2.0	171,372	+1.2	187,783	+10.9	175,838	+3.8

Note: P&R = park and ride; LHP = line-haul peak; LHOP = line-haul off peak.

TABLE 4 Summary of Revenue Forecasts Using SEMTA Fare Change Model Across Service Types

No. of Weekly Transit Trips by Policy

Service Type	Do Nothing	1 Percent Fare Increase		Increase Base 10 ¢		Increase Base 15 ¢		Increase Base 25 ¢, Peak Only		Increase Zonal Charge 25 ¢		Decrease Zonal Charge 5 ¢		Decrease Youth Fare One-Half		Half Fare, Off Peak Only		Flat 50 ¢ Fare, Off Peak Only	
		Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)	Value	Change (%)
P&R	35,510	35,738	+0.64	37,123	+4.5	37,770	+6.4	39,249	+10.5	38,992	+9.8	34,681	-2.3	35,510	0	35,510	-	35,510	-
LHP	70,539	70,949	+0.58	76,711	+8.7	76,939	+9.1	80,484	+14.1	75,925	+7.6	69,125	-2.0	70,539	0	70,539	-	70,539	-
LHOP	31,593	31,698	+0.33	32,675	+3.4	33,140	+4.9	31,593	-	32,415	+2.9	31,232	-1.1	31,084	-1.6	21,243	-32.8	25,291	-19.9
Crosstown (peak and off peak)	9,502	9,545	+0.45	10,090	+6.2	10,484	+10.3	9,961	+4.8	9,755	+2.7	9,435	-0.70	9,513	+0.11	7,292	-23.3	8,680	-8.7
Systemwide	147,144	147,930	+0.53	156,599	+6.4	158,333	+7.6	161,287	+9.6	157,087	+6.8	144,474	-1.8	146,646	-0.3	134,584	-8.5	140,020	-4.8

Note: P&R = park and ride; LHP = line-haul peak; LHOP = line-haul off peak.

lar groups of riders could be instituted. Several are presented in Tables 3 and 4 to illustrate their likely effects. Because off-peak patrons tend to be more sensitive to changes in fares, such changes hold promise as means to encourage increased use of transit, although not necessarily to increase revenues.

Implications for Developing Pricing Policies

Although the empirical work conducted in this study represents a case study of a single increase in fares for a single agency (SEMTA), a number of insights emerge that have interest for service planners generally. First, treating all trips made in a system as identical results in potentially serious mispredictions of the effects of any given fare policy. Stated in more positive terms, differentiating types of service enables much more carefully designed fare policies to be developed. Second, and following from the first point, fares could in many instances be set more closely to full cost-recovery levels. If a single change is applied uniformly across a system, a planner runs the risk of underpricing some services and overpricing others. This means that the agency will both lose more revenues than necessary and not gain enough revenues on various routes and service types. Third, if one accepts the premise that service types can and ought to be distinguished in terms of pricing policies, it should be obvious that a mix of policies over a system may well serve an agency's objectives (e.g., higher proportion of revenues from the farebox) better than a single change applied to the entire system uniformly. Fourth, just as the influence of fares (or in this case, the relative change in fares over time) varies across types of service, so too are there different sets of variables that explain transit use in each service category. When a more differentiated fare policy is developed for a transit agency, these variations should be taken into account.

ACKNOWLEDGMENT

The study described here was conducted at the U.S. Department of Transportation's Transportation Systems Center (TSC) with funding provided by UMTA's Technical Assistance Program through its Office of Service and Management Demonstrations. The work reported here could not have been conducted without the cooperative and collegial support from John Sajovec, Director of Marketing and Planning, and his staff (particularly James Maslanka and Rai Parvataneni) at SEMTA. In addition, colleagues at TSC were very helpful. Thanks go to Paul Zebe, Lawrence Doxsey, Carla Heaton, Jesse Jacobson, and Bruce Spear. Michael Kemp of the Urban Institute also provided valuable comments.

REFERENCES

1. Soaring Transit Subsidies Must Be Controlled. Report CED-81-28 to the U.S. Congress. General Accounting Office, Washington, D.C., 1981.
2. D.C. Hackney. Fares Headed in One Direction: Up. Mass Transit, Vol. 8, March 1981, pp. 12-16.
3. M. Wachs. Pricing Policies and Alternative Fare Structures. Presented at Annual Meeting of the American Public Transit Association, 1982.
4. C. Heaton and H. Slavin. Future Directions for Transit Pricing: Proceedings of the September 1980 Conference on Transit Pricing Innovations. Transportation Systems Center, U.S. Department of Transportation, Cambridge, Mass., 1981.
5. D. Damm. Recommendations for Further Study of the Impacts of Pricing and Service Variations. Staff Study-243-U.3-214. Transportation Systems Center, U.S. Department of Transportation, Cambridge, Mass., 1982.
6. J.F. Curtin. Effect of Fares on Transit Riding. In Highway Research Record 213, HRB, National Research Council, Washington, D.C., 1968, pp. 8-20.
7. D. Young. Fares/Riders: Ups/Downs. Mass Transit, Vol. 10, June 1983, pp. 14 ff.
8. M.A. Kemp. Some Evidence of Transit Demand Elasticities. Transportation, Vol. 2, 1973, pp. 25-52.
9. M.A. Kemp. Planning for Fare Changes: A Guide to Developing, Interpreting and Using Fare Elasticity Information for Transit Planners. Report 1428-05. Urban Institute, Washington, D.C., 1981.
10. Ecosometrics, Inc. Patronage Impacts of Changes in Transit Fares and Services. UMTA, U.S. Department of Transportation, 1980.
11. R. Kirby, K. Bhatt, and M. Kemp. Washington's Metro: Issues and Options (especially Appendix B: Transit Fare Policies: Principles and Practice). Greater Washington Research Center, Washington, D.C., 1982.
12. B. Arrillaga. A Review of Experience of Alternative Pricing Policies and Fare Structures. Presented at Annual Meeting of the American Public Transit Association, 1982.
13. M.A. Kemp. Policies to Increase Transit Ridership: A Review of Experience and Research. Working Paper 5032-1-3. Urban Institute, Washington, D.C., 1977.
14. J. Hausman and D.A. Wise. Attrition Bias in Experimental and Panel Data: The Gary Income Maintenance Experiment. Econometrica, Vol. 47, No. 2, 1979, pp. 455-473.
15. W.G. Cochran. Sampling Techniques. Wiley, New York, 1977.
16. D. Damm-Luhr. Exploration of Methods to Improve Analysis of Transit Fare Policies Using the Case of the Southeastern Michigan Transportation Authority (SEMTA). Technical Paper. Transportation Systems Center, U.S. Department of Transportation, Cambridge, Mass., 1983.
17. J. Tobin. Estimation for Relationships for Limited Dependent Variables. Econometrica, Vol. 26, 1958, pp. 24-36.
18. D. Damm. Interdependencies in Activity Behavior. In Transportation Research Record 750, TRB, National Research Council, Washington, D.C., 1980, pp. 33-40.
19. D. Damm. Parameters of Activity Behavior for Use in Travel Analysis. Transportation Research, Vol. 16A, No. 2, 1982, pp. 135-148.

The Costs of Transit Fare Prepayment Plans and Their Distribution Systems

PATRICK D. MAYWORM and ARMANDO M. LAGO

ABSTRACT

A cost structure is outlined for the analysis of transit fare prepayment plans and estimates of the costs of prepayment in 11 transit companies. Twelve cost categories are analyzed: order preparation, order delivery, direct sales, recording and accounting, design, printing, inventory, advertising, miscellaneous handling, administration, general overhead, and cost of funds. In addition, the costs of alternative methods of distribution (e.g., transit-operated outlets, public and employer outlets, direct mail, and telephone order) are compared. Costs of prepayment by type of plan (passes, tickets, punch cards, and tokens) are analyzed and recommendations are developed for cost-saving strategies.

The last few years have witnessed an increased interest in transit fare prepayment. Spurred by the Huron River Group, Inc., report (1) on fare prepayment, UMTA's Office of Service and Management Demonstrations has conducted demonstrations on aspects of pricing (2-6), traveler responses (7,8), and distribution methods (6,9,10). However, the knowledge about the factors that explain the cost performance of prepayment plans is scant. The basis of this paper is the costing concepts developed by Ecosometrics, Inc. (10) in the design of the Sacramento demonstration on distribution systems for fare prepayment, and the results of research on the costs of transit fare prepayment plans in 11 transit companies are summarized (11). The transit companies included Southern California Rapid Transit District (SCRTD), Los Angeles; Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia; Metropolitan Transit Commission (MTC), St. Paul; Municipality of Metropolitan Seattle (METRO); Queen City Metro, Cincinnati; Tri-County Metropolitan District of Oregon (Tri-Met), Portland; SunTran, Tucson; Dart, Delaware; Tidewater Regional Transit, Norfolk; Greater Richmond Transit Company; and Sacramento Regional Transit District. Analyzed as part of the study were 40 different plans including 20 pass plans (of which 9 were monthly passes, 2 were weekly passes, and the rest included diverse programs such as tourist passes, day passes, and annual passes), 11 ticket plans (of which 5 were 10-trip ticket books and 2 were 20-trip ticket books), 2 punch-card plans, and 3 token plans. The distribution methods analyzed consisted of transit-operated outlets, private and public outlets, employer outlets, direct mail, telephone order, and on-board sales programs. In addition, the fare prepayment plans featured several different methods of order delivery to outlets, such as delivery by transit staff, courier service, or postal service. This rich data base enabled the authors to develop parametric approaches to the costing of fare prepayment plans.

OVERALL STRUCTURE OF THE PARAMETRIC APPROACH

The costing methodology employed consisted of a series of building blocks that related resource requirements (i.e., productivity parameters) and basic resource costs, such as wages and postage (resource parameters), to cost-driving variables (program parameters), such as the number of outlets, number of prepayment instruments sold, and so on.

The cost-estimating relationships were expressed in parametric fashion to gain flexibility in their use. The parametric representations of productivity relationships were standardized across many settings and systems to permit generalizations to other transit settings, thereby incorporating some of the features of standardized costing. Although the costing methodology traced the cost of incremental activities associated with prepayment plans, it nevertheless included the costs of inherited resources within the prepayment program, resources that were valued at replacement costs. In the discussion that follows, a fare prepayment instrument refers to the individual item purchased (e.g., 30 instruments may refer to 30 monthly passes, to 30 weekly passes, or to 30 ten-trip ticket books). A fare prepayment transaction refers to the actual sales activity and is usually equal to the number of instruments sold. An exception is the monthly pass with zone stamps, which corresponds to two instruments but only one sales transaction.

COST CATEGORIES

Both capital (one-time) expenses and recurrent operating costs were considered. Capital costs included vehicles, equipment (e.g., pass counters, token wrappers, photographic equipment, telephones, and ticket or pass shredders), and promotional advertising campaigns. The recurrent or operating costs included labor (wages and fringe benefits), materials (envelopes, postage, business forms, etc.), space or rent, and miscellaneous services, such as commissions to outlets, courier service, design and printing, and normal advertising activities. All capital costs were amortized using capital recovery factors at 12 percent interest rates.

