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Transit Fare Policies

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Use of Urban Public Transportation for Multiperson Trips and the Market Chances of a Family Tariff

WERNER BRÖG, ERHARD ERL, AND GÜNTER MÖTSCH

This paper uses the Stuttgart Integrated Transportation System (VVS) as an example to show the use made of urban public transportation for multiperson trips and the market chances for family passes. In the first part of the paper, the number and structure of multiperson trips are depicted. Three user groups can be differentiated: (a) households that make most of their family trips with public transportation, (b) households that usually make family trips with individual modes of transportation, and (c) households that make no family trips. A situational model based on individual behavior is used to analyze these groups and to study the degree to which public relations work aimed at familiarizing the public with the family passes and the structure of the special family offer would generate ridership. This is followed by a discussion of a family tariff structure adapted to the needs of the users. Finally, the tariff offer that was actualized after the survey referred to in this paper was completed is discussed.

The use made of urban public transportation for group trips is a topic that, for the most part, has been neglected in transportation research. However, precisely for family trips, there is a reciprocal cost relation. Although the question of cost is usually an argument against using cars and for the use of public transportation, this is not so for family trips. Although the cost of using a car to transport only the driver is the same as the cost of transporting a whole family, the price of public transportation is the sum of the prices of each individual ticket. Thus, it seems that a special tariff for families would increase the attractiveness of public transportation for family trips.

This question was studied by using the Stuttgart Integrated Transportation System (VVS) as an example (1). When the VVS's citywide transportation network was introduced in Stuttgart on October 1, 1978, the discounts that had previously been offered by some of the individual transportation lines were discontinued; this resulted in negative public reactions. After the VVS had instituted two temporary special rates for families (Children-Travel-Free-Days and Family-Reduced-Rate-Cards), it planned to adapt a permanent family tariff. The market potential of this family tariff was to be studied in a survey.

The following data were needed to study this topic:

1. Number of family trips;
2. Possibility of using urban public transportation for these family trips; and
3. Willingness to use the family tariff.

In order to collect the necessary data, a three-step empirical approach was called for (2):

1. Selection of households that were a part of the study's target group--i.e., households with children;
2. Behavioral survey on number and type of family trips made in these households; and
3. Analysis of the transportation mode used in light of situational components influencing choice of mode, determining whether the households had the option of using public transportation for multiperson trips, and identifying potential users in an in-depth survey.

In the behavioral survey, 1052 households with children located in the area served by the VVS were questioned about the number of family trips made in a one-week period. When this had been done, a secondary sample of 200 representative households was selected for face-to-face intensive interviews. In these interviews, interactive measurement methods were used (3).

NUMBER OF FAMILY TRIPS

The survey unit of the behavioral survey was multiperson trips--i.e., trips that at least two members of a household made together. The unit of analysis, on the other hand, was family trips--i.e., trips made by at least one adult (over 18 years of age) and one child (between 6 and 18 years of age) living within one household in the area served by the VVS.

RESULTS

Almost one-quarter of the households with children made family trips on weekdays. On Saturdays, this figure increased to 35 percent and, on Sundays, jumped to 48 percent. More than 70 percent of these trips were made by car; about 20 percent were walking trips or bicycle trips; urban public transportation was used for only about 6 percent of the trips. Most family trips (including all modes) were made for recreational purposes.

In almost one-half of the family trips, the size of the group was two persons. However, differences in average group size could be noted for different modes of transportation. Family trips made with urban public transportation had the smallest average group size of any of the modes. The average time traveled with the different modes varied. This was probably caused by the fact that different modes were used for different purposes. However, toward the end of the week, the average travel time increased for all modes.

SITUATIONAL ANALYSIS OF USER GROUPS

The goal of the survey was to determine if and how a family-oriented tariff offer would affect demand for public transportation. Changes in demand were interpreted to be the sum of individual households' reactions to changed framework conditions. The cumulative changes in the behavior of the individual households result in an altered transportation flow. Travel behavior is still understood to be the result of individual decisions made in situations that can generally be clearly defined. The individual situation explains the travel behavior realized under the given conditions and is the basis for forecasting future behavior in changed conditions.

The research concept in this study used the so-called situational approach (4), which had already been successfully used in a number of similar research projects (5). This approach assumes that the individual situation is a construct of several mutually dependent dimensions; in their entirety, these dimensions define situational groups. In order to identify those households that had the option of using the public transportation system's family tariff, this study considered the following factors:

1. Objective option of using urban public transportation,
2. Constraints forcing persons to use other modes,
3. Information about the urban public transportation alternative,
4. Subjective option of using the urban public transportation alternative,
5. Evaluation of price of traveling with urban public transportation,
6. Perception of cost of using the chosen mode and using urban public transportation, and
7. Extent to which the current urban public transportation system's fare was known.

Analysis of these factors makes it possible to explain the behavior noted on the day of random sampling. However, these specific data cannot be used to explain general travel behavior. To collect data on general travel behavior, one must use the so-called sensitization method (6), which filters out temporary constraints applicable only on the day of random sampling. In the following, only general options were considered, since it is these options that are of primary importance in determining potential.

Our analysis differentiated between three user groups: (a) households that usually used urban public transportation to make their family trips, (b) households that generally made their family trips with individual modes of transportation, and (c) households in which no family trips were made.

Family-Reduced-Rate-Cards

While this study was being done, the VVS offered a special tariff for families. Due to the results of this study, these family passes, which offered discounts to children traveling in the company of adults, were to be improved and offered as a permanent feature of the VVS.

The following conditions applied to use of the family passes:

1. Age limit for children--the upper age limit for children in the company of adults was 12 years;
2. Number of children--when the family passes were used, no more than two children could travel for free;
3. Temporal restrictions--the special fare did not apply on weekday mornings between 6:00 and 8:30;
4. Adult fare--the accompanying adult had to pay the full fare;
5. Validity period--the cards were valid for one month; and
6. Price--the price for the ticket was 4 German marks.

Households Using Urban Public Transportation

The survey analyzed whether or not those households that regularly used public transportation to make their family trips had the option of using the special rates available at the time of the survey. The great majority of the households did not make use of the special offer; most of the households did not know that the Family-Reduced-Rate-Ticket existed (Figure 1).

Those households actually using the special offer represented the direct potential demand for the family tariff, while the large group of public transportation users who did not know that reduced fares for families existed were a potential that could be comparatively easily mobilized.

Households Using Individual Modes of Transportation

Whether or not families that usually use individual modes of transportation for family trips have the option of using public transportation to make their trips is frequently influenced by external factors. More than 80 percent of these households do not have the objective option of using public transportation to make their family trips. If one takes various constraints into account, then 85 percent of the households do not have the alternative of using other modes of transportation due to external factors (Figure 2).

The percentage of households that do not use the urban public transportation system for reasons not cost-related increases to 96 percent if one takes subjective options and degree to which informed into consideration. Thus, only a fraction of a percentage (0.6 percent) of households using individual transportation had the subjective option of using the special family tariffs that were being offered.

Households with No Family Trips

The third target group was households that make no family trips. For this group, it was necessary to determine if the households were willing and able to so reorganize their individual activity patterns that family trips could be made. The great majority of the households (87.5 percent), however, was not in a position to do so. Of those households that were able to reorganize their activities in such a fashion, one-half of the households was not informed about the special family rates that were available (Figure 3).

Households with Potential for Use of Special Tariff

An analysis of the three different user groups shows the number of households that could potentially use the family tariff. Initially, 70 percent of the households did not have the objective option of using public transportation, while an additional 10 percent stated reasons other than cost in choosing the modes of transportation they used. One of the important reasons why options were limited was that the households were unaware of the public transportation options open to them.

Only 2 percent of the households thought that their options were limited due to price. Of the remaining households, an additional 11 percent could not be considered to be a potential for the special tariff because they did not know that it existed. Thus, only 7 percent of all households had the subjective option of using the Family-Reduced-Rate-Cards (Figure 4).

In fact, fewer households used the special tariff than were represented by the potential. The actual potential attained was only 1 percent of the households. As the survey results show, these households were willing to regularly use the special tariff in the future.

HOUSEHOLD SITUATION AND SUBJECTIVE WILLINGNESS TO USE SPECIAL OFFER

Not only the specific situation that determines whether or not households have the option of using public transportation for family trips is important, but also the subjective willingness of the households to use this family tariff.

Therefore, it is important to differentiate

Figure 1. Depiction of the observed use of family cards for family trips.

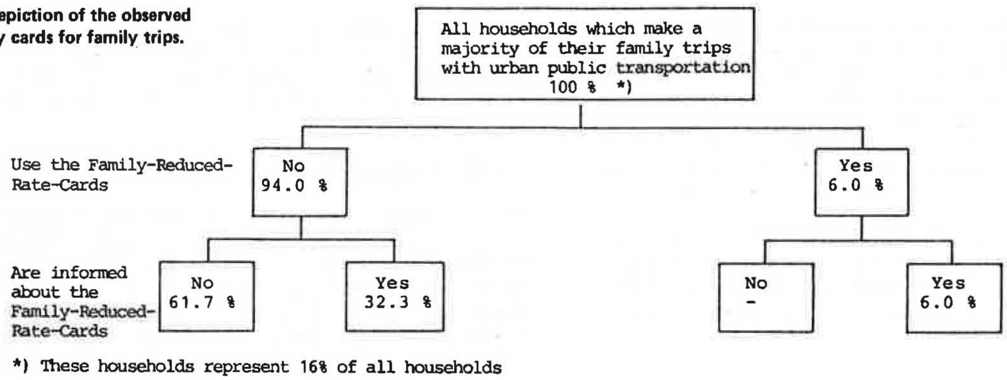
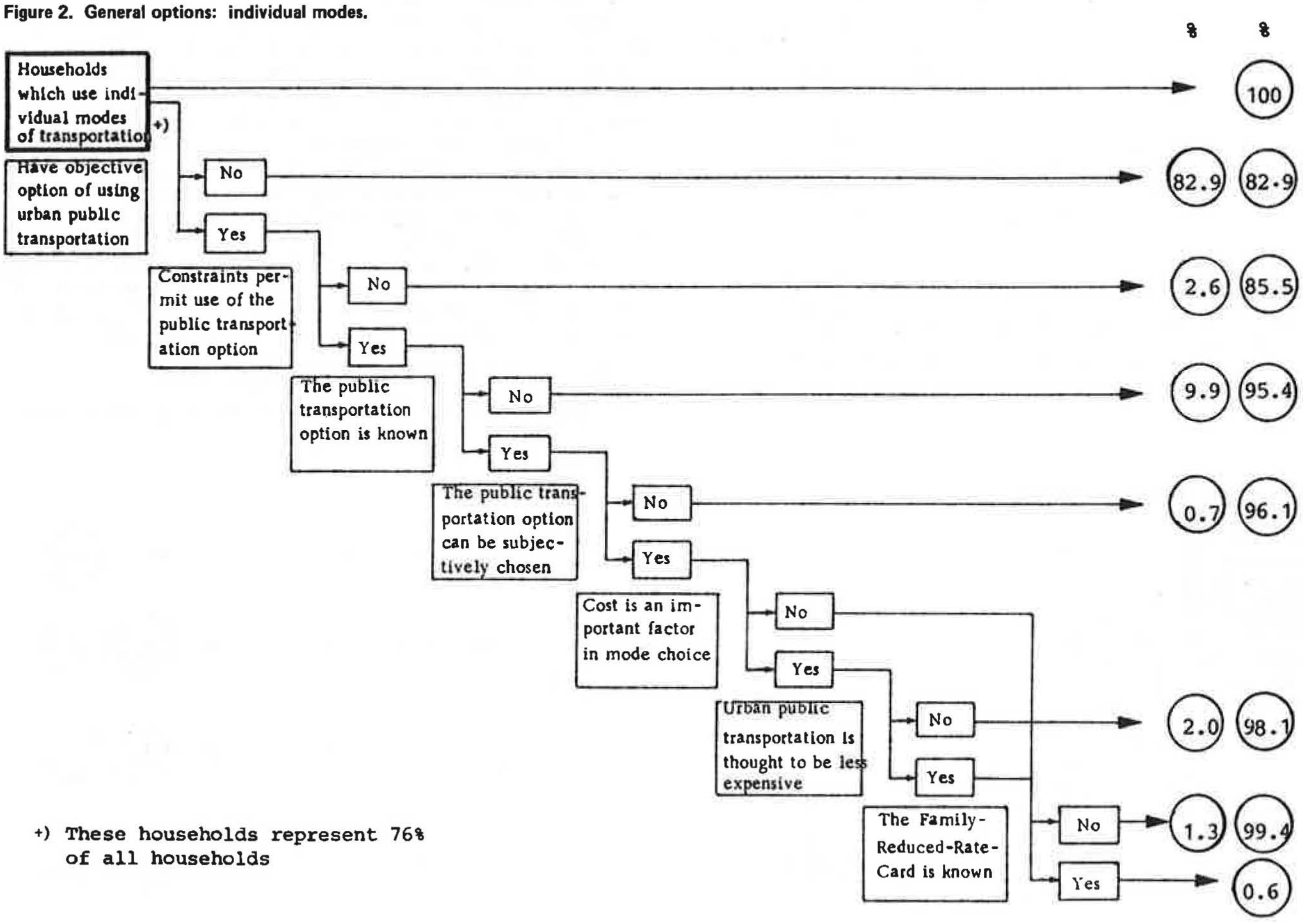


Figure 2. General options: individual modes.



between two groups: (a) persons willing to use the special offer regularly and (b) persons willing to use the special offer occasionally. Methods of increasing the number of users include improving information needs so that persons know enough about the special offer and improving the offer itself.

When one speaks of improving information needs, this means that all households that have the option of using the special offer be informed about the current family passes. When one refers to "improving the offer itself," this means that all those households that did not use the family tariff because they did not (subjectively) think that it suited their needs can be won as potential users.