FUNCTIONAL ACTIVITIES AND COST CATEGORIES

The operation of a fare prepayment program may involve as many as 21 separate activities, which were grouped into the 12 major cost categories presented in Table 1. These cost categories range from order preparation and delivery to sales outlets, recording and accounting, and other miscellaneous functional activities. From an analytical viewpoint these categories can be grouped into the two basic categories presented in Table 1. Transaction-oriented costs were those affected by the size and frequency of fare prepayment sales and deliveries. A second set of cost categories had been grouped into non-transaction-oriented costs because they were not directly

TABLE 1 Key Variables Affecting Prepayment Costs by Functional Activity and Sales Distribution Method

		Sales Distribution Method				
Cost Category	Cost Element	Transit-Operated Sales Outlet	Public and Private Sales Outlet	Direct Mail Program	Telephone Order Program	On-Board Pass Sale
Transaction oriented						
Order preparation						
Sales outlet	Labor, equipment	Per outlet served	Per outlet served	-	-	-
On-board sale	Labor	-	-	-	-	Per day issued
Order delivery						
Staff	Labor, vehicles	Per outlet served	Per outlet served	-	-	-
Courier	Courier service	Per outlet package	Per outlet package	-	-	-
Certified mail	Postal service	Per outlet package	Per outlet package	-	-	-
Direct sales						
Transit-operated outlet	Labor	Per transaction	-	-	-	-
Public and private outlet	Commissions	-	Per revenue dollar	-	-	-
Direct mail program	Labor, materials	-	-	Per transaction	-	-
Telephone order program	Labor, materials	-	-	-	Per transaction	-
Recording and accounting						
Recording sales	Labor	Per transaction	-	Per transaction	Per transaction	-
Accounting sales	Labor	Per transaction	Per transaction	Per transaction	Per transaction	-
Accounting on-board sales	Labor	-	-	-	-	Per day issued
Non-transaction-oriented						
Design	Design service	Per design change	Per design change	Per design change	Per design change	-
Printing	Printing service	Per unit of volume printed	Per unit of volume printed	Per unit of volume printed	Per unit of volume printed	Per unit of volume printed
Inventory	Storage	Per unit of volume stored	Per unit of volume stored	Per unit of volume stored	Per unit of volume stored	Per unit of volume stored
Miscellaneous handling	Labor, equipment	Per instrument handled	Per instrument handled	Per instrument handled	Per instrument handled	Per instrument handled
Advertising	Labor, media	Per instrument advertised	Per instrument advertised	Per instrument advertised	Per instrument advertised	Per instrument advertised
Administration	Labor	Per program size category	Per program size category	Per program size category	Per program size category	Per program size category
General overhead						
Transit-operated outlets	Labor	Per dollar of labor	-	-	-	-
Headquarters	Labor	Per dollar of labor	Per dollar of labor	Per dollar of labor	Per dollar of labor	Per dollar of labor
Cost of funds	Interest	-	Per day of delay	-	-	-

related to the transaction per se, although in a loose sense they may have been correlated with total sales volume (e.g., advertising). This segmentation of the 12 major cost categories into the two cost groups provided the basis for the structure of the cost model.

In Table 1 each cost category is disaggregated into detailed components all the way down to the cost elements. Also presented in Table 1 are the key variables that dominated the cost behavior within each function. Table 1 summarizes the analytical framework of the cost methodology and its building-block structure.

As shown in Table 1, order preparation and order delivery costs were driven primarily by the number of sales outlets served. Direct mail and telephone order programs did not require bulk order preparations or deliveries because each order taken by mail or telephone was processed individually. Direct sales costs at transit-operated outlets and at headquarters for direct mail and telephone order programs were a function of the number of sales transactions. The only sales costs recognized for public and private sales outlets (including employer programs) were the expenses incurred in sales commissions. This does not imply that there were no other costs involved in these activities but simply that these costs were not borne by the transit company. Similarly, there were no costs for recording individual sales transactions at public and private outlets because this function was performed at the outlets at no extra cost to the transit company.

Finally, the costs of some functional activities (e.g., design, printing, and inventory) were incurred irrespective of the sales distribution method used. Overhead costs were computed separately for transit-operated outlets because the rent and supplies for this space were usually independent of the transit company's headquarters offices.

DESCRIPTION OF COST CATEGORIES

Order Preparation Costs

Order preparation consisted of preparing a new supply of fare prepayment instruments for distribution to sales outlets and on-board sales. In the case of sales outlets (transit operated, public, and employer) these costs included the labor and equipment costs involved in assembling and packaging the appropriate number of instruments for each outlet and preparing invoices for the outlets.

The labor requirements of order preparation for sales outlets varied from a high of 1.20 to 1.40 man-hr per outlet preparation in Los Angeles and Seattle to 0.11 man-hr per outlet preparation in Philadelphia. These labor requirements appeared to be more dependent on internal procedures followed than on the size of orders. Some transit companies required that the contents of each order be carefully recorded (e.g., noting serial numbers) before distribution to outlets. Typical labor requirements for this function were 0.25 man-hr per outlet preparation when normal procedures were followed. Equipment requirements consisted of token wrappers, three of which were used by Cincinnati's Queen City Metro, and a pass counter, used in Sacramento.

The order preparation costs of on-board sales covered the labor requirements of preparing passes for driver pickup. These labor requirements varied between 15 min per day of pass sales in Sacramento to 30 min per day for weekend passes in St. Paul and Tucson. Some economies of scale appeared to be present as shown by the longer preparation time per day for weekend day passes than for the daily pass program.

Order Delivery Costs

Delivery of fare prepayment instruments to outlets, whether transit operated, public, or employer, was performed by one of three modes: transit staff, courier, or certified mail. Half of the transit companies interviewed used transit staff delivery, if not for all outlets, at least for those outlets with the greatest sales volume. Staff delivery times per outlet were found to decrease by city size and distance between outlets. In Seattle the 25 outlets served by staff were located downtown, thereby requiring only 10 min of delivery time per outlet delivery. In Portland the staff delivered plans to all 109 outlets, some located 18 miles from downtown Portland, thus requiring 60 min per outlet delivery. Half of the transit agencies used vans for staff delivery and the other half used large or intermediate-sized automobiles. Philadelphia's SEPTA used an armored truck for staff deliveries.

An alternative to the high costs of order delivery by transit staff was courier service. SEPTA was the only transit system interviewed that used a courier service. In that case 75 packages were delivered each week to outlets at a cost of $5.00 per package delivery. However, because of the limited insurance coverage of local messenger service, additional insurance coverage was secured by the transit company.

The U.S. Postal Service was used by 4 of the 11 transit companies interviewed to service low-volume outlets. However, certified mail was inadequate to serve the distribution of ticket books and tokens, which were too heavy to be sent economically by this method. Another problem of using the mail was its inadequate insurance coverage. Because the maximum liability of insured mail was only $400, only 20 monthly passes valued $20 apiece could have been sent per mail package. Guidelines will be presented later for choosing between these alternative delivery methods.

Direct Sales Costs

The direct sales costs included labor, materials, commissions, and equipment costs of selling prepayment instruments at outlets and by direct mail and telephone order. Of the 11 transit companies analyzed, 8 operated their own outlets. The labor requirements for effecting a prepayment transaction at transit outlets varied between 1.5 and 2.5 min per transaction; the time per transaction was inversely related to the number of sales transactions. At outlets where many photographs are taken for the prepayment instruments, the labor requirements exceed 4 min per transaction. Equipment requirements and costs included photographic equipment, validation stamps, and so forth.

All the transit companies analyzed used public and employer sales outlets. These included banks, savings and loan institutions, department stores, hospitals, schools, and employers. A significant number of the outlets charged a commission on sales. These commissions could be based either on a percentage of prepayment sales or on a fixed rate per instrument sold. Commission rates ranged from none to 3 percent (Los Angeles). In general, the larger companies appeared to incur greater commission rates than the smaller ones.

Direct mail sales of prepayment plans were conducted by five of the transit companies analyzed. The direct mail costs included labor requirements and materials, such as order forms, envelopes, and postage. Material costs alone were approximately $0.50 per direct mail transaction. On the basis of the records of the companies analyzed, no relationship was discernible between the sales time per transaction (which varied from 1 to 6 min) and the number of transactions. The reason for this was that other factors unique to each company, such as reporting requirements, credit card verification, and bad check follow-ups affected the transaction times.

Telephone sales were similar to direct mail order in that the transactions took place at the transit company headquarters. However, telephone orders were placed by charges to the customer's major credit card. Only one site, Wilmington, operated a telephone order service, and their records indicated that their labor requirements (3 min per transaction) were not significantly different from those of a direct mail program. Equipment and material costs included telephone installation and monthly service charges ($30 to $50 per month), bank credit card service charges (4 to 6 percent of sales), window envelopes (at $0.03 each), and first-class postage.

Recording and Accounting Costs

A recurrent task in prepayment transactions was recording all sales and accounting for all revenue income. These two tasks were usually performed by different personnel at different times. Recording fare prepayment sales was a function that applied only to transit outlets and headquarters. Sales were recorded by a fare agent at the time the sale was transacted. No recording costs were incurred by the transit company at public and employer outlets. The labor requirements for recording sales depended on the procedures used and the volume of transactions. These labor requirements ranged from 0.25 min per transaction in the large outlets and headquarters to 3 to 4 min at the smaller transit-operated outlets.

Accounting costs were incurred in all the prepayment sales methods. Accounting operations included several activities, primarily posting the accounts receivable by the transit company accountants or making a book entry on the consignment accounts on a periodic basis as the sales outlets were serviced. Economies of scale were present in this function. The labor requirements per transaction varied from 0.08 min in the larger companies (SCRTD, SEPTA, and MTC) to 0.35 to 0.45 min per transaction in Norfolk and Tucson.

Accounting for on-board sales transactions also exhibited economies of scale. The accounting labor requirements varied from 1.0 to 3.5 hr per day, depending on the number of transactions.

Design Costs

Designing prepayment plans included choosing the dimensions of the instrument, the type of paper stock, and the artwork on both sides of the instrument. Tickets, tokens, and punch cards incorporated simple standardized designs with inconsequential costs. Passes were different altogether in that more attention was placed on the design and artwork to make the pass attractive, functional, and counterfeit free. The design costs of pass plans ranged from as low as $57 per design for punch cards in Tucson to $3,500 per design for passes in Philadelphia. Designs were changed every 6 months in some instances (Norfolk and Portland) and every 2 to 3 years in other cases (Tucson and Philadelphia). In general, these costs were minor, amounting to at the most $5 (in 1981 dollars) per 1,000 instruments printed.

Printing Costs

Except for SunTran in Tucson, all the other transit companies analyzed used outside professional printing companies for printing the prepayment instruments. As a general rule, printing costs were affected by four factors: the type of prepayment plan, the quality of materials and printing, the volume printed annually, and the printing frequency. There were economies of scale in printing; the unit cost of printing materials diminished until order sizes of between 100,000 and 200,000 instruments were reached and remained constant after this level had been reached. Costs per 1,000 instruments printed (in 1981 dollars) for orders of 150,000 and more were $25 for passes, $20 for ticket books, $7 for punch cards, and $75 for brass tokens of 0.984-in. diameter.

Inventory Costs

Inventory costs included the storage of prepayment instruments. Two factors affected the space requirements for fare prepayment storage: the type of prepayment plan and the size of each printing order. Thus, there was a cost trade-off between printing frequency and inventory space. Normal space requirements were 220 instruments per cubic foot for conventional plans. The storage costs were estimated as $0.06 (in 1981 dollars) per cubic foot per month.