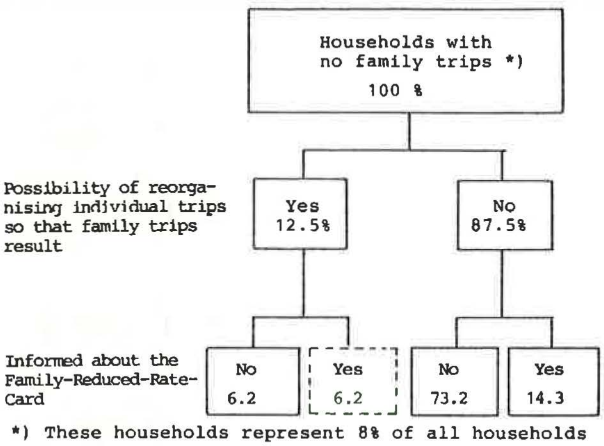
Situational Group Model Versus Demoscopic Results

A model structure, such as that upon which this study is based, is different from a number of other attempts to forecast future behavior in changed framework conditions (7). Demoscopic approaches are frequently used to study similar topics. However, when these demoscopic approaches are used, persons are only questioned about whether they might be willing to change their behavior (8). The large variety of factors that influence actual behavior is ignored. In order to show the results attained by such demoscopic approaches, one can analyze the portions of our survey that deal with the household's willingness to use the special offer in isolation--i.e., with no situational context.

If the offer were improved, 43 percent of all households with children in the tariff area would use the Family-Reduced-Rate-Cards. It is obvious that this does not correlate with actual behavior or with possible changes in behavior. It merely reflects the households' opinions of their own behavior, and this has nothing to do with their actual behavior (9).

Verbal opinions or the judgments of the persons involved cannot be used to determine if improving the special offer will generate increased demand for the offer. This can only be done by analyzing the individual situations that define the options a person has to behave differently. Individual situations are frequently of such a nature that persons do not (cannot) transform their intentions into actions.

Figure 3. General options: households with no family trips.



Potential Achieved Without Improving Offer

The potential that can be reached without making further improvements in the offer includes the households already making use of the special offer--i.e., the potential of 1 percent of the households with children, which has already been attained. The upper limit of the status quo condition is reached when those persons who have the option of occasionally using the offer are added to this figure. This upper limit of 2.5 percent shows the percentage of households that can be reached with the existing supply (Figure 5).

When public relations work is done to make the Family-Reduced-Rate-Cards more widely known, a further potential is exploited. The lower limit can be represented by the number of current users plus those persons who are not informed but are willing to use the offer regularly. The upper limit is represented by those persons who are not informed but willing to use the special offer occasionally. This results in a spectrum of 1.5-6.0 percent of the households with children.

These figures show how many persons might use the Family-Reduced-Rate-Cards available at the time of the survey. However, a precondition for this is that the public is informed about the special tariff.

Determination of an Offer Suited to Needs

In order to plan family tariffs so that they cover

Figure 4. General options: all households.

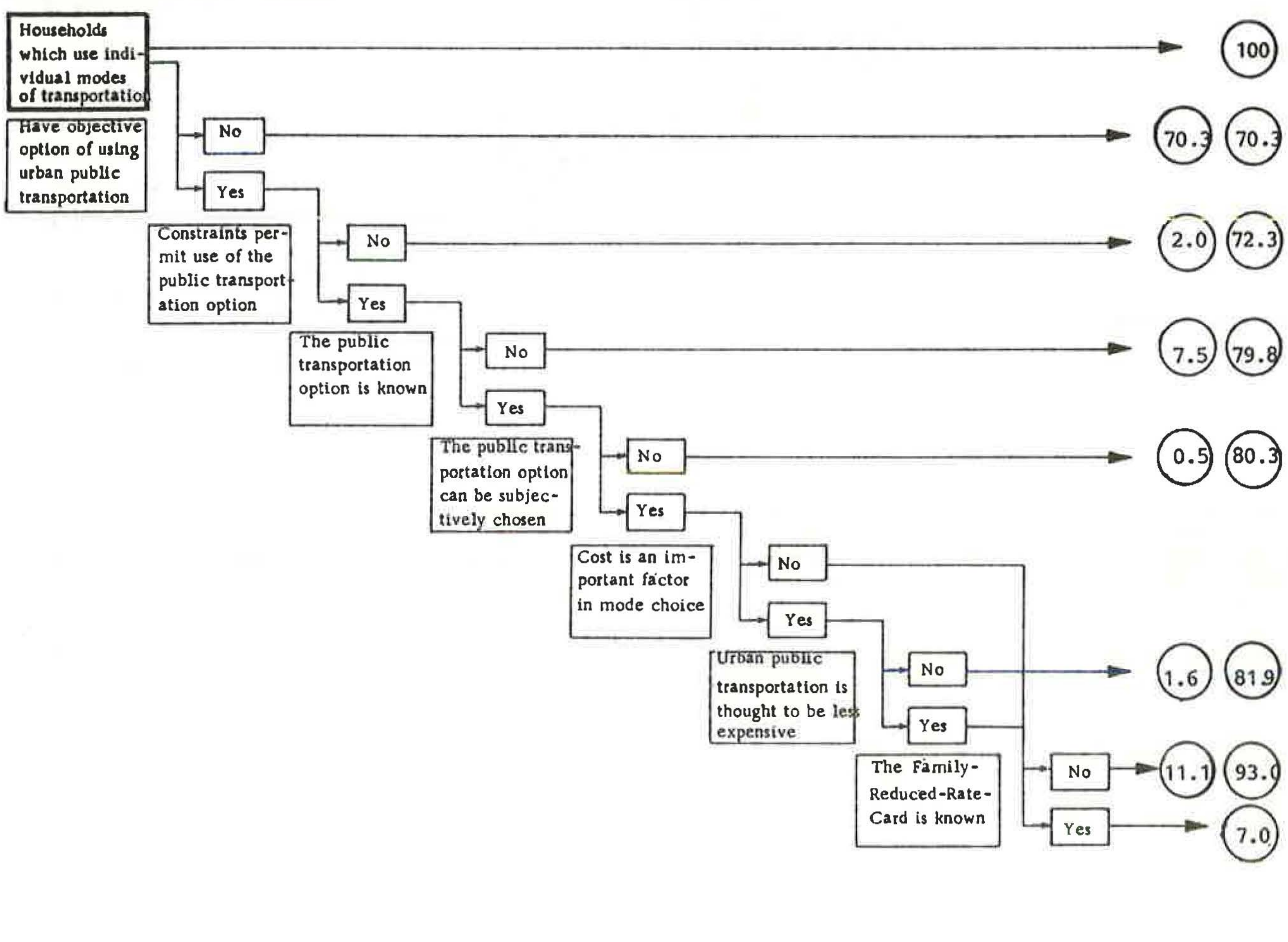
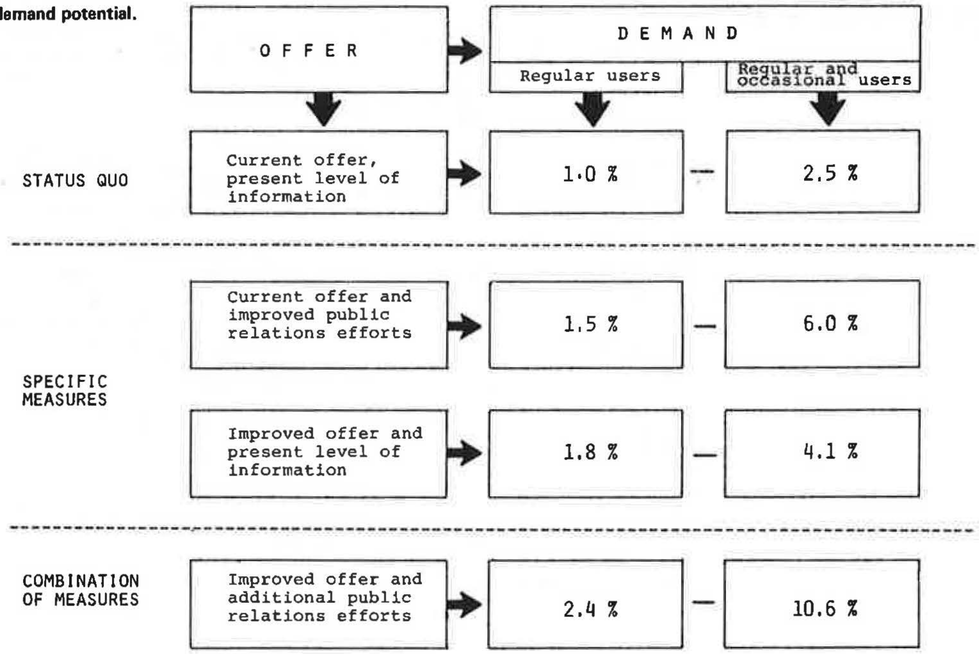


Figure 5. Depiction of the demand potential.



needs as adequately as possible, it does not suffice to use an approach in which the interviewees are simply asked for their opinions about a special offer optimally adapted to their wishes. For if this were done, it would result in suggestions for so radical an improvement of the offer that it would be unrealistic.

Rather, interactive measurement methods must be used (3) to analyze the interviewees' ideas. The following steps were taken to determine the family tariff design that the interviewees actually wished for:

1. The degree to which the households were informed about the family passes was determined;
2. When necessary, the interviewees were informed about the current family passes;
3. They were asked to evaluate these family passes; and
4. If they wished to improve the character of the family passes, they could change three of the following: (a) If the offer was changed, the price was changed; (b) If a higher price was accepted, additional improvements could be suggested; (c) When the price was no longer accepted at some point, the nature of an actually feasible offer should be identified; (d) Other suggestions pertaining to family-oriented fares could be made; and (e) Interviewees who intended to use the special family passes could list minimal changes necessary to ensure their use of the offer.

Analysis of Suggestions for Special Family Tariff

When one looks at the changes suggested by the households that claimed to be able to use the Family-Reduced-Rate-Cards, one gets an idea of the specific reasons that cause dissatisfactions with the special offer. The households that claimed to have a use for the special tariff (80 percent of the sample questioned) wanted considerable changes to be made in the individual parameters of the special offer. Almost all of these changes had to do with extending the current conditions. These households reflect public opinion such as it is sometimes depicted in the press.

However, if one wishes to collect data that are actually relevant to policymaking, one must use a differentiated approach:

1. As a first step, the special offer has to be adapted to the needs of those households identified as a further potential for the family tariff.
2. The interviewed household's wants and needs, which had been identified predominantly by demoscopic means, could not be used as the basis for possibly modifying the special tariff. For this purpose, the last stage of the interactive measurement process had to be used--the stage at which the interviewees formulated their actual suggestions with the additional corrective price of the Family-Reduced-Rate-Cards in relation to changes to be made in the special offer.

The individual wishes of these potential users concerning a family tariff will not be discussed in detail here. However, when interactive measurement is used, one can generally say that desired changes become more realistic and can identify the characteristics of the individual parameters for which they remain relatively constant (Figure 6).

Potential Attained by Making Changes in Special Offer

An analysis of the household-related responsiveness shows that a further potential can be attained if the offer is changed to correspond to the household's subjective notions of how the offer can be adapted to their needs. When the offer is thus changed, even if no public relations work is done, the minimal potential that can be reached consists of those persons who would then regularly or occasionally use the special offer and had not previously used it because they (subjectively) thought that it was inadequate. This group consists of 1.8-4.1 percent of households with children (Figure 5).

The maximum potential can be reached when improvements in the special offer are combined with policies aimed at informing the public about the offer. When suitable measures are taken to improve the special offer and increase familiarity with the

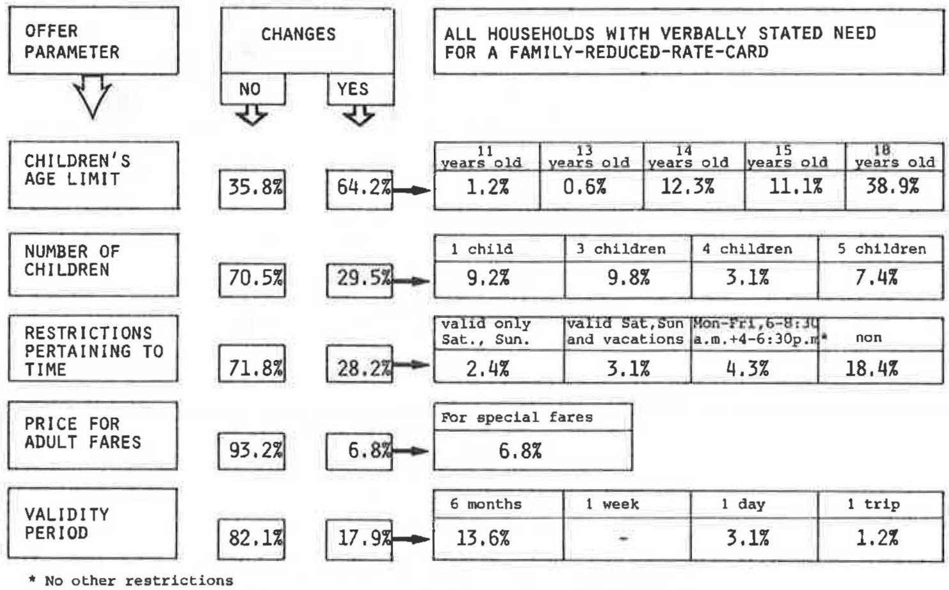


Figure 6. Family tariff: desired supply and public opinion.