Miscellaneous Handling Costs

Three of the 11 transit companies analyzed performed special functions on the operation of their ticket and pass programs. Norfolk, for example, counted all new passes arriving from the printer and destroyed unsold passes during the month that the passes were still valid. Wilmington and Portland both separated tickets from the farebox, weighed them, and destroyed the tickets with a shredding machine.

Advertising

Few of the transit companies interviewed operated on-going advertising programs. Three companies (SCRTD, SunTran, and METRO in Seattle) incurred monthly advertising and publicity costs. In addition to these companies, three others (Tri-Met, Sacramento Regional Transit District, and SEPTA) incurred one-time promotional campaigns to introduce new prepayment programs or to advertise new sales outlets. In amortizing the effect of advertising expenses, it was assumed that recurrent advertising expenditures would have a short-term effect on sales fully depreciable during 1 year. The one-time introductory promotional campaigns were assumed to have a sales effect within an 18-month period. These assumptions corresponded to the amortization rates of advertising for nondurable and durable goods (12). The costs of one-time introductory campaigns were estimated at $0.03 to $0.05 (1981 dollars) per instrument sold. The recurring expenditures were estimated to vary between $0.12 per instrument sold for the Los Angeles monthly pass to the much larger $0.65 to $0.80 per instrument sold in Tucson and for the Los Angeles tourist pass.

Administrative Costs

Administration of the prepayment programs included operations such as staff supervision and administration of transit-operated outlets. In addition, there were the expenses of support and maintenance of the existing public and employer outlets and the marketing efforts in outlet expansion. The administrative costs depended on the extent of effort committed to outlet promotion and expansion. In Philadelphia, where no significant outlet expansion programs were in effect, 52 man-hr per month were spent in supervisory activities. In St. Paul and Seattle, which had significant outlet promotion efforts, 100 to 173 man-hr were spent by supervisory personnel per month.

General Overhead Costs

The program overhead costs included general supplies, telephone, utilities, maintenance, and rent. These expenses were estimated as percentage of direct labor costs. The general overhead costs of the transit companies were estimated as a percentage of direct labor costs from the Section 15 Reporting System (13) and applied to all the direct labor costs incurred in the transit fare prepayment program.

SUMMARY RESULTS OF THE COST ANALYSIS

The costs incurred at each of the 11 case sites were analyzed in detail in order to develop the parametric cost equations that appeared in the technical report (11). A summary of the results of this analysis is presented here.

Fare Prepayment Plan Costs by Transit Company

The 11 transit companies reviewed offered a variety of fare prepayment plans to their riders. Nearly all of them offered at least one pass plan (usually a monthly pass) and an unlimited-duration ticket or token plan. The number of plans offered varied between one and four.

The principal plans offered by the 11 transit companies are presented in Table 2 along with their unit costs. Monthly passes in Los Angeles cost $0.95 each, whereas in Norfolk they were only two-thirds that price. However, because Los Angeles pass holders used their pass more than 70 times each month, the cost per monthly pass trip in Los Angeles was only slightly higher than the cost per trip in Norfolk. Of the 11 transit companies, only those in Norfolk and Portland offered comparable programs, and their costs were remarkably similar. Both transit companies sold monthly passes and 10-trip ticket books. Costs per instrument were slightly higher in Norfolk than in Portland because of the difference in the size of the two programs. More than eight times as many plans were sold in Portland than in Norfolk, which reduced its unit costs by about 25 percent.

The unit cost per fare prepayment transaction has been disaggregated into its cost categories and is presented in Table 3 in order to provide an opportunity to compare costs across sites. As shown in Table 3, among the transaction-oriented costs, those for order preparation were fairly consistent across sites. Cincinnati was the most costly site in this category because of the cost of wrapping tokens. Norfolk had unusually high order delivery costs because all outlets were serviced by staff and relatively few passes were sold, thereby bringing the average cost up. Direct sales costs were extremely high for the four largest transit systems because of commissions paid to sales outlets. In Richmond and Tucson neither sales outlets were operated nor commissions were paid to public outlets. Accounting costs were relatively low for most programs except for Cincinnati's, and design costs were insignificant.

TABLE 2 Prepayment Costs in Selected Transit Companies

Location and Instrument	Cost ($1981) Per Instrument	Per Trip
Los Angeles		
Monthly pass	0.95	0.016
Tourist pass	1.82	0.171
Individual ticket (10)[a]	0.38	0.038
Ticket book (10-trip)	0.56	0.056
Philadelphia		
Monthly pass	1.02	0.018
Weekly pass	0.77	0.055
Token (10)[a]	0.54	0.054
St. Paul		
Monthly pass	0.96	0.020
Ticket book (10-trip)	1.45	0.145
Punch card (10-trip)	0.92	0.092
Token (20)[a]	1.44	0.072
Seattle		
Annual pass	8.91	0.018
Monthly pass	0.90	0.021
Ticket book (20-trip)	0.96	0.048
Ticket book (40-trip)	0.96	0.024
Cincinnati		
Token (20)[a]	0.48	0.024
Portland		
Monthly pass	0.45	0.009
Ticket book (10-trip)	0.41	0.041
Norfolk		
Monthly pass	0.61	0.013
Ticket book (10-trip)	0.49	0.049
Sacramento		
Monthly pass	0.58	0.012
Token (20)[a]	0.57	0.028
ID card	2.71	N.A.
Richmond		
Weekly pass	0.15	0.014
Ticket book (10-trip)	0.13	0.013
Ticket book (20-trip)	0.13	0.007
Ticket book (45-trip)	0.13	0.003
Wilmington		
Monthly pass	0.42	0.009
Strip ticket (10-trip)	0.11	0.011
Tucson		
Semester pass	2.96	0.019
Monthly pass	0.34	0.008
Punch card (20-trip)	2.96	0.148

[a]Assumed sold in quantities indicated.

Focusing on the non-transaction-oriented costs, printing costs were high in Philadelphia, Seattle, Cincinnati, and Norfolk. In Seattle and Norfolk relatively small volumes were printed of some of the plans; in Cincinnati costs were exclusively minting costs for tokens. A special printing process was used in Philadelphia to reduce the opportunities for counterfeiting, which explained its high printing costs. Inventory and miscellaneous handling costs were minor for most systems. Advertising costs were insignificant for most programs, although they were significant in some systems. More than $0.10 was spent on each fare prepayment instrument sold at the three sites with advertising programs. Administrative and overhead expenses were high for the large fare prepayment programs and the two demonstration sites.

As a percentage of cost, direct sales costs clearly increased with the size of the program. Once again this reflects the fact that managers in small programs could usually persuade banks and department stores to sell fare prepayment plans without charging a commission. At large volumes, however, most public outlets required a commission on sales or another form of payment.

Order delivery, accounting, printing, inventory, and overhead costs generally increased as a percentage of total costs as the size of the program decreased. Thus, although direct sale was the dominant cost factor in large programs, accounting, overhead, printing, and delivery incurred the most costs in small fare prepayment programs. Understanding the differences in the cost elements is critical when planning a fare prepayment program.

Generally, large fare prepayment programs incurred a higher unit cost than small programs as shown by the data presented in Table 3. Transit companies with large fare prepayment programs spent proportionally more money in two aspects of the program than companies with small programs. These included

1. Sales commissions to public outlets (small transit companies could usually secure a network of public outlets without having to pay commissions) and
2. Advertising (small transit companies with set programs usually did not advertise).

As shown in Table 3, the largest fare prepayment programs spent $0.86 (in 1981 dollars) for each instrument they sold. Average-sized programs spent $0.44 per instrument and small programs spent only $0.14. In both Sacramento and Tucson high costs were incurred, in part because of the demonstration activities at these sites.

Costs by Type of Prepayment Plan

The prepayment plan cost estimates for the 11 transit companies are summarized in Table 4 according to the major types of instrument. In this section a comparison of the unit costs of the fare prepayment plans in all 11 transit companies are presented. For a true cost comparison, however, the standardized costs of operating selected fare prepayment plans are also presented. As shown in Table 4, the cost per trip was generally higher for the short-term instruments (such as 10-trip ticket books and weekly passes) than for prepayment instruments of longer-term duration. The cost of issuing a weekly pass was only two-thirds the cost of issuing a monthly pass because the normally higher volume of weekly passes sold each month resulted in some economies of scale. A weekly pass program, however, was twice as expensive as a monthly pass program on a per-trip basis. This was generally because of the higher printing and delivery costs.

However, because the prepayment programs at the 11 sites were not identical, too much should not be read into the comparisons presented in Table 4. Instead, the costs of a typical program have been estimated by standardizing some of the resource costs and program parameters. Thus, the standard costs presented in Table 5 assumed 1981 wage rates of $8.25 per hour for order preparation, delivery, and outlet personnel; $9.50 per hour for accounting personnel; and $11.00 per hour for supervisory personnel. Fringe-benefit rates of 36.2 percent and headquarters overhead rates of 39.5 percent were assumed. Prepayment instruments were assumed to be sold at headquarters, at two transit-operated outlets, and at 150 outlets, of which two-thirds charged 2 percent commissions on sales. Staff delivery times were assumed to be 30 min per outlet delivery. No promotional expenses were included among the costs. The resulting costs by type of plan are presented in Table 5.

As shown in Table 5, weekly passes and 10-trip ticket books were the most costly of the six plans to implement because they were consumed and replaced so rapidly. Tokens were slightly more expensive than tickets of the same quantity. Monthly passes and 40-trip ticket books, the two plans with the longest duration, were the least expensive. Thus, when decisions are made on the selection of an appropriate

TABLE 3 Unit Transaction Costs by Cost Category, 1981

	Cost Category[a] ($1981)											
Site	Order Preparation	Order Delivery	Direct Sales	Recording and Accounting	Design	Printing	Inventory	Miscellaneous Handling	Advertising	Administrative	Overhead	Total Cost
Los Angeles	0.017	0.010	0.601	0.033	0	0.040	0.002	0	0.116	0.025	0.049	0.893
Philadelphia	0.002	0.015	0.432	0.054	0.001	0.153	0	0	0	0.005	0.082	0.744
St. Paul	0.026	0.020	0.839	0.026	0.001	0.045	0.001	0	0	0.034	0.026	1.018
Seattle	0.059	0.008	0.388	0.027	0	0.117	0.001	0	0.260	0.029	0.036	0.925
Cincinnati	0.075	0.044	0.004	0.131	0	0.110	0.002	0	0	0.023	0.091	0.480
Portland	0.016	0.038	0.174	0.070	0.002	0.044	0.002	0.010	0	0.007	0.062	0.425
Norfolk	0.020	0.105	0.112	0.079	0.003	0.129	0.004	0	0	0.002	0.063	0.537
Sacramento	0.027	0.033	0.233	0.070	0.003	0.028	0.001	0	0	0.153	0.225	0.773
Richmond	0.006	0.030	0	0.030	0	0.018	0.002	0	0	0.004	0.045	0.137
Wilmington	0.002	0.002	0.014	0.043	0	0.030	0.001	0.013	0	0.005	0.022	0.134
Tucson	0.029	0.037	0	0.068	0.001	0.066	0.006	0	0.431	0.057	0.134	0.829
Weighted avg	0.017	0.017	0.463	0.043	0.001	0.079	0.002	0.001	0.063	0.021	0.061	0.768
Percent of total	2.2	2.2	60.3	5.6	0.1	10.3	0.3	0.1	8.2	2.7	8.0	100.0

[a]Computed by dividing each cost by the total number of monthly transactions at each site.

TABLE 4 Average Unit Costs for Selected Prepayment Plans

	Cost ($1981)	
Instrument	Per Instrument	Per Trip
Annual pass (one plan)	8.91	0.018
Semester pass (one plan)	2.96	0.019
Monthly pass (nine plans)	0.69	0.014
Weekly pass (two plans)	0.46	0.035
Ticket book (20-trip) (two plans)	0.55	0.028
Ticket book (10-trip) (six plans)	0.53	0.053
Token (20 each) (three plans)	0.83	0.038

TABLE 5 Standard Costs per Instrument for Six Fare Prepayment Plans by Cost Category

	Instrument Cost ($1981)					
Cost Category	Monthly Pass	Weekly Pass	10-Trip Ticket	20-Trip Ticket	40-Trip Ticket	20-Token Roll
Order preparation	0.010	0.010	0.002	0.005	0.010	0.020
Order delivery	0.025	0.025	0.006	0.012	0.023	0.012
Direct sales	0.303	0.080	0.080	0.147	0.281	0.147
Recording and accounting	0.044	0.023	0.023	0.030	0.044	0.030
Design	0.002	0.001	0	0	0	0
Printing	0.038	0.038	0.020	0.020	0.020	0.026
Inventory	0.002	0.002	0.002	0.002	0.002	Negligible
Administration	0.011	0.003	0.003	0.005	0.010	0.005
General overhead	0.035	0.024	0.014	0.021	0.033	0.027
Total per instrument	0.470	0.206	0.150	0.242	0.423	0.267
Total per trip	0.011	0.021	0.015	0.012	0.011	0.013

fare prepayment plan, the relative costs presented in Table 5 should provide an indication of the monthly and unit costs that will be incurred.

Standard Delivery Costs by Alternative Delivery Methods

As discussed earlier, three methods were generally used in the delivery of prepayment plans to outlets, namely, transit staff delivery, courier delivery, and certified mail delivery. To compare the costs of alternative delivery methods, standard costs of a typical system were developed by using identical assumptions to those presented earlier.

Based on these three methods of delivery, the standard cost of delivering fare prepayment plans to each sales outlet can be as low as $2.05 per outlet with certified mail or more than $20 per outlet if staff are used for the delivery. The actual cost per outlet in a particular setting will depend on the number of outlets served, the average distance between outlets, the density of the city, and the number of fare prepayment instruments delivered to each outlet. Given this information, it is possible to choose the least costly method of fare prepayment delivery.

Figure 1 shows the costs of servicing each outlet in a medium-density environment. All three methods of fare prepayment delivery are represented. Certified mail costs increase as the number of passes sent per outlet increases. Courier delivery costs are not affected by the volume of passes sent to each outlet but rather by the number of outlets served. It is assumed that more than 50 sales outlets are served during each delivery period. Transit staff delivery costs depend on the distance (and time) between outlets. The delivery costs per outlet for 1- and 2-mile average distances between outlets are shown in Figure 1.

With the costs of the three delivery methods superimposed on Figure 1, it is possible to determine which method results in the least cost to the transit company at different volumes of passes delivered. Certified mail is the least costly method at volumes below approximately 50 passes per outlet. Beyond that volume, transit staff delivery is the most economical method if outlets are typically spaced 1 mile apart. If the distances between outlets are greater than 1 mile, courier service is less costly.

Any one of the three methods can be the lowest-cost delivery method depending on the set of conditions under which the transit company is operating. Moreover, because the same volume of passes is usually not sent to all sales outlets, utilization of more than one delivery method could result in the lowest operating cost to a transit company. For example, in a low-density site where outlets are typically spaced 2 miles apart, transit staff should be used for the delivery of passes to high-volume outlets only; that is, staff delivery should be employed only when more than 50 passes are delivered to an outlet. For those outlets receiving less than 50 passes, certified mail should be used. Thus, the combination of staff and certified mail delivery will result in the lowest operating cost for the program.

Standard Sales Costs by Sales Method

Standard costs following the assumptions presented earlier were developed for five sales methods, including transit-operated sales outlets, public and employer sales outlets, public outlets with sales contracts such as the Seven-Eleven contract with Portland's Tri-Met, direct mail order, and telephone order programs. The standardized sales costs by sales method are summarized in Figure 2, which also shows that with the exception of sales contracts that provide variable commission rates, sales distribution methods exhibit economies of scale at relatively low sales volumes. At high volumes all five methods have constant average costs.

As shown in Figure 2, telephone order and direct mail programs are relatively expensive programs to operate with little or no economies of scale. In order to make them cost effective, they should only be employed at low volumes and marketed to those transit users without access to the less expensive sales outlets.

Depending on the sales commission rates asked by public and private sales outlets, it may be less expensive for the transit company to staff and maintain a sales outlet if high outlet volumes are obtained. In this analysis it was found that a staff-operated outlet is less expensive than public outlets charging more than 2.5 percent in commissions only at volumes of more than 10,000 pass sales per month. Because few staff-operated outlets meet this test, most staff-operated outlets must therefore be judged and justified on grounds other than pass sales. Finally, transit managers should seriously consider negotiating a contract with a retail chain for the distribution and sales of fare prepayment plans, because such contracts can be less expensive if public outlets charge higher commissions.

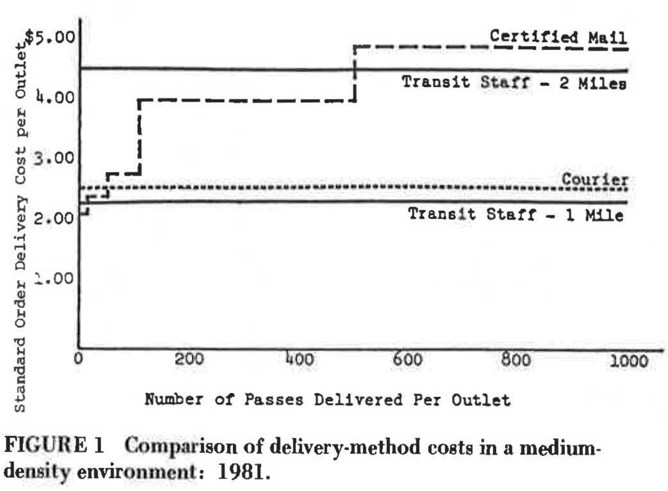

FIGURE 1 Comparison of delivery-method costs in a medium-density environment: 1981.

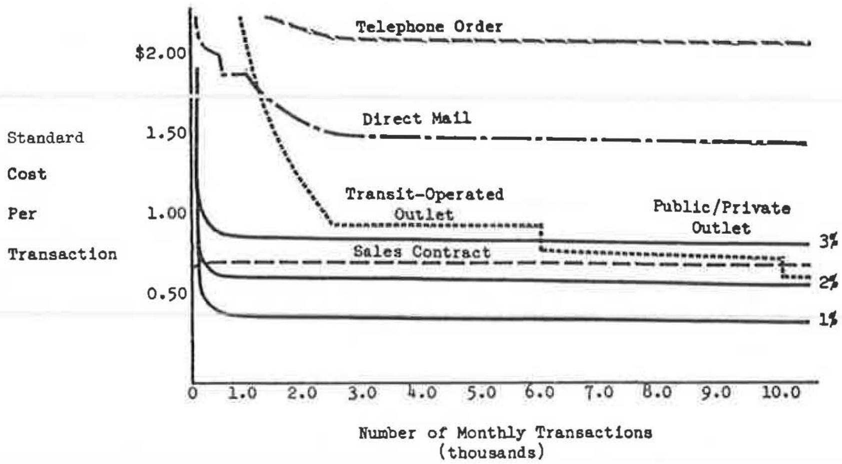

FIGURE 2 Comparison of average costs for five distribution methods at high sales volume: 1981.

In addition, contracting for the distribution and sales of fare prepayment plans frees the transit company from these activities.

CONCLUSION: THE NEED FOR COST REDUCTIONS

The authors have shown in a recently completed paper (7) that the potential benefits of transit fare prepayment programs can be between $0.78 and $1.05 per prepaid instrument sold. At these benefit levels, fare prepayment programs are cost effective if properly priced to avoid farebox revenue losses because the potential benefits exceed the costs presented in Tables 2 and 3. However, a conscious effort should be made by managers of large fare prepayment programs to reduce costs because there is no technical or operating reason why the unit costs of large programs should be greater than the unit costs incurred in medium-sized programs.

The opportunities for reducing the prepayment program costs are several. Staff delivery of fare prepayment plans to outlets should only be used when the distance between outlets is short. A cost-effective alternative to staff delivery is either a courier service or certified mail for the smaller sales outlets. Because the largest single cost of prepayment plans is the sales commission at the larger companies, every attempt should be made to develop a network of sales outlets without paying commissions. Finally, a more prompt collection of funds from sales outlets is warranted so that the transit company can earn interest on the revenues from prepayment collected in advance of services being rendered and thus take advantage of one of the benefits of prepayment programs.

ACKNOWLEDGMENT

This research was funded by UMTA. The study was prepared for the Pricing Division of the Office of Service and Management Demonstrations within UMTA's Office of Transportation Management and Demonstrations.

REFERENCES

1. Huron River Group, Inc. Transit Fare Prepayment. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation, Aug. 1976.
2. P. Bloomfield and J. Crain. Transit Fare Prepayment Demonstrations in Austin, Texas and Phoenix, Arizona. Final Report. Transportation Systems Center, U.S. Department of Transportation; Crain and Associates, Menlo Park, Calif., June 1979.
3. P.D. Mayworm. Demonstration Plan for the Student Transit Fare Prepayment Demonstration: Tucson, Arizona. Research Report 125-3. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation; Ecosometrics, Inc., Bethesda, Md., Jan. 1980.
4. P.D. Mayworm and A.M. Lago. Demonstration Plan for the Variable Work Hours/Employee Pass Demonstration: Duluth, Minnesota. Research Report 125-4. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation; Ecosometrics, Inc., Bethesda, Md., May 30, 1980.
5. J.I. Riese, A.M. Lago, and P.D. Mayworm. Management Plan for the Queen City Metro Monthly Pass Pricing Demonstration. Research Report 125-6. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation; Ecosometrics, Inc., Bethesda, Md., Dec. 1981.
6. Systan, Inc. Sacramento Transit Fare Prepayment Demonstration. Transportation Systems Center, U.S. Department of Transportation, Los Altos, Calif., July 1981.
7. A.M. Lago and P.D. Mayworm. Economics of Transit Fare Prepayment: Passes. In Transportation Research Record 857, TRB, National Research Council, Washington, D.C., 1982, pp. 52-57.
8. P.D. Mayworm, A.M. Lago, and J.M. McEnroe. Patronage Impacts of Changes in Transit Fares and Services. Research Report 135-1. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation; Ecosometrics, Inc., Bethesda, Md., Sept. 3, 1980.
9. D. Krechmer, F. Spielberg, and V. Milione. Evaluation of Employer-Based Transit Pass Programs. In Transportation Research Record 857, TRB, National Research Council, Washington, D.C., 1982, pp. 58-60.
10. P.D. Mayworm, A.M. Lago, and B.F. Beach. A Comprehensive Demonstration of Distribution Systems for Transit Fare Prepayment: The Sacramento Regional Transit Project. Research Report 125-5. Office of Service and Methods Demonstrations, UMTA, U.S. Department of Transportation; Ecosometrics, Inc., Bethesda, Md., Feb. 1981.