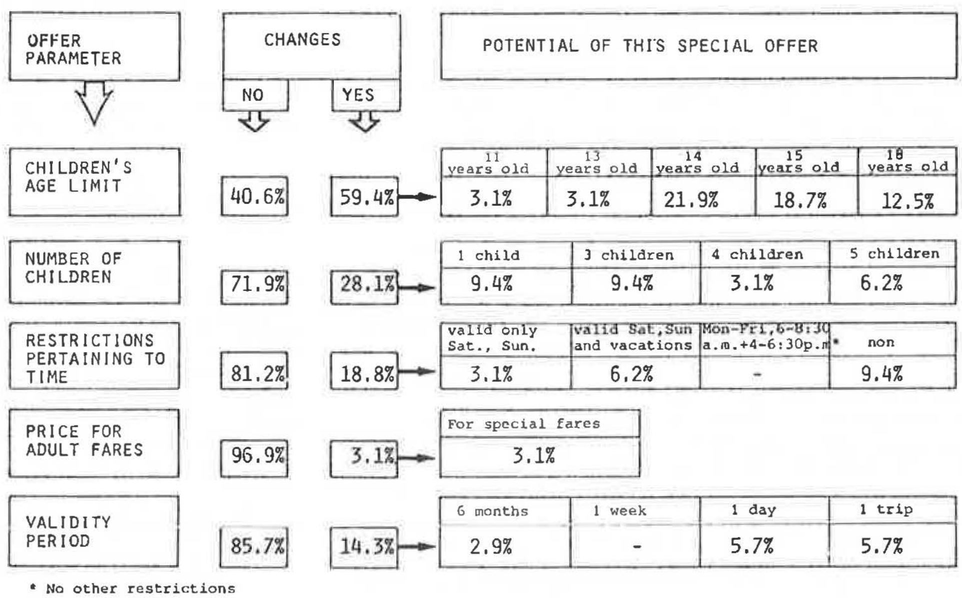


Figure 7. Family tariff: actual offer.

Family-Reduced-Rate-Card, 2.4 percent of all households with children in the tariff area of Stuttgart would regularly use the family tariff, while up to 10.6 percent of the households with children would occasionally buy a family card (Figure 5). However, these percentages are based on the assumption that the special offer is designed to conform to each individual's wishes and that the price for the tickets would not go up.

Summary of User Potential

Under status quo conditions, i.e., if the offer is not improved and no additional public relations work is done, demand will be limited to a small number of households. However, the number of potential users can be increased even if only a part of the possible measures are put into action. The number of households that regularly use the special tickets can more likely be increased by an improved offer than by improved information policies, while the number of households that occasionally use the special offer can more likely be increased if better public relations work is done than by improving the offer (Figure 7).

When the offer itself is improved and information policies are improved, the percentage of potential demand can go up to 10.6 percent of all households with children. However, one should not forget that this percentage refers to an optimal situation in which the offer is perfectly suited to needs and wants and that the information strategies are successful in reaching all pertinent households. Realistically, this is not totally possible.

Actual Design of New Family Tariff

As of May 1, 1980, the VVS offered a new special tariff for families--the so-called Jumbo-Card. This Jumbo-Card took most of the insights of this research contract into consideration.

In a family, all children under 12 years of age can travel for free, and children from 12-18 years of age pay a child's fare if they are accompanied by a parent (parents) possessing a family pass and paying full price. In order to simplify the processing of the tickets, the family card is valid for an entire year and costs 60 German marks. The time limits that were in effect (no reduced rates from Monday through Friday from 6:00-8:30 a.m.) remain in effect.

SUMMARY OF RESULTS

Public opinion, which represents the social point of view, and monetary considerations (increasing use of public transportation during slow hours) cause the family tariff to remain in the limelight. A social-scientific study oriented to individual behavior can be an important aid in forecasting the potential demand that might be reached. On the other hand, a market strategy that tries to deduce potential demand from secondary statistics cannot usually be used for forecasting. The situational analysis of the target group for a family tariff (i.e., households with children) shows that individual options are limited and that the introduction of different measures would have different effects on increased ridership. Since most of the households that use the family tariffs also previously used public transportation to make family trips, the increased number of family tariff users might actually represent a revenue loss. Only a small number of households can be expected to switch from private transportation to the use of public transportation. Thus, the ridership generated by the family passes is minimal.

Although the potential number of persons taking advantage of the family tariff can more likely be increased by public relations work aimed at improving the general image of public transportation than by optimally improving the special offer, the greatest number of persons can be induced to use the special family tariff if both information strategies and the family offer itself are improved.

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Efficiency and Equity Impacts of Current Transit Fare Policies

ROBERT CERVERO

Over the past decade, most transit operators in this country have switched from graduated and zonal pricing to predominately flat fares. Many have hypothesized that flat-fare systems are both inefficient and regressive. This paper statistically tests several hypotheses related to the redistributive effects of three California transit operators' current fare structures. Disparities between users' fares and trip costs were found to be greatest as a function of trip distance. Those traveling less than 2 miles tended to pay inordinately high fares per unit of service. Trips beyond 6 miles were generally cross-subsidized by short-distance users. Moreover, off-peak patrons were found to return between one-quarter and one-half more of their costs through the farebox than peak-hour riders. On the whole, redistributive effects of current pricing appeared to be only modestly regressive. Lower income, transit-dependent, and minority users tended to return a higher share of their costs than the average passenger, although equity impacts varied appreciably among study sites.

Virtually every U.S. bus system today charges most of its customers a single, flat fare. Since the mid-1960s, graduated and zonal fares have been largely abandoned in response to users' demands for simple and convenient services. The availability of federal operating assistance added impetus to the flat-fare renaissance, providing some compensation for revenue losses incurred in eliminating distance surcharges. Simple pricing approaches have also gained steady support from labor unions over recent years, largely because they relieve drivers of major responsibilities in collecting fares.

Despite their growth in popularity, flat-fare structures can be attacked on both efficiency and equity grounds. Transit costs are markedly higher during peak periods and for long trips because additional employees must be hired to accommodate rush-hour loads and driver tours must be extended to serve outlying areas. By charging a constant fare regardless of when or how far one travels, uniform pricing forces the five-block, off-peak rider to offset the high costs of serving the 15-mile rush-hour commuter.

Many have hypothesized that the incidence of fare cross-subsidization is regressive since those with lower incomes are commonly thought to travel shorter distances and more often during off-peak periods (1, p. 284; 2). Not only do simple pricing systems possibly benefit the rich, some argue, but they potentially deprive needy persons the opportunity to even make a trip. Many journeys that would be worthwhile at a fare approximating the cost of providing service are frequently not justifiable at the cost plus the price of subsidizing longer, peak-period trips (3). Transit operators, in turn, lose the opportunity to bring in more revenues from these latent trips and to make efficient use of excess off-peak seating capacity.

This paper examines the efficiency and equity implications of current fare policies. Hypotheses regarding the redistributive impacts of current pricing are tested statistically by using revenue, cost, trip-making, and demographic data from three California transit properties. The intent is to shed light on the structure of mispricing under flat-fare systems as well as to identify the incidence and severity of fare cross-subsidization.

EFFICIENCY AND EQUITY CONCEPTS

Efficiency and equity are dual criteria used frequently in evaluating the policy implications of public decisions. Together, they provide a basis for probing the question, What is a fair fare? This study views efficiency in terms of what welfare economists call the benefit principle: Users should contribute to the costs of services in line with the benefits they receive. Accordingly, price efficiency is achieved when transit users are assessed the marginal cost of their services. Equity, on the other hand, can be viewed in terms of the ability-to-pay principle: Users should contribute to the costs of services according to their income capacities. At minimum, then, any redistributive impacts of pricing should not be advantageous to those most able to afford and least dependent on transit services. It follows that the fairest fare would be one that eliminated transfer effects altogether by charging users the marginal costs of serving them.

Measuring the true marginal cost of individual transit trips is an exceedingly difficult task. Public transportation confers many tangible benefits on society (e.g., cleaner air and energy conservation) that effectively reduce the true marginal cost imposed by each patron. Placing a precise monetary value on such noncommensurable benefits as reduced pollution and improved land development complicates an analysis greatly. Consequently, this study considered only direct (vis-à-vis social) costs and benefits as reflected by transit managers' expense ledgers and users' fares. Second, the pure marginal cost of accommodating one additional passenger or of providing slightly-longer-distance service is in most cases so negligible as to defy measurement. Yet, we know that peaking and service expansion increase transit operating costs appreciably. The most theoretically satisfying way to conceptualize units of transit costs is in incremental terms. Larger unit measures of transit output, such as trip-distance increments and separate time periods of service, provide pragmatic yardsticks for gauging relative cost differences among trips. By comparing the unit cost of serving patrons traveling different increments of distance or during different times of day, reasonable approximations of marginal costs can be attained.

In light of these arguments, this study evaluates efficiency by comparing mean ratios of revenue and cost per passenger mile (hereafter abbreviated RPM/CPM) among various categories of trip distance and between periods. The RPM/CPM index can be thought of as a farebox recovery ratio computed for each transit user (i.e., a unit measure of the ratio of each patron's fare to the cost of his or her trip). The fairest price system, then, would produce a similar RPM/CPM ratio for all users, regardless of how far or when they traveled. The first two hypotheses of this study test whether the study sites' current fare structures embody disparities as functions of trip distance and time period of use. Thus, they analyze price efficiency in both a spatial and a temporal context. The final hypothesis assesses the equity repercussions of current pricing by comparing RPM/CPM discrepancies among various income, vehicle-availability, ethnicity, sex, and age categories.

STUDY SITES

Fare policies of three California transit properties were studied (4): the Southern California Rapid Transit District (SCRTD) serving the Los Angeles area, the Alameda-Contra Costa Transit Authority (AC Transit) serving the Oakland area, and the San Diego Transit Corporation (SDTC). The analysis was conducted by using recent revenue and cost data from each property; in the case of SCRTD and AC Transit, data were from FY 1978/1979 while for SDTC the analysis time frame was FY 1977/1978

The SCRTD, AC Transit, and SDTC represent interesting case-study sites because of their varying scales of operation and their contrasting financial positions. During calendar year 1979, SCRTD served 334 million passengers compared with 52.6 million and 36.6 million for AC Transit and SDTC, respectively. Efficiency levels also differed, ranging from an average cost per service hour of $23.60 for SDTC to $30.65 for SCRTD. During their respective analysis period, AC Transit and SDTC recovered approximately one-third of their costs through the farebox whereas SCRTD's operating ratio was slightly higher--40 percent.

Since the early 1970s, each property has initiated essentially a flat-fare structure, collecting distance surcharges on only a handful of freeway express services. Both AC Transit and SDTC priced basic services at $0.35/ride during 1978 and 1979 while SCRTD charged most users $0.45/ride. Each agency also offered an assortment of prepayment programs as well as special elderly and youth discount arrangements.

RESEARCH METHODOLOGY

The basic framework of analysis involved a cross-sectional comparison of revenues and costs among a sample of users. Thus, the study was conducted at a disaggregate level, employing individual passengers as units of analysis. User responses to on-board surveys provided data on each passenger's fare, trip length, time period of travel, and demographic characteristics. Cost data were obtained from internal accounting records and apportioned at the passenger level on the basis of each user's particular bus route and time period of travel.

The first step of the analysis entailed choosing a representative sample of each property's bus lines among those surveyed. Proportional random sampling was used to select data cases among sampled routes, producing more than 10 000 sample cases for each study site. Due to variations in the response rates among user groups, systems of weights were developed to reduce undersampling biases.

Next, an RPM/CPM estimate was assigned to each surveyed passenger. By using fare and trip-distance data from completed questionnaires, revenue per passenger mile (RPM) estimates were calculated. In cases where patrons boarded with passes, cash-fare equivalents were computed based on known use rates per month for the particular pass type. Since the estimation of the cost per passenger mile (CPM) for each sample trip was a fairly complex task, this step of the analysis is discussed separately in the next section.

COST ESTIMATES

The estimate of each sampled user's cost per passenger mile evolved from a multistage process of refining cost-allocation models and apportioning expenses between time periods. Initially, systemwide equations were derived for each agency that linked specific cost categories (e.g., driver wages) to various explanatory factors (e.g., vehicle hours). Referred to as the unit-cost method (5), this allocation approach produces multivariable equations that can be used to estimate daily operating expenses on any particular bus route. The unit-cost formulas employed by the three properties during the fiscal periods corresponding with this analysis were

$$\text{SCRTD: } OC = 0.41(VM) + 16.44(VH) + 17.57(PO) + 107.77(PV) \quad (1)$$

$$\text{AC Transit: } OC = [0.47(VM) + 13.56(VH)]\ 1.298 \quad (2)$$

$$\text{SDTC: } OC = 0.43(VM) + 20.76(VH) \quad (3)$$

where

OC = operating cost (dollars),
VM = vehicle miles (total vehicles miles covered during revenue service),
VH = vehicle hours (total vehicle hours during revenue service),
PO = pull outs (sum of the morning and evening buses less the number of midday vehicles), and
PV = peak vehicles (largest number of buses in operation at any point in time, whether the morning or evening period).

Thus, inserting data on a particular bus route's daily bus miles, hours, and so forth into the appropriate equation produces a daily cost estimate for that route.

The use of systemwide data to apportion operating costs among lines is a major drawback of these equations. Realistically, cost characteristics among routes would be expected to differ as surrounding surface street congestion, frequency of passenger boarding and alighting, and so forth varied among lines. The concept of cost centers offers a way to capture the individual expense characteristics of bus routes. Cost centers can be defined as homogeneous units within an organization that represent natural divisions for cost-finding purposes (6). In the transit industry, these homogeneous units are best represented by operating divisions--i.e., facilities from which groups of bus lines operate, drivers receive specific work assignments, maintenance activities are conducted, and specific accounting records are maintained. To the extent that routes operating from each division are relatively homogeneous in terms of service type, ridership makeup, and geographic area of service, cost estimates of these lines can be refined by respecifying unit cost formulas at the division level.

In the case of both SCRTD and AC Transit, routes within divisions were found to be quite similar in terms of their operating characteristics; separate unit cost equations were consequently computed for AC Transit's and SCRTD's 4 and 11 divisions, respectively. (SDTC operates as a single division, thus precluding any cost center breakdown.) These refinements gave rise to significant differences in the factor coefficients of divisional equations. In the case of SCRTD, divisional coefficients varied around the systemwide coefficients shown in Equation 1 by between 10 and 12 percent, while for AC Transit coefficient differentials were slightly smaller.