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

JOSEPH M. MORRISSEY

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	1,621	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

Transit System	Specification	Performance Results (in-service data) 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

Transit System	Specification	Performance Results: In-Service Data: 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.

ACKNOWLEDGMENT

This paper was written as part of the UMTA RTFC Project being conducted by the Transportation Systems Center (TSC). The support of Joseph Koziol of TSC is gratefully acknowledged.

An Examination of Transit Telephone Information Systems

WALTER J. DIEWALD

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 to turn potential users into riders. It helps people use the service by answering some basic questions that they may have. Typical questions and the information aids used to respond to them include the following (1):

Question	Aid
What kind of service is offered?	Information on regular route service, special service (dial-a-ride, subscription, charter, contract, and so forth)
Where does the system go?	Maps
When can I use the system?	Schedules
Where can I catch the bus?	Shelters and bus stop signs
How much are the fares?	Fare schedules and promotions
How can I use it?	Schedules, maps, signs, promotional materials

The passenger information system has two main functions to perform. It provides general information (e.g., types of transit service, how-to-use information) that tells the potential passenger how to make a trip and where to get more specific information (e.g., detailed routing, station and stop locations, schedules, fare information) and it provides specific trip information so the passenger can find his way through the system, as illustrated by the following.

Figure 1 shows the major components and subcomponents of a transit passenger information system and which of the functions each component of the information system performs. The darkened squares indicate the type of information listed at the top of the column that each component is capable of delivering. A newspaper ad, for example, can include basic information about the transit system and the service it offers or sell a particular service such as express buses for baseball games. How-to-ride information may fit into the ad as well.

TELEPHONE INFORMATION SYSTEM

The TIS is most effective when used for delivering specific information. It is usually used by passengers who have a general idea of where the system goes and how to use transit (a first-time rider knowing nothing about the system calls to find out if he can use it to reach his destination). Telephone systems are the most complete single source of detailed transit information.

Useful as it is, however, a telephone system cannot stand alone as a passenger information system. Because telephone information is not printed, it has a short life. Unlike a timetable, it cannot be referred to again en route. The information it conveys is extremely specific; normally it is used for only one itinerary. Whenever the rider wants to change his destination or his travel time he must make another call.

The objectives and to a large extent the accomplishments of a TIS can be summarized as follows:

- Personalized service: The telephone system can give the prospective rider all the exact information needed to make a particular trip. An information agent can tell the caller where and when to catch a bus or train, where to transfer if necessary, and where to get off as well as fare and other information.
- Convenience: The telephone provides a method of giving out transit information when it is convenient for the rider. Every other information component requires the rider to obtain some form of printed information from the agency.
- Special information: The TIS is a good means for the transit agency to disseminate information about service interruptions, special services, or new routes and schedules. Accurate information can be passed along to the passengers in less time than it takes to print new schedules and maps.

CATEGORIZATION OF TIS

The component parts of a TIS are determined by many factors, including size and complexity of the transit system, marketing budget, and number of incoming calls. Four broad categories have been chosen that encompass all the functions of the information systems and the majority of equipment currently in use. These are manual systems, microfiche-assisted manual systems, computer-assisted manual systems, and automated systems.

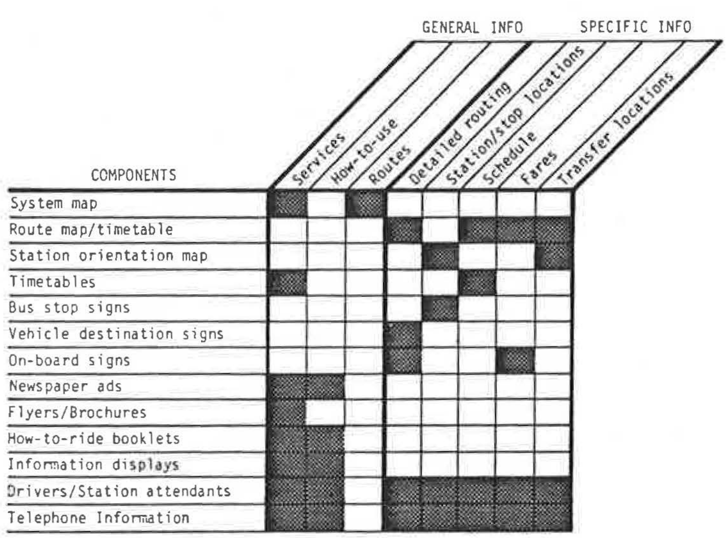

FIGURE 1 Functions of passenger information system components.

Manual Systems

Manual systems are the least complex in terms of technology and also the most common among North American transit systems. A manual TIS requires an information agent for all communication with the caller and for determining the response to the caller based on some type of hard-copy data base. The data base can consist of route maps, local street maps, headway sheets, drivers' schedules, timetables, notes and memos the agent uses as memory aids, daily bulletins on service interruptions or street closings, and other such information. The data base also includes the information the agent may have memorized over the course of his employment with the transit authority. Memorized information can be the most valuable, because it requires no retrieval time and thus results in the fastest call handling. It is of course crucial that the information memorized be up to date.

Microfiche-Assisted Manual Systems

Microfiche systems operate in much the same way as manual systems, with the exception of information storage. Instead of paper copies of maps and schedules, these data are microfilmed onto sheets, typically 4 x 6 in. (10.2 x 15.2 cm). The amount of space needed to store the route and schedule information is reduced immensely. Sorting can also be improved if some thought is given to the order of the pages as they are microfilmed.

Microfiche, with an automatic retrieval reader, may speed up the task of searching for information, changing the task from one of flipping through pages of schedules to keying in the route number on the reader. Bulletins, notes, and changes would still be kept on paper at each agent's station.

Computer-Assisted Manual Systems

Computer systems can give the information agent more capabilities than a microfiche system, or they can be used as a simple electronic data storage device. If used to project route and schedule information, computers have two advantages over microfiche. First, information retrieval is faster, and second, changes in the data base can be processed immediately, without need for refilming and printing microfiche for every agent station.

A computer-assisted system can also be designed to calculate itineraries, transfers, and fares for the caller, with appropriate inputs regarding origin, destination, and time of travel. The Automated Information Directory System (AIDS) in use at the Washington Metropolitan Area Transportation Authority (WMATA) has this capability. For a complex transit system, the ability to calculate itineraries can save an agent a significant amount of time in the handling of difficult calls. Information agents at WMATA, including the more highly skilled agents, value the ability of the computer to calculate trips based on a desired time of arrival, complex suburban trips, and long-distance trips. Questions about these trips are the most difficult ones to answer because of the necessity of backing up through successive timetables on different routes to determine the correct departure time.

The heart of a computer-assisted manual system is the computer. It can be time shared with other departments of the transit authority or dedicated for the use of the information section. The latter is preferable, because it will be in use constantly as the agents search and retrieve data and time-sharing activities can delay the system retrieval time.

Each agent should have a video display terminal (VDT) along with a complete set of paper schedules and maps. Because the fastest method of call handling has proven to be a mix of memory and manual and computerized information handling, it is important that all the materials required for a manual system be present for a computer-assisted system.

There may not be any money saved in training or printing costs by switching to a computer-assisted system, but it can be expected that the overall call-handling rate and the consistency of responses of the information center will improve.

Automated Systems

Because they are the most technologically sophisticated of the four categories, automated systems are somewhat difficult to describe. Nearly every automated system is unique, both in capabilities and in hardware. Telerider systems are designed to answer one particular kind of question (arrival time of the next bus at a particular bus stop). Telerider uses a unique telephone hookup: Instead of there being a general information number and having all callers answered by a central facility, each bus stop has an individual telephone number. The Telerider data base and voice synthesizer equipment provide the desired response. The act of calling Telerider is also the information request; the automatic response is initiated by the telephone call.

The automated telephone information system in use in Hamburg [Automatische Fahrplan Information (AFI)] is a fully automated operation with a user-machine dialogue utilizing synthetic voice generation. The caller asks a question by dialing a preselected sequence of numbers. AFI selects the optimum route for the caller from among the feasible connections between the origin and destination points and presents it to the caller together with fare information via a speech synthesizer.

ASSESSMENTS OF THREE REPRESENTATIVE SYSTEMS

Assessments of three representative TISs are summarized that range in technical complexity from labor-intensive manual systems to fully automated computerized systems. The manual system examined was that at the Nashville--Davidson County Metropolitan Transit Authority (MTA). The MTA, with approximately 115 buses in peak service, is a medium-sized system but larger than 75 percent of all U.S. bus systems; if systems of this size have a TIS, it is likely to be a manual one. The second system examined was AIDS, in operation at WMATA in Washington, D.C. Conceived as a demonstration program, AIDS has evolved into an operating system that forms the basis of all WMATA TIS operations. AIDS is a computerized data storage and retrieval system that automatically provides route, schedule, itinerary, and fare data to the information agents. The third system examined was the AFI system in Hamburg; AFI is a fully automated, computerized system with which a caller can carry out an inquiry dialogue.

MTA Manual System

The Nashville--Davidson County MTA operates approximately 115 buses during the peak periods over 531 mile^2 (1,377 km^2). The MTA telephone information center operates from 6:00 a.m. to 7:00 p.m. Monday through Friday and from 8:00 a.m. to 5:00 p.m. on Saturday. The average number of calls per day is 1,400, the maximum about 4,500. An information agent handles an average of 250 calls per day and a maximum of about 500 calls per day.

The telephone information center is perceived as a public service operation provided for customers seeking any information about MTA service. Telephone information agents respond to all calls, including those that are not related to MTA business; information on schedule or route changes during weather (or other) emergencies is considered extremely important (call volume increases noticeably during such periods). The information center personnel believe that transit users are dependent on them for system operations information, particularly for work trips.

No surveys have been conducted by MTA with regard to the nature of telephone inquiries. It was indicated that the center gets all kinds of calls; the telephone information center number is highly publicized as a general information number and callers seek all types of information, including on occasion time and temperature. The information agents are located in a single office with six desks for the information agents and a partitioned space and desk for the Director of Information; no additional dividers or sound-deadening materials are used.

At the time of this study the system hardware consisted of six call directors with a rotary system (definitions of equipment hardware are given in a later section). Seven incoming lines are used by the information center; an eighth line, dedicated to ridesharing information, is also manned by the information agents. An automatic answering device is used when the phones are not being manned. There is a TTY system (an electromechanical device that enables a telephone to be used to communicate between two typewriting devices) for the hearing impaired at a specially designated number.

The system has been in operation since 1974 and MTA reports that it has had no problems with the equipment. While the study was in preparation, MTA purchased an automatic call distributer (ACD) system that can serve up to 8 lines and 8 agent positions and is expandable to 32 lines and 32 positions.

The MTA information agents respond to inquiries from memory or through the use of printed schedules, route maps, and route descriptions that they keep at their desks. The caller is generally asked to provide information regarding his location, his destination, and his arrival or departure time or both. Once these inputs are established the agent can determine the appropriate response and convey it to the caller. In addition to providing immediate verbal responses to caller questions, the information agents take requests for route or schedule information and mail it out; they also fill out inquiry forms for the ridesharing program.

MTA estimates that the average time per call is less than 2 min and that 60 percent of the calls are 1 min or less. An internal study of agent activities revealed that there are few lost calls and that a call is usually answered within three rings. No lost-call information is available, although it would be possible to request that it be collected by the local phone company. The data collection period would have to be from 8:00 a.m. to 4:30 p.m., the hours of operation of the phone company.

Although MTA does not isolate all costs directly related to the information center, it was possible to estimate the cost of the system from the data available. An internal report indicates that the annual operation (service charge) cost of equipment is approximately $6,200. Annual cost of agent salaries, fringe benefits, and overhead is approximately $132,000 for a total of $138,200. Based on the weekly call records the annual number of calls answered is between 300,000 and 400,000. The cost per call therefore ranges between $0.30 and $0.37.

WMATA AIDS Computer-Enhanced System

AIDS, used by WMATA in Washington, D.C., is one of the most sophisticated transit telephone information systems in North America and has been the subject of an extensive development program. AIDS is a computerized data storage and retrieval system that allows information agents to provide detailed routing and schedule information for trips on the fifth-largest multimode transit system in the United States.

WMATA operates some 1,767 buses over 775 bus routes (143 bus lines). There are four rail lines at present covering 42.4 miles (67.8 km). When it is completed, the rail system will have five lines covering 101 miles (162 km). The transit ridership in 1981 was 182,532,237 passengers.

The objective of the WMATA telephone information system is to provide a transit customer with personalized information about transit system service. For customers who do not possess printed transit schedules or maps, calling the transit telephone information service is a quick and convenient method of learning how to make a particular trip via transit. Even customers who possess printed transit schedules or maps often find it useful to call a telephone inquiry service in order to interpret or verify information. The AIDS project was sponsored by UMTA as a demonstration effort to develop and evaluate a usable and effective computer-aided transit information system that could be used throughout the United States, particularly where companies operate a complex transit network (2).

The information staff consists of 57 agents and 7 supervisors with one trainer and an AIDS coordinator. There are at most 30 agents on duty at any particular time. The average call load per agent is 180 calls per day; the maximum is approximately 300 calls per day, although one agent logged a record 700 calls during a blizzard (this was before AIDS). On that day there were a great many short calls inquiring about a change in the transit schedules for workers going home early or inquiring whether federal employees would be released early. Such calls are common during bad weather. It is assumed that because there are so many workers with one employer (the federal government), the transit system will be forewarned when the commuting pattern is changed, which does not occur at this time.

WMATA's Stromberg-Carlson ACD is equipped with a peg counter that counts the number of calls received and the number of calls answered. The difference between these two indicates the number of calls lost. The counter is read hourly, and although it can be reset, this is not done. The counter will reset itself to 000 after 999 calls have been counted. It will also count the number of calls handled at each agent position. The counting of calls is by work station rather than by agent identification. No reports are available on average caller waiting time, average call length, or trunk condition.

The AIDS system uses Hazeltine 1510 VDTs and two identical Hewlett-Packard HP-3000 Series II computers, installed in 1978, and it is in the process of being expanded with an HP-3000 Series III computer. The two Series II computers are being upgraded to Series III models as well. The computers are dedicated to the information system during the hours it is in operation; in the off hours they are used for related activities, including generation of bus-stop files, landmark files, and lists of routes for cost allocation. These data are readily available through the AIDS data base and can be used for planning and scheduling.

The applications program for the AIDS system was custom written for the system. It includes data base search, retrieval, and handling. The computer does not store the entire data base in internal memory during operation. Data called up most recently stay in internal random-access memory, and periodically they are all copied onto a disk. Data used most often tend to stay in internal memory, which provides shorter response times. The programs will calculate itineraries based on shortest travel time, shortest wait time, or shortest walking distance as requested by the caller.

AIDS uses a geographic data base constructed by overlaying a grid of squares 25 ft (7.6 m) on a side on the Washington region; 13,000 bus stops, 700 routes, 26,000 streets, 40,000 intersections, and other landmarks are located by coordinates on the grid.

The AIDS system provides agents with a prompting method of data entry. The system displays on the VDT a series of statements and blanks to be filled in by the agent. When all entries have been completed, the system evaluates the entries to determine the type of query and selection ranking. It then performs the calculations and displays a reply.

At any point during the entry and processing of a query, the agent may correct or alter any entry already made. The AIDS system recognizes erroneous entries and displays a prompting message so the agent can reenter the data. Once the entry has been made properly, the system continues handling the transaction normally.

Information agents at WMATA are given a 5-week training course in the transit and telephone information system before they are put to work full time. The training manual used by WMATA emphasizes the sales aspects of the job. Information agents are trained to think of themselves as WMATA's first sales contact with the customer. As a result, the attitude and courtesy of the agents is considered very important.

System familiarization is made up of two parts: learning the routes and schedules from maps and headway sheets and learning the routes and route surroundings from riding trains and buses. Trainees are encouraged to take their area maps with them while riding the system and to mark down the route as they travel, writing in landmarks and other aids for future calls. Altogether, system familiarization takes up more than half of the time spent on training.

Operating costs for the AIDS system are estimated at approximately $1,743,950 annually, and the total capital cost of the AIDS system was approximately $1,258,000. Daily call counts are approximately 6,000 calls, averaged over a week, resulting in an annual total of 2,190,000 calls. The operating cost per call, therefore, is on the order of $0.72. If the AIDS development costs were amortized over a 10-year period, this would add $0.06 to each call for a total of $0.78 per call.

The implementation of AIDS, as stated earlier, was originally a demonstration of new technology rather than the application of existing technology. UMTA's goal was to determine whether a computer system could be developed that would provide for automation of the telephone information function and to determine the cost of such a system. AIDS must be evaluated as being a first-of-a-kind application. In comparing the results of the AIDS system with the system goals and the expected benefits, it appears that UMTA's goal of demonstrating computer technology for a TIS has been met satisfactorily. The system is workable, useful, and, after the initial debugging period, has not required an inordinate amount of maintenance and repair. As a result of the AIDS demonstration, information has been obtained that will prove useful in reducing errors and avoiding unnecessary costs in other deployments.

An AIDS evaluation study (3) indicated that before AIDS, 72 percent of the calls lasted 2 min or less; after installation 72.5 percent of calls were of this same duration. The percentage of calls 3 min or less was 86.5 percent and 87 percent before and after, respectively. There is some indication of a reduction in call length since AIDS was implemented. It was expected that the longest calls would be most affected because they involve more complex calculations. The computer should speed up these calls, so there would be fewer calls on the long end of the spectrum.

WMATA does not have the ACD equipment and software necessary to monitor and compare a single agent's performance while using AIDS and while relying on manual techniques. Should they acquire such equipment in the future, it would be useful to monitor the system in a controlled experiment to get a better idea of productivity changes.

The information agents indicate that AIDS provides reliable information while making a greater quantity of information available for callers. It is also reasonable to assume that when the agents use AIDS, they will be drawing from a consistent data base and, particularly for complex inquiries, the agent response will be consistent throughout the section for the same inquiry. The penalty attached to a longer call that provides improved quality and quantity of information is considered acceptable.

The expected benefit of reducing the amount of time needed for agent training has not come about. The agent training course now is as long as it was before AIDS implementation. However, with AIDS, once training has been completed, the agent achieves an acceptable level of productivity more quickly.

The computer system does not collect information on agent performance. It can keep track of the length of time required to key in a query, the data retrieval time, and the length of time before another query is input, but these numbers may have little to do with how long it takes an agent to answer a caller. The AIDS system is not connected with the ACD in any way and does not collect data on how long the telephone is in use for each call. Agent performance data can be collected with a state-of-the-art ACD or private automatic branch exchange (PABX), and although WMATA does not have this kind of equipment at present, it is in the process of purchasing a computer-based ACD.

WMATA has also considered installing remote terminals connected to the AIDS computer so that passenger information can be accessed without a telephone. Likely places for such an installation are the two metropolitan airports, large shopping centers, hotels, and so forth. Hardware procurement was being planned in late 1982. WMATA is actively pursuing other spin-off applications of the AIDS system and its data base, including market and planning research, graphics, and bus-stop information. Consideration is also being given to the integration of AIDS with interactive cable television and information systems.

Hamburg AFI Automated System

The automated TIS in Hamburg was examined to present a description and assessment of a system that operates in a large multimodal transit system and provides 24-hr access to full, spoken schedule information. The Hamburg AFI system is a highly complex passenger information system that is fully automated and capable of user-machine dialogue using synthetic voice generation. AFI has no human information agents.

The conventional central TIS has been in operation since 1980. It is completely manual and concentrates previously decentralized functions under one published telephone number at the Hamburg Transit Association. Total staff for the manual TIS is five. The service operates on weekdays from 7:00 a.m. to 10:00 p.m. In the absence of the automated TIS, approximately 500 to 600 calls per weekday are serviced by the manual system. Of these calls, about 60 percent are related to schedule information, about 28 percent to fares, and about 12 percent are classified as other.

From June 1979 until May 1981, AFI was operated as a demonstration and test system in Hamburg. During the demonstration, periodic changes were made to hardware and software, and accompanying studies were performed. In these studies user surveys were conducted to measure acceptance, cost-effectiveness, and influence on user behavior.

At the completion of the demonstration, work was continued on development of final modifications to the hardware, software, and operation of the system. This work is nearing completion. The implementation of such a system with full access for the total service population is being planned. Hamburg is interested in having the first fully implemented AFI system; other cities and regions are also interested in acquiring such a system.

The AFI automated TIS as demonstrated in Hamburg consists of three main parts:

1. A central processor unit (CPU), which stores all schedule data and computes the best connection based on trip request inputs;
2. Five automated auxiliary machines, which provide hard-copy printouts of the trip information after user input of destination code numbers; and
3. The telephone interface system, which includes the speech-generation component.

The caller communicates with the system via either the keyboard on the automated auxiliary machines or a telephone at home or any public telephone in the local call area.

A PDP 11560-CD from Digital Equipment Corporation (DEC) was used as the CPU. This unit has a 16-bit processor and a 128K memory capacity. For the speech output, nine CAMAC telephone interface modules were used, one for each line. Each module had one telephone connection dedicated to one output. The output from the CAMAC telephone interface module is routed through the appropriate channel of the multiple call director to the correct outgoing telephone line.

The system software is programmed in FORTRAN IV. The main part of the program is the route search routine, which is designed to select the optimum route for the caller from a large number of possible connections between the origin and destination points. The trip recommendation is determined in four steps:

1. Search for feasible connections,
2. Preliminary evaluations of connections,
3. Determination of trip data, and
4. Evaluation and selection.

Feasible connections between origin and destination are searched and calculated by using a stepwise approach. In the first step connections with a minimum number of transfers are calculated. The second step establishes connections with one additional transfer required. If a second step connection is not feasible, the third step is initiated and connections with more transfers are searched.

Once a set of feasible connections has been established, a preliminary evaluation is performed. This is done to reduce computer time, because both accessing schedule data and evaluating connections are time consuming. In the preliminary evaluation, the connections are evaluated by using factors that are available without disk access. These factors include average ride time between stations or stops and average transfer times. The preselection routine results in a rank ordering of connections.

Operation of the system via telephone requires the user to first look up the code numbers for his origin and destination station or stop in an address directory, which includes simple instructions for system use. After making telephone connection with the system, the user starts his dialogue, during which the system takes the speaking part and the user responds by dialing code numbers on his telephone.