Daily cost estimates of sample routes derived from cost center equations were next factored on the basis of passenger miles and regressed to determine whether they declined as a function of various distance indicators. Unit cost estimates were found to decline nonlinearly with distance (Equations 4 through 6), suggesting that routes serving longer trips and covering more miles generally reaped some economies (* = significant at the 0.05 level, and ** = significant at the 0.01 level):

$$\text{SCRTD } (n = 29)\text{: } CPM = 0.16 + 1.17(ATD)^{-2**} - 0.0065(PASS)^{**} + 10\,160(ABM)^{-2**} \quad R^2 = 0.91 \quad (4)$$

$$\text{AC Transit } (n = 19)\text{: } CPM = 0.62 - 0.66(LF)^{**} + 0.76(ATD)^{-2**} \quad R^2 = 0.64 \quad (5)$$

$$\text{SDTC } (n = 9)\text{: } CPM = 0.23 - 0.0086(ATD)^{**} + 1.90(PASS)^{-2**} \quad R^2 = 0.96 \quad (6)$$

where

ABM = average daily in-service bus miles during typical weekday;
ATD = average trip distance on route (miles);
CPM = cost per passenger mile (dollars);
LF = load factor, representing average ridership divided by average seating capacity of vehicles assigned to the route;
PASS = daily passengers (thousands) over average 24-h period, representing a proxy for the relative service density of a route; and
n = number of routes (note: one route with outlier data was removed from the analysis of each property).

With the exception of SDTC's data, CPM declined as a hyperbolic function of distance. That is, CPM estimates were generally high for routes characterized by short-distance travel and comparatively low for those serving moderate- to long-haul journeys.

The next step in the allocation process involved dividing cost estimates into peak and base period components. Estimates produced by unit cost models represent weighted averages of peak and off-peak conditions. However, it is widely accepted that stipulations in most labor contracts that prohibit the hiring of part-time drivers, limit split shifts, and spread time duties have increased the cost of transit services appreciably. The effects of these restrictions are particularly important because transit is a labor-intensive industry, with wages and fringe benefits typically accounting for 80 percent of all costs. Previous studies report that labor union influences may increase the unit costs of peak services anywhere between 10 and 100 percent about those of the base (7; 8; 9, pp. 52-74).

A procedure developed by Cherwony and Mundle (7) was adopted in this study to reflect the cost impacts of restrictive labor agreements. Their approach adjusts the vehicle hour coefficient upward for the peak model and downward for the base model. These adjustments rely on a ratio comparison of pay hours to vehicle hours during the peak and base periods (i.e., the relative number of hours drivers are paid to the hours they actually serve revenue passengers for both time periods). When applied to cost-center equations, this labor productivity index respecifies the vehicle hour coefficients by time of day. Applying rules for attributing pay hours between time periods, similar to those employed by Reilly (8), peak ratios of pay hours to vehicle hours were found to exceed base ratios by 33.7 percent for SDTC, 30.2 percent for SCRTD, and 14.2 percent for AC Transit.

The final stage in the allocation process involved incorporating capital depreciation expenses into peak and base period cost estimates. Based on previous research (10), 85 percent of each property's annual depreciation was apportioned to the peak period. Factoring the total (i.e., operating plus depreciation) cost estimates by passenger miles in each respective time period produced fairly small differences: SCRTD's average peak CPM of 17.6 cents exceeded that of the base by 10 percent, while for the other two agencies time-of-day differentials in CPM were less than 0.5 percent. Generally, the higher costs of peak services were countered by higher ridership levels and longer trips, producing CPM estimates only slightly above those of the base period. However, to the extent that revenues per passenger mile are relatively lower during the peak (due to longer trips), current fare policies would be embodying price inefficiencies and possibly inequities. This possibility is explored next.

FINDINGS

Revenue and cost estimates assigned to each sample passenger were combined to form the criterion variable RPM/CPM. As mentioned previously, RPM/CPM estimates approximated the farebox recovery ratios associated with specific trip distance, time period, and user group categories. To facilitate comparisons among study sites, these ratios were also expressed in graphic form as proportions of each property's mean RPM/CPM estimate (i.e., as a proportion of each system's farebox recovery ratio). This provided a comparable basis for assessing relative levels of fare cross-subsidization among properties.

It should be noted that the tests of significance presented in this section were hypersensitive to sample sizes. Since each property's sample size exceeded 10 000 cases, differences in RPM/CPM were magnified by both t- and F-tests [see Blalock (11, p. 162)]. It follows that the statistical importance of these hypothesis tests lies not so much with reported significance levels but rather with the directions and magnitudes of differences in RPM/CPM.

Trip-Distance Analysis

The following null and alternative hypotheses were tested: (a) H_0--transit services are efficiently priced with respect to trip distance and (b) H_1--estimates of RPM/CPM are significantly lower for long-distance trips (exceeding 6 miles) than for short-distance ones (under 6 miles). The test results in Table 1 indicate that the null hypothesis was easily rejected for all study sites. Those traveling less than 6 miles were generally paying between 2.7 (for SDTC) and 5.2 (for SCRTD) times as much per mile of service as those traveling beyond 6 miles.

The structure of mispricing as a function of trip distance is even more clearly revealed in Figure 1. Here, RPM/CPM estimates were stratified into 12 categories of trip distance and then expressed as a proportion of each system's mean RPM/CPM, i.e., as a proportion of each system's overall farebox recovery ratio. (For example, the adjusted RPM/CPM of 1.5 for SCRTD's 2-mile trips is equivalent to an actual RPM/CPM of 1.5 x 0.463 = 0.695, a recovery ratio of nearly 70 percent.) The horizontal line in Figure 1 serves as a subsidy threshold--those traveling distances with RPM/CPM estimates above it were, in effect, cross-subsidizing those riders from distance categories below the line. For SCRTD and AC Transit, the 2-mile mark separated trips into gainer and loser categories. SDTC's subsidy threshold was somewhat longer--approximately 3 miles.

Price inefficiencies were most prominent between trips of less than 1 mile and all others. For all three operators, those riding less than 1 mile returned more than twice as much through the farebox as those traveling 2 miles. Disparities were most perverse between distance extremes. The most striking differential was among SCRTD trips, where the mean RPM/CPM of the shortest trips was 35 times that of the longest ones. On average, trips beyond 10 miles in length returned less than one-half of each system's mean recovery rate, which means they generally met less than 10 percent of their costs.

The marked decline in revenue productivity as a function of distance can be mathematically expressed in terms of exponential decay or hyperbolic relationships. Equations 7 through 9 indicate that price discrepancies were far greater between short- and mid-distance travelers than beteen mid-distance and long-haul patrons. These nonlinear relationships suggest that current disparities in pricing could be reduced by setting low base fares and assessing distance surcharges with declining steps (i.e., pricing as a logarithmic function of distance). In Equations 7-9, TL equals trip length in miles:

$$\text{SCRTD: } RPM/CPM = 0.539e^{-0.095(TL)} \quad r^2 = 0.66 \tag{7}$$

$$\text{AC Transit: } RPM/CPM = 0.072 + 1.31(TL)^{-1} \quad r^2 = 0.46 \tag{8}$$

$$\text{SDTC: } RPM/CPM = 0.512e^{-0.079(TL)} \quad r^2 = 0.72 \tag{9}$$

Time-of-Day Analysis

A second set of hypotheses tested was (a) H_0--transit services are efficiently priced with respect to time of day and (b) H_2--estimates of RPM/CPM are significantly lower for peak-period trips than for nonpeak ones.

Whether peak services return a higher proportion of their costs through the farebox than base services has been a subject of spirited debate within the transit industry. Several analysts (7; 12, pp. 83-154; 13, pp. 14-30) have argued that higher peak-period revenues are overshadowed by comparatively higher peak costs. Others (8, p. 3), however, have asserted that "the transit industry's prevailing opinion has been that the (peak's) revenue effect exceeds the cost effect. That is, peak service has better financial performance in terms of the ratio of revenue to costs than the base service." Perhaps transit managers tend to view the peak's financial performance favorably because of the longstanding industry practice of apportioning expenses on an average cost basis. Whenever the true cost of peak demand is overlooked, "the peak usually does show more favorable revenue-to-cost ratios than off-peak periods and ... is fully exploited as the high-yield market" (12, p. 138). To the extent that the cost models of this study captured the true incremental costs of peak services, the following test results should provide a reasonable basis for comparing efficiency levels between time periods.

Table 1 indicates that off-peak users were generally found to subsidize their rush-hour counterparts. Off-peak patrons returned between one-quarter and one-half more of their costs through the farebox than peak users. This translated into an estimated loss per trip among the three properties of $0.61 during the peak compared with $0.41 during the base. These disparities were statistically significant, confirming the alternative hypothesis that rush-hour commuters benefit the most under flat pricing.

Table 1. Test of differences in RPM/CPM means by trip distance and time of day.

Analysis	SCRTD	AC Transit	SDTC
Trip distance			
Mean RPM/CPM for trips <6 miles	0.637	0.574	0.492
Mean RPM/CPM for trips ≥6 miles	0.122	0.139	0.183
t-value	-17.673	-62.811	-65.104
Degrees of freedom	12 408	44 305	19 154
One-tailed probability	0.000	0.000	0.000
Time of day			
Mean RPM/CPM for base period	0.555	0.437	0.418
Mean RPM/CPM for peak period	0.367	0.352	0.323
t-value	-5.389	-14.255	-18.010
Degrees of freedom	11 640	47 145	19 154
One-tailed probability	0.000	0.000	0.000
Mean RPM/CPM (all sampled trips)	0.463	0.397	0.354

As with the trip-distance variable, RPM/CPM estimates were further disaggregated into time-period categories and expressed as a proportion of each system's recovery ratio. Figure 2 indicates that midday services generally returned the highest share of unit costs through the farebox. Evening services were found to match each system's overall recovery rate while the productivity of owl-period service appeared to deviate markedly among properties. These periods accommodated less than 6 percent of each system's daily ridership, however, and therefore played a small part in the overall cross-subsidy picture. In contrast, morning and evening services were by far the least efficient, generally recovering less than one-third of their costs. On average, peak-period subsidies were between 17 and 20 percent higher than each system's average recovery rate.

A reasonable query at this point would be, Which pricing approach could reduce overall inefficiencies to a greater extent--distance-based or time-dependent fares? Since peak trips were generally found to be 1-2 miles longer than each agency's average trip, time-of-day fare differentials could incorporate the distance factor into the pricing structure. Likewise, distance-graduated fares could capture some of the differentials between peak and off-peak costs. For all study sites, the difference in RPM/CPM between trips less than 6 miles and those greater than 6 miles was more than 2.5 times as great as differences between peak and base periods. In the case of AC Transit, the differential was more than five times as large. Since both the 6-mile mark and the peak-base dichotomy generally divided each property's total number of trips into almost equal halves, it follows that disparities were a much stronger function of distance than time period of travel. Distance-based fares, therefore, would seem to hold a clear advantage over time-differentiated fares for improving the efficiency of all three properties' pricing policies.

Equity Analyses

The following hypotheses were tested to probe the equity implications of current pricing: (a) H_0--transit services are priced equitably among user groups and (b) H_3--estimates of RPM/CPM are significantly higher for users who have lower incomes, own fewer cars, represent an ethnic minority, are female, and are not at a nonworking age.

The tests of RPM/CPM differences on the basis of each sample respondent's family income produced mixed results among the three study sites (Table 2). Only in the case of AC Transit and SDTC were flat fares found to be regressive. Disparities were small, however, with the differential in RPM/CPM no

Figure 1. Price disparities among trip-distance categories.

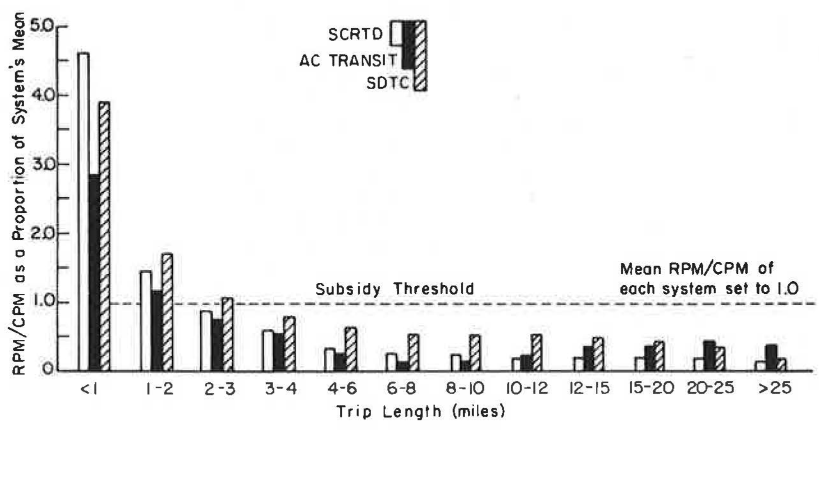


Figure 2. Price disparities among time periods.

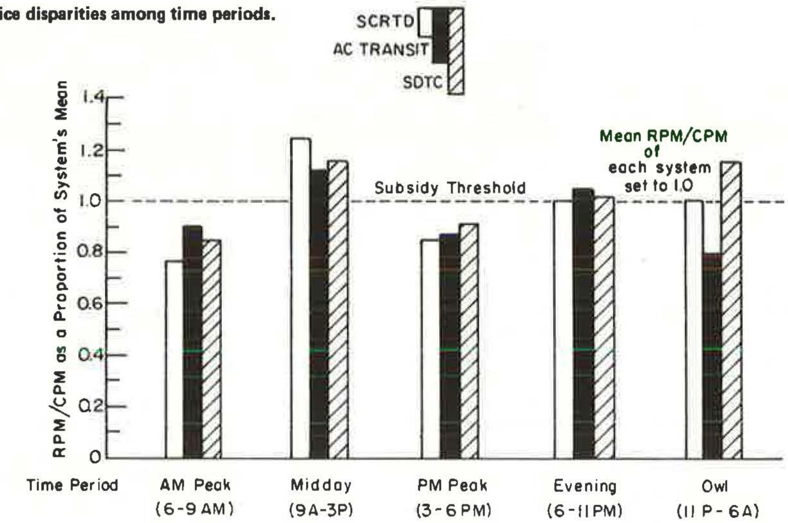


Table 2. Test of differences in RPM/CPM means by income, vehicle availability, and ethnicity.