The dialogue sequence starts when the machine requests the required inputs from the user. The caller then dials the code numbers for departure station, destination station, the weekday, the desired time, and a number for designating the desired time as departure or arrival time. Special note pads are provided to assist the caller. If the caller makes an input error, dialing 99 allows him to start the sequence again from the beginning without losing the connection. The number of digits to be dialed is 14 plus the telephone number to access the system.

The Hamburg automated TIS application was a test and demonstration program. Therefore, a system with only limited capacity was installed. To avoid overloading the system, the distribution of directories and the number of automatic auxiliary machines installed was limited. Several surveys and accompanying studies have been performed during the more than 2 years of system operation to measure system performance and acceptance by the user.

At system startup, directories enabling callers to use the system were distributed to 1,500 households that statistically represented the service area. After the system software and hardware were performing well, an additional 8,000 directories were distributed to interested persons.

After the issuance of both the first and the second set of directories, user frequency was high. However, after some initial fluctuations in demand, the user frequency stabilized. The average demand on the system was about 1,000 calls per day and 100 calls per peak hour. An extrapolation of the experienced-user frequency from the test households to the 750,000 households in Hamburg was performed. It was projected that if the system were made accessible to all households in Hamburg, approximately 10,000 to 12,000 calls per day would be made. The peak-hour frequency would be approximately 1,000 calls per hour.

It takes approximately 3 min to obtain a trip recommendation over the telephone. Many users became adept with the system and needed only 2 min or less. Lost calls were not a problem. According to German communications regulations, all telephone systems must be sized so that no more than 3 percent of incoming calls encounter a busy line.

Data on the system availability during the demonstration period were not made available. The system was maintained by the supplier (Dornier). Based on the demonstration experience, the operator expects an availability of 99 percent when the final expanded system is installed. This expanded system will have 80 incoming lines to fill the demand as outlined previously.

Cost estimates for the planned expanded system with 80 incoming telephone lines and sufficient capacity for 10,000 to 12,000 calls per day have been made by the operator in cooperation with the suppliers. It is estimated that the capital costs will be $5 million. The annual costs, including operation and maintenance, are estimated to be $1.8 to $1.0

million and approximately $1 million for annualized capital costs.

A potential limitation in some applications in Germany is the lack of accessibility with some telephone systems from outside the local call area. In Hamburg, the system could only be accessed by local calls. Long-distance call use was not possible. Touch-tone telephone systems provide unlimited access. Special technical provisions by telephone company authorities are needed for non-touch-tone telephone users to allow code number input to such an information system.

Three surveys were performed during the operation of the system. In the first 4 weeks after system operation started, 26 percent of the subjects used the system an average of eight times each. This user frequency stabilized at 10 percent of the test population using the system an average of 1.4 times per week per subject.

Surveys indicated that more than three-quarters of those calling the system also made a trip. One-third of the test population made transit trips for which private automobiles would have otherwise been used. Normalizing the statistical results shows that 0.053 transit trip per household per month is made for which an additional fare needs to be paid. It should be noted that in Germany use of passes or multitrip tickets is much more common than in the United States. Most of the trips resulting from use of the information system were nonwork or occasional trips, for example, 26 percent for visits, 21 percent for shopping, and 17 percent to special entertainment. This shows that such a system not only can attract riders but also increases revenue. The high proportion of occasional riders also increases transit use in the off-peak hours.

NEW TECHNOLOGY: TELERIDER TIS

Telerider is an automated schedule information system that enables a caller, by dialing a special telephone number, to obtain information regarding the scheduled arrival of buses (usually the next two to arrive) at a particular stop as well as preprogrammed status information and public service messages for the route or the transit system in general. Each bus stop can be assigned its own telephone number, and the computerized Telerider data base and voice digitizer equipment provide the specific information desired within a short period of time and without the cost or delays of human information agents.

A call to Telerider represents the information request function; the system is capable of only one response: the time of the next (one or two) bus arrival or arrivals at that stop. The caller selects a particular bus stop by the number that he dials; he cannot provide any other information or make other inquiries. The response information is stored in the Telerider computer and the call into the system initiates the automatic response.

An advantage of the Telerider system is that once implemented, it can provide responses quickly, efficiently, and reliably without using information agents and without busy signals. Schedule changes can be accommodated almost immediately from output from a computer program (RUCUS) or direct input into the data base.

The system includes an automatic message-shortening capability that is activated when most of the telephone trunk lines are busy. This provides an automatic capacity increase in the event of high demand without the cost of adding more capacity; it also provides more flexibility for system sizing. In the rare event that all trunk lines are busy and additional calls come in, excess calls receive a busy signal.

The Telerider computer (both DEC and IBM Series I hardware have been used) has two basic data bases, a stop file, and a schedule file. An incoming call actuates the stop file first (because each telephone number identifies a unique bus stop) and then a request is made to the schedule file for information. Additional messages can be accommodated and any voice can be used to present the message; the voice used may be chosen on the basis of its information clarity or its promotional value. Messages regarding route status information, route or weather emergencies, and route or fare changes are particularly useful.

Telerider uses digitized speech because it is considered to be simpler and of higher quality than formant synthesized speech. Telerider modifies existing off-the-shelf equipment to suit its purposes.

Test applications of Telerider systems in Ottawa, Ontario, and Columbus, Ohio, have been deemed successful by the local transit agencies. Expansion to full system coverage has been implemented in Ottawa and has been initiated in Columbus. Other tests are under way in a number of U.S. and Canadian cities.

TIS SURVEY

There is little information available regarding the state of the art of the transit TIS; in particular, little has been documented about the nature and types of TISs currently in place throughout the United States. Information about the TISs in 28 transit systems has been included in the Mitre TIS workshop proceedings (4). However, the author knows of no update or additional information of this type.

In an attempt to expand on and update the Mitre information, a one-page information request was prepared and sent to 130 transit authorities in the United States. The request form is shown in Figure 2. The information requested includes items that were of most interest in the study described earlier and that were most often mentioned by transit authority representatives with whom the project was discussed. Careful attention was given to preparing a single-page request form; an introductory letter and an addressed return envelope were also included.

The results of 73 returned information request forms (5) are presented in the following in the same order as the items on the information request form. In some cases a composite result has been prepared; in others, averages or ranges of values are given. Where appropriate, the results are presented by category; each category is defined by a range of number of buses according to the following: small (S), less than 100 buses; medium (M), 100 to 250 buses; medium-large (ML), 259-500 buses; and large (L), more than 500 buses.

Objective

The composite response to the first question is expressed as follows: The objective of the TIS is to provide accurate and timely information on schedules, routes, fares, and other services in a courteous and efficient manner to customers and potential customers.

Hours of Operation

The responses to this question are presented in Table 1 in relation to the categories of systems discussed previously. L systems have longer hours of TIS operations, reflecting the longer hours of oper-

With regard to your telephone information system (TIS) please provide the following information. If it is helpful to attach additional sheets or forms which provide the requested information, please feel free to do so.

1. What is the primary objective of your TIS?
2. TIS hours of operation: Weekdays ______ Weekend ______
3. TIS information agent:
   - (a) Staff positions ___ (d) Salary range ___________
   - (b) Staff positions filled ___ (e) Supervisory positions ___
   - (c) Peak agent loading ___
4. What skill level do you require for entry level TIS agents? ___________
   How long is your training program? ___________
5. Where is the TIS located in your organization (marketing, operations, etc.)?
6. Number of incoming trunk lines for your TIS ____.
   Number of stations for TIS information agents ____.
7. TIS equipment in place and year of installation.
8. TIS equipment you would like to have.
9. What changes/improvements would you make to your TIS?
   - Add work stations ☐ Improve TIS agent reference materials ☐
   - Improve call traffic data ☐ Improve TIS agent training program ☐
   - Install computer data base ☐
10. Do you assume that a TIS inquiry generates a transit fare, or a portion of one? YES ☐ NO ☐
    If yes, what is the basis for your answer?
    If no, would an estimating procedure be helpful to you?
11. Please provide data on calls per hour and calls per day for an average or typical day and week.
12. Is there any information you would like to have which you think would help you to evaluate the service provided by your TIS? What is it?

FIGURE 2 Information request form.

ation of the transit system. Every responding system has a TIS in operation between 8:00 a.m. and 5:00 p.m.

Information Agent Staffing Data

This information is summarized in Table 2, which presents average sizes for the responding systems in each category; the average number of staff positions; the average number of staff positions filled; the average number of supervisory positions; and the average salary range for information agents.

Qualifications for Information Agents

Although it is difficult to develop a consensus in view of the range of qualifications reported, most transit agencies require someone with a high school education or equivalent, supplemented if possible by clerical skills and communications skills. Agent training ranges from 1 or 2 days to 6 months; in most cases 3 to 4 weeks of training are given. Larger transit systems have longer periods of training. This is reasonable because the requirements of the job must be learned along with the transit system. Because route structure complexity increases with increasing system size, the job demands are much greater for larger systems.

Location Within Transit Organization

All the L systems and most of the ML systems have the TIS located in a marketing group or a customer service group within a marketing section or department. In M and S systems, the TIS is primarily located in a marketing group or operations and administrative units. These differences appear to reflect the increasing specialization and organizational diversity of larger systems.

Number of Trunk Lines and Agent Stations

In Table 3 the information provided on trunk lines and agent stations is summarized with respect to the system sizes. Preliminary statistical analyses yielded no useful information relating size to either trunk lines or agent stations. (Further analysis was under way at the time of the preparation of this paper.)

TIS Equipment in Place

Information provided on equipment in place is summarized as follows:

	No. of Items by Category			
Equipment	S	M	ML	L
Call distributor or standard phone	8	5		
Call sequencer	5	2		
PBX or PABX	2	2		2
ACD			6	9
Unidentified or miscellaneous	15	10	2	2

In order to fully explain these results, a number of definitions of generic equipment types from the study mentioned earlier (4) are presented in the following.

Call Director

A call director gives every telephone receiver direct access to all incoming trunk lines via keysets

TABLE 1 Number of Transit Systems and Hours of TIS Operation

	HOUR																							
CATEGORY	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M
S				1	4	10	20	23	23	23	23	23	23	23	23	23	17	11	7	4	2	1	1	
M	2	2	2	2	3	12	19	19	19	19	19	19	19	19	19	19	18	13	10	6	4	3	2	2
ML					1	6	6	6	6	6	6	6	6	6	6	6	6	4	2	2	1			
L	1	1	1	2	3	9	11	12	12	12	12	12	12	12	12	12	12	12	8	7	6	6	5	

TABLE 2 TIS Information Agent Staffing Data

	CATEGORY			
	S	M	ML	L
Avg. Size of Respondents (No. of Buses)	69.2	168.5	356.8	1,091.0
No. of TIS Positions	2.7	5.9	11.6	23.4
No. of Positions Filled	2.7	5.8	10.8	22.6
No. of Supervisors	0.7	1.2	1.4	2.8
Avg. Salary Range ($)	10,018-13,671	9,126-12,145	11,410-15,980	15,139-19,541

that include a hold button so that each receiver can be used to put callers on hold. There is no priority queuing on this system; calls are taken off hold at random, with no relation to how long each caller has been waiting. Agents select which call to answer and how long to take before answering calls.

Call Sequencer

A call sequencer can be used with a call director or with a PABX (see the following). All incoming trunks connect to the call sequencer, which places incoming calls in a holding queue and then signals all the receivers which call is the oldest (first in line) with a light that flashes faster than the others. It is designed to be used with keysets, but because it is an interface between trunks and receivers, it can accommodate more trunks, and therefore more callers, than a straight call director. Agents can select which call to answer and how long they will wait to answer, but a signal indicates the oldest call in line and agents are trained to answer that call first. In addition, call sequencers are available with additional features such as voice recordings and music.

ACD

An ACD takes incoming calls and puts them on hold if necessary. In this respect an ACD incorporates some of the same features as the call sequencer, but it differs in having a feature called call forcing. An ACD will automatically route calls to available agents instead of allowing agents to connect themselves to incoming calls by pushing a button. An agent's receiver in an ACD system can be a single-line set. Receivers do not have any access to trunks unless routed by the ACD, which acts as a sequencer

TABLE 3 Number of Trunk Lines and Agent Stations Versus Size of Transit Authority

Type of System	No. of Buses	Incoming Trunks	Agent Stations	Type of System	No. of Buses	Incoming Trunks	Agent Stations
Small	54	2	3	Large	520	14	10
	74	5	6		599	25	20
	54	3	2		2,500	36	30
	58	3	1		837	34	20
	78	1	4		1,300	22	21
	52	4	2		1,004	26	23
	57	4	2		528	10	10
	70	3	1	Medium-large	365	20	10
	44	4	2		335	36	9
	56	3	5		445	10	13
	82	4	5		366	23	23
	86	5	4		254	8	6
	99	5	2		310	10	9
	58	3	2		456	8	7
	77	8	3		323	10	8
	65	4	2	Medium	210	3	3
	64	1	2		223	15	15
	80	3	4		101	6	13
	85	5	4		228	12	12
	81	5	4		102	1	1
	93	8	3		163	7	7
	54	8	1		196	1	7
	60	5	3		115	2	3
	59	4	3		116	4	3
	53	1	3		111	4	3
	83	5	3		106	8	4
	60	3	2		212	8	4
	45	3	1		235	16	4
	81	5	1		235	4	4
Large	997	35	23		220	3	4
	554	21	13		217	7	9
	1,069	39	19		102	4	5
	1,202	16	16		118	6	4
	557	11	11		100	8	3
	1,059	23	15		211	11	9

and an automatic switch. There are several ways to route calls to agents; in most cases, calls enter and leave in a first-in first-out (FIFO) pattern. This ensures that all calls are served with an approximately equal wait, and none are lost by being accidentally ignored. Other methods of routing are first available agent, uniform call distribution (levels agent workload), longest available agent, terminal hunting, and circular hunting. At peak traffic periods, it is desirable to connect incoming calls to information agents as rapidly as possible. In this case, as soon as an agent becomes available, another call should be routed to him. As a result, the speediest and most efficient agents will end up taking the most calls, thus increasing their workload.

PBX or PABX

A PBX or PABX is a user-owned internal telephone switch. The PBX uses a switchboard with an operator and is all but obsolete, having been replaced by the PABX, which uses an automated switch. A PABX allows all in-house phones to dial each other, to receive incoming calls, and to dial outside. All calls to or from the outside go through the PABX switch. Trunks terminate in the PABX, which switches them among users as required. The newest generation of PABX equipment is computerized. Although the switch itself may be electromechanical, analog, or digital, the computer control gives it much greater capabilities. Among these are call forwarding, transfers, conference calls, call parking, and so on. Hardware is usually modular, with a set number of ports (for trunks, receivers, and features like recordings and music) that can be expanded two, four, or eight at a time. Generally the electronics are rack mounted with pull-out printed circuit boards (cards) that determine the configuration of lines and trunks. An ACD installation based on a computerized PABX, as most of them are today, can easily be tailored to meet individual transit authority requirements by simply adding or removing specific features.

Centrex System

A Centrex system is owned and operated by the local telephone company, which performs the same function as a PABX. The only difference is that the switch is located in the telephone company central office instead of on user property.

Management Information System

The Management Information System (MIS), also known as Station Message Detail Recording (SMDR), is a sophisticated form of traffic reporting and performance measurement for the telephone systems described above. MIS is one of the major features of a computerized ACD or a PABX. In these systems, it is software oriented. No additional hardware is necessary; the only task is to write and integrate the programs that will read the data generated by the PABX and organize it into reports that are valuable for the user. An MIS reports on agent performance (number of calls routed to the agent, calls handled, and average length of calls), traffic information (calls offered, calls handled, calls overflowed, calls abandoned, average waiting time, and average talking time), and trunk use (calls handled, total calls by line or by trunk group, call seconds of use, number of busy signals, percent of times all trunks are busy, and trunk condition).

Equipment Desired

The results of the question about equipment desired are summarized by category in Table 4.

Desired Changes and Improvements

The results of the question about desired changes are summarized by category in Table 5.

Generation of Transit Fare

Does a TIS inquiry generate a transit fare and if so, what is the basis for the affirmative response? The responses to this question are summarized in Table 6. It is interesting to note that the number of respondents who do not think that a TIS inquiry generates a transit fare is largest in the L and S systems.

TABLE 4 TIS Equipment Desired

	Number of Respondents Indicating Desire for Specific Equipment			
Equipment Type	S	M	ML	L
Independent system	1			
Display board	1			
Automatic hold	1			
Recorded messages	1	2		
Computerized system	3	2	2	4
Automated system	2	3	1	
MIS	2	5	1	3
Call sequencer	2	3	3	
Furniture		1		
ACD		1	1	4

TABLE 5 TIS Changes and Improvements Desired

	Number (%) of Respondents Reporting by Category			
Changes/Improvements	S	M	ML	L
a. Add work stations	7 (.14)	3 (.08)	1 (.05)	3 (.08)
b. Improve call traffic data	13 (.27)	11 (.3)	3 (.16)	10 (.25)
c. Install computer data base	10 (.2)	10 (.27)	7 (.37)	11 (.28)
d. Improve TIS agent reference materials	10 (.2)	7 (.19)	6 (.32)	9 (.23)
e. Improve TIS agent training program	9 (.27)	6 (.16)	2 (.11)	7 (.18)

TABLE 6 TIS Generation of Transit Fares

	Number of Respondents Reporting by Category			
Response	S	M	ML	L
No	7	2	2	6
Yes: ridership increases in relation to call increases	1	1	2	1
Yes: calls are about schedules	2			
Yes: specific information request	6	5	1	2
Yes: correct information stimulates ridership	3	3		1
Yes: callers are transit dependent	1			
Yes: callers are first-time users	3	3	1	
Yes: blind faith/optimism	2			
Yes: passenger feedback/surveys		3	1	1
Yes: no evidence		3	1	3

TABLE 7 Number of Calls per Time Period Versus Size of Transit Authority

Type of System	No. of Buses	Calls per Hour	Calls per Day	Calls per Week	Type of System	No. of Buses	Calls per Hour	Calls per Day	Calls per Week
Small	54	25	225	NA	Large	599	410	3,875	NA
	74	43	346	NA		2,500	NA	7,000	NA
	54	20	NA	NA		837	NA	4,700	NA
	58	35	250	NA		1,300	NA	NA	33,903
	78	20	270	NA		1,004	375	5,000	25,000
	52	20	200	NA	Medium-large	365	164	2,460	17,220
	57	NA	150	NA		335	68.25	1,092	NA
	70	38	304	NA		445	200	2,500	NA
	44	NA	170	850		366	NA	3,000	NA
	56	21	175	NA		254	NA	1,000	NA
	82	NA	385	NA		310	123	1,234	NA
	96	NA	140	NA		456	165	2,729	19,101
	99	38	400	NA		323	NA	2,000	10,000
	58	21	172	NA	Medium	210	NA	510	NA
	65	NA	300	NA		232	167	2,500	NA
	64	NA	575	NA		101	28.6	258	NA
	80	NA	450	NA		228	50	2,000	NA
	85	65	621	4,346		102	20	170	NA
	81	NA	800	NA		163	NA	800	NA
	93	115	700	NA		196	58	700	NA
	54	50	413	NA		115	8	65	NA
	83	NA	670	3,360		116	NA	800	NA
	60	30	250	NA		106	67	845	NA
	45	40	500	NA		212	NA	NA	5,000
Large	997	NA	NA	NA		235	NA	550	NA
	554	NA	2,505	NA		220	63	991	NA
	1,069	340	6,000	37,000		217	NA	2,500	NA
	1,202	309	3,708	16,173		102	60	800	NA
	557	NA	1,120	NA		118	36	394	NA
	1,059	178	2,536	17,807		211	75	600	NA
	520	240	3,000	16,500					

Number of Calls

Data on number of calls per hour and per day are summarized in Table 7.

Evaluation

Information that would be helpful in evaluating the service provided by the TIS is summarized as follows:

Response	No. of Respondents Reporting by Category S	M	ML	L
MIS	5	4	2	2
TIS source information	1	1		
TIS state-of-the-art information	1	3		
Accuracy of outgoing information	1		1	
Evaluation of public perception of service	1	1	1	

SUMMARY COMMENTS

The majority of TISs in use are manual systems. Few transit systems are of the size and complexity to require a more sophisticated information data base than paper schedules and route maps. It has been suggested by some transit agencies that improved filing of these materials helped their information agents increase their speed and that the main benefit of using microfiche was that it forced attention toward filing and information retrieval.

Communications technology, on the other hand, has changed so radically in recent years that there may be opportunities for all but the smallest transit authorities to make improvements. The cutoff at which a PABX or computerized ACD becomes economically feasible is not certain, but estimates indicate that it is somewhere between 10 and 25 information agents. Additional analysis needs to be carried out to determine equipment requirements.

The three TISs that were examined in detail--the MTA manual system, the WMATA AIDS, and the Hamburg AFI system--represent the range of technical complexity of these systems and also point out the lack of data and information available about these systems. Much more information is needed about the performance characteristics of the various TIS components and how various components can be efficiently combined to provide a transit authority with the most appropriate equipment.

The survey results (5) give some indication of what is in place and what transit authorities think about their systems and what they hope for in the future. However, further investigations are necessary to determine the primary transit system, service area, and service population characteristics that are important to the selection and operation of TIS equipment.

REFERENCES

1. G.M. Smerk and R.B. Gerty, eds. Mass Transit Management: A Handbook for Small Cities, 2nd ed., rev. 1980, Vol. 4: Marketing. UMTA, U.S. Department of Transportation, Sept. 1980.
2. M.P. Munkasey, M.L. Noonchester, and D.F. O'Sullivan. An Automated Information Directory System (AIDS): Review and Specification. Mitre Report MTR-7571. Mitre Corporation, Falls Church, Va., July 1977.
3. Wilson-Hill Associates, Inc. The Automated Information Directory System (AIDS) at the Washington Metropolitan Area Transit Authority. Draft Evaluation Report. Transportation Systems Center, U.S. Department of Transportation, Cambridge, Mass., Feb. 22, 1982.
4. D. O'Sullivan, ed. Summary of the Telephone Transit Information Systems Workshop. Report UMTA-VA-06-0052-81-1. UMTA, U.S. Department of Transportation, Feb. 1981.
5. W. Diewald et al. Assessment of Passenger Information Systems. Final Report UMTA-IT-06-0248-83-1. UMTA, U.S. Department of Transportation, March 1983.