Analysis	SCRTD	AC Transit	SDTC
Income			
Mean RPM/CPM for annual family income			
<$15 000	0.458	0.404	0.365
≥$15 000	0.480	0.370	0.327
t-value	-0.390	-4.379	-5.702
Degrees of freedom	7 393	34 148	15 092
One-tailed probability	0.348	0.000	0.000
Vehicle availability			
Mean RPM/CPM for those with			
No vehicle available	0.472	0.393	0.401
≥1 vehicle available	0.459	0.400	0.335
t-value	-1.090	-0.919	-7.531
Degrees of freedom	9 462	40 814	17 380
One-tailed probability	0.181	0.333	0.000
Ethnicity			
Mean RPM/CPM			
Asians	--	0.466	--
Blacks	--	0.400	--
Hispanics/Spanish-speaking	0.477	0.463	0.287
Whites	--	0.382	--
English-speaking	0.460	--	0.356
Between-group mean square	1.213	26.598	7.481
Within-group mean square	12.194	1.715	0.270
F-ratio	0.099	13.553	27.920
F-probability	0.752	0.000	0.000
Mean RPM/CPM (all sampled trips)	0.463	0.399	0.354

greater than 6 percent for those riders with annual family incomes below and above $15 000. Surprisingly, the net transfer effect of SCRTD's fares were found to be mildly progressive, although the relationship was statistically insignificant. Thus, the null hypothesis was rejected only with respect to the pricing policies of the two smaller transit properties.

The degree of access transit users had to an automobile served as a direct measure of transit dependency. Table 2 indicates that only SDTC's fare structure led to a significant difference in RPM/CPM estimates among those with and without vehicle access. SDTC's transit-dependent patrons were generally found to travel predominantly during off-peak hours when service costs were relatively low. For the other two properties, virtually no price disparities emerged with respect to the vehicle-availability variable.

Equity was also analyzed in terms of either the ethnicity or primary language of survey respondents. The analysis-of-variance (ANOVA) results in Table 2 reveal that RPM/CPM estimates varied significantly between minorities and whites. AC Transit's Asians and Hispanics were major cross-subsidizers, on average generating farebox recovery rates 22 percent higher than whites. The most surprising finding was that SDTC's English-speaking patrons paid higher fares per mile in relation to costs than Hispanic passengers, in spite of the earlier evidence that the system's price structure embodied some regressivity. SDTC's Hispanic users were generally found to pay lower average fares and to patronize those sample routes that were the least profitable.

Finally, RPM/CPM rates were analyzed according to users' gender, age mixes, and trip purposes. In all three study cases, females traveled comparatively shorter distances and more frequently during the midday than male passengers. Female patrons generally returned a larger share of their trip costs through the farebox, although disparities were significant only for SDTC operations. The incidence of cross-subsidization was more sensitive to users' ages. SCRTD's and AC Transit's college-age passengers paid comparatively high fares for their trips, most of which occurred during the midday. The major beneficiaries of fare cross-subsidization were senior and handicapped patrons. In general, the farebox recovery rates generated by elderly users' trips were less than one-half of each property's average (i.e., less than 20 percent), indicating that current pricing policies satisfy the Urban Mass Transportation Administration's Section 16 mandate calling for substantial senior-citizen fare discounts. With respect to trip purpose, work and school journeys were cross-subsidized, reflecting the concentration of these trips during peak hours. Among all trip purposes, medical journeys produced by far the highest revenue returns. AC Transit's medical trip makers generally paid 25 percent more per mile than other travelers. For SCRTD, the differential exceeded 100 percent.

SUMMARY AND CONCLUSIONS

Current fare policies of three California transit operators were analyzed by comparing differences in the fares paid and costs imposed by various user groups. A multistage cost-allocation procedure was used in apportioning system costs among sampled users. By factoring revenue and cost estimates on the basis of passenger miles, current price disparities were analyzed by using both efficiency and equity criteria.

All three transit properties' fare structures were found to embody considerable inefficiencies with respect to users' distance and time period of travel. By assessing uniform charges against all users, current fare practices seemed to operate on a compensatory basis: Short-distance, off-peak patrons paid inordinately high fares to offset losses incurred in serving long-haul, peak-hour trips. Disparities between fares and costs were greatest as a function of trip distance. Among all three operators, those traveling less than 2 miles generally met their costs through the farebox while also cross-subsidizing others. Patrons traveling beyond 6 miles were generally found to return less than 20 percent of their trip costs through fares. In terms of time period of travel, off-peak patrons appeared to return between 25 and 45 percent more of their costs than did their peak-hour counterparts.

Equity impacts were found to vary appreciably among properties. The net redistributive impact of SCRTD's fare structure appeared relatively neutral; only those patrons below 22 years of age and those making medical trips paid significantly more than the average user. In contrast, the redistributive effects of both AC Transit's and SDTC's pricing exhibited some regressivity. Those losing from fare cross-subsidization included AC Transit's ethnic minorities, low-income patrons, and college-age passengers as well as those SDTC users who were carless, female, unemployed, and from low-income families.

Figures 3 through 5 summarize these findings by ordering efficiency and equity variables in terms of relative RPM/CPM differentials. Clearly, the two efficiency indicators--trip distance and time of day--dominated all other factors. Disparities in RPM/CPM were generally more than three times as great when expressed in terms of trip distance as with any of the equity variables. It seems apparent that discrepancies in RPM/CPM were much more closely related to the characteristics of trips than the characteristics of travelers. In general, equity impacts seemed incidental to the larger problem of inefficient pricing. Maldistributive effects of the three study sites' price policies were generally less pervasive than what might have been expected based on the literature. Indeed, there actually appeared to be a progressive side to some of the subsidy transfers. Overall, however, those who were transit-dependent and captive users were still found to lose more from fare cross-subsidization than others.

To summarize, short-distance users are being hurt the most by current transit fare policies. Off-peak riders also suffer under current pricing programs, but to a lesser extent than short-distance users. Trip distances and time periods of travel vary so much within all classes of users that no particular socioeconomic group stands out as the major cross-subsidy loser. Rather, it is the short-distance, non-rush-hour traveler who pays an excessive and unjust fare, with his or her race, income, and degree of transit dependency being of largely secondary importance.

These findings suggest that changes in current pricing practices should be directed toward correcting price inefficiencies. There also appear to be opportunities for improving the distributional equity consequences of current fare policies through more differentiated pricing of services (but probably only to a modest extent). Graduated fare structures with declining steps seem to offer the greatest potential for eliminating current disparities in pricing. Through current subsidy programs, governments should play a more active role in encouraging pricing innovations that embrace both efficiency and equity principles. Subsidy programs that reward operators for introducing differentiated pricing could not only improve overall efficiency, but could probably improve the industry's financial performance. The success of any transit fare innovation also rests to a large extent on pricing improvements made in other competing transport sectors. As long as highway use is underpriced and parking is subsidized by employers, for example, efficiency-based fare reforms could prove counterproductive. Therefore, transit fare innovations should be part of a larger effort to correct pricing distortions found throughout the transportation system.

Some observers discount the feasibility of major transit fare reforms on both technological and political grounds. Collecting finely graduated fares on conventional bus transportation poses a range of logistical problems. Moreover, opponents

Figure 3. Ordering of SCRTD efficiency and equity factors.

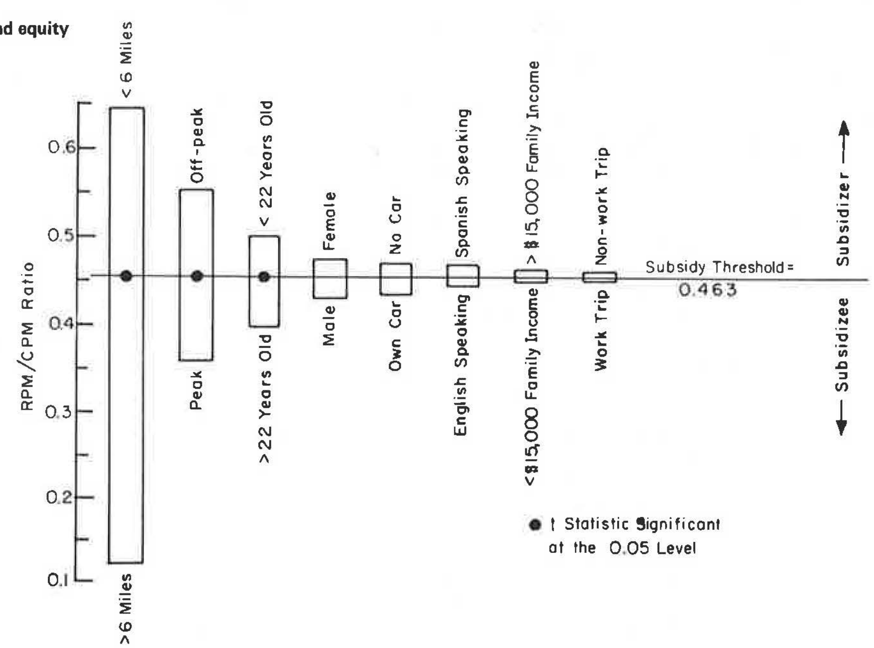


Figure 4. Ordering of AC Transit efficiency and equity factors.

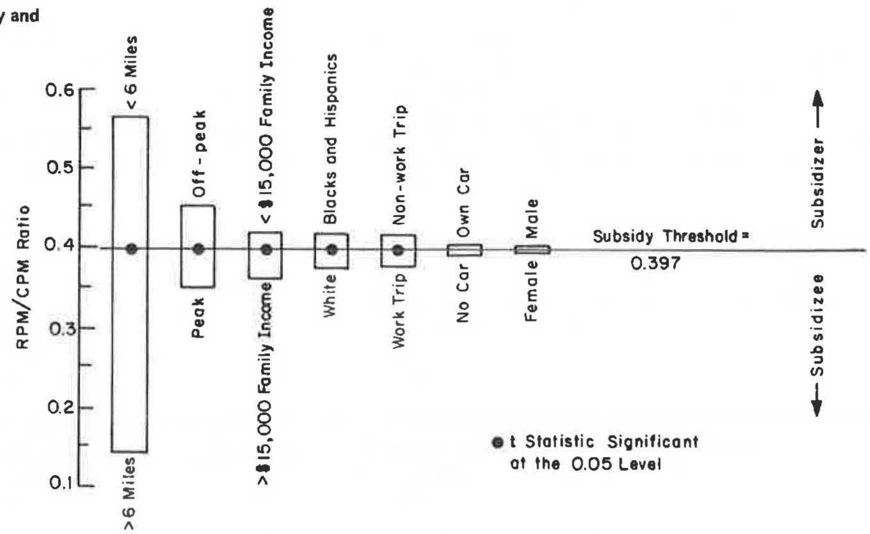
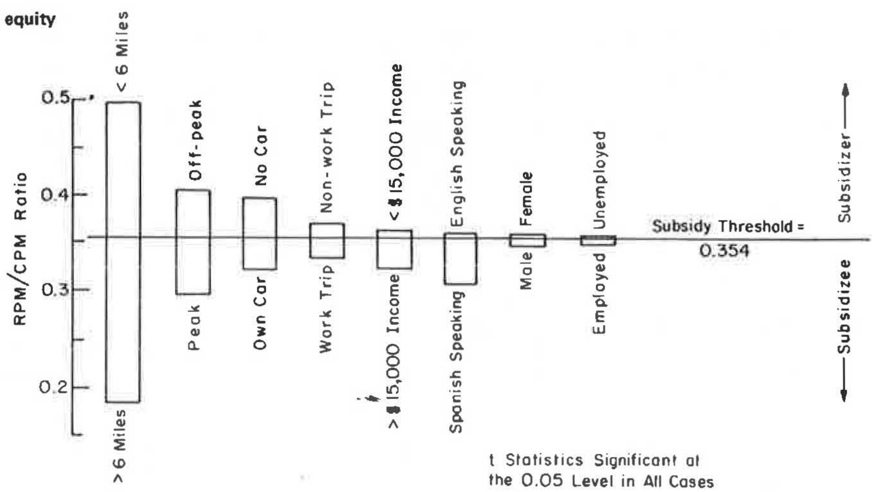


Figure 5. Ordering of SDTC efficiency and equity factors.



of differentiated transit pricing maintain that the riding public will never accept anything other than simple fare concepts. Clearly, the development of a mechanized fare-collection analog to San Francisco's Bay Area Rapid Transit and Washington, D.C.'s subway systems for use on rubber-tired vehicles will test our ingenuity. Europe's success with differentiated pricing of bus services provides the U.S. transit industry with a rich exemplar of possible fare-collection innovations. There, transit agencies have pioneered the use of on-board ticket dispensers and cancellers, curbside ticket-issuing automats, and roving fare-inspection programs to institute and enforce graduated pricing of transit services. Perhaps U.S. attitudes toward differentiated pricing of bus services will improve as consumers grow accustomed to the automated fares of rapid rail transit in large cities and as such pricing arrangements as weekend car rental discounts, night-coach airline saver fares, and reduced long-distance telephone rates during nonbusiness hours gain acceptance in other industries. With transit costs steadily increasing in the wake of possible government cutbacks in subsidy programs, more than ever, it is incumbent on today's transit officials to develop necessary fare-collection systems and marketing programs that will accommodate and promote more-efficient pricing structures.

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Transit Fare Prepayment Innovations in Sacramento

MICHAEL HOLOSZYC AND BETH F. BEACH

In October 1977, the Sacramento Regional Transit District received a demonstration grant from the Urban Mass Transportation Administration to expand its monthly-pass program to include employer sales outlets. Although employers showed little interest initially, a temporary promotional discount and a general advertising campaign eventually induced more than 60 firms to sell passes to their employees. The program generated modest increases in pass use and transit ridership. Other benefits included improved cash flow, relatively low administrative costs for both the transit operators and participating employers, and a possible enhancement of ridership retention and commitment. Both the employer program and the general fare prepayment concept became very popular with the Sacramento Regional Transit District. The district has since increased the relative discount of monthly passes compared with daily cash payment and has proposed a new 2-year demonstration to determine which fare prepayment methods are most cost effective.

Transit fare prepayment--the purchasing of transit rides prior to using the service--is offered by almost every transit system in the country. The most common prepayment techniques are passes, allowing unlimited transit use during a specified period of time, and tickets (or tokens) that are valid for individual rides. These prepayment instruments are usually sold by the transit operator and sometimes at government offices, banks, and retail stores. Transit operators offer fare prepayment programs because they enhance the convenience of using transit and their administrative costs are relatively low.

Recently, there has been a growing interest among transit operators in expanding their fare prepayment programs. An important innovation has been the sale of monthly passes or tickets by employers, paralleling the emphasis that carpool programs have placed on employer promotion. Four years ago, there was only a handful of employer pass programs, but a survey conducted by the American Public Transit Association (APTA) in April 1980 disclosed more than 30 such programs today.

One of the pioneers in this field has been the Sacramento Regional Transit District (RT). Assisted by service and methods demonstration funding from the Urban Mass Transportation Administration (UMTA), RT began an employer pass program in 1978 that today includes more than 50 employers. Other innovations involving monthly passes were also implemented, and a follow-up demonstration has recently been proposed. During the next 2 years, RT will introduce new prepayment instruments and several new distribution systems, including mail and telephone ordering, vending machines, credit card sales, and direct account transfers through banks. Each of these will be evaluated to determine their relative cost-effectiveness.

INITIAL DEMONSTRATION

The first demonstration's primary objective was to get public and private employers to sell monthly transit passes to their employees, thereby increasing pass use. RT had already been selling the monthly pass to the general public at 35 locations, including 2 outlets operated by RT, 4 government office buildings, 6 retail stores, 20 banks, and 3 colleges. Since a fare change in September 1976, the monthly pass has offered a substantial discount over on-board cash payment for the daily commuter (14 percent between 1976 and 1979, and 20 percent after September 1979 based on 40 rides/month). Consequently, about 20 percent of all riders (and 60 percent of the daily bus commuters) were already using monthly passes when the demonstration began.

Preliminary demonstration activities began in November 1977, and employers were actively solicited to sell passes from March through October 1978. The first employer began selling passes in May 1978, with most employers beginning pass sales in the fall of 1978. During the demonstration, employers promoted pass sales in various ways. RT encouraged employers to sell passes through payroll deduction and to subsidize the cost of passes for their employees.

IMPLEMENTING EMPLOYER PASS SALES

Employer Solicitation

Initial employer contact was done with an introductory letter from the RT general manager. This was followed by a telephone call from an RT representative during which more information on the program was supplied. If an employer expressed interest, a meeting was arranged. At this meeting, the project manager presented and reviewed an information kit with the employer. The kit included a brochure on procedures, the forms to be used, a sample employee survey to be conducted three times during the demonstration, and marketing materials to encourage employee participation. RT also supplied the employer with the Bus Book, a collection of all RT route schedules and user information, and with specific transit service information for the employer's location.

RT also organized a booster committee comprised of 11 local government and business leaders. The booster committee's function was to help develop public awareness and generate employer participation. Two committee meetings were held, with the first one being used as the media publicity kickoff, which was covered by local television, radio, and newspapers. Formal endorsements of the program were obtained from each of the committee members.

Employer Response

The employer response to the initial solicitation efforts was disappointing. Of the more than 140 employers contacted, only 10 agreed to participate. The major reason for employer disinterest was the feeling that few of their employees used the bus, so that it would not be worthwhile to establish a program. Other reasons given by employers were that their working hours started and ended when RT offered little service, that RT provided poor service to their workplace even during peak periods, or that their employees needed their cars during work hours. Several employers were initially interested but, after taking an informal survey of their employees, found insufficient interest to warrant participation. A few were discouraged by possible administrative costs or had a company policy that did not permit involvement in what they perceived to be employees' personal concerns. Several employers also saw little benefit to their employees since the passes were already available at numerous public outlets.

Expanded Promotions

After two months, it was apparent that employers did not perceive the pass program to be sufficiently beneficial to induce their participation. As a result, RT made two major changes to the program. First, the originally planned one-month 25 percent discount for employer-sold passes was expanded to three months, and rescheduled to earlier in the demonstration. Second, the solicitation effort began to be directed at employees under the hypothesis that employers would be more responsive to employee pressure to join the program than to RT's solicitations.

The first technique used to create employee interest was a brief on-board survey of all morning peak-period bus riders. This survey, conducted in June 1978, simply described the employer pass program and requested the name of the rider's employer. RT had three reasons for conducting this survey. First, it made the riders aware of the program and its potential benefits to them, which would hopefully result in inquiries to their employers who would then call RT. Second, RT hoped to identify new employers who had substantial numbers of bus-riding employees. Third, RT hoped to produce evidence showing that there were in fact bus riders from those firms where the managers were skeptical regarding employee bus use.

The survey resulted in many employers and employees contacting RT for information on the program, and RT had little need to use the survey results to find new employers. About 10 of the employers starting pass sales in September, October, and November did so as a result of the interest generated by the survey.

The new solicitation approach also included an advertising campaign directed at the general public. Conducted during August and September 1978, this campaign included newspaper ads, interior and exterior bus advertisements, and ads on bus benches. The initial advertisements were teaser ads with the question, How would you like a $198 a month raise? This was followed a week later by "Ask your employer about the RT PASSport Program or call 444-BUSS for more information." The $198 figure was the difference between the average monthly cost of automobile travel, calculated by the California Department of Transportation, and the cost of an RT bus pass. Later advertisements also stressed the 25 percent three-month discount and listed firms already signed up, thus encouraging others to join the bandwagon. In addition to the advertising, RT ran radio public-service announcement spots, the RT project manager appeared on two local television talk shows in August and September, and local newspapers and magazines ran feature articles on the program following several press releases.

Results

The new solicitation approach greatly increased employer interest in the program. Forty-two employers began pass sales in September, October, and November, compared with 11 firms between May and August. The demonstration goal of 30 participating employers was greatly exceeded, and RT was forced to institute two restrictions on future employer eligibility in order to limit its administrative costs. First, employers had to commit themselves by October 15 in order to receive the 25 percent discount during October through December. Second, any employers signing up after that time had to guarantee that at least 10 bus passes would be sold each month. Prior to this, RT accepted any employer regardless of their size or the quantity of passes they were able to sell each month.

Although the new solicitation approach was extremely successful in terms of generating employee interest and increasing the number of participating employers, the 25 percent discount had one drawback: RT received considerable criticism for applying a selective discount that benefited only part of the population. From the time the discount was publicly announced in mid-September until the end of October, RT received numerous complaints that the program was unfair to those who were ineligible. RT estimated that 30-50 telephone calls were received daily during that period that were either complaints as to the fairness of the discount, employees wanting a refund because they had purchased their pass at a public outlet for full price instead of from their employer, or employees checking to see if their employer was participating. Pass sales figures suggest that many ineligible employees had others buy discount passes for them. In fact, more than one-half of the passes sold during the discount were through employers.

CHARACTERISTICS OF PARTICIPATING EMPLOYERS

Initially, employers were to have been selected based on a careful screening procedure designed to obtain a representative sample according to the number of employees, transit availability, type of industry, geographic location, and parking availability. However, because of the poor response to

Table 1. Characteristics of participating employers.

Characteristic	Percentage
Type of industry	
Government	58
Finance and insurance	15
Retail trade	8
Hospitals	6
Other services	6
Manufacturing	4
Wholesale trade	2
Public utility	2
Size	
1-49 employees	12
50-200	40
201-999	23
≤1000	25
Location and level of transit service	
CBD	67
NonCBD but served by three or more routes	13
Served by one or two routes	19
Parking availability (off-street spaces provided/ employees)	
None	17
0.01-0.25	37
0.25-0.50	22
0.50-0.75	11
0.75-1.00	4
1.00-1.25	9
Perceived parking availability by employer (including available on-street spaces)	
Inadequate	69
Adequate	31

initial solicitation efforts, the program was open to all employers.

Table 1 shows the distribution of participating employers according to type of industry, size, location, and parking availability. Government agencies comprised the majority of participating employers and, because they were generally larger than the participating private firms, included more than 80 percent of the eligible employees. The preponderance of government employers in the program partly reflects their greater propensity to participate but in large part is due to the unique characteristics of Sacramento, where most of the large central business district (CBD) employers are state government agencies. Employers in the CBD were more likely to join the program since these employers received the best transit service and were also least likely to have sufficient employee parking.

PASS SALES METHODS

Three methods of pass sales were used by participating employers: over-the-counter, payroll deduction, and subscription. For over-the-counter sales, the employer ordered the quantity of passes it anticipated selling and sold them individually from the 25th of the month preceding the month for which the pass is used through the 5th of the month. For payroll deduction, the cost of the pass was deducted from the employee's paycheck. Some employers required the employee to sign up for the payroll deduction in advance and ordered only the number of passes specifically authorized by employees. Other employers ordered a larger quantity of passes and took the deductions after distributing passes to employees who wanted them. Under the subscription method, employees signed up in advance for the pass, the employer ordered the specific number requested, and employees paid for the passes with cash or checks on receipt of the pass. Under all three methods the employer forwarded all unsold passes and money received for sold passes to RT on the 6th of the month.

Almost 80 percent of the participating employers sold passes over-the-counter. Employers generally rejected payroll deduction because of the higher administrative costs required for this method. Payroll deduction also proved to be unpopular among employees: Among CBD employers, those employers selling passes by payroll deduction sold about 20 percent as many passes per employee as firms selling passes over-the-counter or by subscription. The extra effort required to order and cancel passes seemed to make payroll deduction an undesirable payment method. The required advance notice also acted as a deterrent.

SUBSIDIES AND ADMINISTRATIVE COSTS

Seven employers subsidized the cost of passes for their employees. Three employers provided 100 percent subsidies, three provided 50 percent subsidies, and one subsidized up to 42 percent of the cost during the first two months of pass sales as a start-up promotion. By contrast, one-third of all employers provided free employee parking, and one-half charged well under the current market price for parking. (Most of the latter group were state agencies, which charged $10.50/month for parking compared with public rates of $20 and up.) The remaining employers did not provide parking.

Participating employers were asked to record monthly expenditures associated with pass sales through June 1979. Costs were roughly proportional to the number of passes sold, rising by about $0.50/pass sold. Employers almost unanimously perceived these costs to be negligible. RT's administrative costs for the pass program (including both public and employer outlets), were about $0.16/ monthly pass sold during the first year of the demonstration. Following an administrative reorganization of the pass program in mid-1979 and the start of the county welfare distribution of passes in March 1980 (which greatly increased total pass sales), the administrative costs per pass dropped to about $0.10, or about $0.03/bus trip made with the passes.

EMPLOYEE RESPONSE

Monthly-Pass Sales

Employer pass sales began while monthly-pass sales at regular outlets were still rising (Figure 1). The growth, while continuous, was punctuated by a strong seasonal pattern. Sales during December, January, and the summer months, when people took vacation, were notably lower than other months. By comparing sales totals with the same month in the previous year (Figure 2), the seasonal effects were eliminated, and a consistent predemonstration growth pattern emerged. At the time that employer pass sales began, pass sales were growing at an approximately 30 percent annual rate, but the rate of growth was decreasing.

Spurred by the three-month 25 percent discount in the fall of 1978, pass sales rose significantly during the demonstration. Among employees of firms selling passes, there were about three times as many first-time buyers during the discount period as would normally occur, and pass use by this group rose by 89 percent. This caused total systemwide pass sales to increase, and during the last month of the discount, sales were 26 percent above the existing sales trend extrapolation. As discussed later in the article, only part of this increase was due to new transit riders; most of the new pass users previously rode the bus but paid cash fares.

The three-month discount, limited to employer-sold passes, was also responsible for shifting where

Figure 1. Monthly-pass sales.

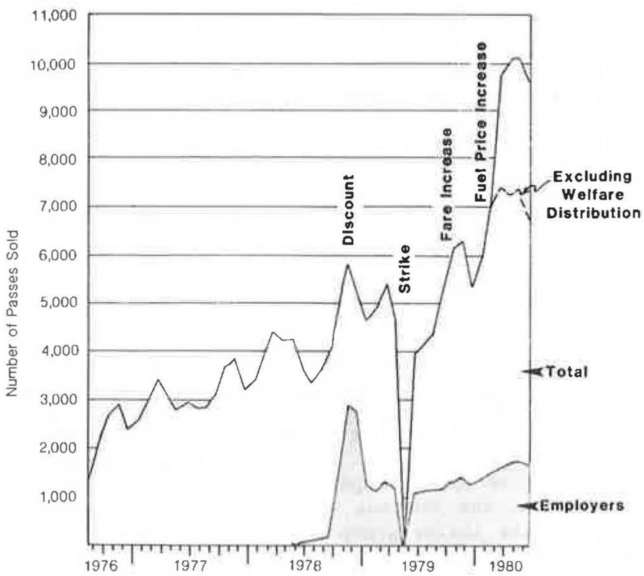
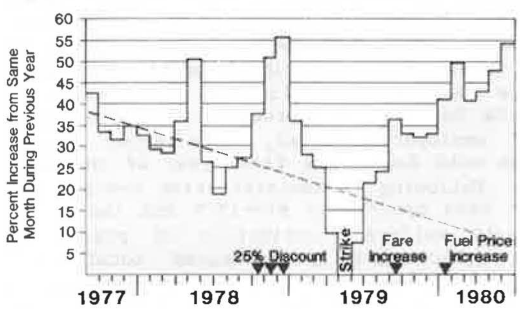


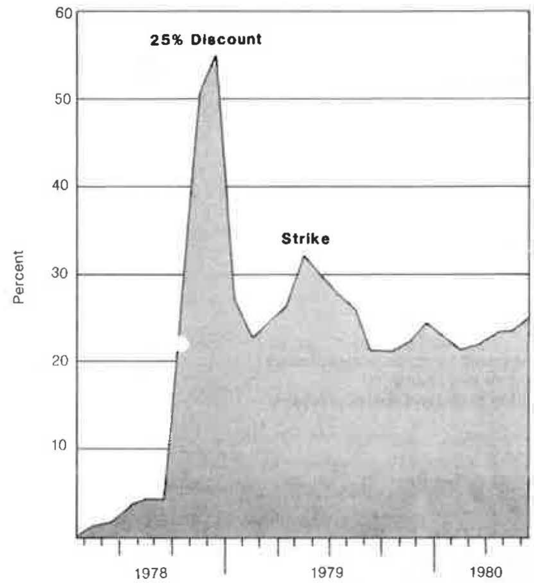
Figure 2. Increases in pass sales (excluding welfare distribution).



employees purchased passes. At the 17 employers who were selling monthly passes before the discount, pass sales at those firms more than tripled during the discount. Prior to the discount, about one-third of the employees purchasing passes bought the pass at their work place. During the discount, almost all bought the pass at work, while after the discount, about three-quarters of the employees purchasing passes continued to buy their passes at work.

Although the number of passes sold by employers dropped by 50 percent following the discount, employer-sold passes have continued to comprise about 25 percent of all monthly passes sold, excluding county welfare pass distribution (Figure 3). Furthermore, the employer pass program has caused total pass sales to be 6 percent higher than would otherwise occur. This conclusion is derived from a comparison of pass sales following the discount with the prediscount sales trend extrapolation. Only five-month data (January-March and July-August 1979) are considered, because April-through-June sales were depressed by the 24-day transit strike in April and May, and a fare increase in September 1979 changed the relative discount of passes versus daily cash payment (14.3 percent to 20 percent, based on 40 trips/month). Following the fare change, total pass sales rose an additional 10 percent, and the sharp gasoline price increases in January 1980 appear to have increased pass sales an additional 8 percent.

Figure 3. Percentage of total monthly passes (excluding welfare distribution) sold by employers.



Transit Ridership

Information on travel behavior and transit ridership changes induced by the demonstration is derived from three comprehensive employee surveys conducted in May-October 1978 (before an employer joined the program), in December 1978 (during the discount), and in August 1979 (after the discount). Altogether, more than 11 000 survey responses were tabulated.

Almost 15 percent of the persons buying discounted monthly passes at work were new transit users. However, about one-third of these new users would have bought passes anyway as part of the usual turnover of people who use transit. Altogether, a 9.5 percent increase in transit ridership occurred during the discount period among employees of participating firms. About a 7.5 percent increase was attributed to the new transit riders and a 2 percent increase resulted from former cash-paying riders using transit more often now that they had passes. Altogether, the increases caused an estimated 1.6 percent increase in systemwide transit ridership.

In the first few months after the discount, the increased trip making by former cash-paying customers had mostly ceased, but there was an approximate 60 percent retention rate for new transit riders attracted during the discount. This rate was about the same as the retention rate for those who started using transit at other times, as part of the normal turnover of transit ridership. The overall residual ridership impact of the demonstration, then, was a 4.5 percent increase among eligible employees. This represents a 0.7 percent increase in systemwide ridership.

Revenue Impacts

The three-month 25 percent discount on monthly passes resulted in an estimated 11.4 percent decline in transit revenues from employees of participating organizations. The estimated dollar loss in revenue over the three months of the discount was just under $12 000. However, this revenue loss was made up in about six months by new users attracted by the discount, and an estimated $18 500 in extra revenues from these new riders was estimated to result over the following year. The discount was thus economically beneficial in the long run.

Fare Prepayment and Transit Commitment

One unexpected result of the employee surveys was the extent that individuals started and stopped using transit. Among employees commuting by transit and still working at the same location 16 months later, 30 percent had stopped using transit. Since transit ridership was growing slightly over this period, this group was replaced by a slightly larger group of new riders.

Limited data suggest that monthly-pass users were a little less likely to stop using transit than daily cash payers. Based on a sample of 140 regular bus commuters, the dropout rate after 16 months was 33 percent for cash payers, compared with 27 percent for monthly-pass users. However, the difference was not statistically significant, and the results are therefore not conclusive. Given the extremely high turnover rates for transit use, the issue of whether fare prepayment enhances rider retention is an extremely important one and deserves further investigation by researchers.

OTHER INNOVATIONS DEVELOPED

Besides employer pass sales, several other innovations were developed and tested during the first Sacramento demonstration.

Commercial Discounts for Transit Pass Users

In May 1979 the first commercial discount for pass holders was arranged with the Sacramento Jazz Festival, a Memorial Day weekend event. Discounts worth $12, the full cost of the bus pass, were available to all holders of May and June 1979 monthly passes. Unfortunately, the RT strike limited the effectiveness of the promotion, and only about 40 persons took advantage of the offering. A second commercial discount was negotiated with the California State Fair in August 1979. Each pass purchaser received a $0.50-coupon good toward general admission to the state fair. Of the approximately 6700 coupons distributed, 227 were ultimately cashed in. The third commercial discount was with the Circus Vargas in May 1980. Each pass purchaser received a coupon worth $2.00 toward purchase of a Circus Vargus ticket. Results from this promotion are unavailable. The state fair discount will be repeated in 1980, and RT is trying to repeat the other discounts and establish additional commercial discount programs. The concept is attractive to commercial ventures because they get substantial free publicity, and the discount is made available to a group that is less affluent than the overall public.

State Employee Payroll Deduction

RT designed a legislative bill that would allow a payroll deduction for all California state employees for any monthly transit prepayment instrument. The bill went into effect January 1, 1980, and is currently going through legislative interpretation. RT is working with the state controller's office to establish the procedures for the program.

Welfare Distribution of Passes

As part of Sacramento County's general assistance program, the county purchases an RT monthly bus pass for each welfare recipient. This program began in March 1980 and has resulted in almost 3000 additional pass sales per month, boosting total pass sales by about 40 percent. The county also purchases RT bus tokens for persons who start receiving welfare assistance between the 16th and the end of the month. The exact fiscal impact of this program is unknown, but it seems likely to have generated a significant net revenue increase for RT.

Passes as Fringe Benefits

RT is currently working on a plan with several government agencies to have a transit pass as an employee fringe benefit. The success of this proposal will be determined in the coming months.

New-Home Buyer Promotion

In 1980, a major residential developer agreed to provide a roll of bus tokens (worth $10) and area-specific transit information to all purchasers of new homes. This will introduce new residents to the transit service available in their neighborhood. RT is now trying to enlist other developers and real estate agents in this program.

NEW DEMONSTRATION

A new 2-year UMTA-funded demonstration has been proposed to follow the first demonstration. During these 2 years, existing prepayment programs will be expanded, and additional distribution methods will be tested and evaluated. The new demonstration's objectives are to further increase the availability of fare prepayment instruments and to determine the relative cost-effectiveness of different sales methods. Specific tasks to be undertaken include the following:

1. Development of 10- and 20-ride ticket booklets to supplement the monthly pass (Employee surveys during the first demonstration found that for every five people commuting by bus five days a week, and likely to buy a monthly pass, there are four persons who ride one to four days a week, and are unlikely to buy a pass. Discounted ticket books can reach this large market);
2. An expansion of public pass-sales outlets, maintaining RT's policy of not paying sales commissions;
3. Expansion of the employer pass-sales program;
4. Implementation of mail-order pass sales with payment by check or credit card;
5. Implementation of telephone sales with credit card payment;
6. Implementation of direct bank account transfers as a payment technique; and
7. Use of vending machines at major activity centers to sell prepayment instruments.

CONCLUSIONS AND IMPLICATIONS

The results of the Sacramento monthly-pass program have led to several conclusions regarding fare prepayment and employer pass sales. Although the ridership impacts of the demonstration were modest, several additional benefits of fare prepayment have made the Sacramento Regional Transit District a strong supporter of fare prepayment.

Operations and Cash Flow

RT perceives an improved cash flow situation as a result of fare prepayment. Revenues are generated early in the month, and cash flow over the month can be more accurately projected. RT also views fare prepayment, including future ticket sales, as the means by which customer use of dollar bills in fareboxes can be eliminated. Such current use results in a considerable inefficiency in revenue collection.

Transit Commitment

RT feels that monthly-pass users, particularly persons purchasing their passes at work, are more committed to transit than cash users. Several demonstration findings support this belief, although the evidence is not yet fully conclusive. First, cash payers who bought passes during the 25 percent discount increased their transit use by 10 percent. Second, among regular transit users surveyed over a 16-month period, pass users were slightly less likely to stop using transit than cash users. Finally, pass users, and particularly pass users buying their passes at work, were quickest to return to transit following the May 1979 strike.

Since almost 30 percent of Sacramento's regular transit riders stop using transit each year, any strategy that lowers this dropout rate even slightly is highly desirable. In recognition of this, RT increased the relative discount of monthly passes compared with daily cash payment in September 1979, when all fares were raised.

Administrative Costs

The costs of administering the monthly-pass program were perceived by both the transit operator and the individual employers to be small. RT's administrative costs totaled only about $0.03/bus trip taken with a pass (exclusive of special demonstration costs). Through the results of the second demonstration, RT hopes to further reduce this figure. While the unit costs incurred by employers were higher ($0.50/pass, or about $0.01/bus trip), only a handful of the more than 60 firms that participated in the program felt that their costs were significant.

Recruitment of Employers

The initial recruitment of employers to sell passes proved to be extremely disappointing, with few employers viewing the program as beneficial. The Sacramento experience demonstrated that a strong incentive is necessary to induce employer involvement. Generating employee interest, rather than appealing only to management, is also very helpful. Little success can be expected if a transit operator only appeals to an employer's social conscience, even if the employer heavily subsidizes employee parking, as was the case for most Sacramento employers.

Payroll Deduction

The initial demonstration plan called for employers to sell passes by payroll deduction, but this requirement was subsequently relaxed, and the vast majority of firms sold passes over-the-counter. Payroll deduction was viewed as a burdensome technique, and few employers offered it. Among those who did offer payroll deduction, pass sales per employee were 15-20 percent of those occurring at firms selling passes over-the-counter. The implied long-term commitment of signing up for payroll deduction discouraged pass use, and this sales technique is not very promising for transit fare prepayment.

Pass Sales and Ridership Impacts

Although monthly-pass sales and transit ridership increased substantially over the course of the first demonstration, much of the increase can be attributed to two exogenous events that occurred during this time: a fare restructuring that decreased the relative cost of passes and an increase in gasoline prices that encouraged transit ridership. Nevertheless, the employer pass program, including the three-month 25 percent discount, caused a long-term increase in total monthly-pass sales of 6 percent. Transit ridership among participating employees rose by 4.5 percent, resulting in an 0.7 percent increase in systemwide ridership. While these gains are not spectacular, the additional revenue that they brought in far exceeded the lost revenue due to the three-month pass promotion discount.

ACKNOWLEDGMENT

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Factors That Influence Choice Among Transit Payment Methods: A Study of Pass Use in Sacramento

ELIZABETH PAGE

During the 1960s, as exact change requirements were instituted on most transit systems, many operators developed transit fare prepayment (TFP) programs as a convenience to their passengers. In recent years, operators have broadened their views of these programs and attention has focused on identification of the market for TFP, determination of the magnitude of any benefits realized by purchaser or operator, and development of ways to promote its use. In this paper, a choice model is developed and estimated to explain the factors that influence a transit rider's decision to purchase a monthly pass or to pay cash fare on a daily basis. The population under study is a sample of employees at worksites participating in an Urban Mass Transportation Administration service and methods demonstration project of employer-sponsored pass sales. The estimation results indicate that the initial cash outlay required to purchase a

monthly pass may be a deterrent to its use by some persons with limited incomes. The most important determinant of all transit rider's choices between paying cash fare and buying a pass is the relative cost of the two payment methods. Low-income persons are more sensitive than high-income persons to the savings that can be realized when a pass is used.

During the 1960s, as exact change requirements were instituted on most U.S. transit systems, many operators developed transit fare prepayment programs as a convenience to their passengers. Transit fare prepayment (TFP) encompasses all methods of paying for transit trips before they are actually taken and includes passes, tickets, punch cards, and tokens. As of 1976, 93 percent of U.S. transit systems use some form of TFP instrument and many systems offer a wide variety of prepaid plans.

Generally, prepaid instruments fall into two categories--those that allow an unlimited number of transit boardings within a specified time interval and those that allow a specified number of boardings over an unlimited period of time. The first type--passes--varies in duration from one day to one year and may carry time-of-day restrictions. Tickets, punch cards, and tokens--the second type--are commonly sold in various denominations (e.g., single-ride, 20-ride).

When tickets, punch cards, and tokens are not discounted in price relative to cash fare, the attractiveness of the payment method to the purchaser is due to the convenience of not having to carry exact change and to the ability to budget for transit trips over a desired time interval. Passes, on the other hand, offer a potential discount to the purchaser. The savings (relative to cash fare) that are realized by a purchaser will depend on the frequency of use within the time period--the more the pass is used, the lower will be the cost per trip. The transit rider, then, in deciding whether or not to purchase a pass, must weigh his or her expected discount (based on anticipated transit use) against the probability that actual transit use will be less than the break-even level. Therefore, the pass purchaser bears a set of risks. Actual transit use may be less than expected due to illness, weather conditions, family matters, and so forth. On the other hand, external factors may also cause actual transit use to be greater than expected, resulting in the realization of unanticipated savings. In addition to the potential discount that they provide, passes also eliminate the need for exact change and serve as a budgetary mechanism for transit trips.

In recent years, operators have broadened their view of prepayment programs. Instead of being considered solely as a convenience item for riders, transit fare prepayment is also being viewed as a marketing mechanism for transit. TFP users may exhibit a stronger commitment to transit than do cash payers and may be more likely to continue using it regularly. Since the marginal cost of an additional bus trip is zero when a pass is held, pass purchasers may use transit more frequently than do cash payers. In addition to these ridership benefits, TFP has been associated with improved cash flow and lower cash management costs for the operator, shortened boarding times, and heightened public awareness of transit. Consequently, attention has focused on identification of the market for TFP, determination of the magnitude of any benefits realized by purchaser or operator, and development of ways to promote its use.

The Office of Service and Methods Demonstrations of the Urban Mass Transportation Administration (UMTA) has sponsored a number of demonstrations in recent years that were designed to address these questions. In Austin, Texas, and Phoenix, Arizona, the impacts of short-term price reductions on longer-term purchasing behavior, transit riding, and the transit operator were examined. In Tucson, Arizona, marketing efforts are being directed at university students--a group felt to be particularly receptive to transit and to prepayment. Finally, demonstration projects in Jacksonville, Florida, and Sacramento, California, tested the viability and effectiveness of enlisting the support of employers in selling and distributing monthly passes at the work place. Data from the Sacramento project were used in this study of the factors that influence a transit rider's decision to purchase a monthly pass.

SITE AND DEMONSTRATION PROJECT DESCRIPTION

Sacramento is a rapidly growing, low-density city of 262 000 persons. A key feature of the area is a heavy reliance on public employment. Two U.S. Air Force bases are located in Sacramento; consequently, it has twice as many government workers as the national average and relatively little manufacturing employment. Personal income in Sacramento is higher than the national average, as is automobile ownership. Public transit use is low compared with cities of comparable size, although transit ridership roughly doubled during the mid-1970s. An extensive freeway system provides fast automobile travel.

Sacramento's Regional Transit (RT) uses 223 buses to transport approximately 45 000 passengers/weekday. During the demonstration period the base fare was $0 35, and riders from several outlying cities were charged $0.50 inbound and $0.35 outbound. Monthly passes and individual ride tokens were sold at 35 outlets throughout the Sacramento area (e.g., banks, schools, stores), and daily passes could be purchased on board the buses. Table 1 gives the fare structure prior to September 1979.

RT's monthly pass is transferable--purchasers are permitted to lend their passes to family members or friends when they are not using it. The break-even trip frequency for both base and zonal monthly passes was 34. Any additional trips taken with the pass resulted in an average cost per trip that was below the standard fare. A pass purchaser who commuted to and from work every day by bus and took no additional trips realized a 14 percent savings over cash fare. Approximately 20 percent of all boarding passengers show a monthly pass.

Although there are no free or reduced-cost transfer fares, a passenger making a round trip by transit can purchase a daily pass (with exact change) when boarding the bus and thereby obtain free transferring privileges. Persons using daily passes can be assumed to be those using the pass for convenience only, those having to transfer, and those boarding the bus more than twice that day. Since the time interval over which the trips must be taken is so short and the cash outlay is so low, daily-pass purchasers bear little risk of not making the anticipated number of trips and breaking even.

The Sacramento demonstration involved the solicitation of 52 employers to participate in the distribution of monthly passes at the work place. A three-month discount of $3.00/pass was offered at the beginning of the program to generate employer participation and to stimulate employee interest. Few employers chose to subsidize the pass or to permit payment through payroll deduction. Evaluation issues concerned the effectiveness of employer-sponsored pass distribution in attracting new transit users, inducing cash payers to switch to passes, and increasing transit ridership. Sacramento was also considered an excellent site in which to study the factors that determine a transit

Table 1. RT fare structure.

Type of Fare	Cost ($)
Cash fare	
Base	0.35
Youth, elderly, and handicapped	0.15
Outlying cities (inbound only)	0.50
Tokens	0.35
Daily pass	
Base	0.70
Youth, elderly, and handicapped	0.30
Outlying cities (inbound only)	0.85
Monthly pass	
Base	12.00
Elderly and handicapped	3.00
Outlying cities	15.00

rider's choice between purchasing a monthly pass or paying cash fare.

DATA

The data used in this study were obtained in a self-completion mail survey of employees at participating employers conducted in late August 1979. Survey forms were distributed at 28 firms that had been selling passes for approximately 1 year. Of the 22 130 surveys distributed, 4556 were returned--resulting in a response rate of 20.6 percent.

Since the decision of whether or not to purchase a pass or to pay cash fare is relevant only for those who have already made the decision to travel by transit, the sample was first reduced to study of the 1104 respondents who reported that they ride the bus at least once per month. Second, transit riders who normally purchase tokens or daily passes were culled from the data set. Finally, when all individuals who had missing data for any of the relevant variables were excluded, a sample of 732 respondents remained.

MODEL

Econometric methods were chosen instead of cross-classification techniques for analysis of the payment method decision because they permit apportionment of the variance in purchasing among a host of relevant variables. By explicitly controlling for multiple influences, the multivariate approach is better than cross-classification for testing hypotheses regarding causality. The coefficients of the model indicate the marginal contribution of the independent variables to the variance in the dependent variable. When formulated on a sound theoretical basis, an econometric model can be used to explain and, ultimately, to predict phenomena such as pass-purchasing behavior. The objective of this study was to develop sound explanatory econometric models of pass-purchasing behavior.

The model specified for this study was of the binary logit structural form with alternatives corresponding to "normally purchases a monthly pass" and "normally pays cash fare." The model was estimated on a sample of transit riders whose employers sell monthly passes at the work place and who normally buy a monthly pass or pay cash for their transit trips. The model form estimated for the study was $\text{Prob(Pass)} = 1/[1+\exp(U_c-U_p)]$ where U_c refers to utility associated with paying cash and U_p refers to utility associated with using a pass.

The logit model is particularly well-suited to this analysis. The basic axiom of behavioral disaggregate choice theory is that the individual, the decision-making unit, chooses from a set of discrete alternatives the one with the greatest attractiveness, or utility. This choice process is appropriate in analyzing a transit rider's decision regarding fare payment method. The individual evaluates the convenience and the relative cost of each method and chooses the one that is most attractive. An individual's observed choice, then, may be explained by the attributes of the alternatives and selected characteristics of the individual. Of the available disaggregate choice models, logit is theoretically appealing and relatively easy to estimate. It permits evaluation of the impacts of various policies--for example, pass price, on the share of transit riders who use passes and pay cash. Elasticities of the probability of purchasing a pass with respect to included variables are also obtained.

UTILITY FUNCTION

It was postulated that an individual's decision regarding purchase of a monthly pass would be strongly influenced by the anticipated savings relative to cash fare. Those who would save money by using a pass are more likely to buy one than are those who would not save money. Ideally, construction of such a variable would include information regarding an individual's expected use of transit over the coming month. This information was not available from the employee survey. Respondents were asked to report their transit trip frequency for work and nonwork purposes during a normal week, and this frequency was multiplied by 4.3 and used as a proxy variable for anticipated frequency. The variables SAVPOS and SAVNEG were constructed by multiplying each respondent's number of monthly transit boarding times the base fare and subtracting the price of the pass. For those individuals who would realize positive savings with the pass, the value of the savings was included in SAVPOS and a value of 0 was assigned to SAVNEG. For those individuals who did not travel enough to make purchase of the monthly pass economical, the loss (a negative value) became the variable SAVNEG. A zero was assigned to SAVPOS.

It is important to note the shortcomings of employing reported trip frequency as a proxy for anticipated frequency. If holding a pass induces increased trip making, the trips are overvalued when they are multiplied by the base fare and included in the savings variables as determinants of payment method. This overvaluation may have been partially offset by excluding trips made by other persons with the purchaser's pass. It was felt that an individual's primary consideration in deciding whether or not to purchase a pass is the savings realized through his or her own trip making, not that of other persons. To the extent that trips made by one's family, friends, or coworkers are valued at some level greater than zero, the saving realized with a pass is understated.

Separate variables were entered into the utility function for negative and for positive savings because it was hypothesized that the magnitude of their effects on the probability of purchasing a pass would differ. It was expected that a unit increase in SAVNEG would have a greater impact on pass purchasing than would a unit increase in SAVPOS. Therefore, a positive coefficient for SAVPOS and a positive coefficient of greater magnitude for SAVNEG were expected.

As noted earlier, a prospective pass purchaser weights his or her expected discount against the probability that actual transit use will be greater or less than anticipated. Presumably the decision maker considers an anticipated trip frequency and recognizes that there is some variance associated with it. In formulating the model, an attempt was made to construct variables that would represent the effect of the variance of anticipated frequency on purchase choice. The percentage of total boardings for work trips was included for this reason.

An individual who uses the bus exclusively for work trips presumably has a smaller variance associated with anticipated trip frequency. The number of work trips required in a month can be easily predicted by the decision maker. The actual number of work trips taken can, of course, be less than anticipated due to illness or travel but will rarely exceed the anticipated number. Therefore, the decision maker can calculate the savings associated with pass use and bears only a small risk of actual transit use falling below the level. Similarly, there is little chance that actual use will be greater than anticipated.

On the other hand, an individual who uses the bus for both work and nonwork purposes has a greater variance associated with anticipated transit use. Although the individual bears a greater risk of actual transit use falling below the anticipated level, he or she also has the potential for reaping unanticipated windfall with a pass. The probability of making unplanned nonwork trips may serve as an inducement to buying a pass.

The ratio of work trips to total trips, WKRATIO, was therefore included in the model with its expected sign uncertain. If the first effect predominates, persons with higher work ratios purchase passes, and WKRATIO would exhibit a positive sign. If the second effect is dominant, however, persons who take a large percentage of nonwork trips purchase passes and the coefficient would have a negative sign.

Another variable that was formulated to represent the risk associated with purchase of a pass was the number of automobiles per household worker. It was hypothesized that the fewer alternatives available to a transit rider, the more likely he or she would be to make the anticipated number of trips by bus. Therefore, a negative coefficient was expected for CARSPW.

It has been suggested that the relatively large cash outlay required to purchase monthly passes may be a barrier to their use by low-income persons. In the Austin demonstration, 10 percent of the nonusers who were interviewed reported that the primary reason they did not use passes was "I can only afford to pay for one bus trip at a time." If the cash-outlay barrier is significant, the flow of benefits from monthly passes is regressive, accruing to those persons with higher incomes. To test the hypothesis that low-income persons are less likely to buy passes than high-income persons, a household income dummy variable was included in the model. Since the respondents to the survey were all employed, very-low-income persons were not represented in the sample. The binary variable INCD was assigned a 1 for individuals who reported a total household income of $15 000 or less, zero otherwise. A negative coefficient would support the notion that the cash-outlay requirement is a significant deterrent to pass use by lower-income persons. A positive coefficient would not support this hypothesis and would indicate instead that low-income persons are more sensitive to the savings that could be realized by using a pass and, hence, more likely to purchase one.

Finally, a male-female dummy variable was included in the model. There were no expectations as to the sign of this variable, but it was intended to represent household decisions regarding access to family automobiles. If primary workers (predominantly male) have primary access to the family automobile, presumably their transit trip frequency would exhibit greater variance than would the secondary worker's. On the other hand, if the secondary worker has primary access to the family automobile so that household-related trips may be made enroute to work, the secondary worker's transit trip frequency would exhibit greater variance. A significant coefficient on the dummy variable, MALE, could also indicate that males and females value the attributes to passes and cash fare differently.

ESTIMATION RESULTS

The model was estimated by the maximum likelihood method and the results are presented in Table 2.

As was expected, the savings variables are of primary importance in explaining transit riders' choices between fare payment methods. The elasticity for those persons who do not ride transit often enough to break even with a pass is greater than for those persons who would realize savings by purchasing a monthly pass. Therefore, a unit decrease in the price of a pass (hence, a unit increase in savings) will have a greater impact on the choices of those who have negative savings.

In Figure 1, the choice probabilities predicted by the model for a range of values of the savings variables are illustrated. In estimation of the function, all other variables were evaluated at their means, and a weighted average of choice probabilities for lowand high-income persons was taken. The figure illustrates, for example, that an individual exhibiting mean values of the other variables who rides the bus infrequently enough so that he or she would lose $6.00/month by buying a pass has a 12 percent probability of buying one. If savings were increased (by either a reduction in the price of the pass or an increase in trip frequency) so that the monthly pass cost only $3.00 more than cash fare, the probability of choosing it would rise to 28 percent. If the same individual rides transit often enough so that a $3.00 savings over cash fare would be realized by buying a pass, the probability that it is chosen is 60 percent. If savings were increased to $6.00/month, the probability of choosing the pass would increase to 68 percent. Also, if he or she reported making the break-even number of trips each month, the probability of selecting the pass over cash fare would be 51 percent.

The estimation results indicate that low-income persons are somewhat less likely to buy passes than high-income persons. This could be due to the relatively high initial cost being a deterrent to its use by some employees with limited incomes. However, the low significance of this variable (80 percent level of confidence for a two-tailed test) leaves this interpretation open to debate. In addition, the model reveals that males are much less likely to buy passes than females. Since the automobile-availability coefficient is not significantly different from zero, this reflects a fundamental difference in the way men and women value cost savings and convenience rather than the male's access to household automobiles. The ratio of work trips to total trips has a coefficient close to zero. As noted earlier, two competing effects, neither dominant, are likely to have produced the small coefficient. Those who have high work-trip ratios buy passes because they can closely predict the savings that will be realized. On the other hand, those who have lower work-trip ratios buy passes because their potential for increased savings is greater. The presence of both these effects in the estimation sample probably resulted in the small coefficient.

Despite the model's overall goodness of fit and the fact that most of the coefficients exhibited the expected signs, it was hypothesized that the utility

Table 2. A fare payment method choice model (binomial logit fitted by the maximum likelihood method) estimated on data collected in Sacramento.

Independent Variable	Estimated Coefficient	t-Statistic	Elasticity at the Mean
SAVPOS [monthly transit boardings times cash fare minus pass price (in cents)—positive values]	0.117	4.65	0.25
SAVNEG [monthly transit boardings times cash fare minus pass price (in cents)—negative values]	0.336	6.92	-0.35
WKRATIO (monthly work trip boardings divided by total monthly boardings)	0.054	0.113	-0.02
CARSPW (number of household cars divided by number of household workers)	-0.062	-0.454	-0.03
YDINC (1 if annual household income is ≤$15 000; 0 otherwise)	-0.264	-1.35	-0.14
MALE (1 if respondent is male; 0 if female)	-0.50	-2.81	-0.15
CONSTANT	0.412	0.762	

Notes: Likelihood ratio, 328.86.
Likelihood ratio index, 0.298.
Log likelihood for the model with the constant only, -551.58.
Log likelihood for the full model, -387.148.
Percentage correctly predicted, 76.
Number of people in sample who chose monthly pass, 363; cash fare, 369; total sample size, 732.

Figure 1. Predicted probabilities of pass purchase.

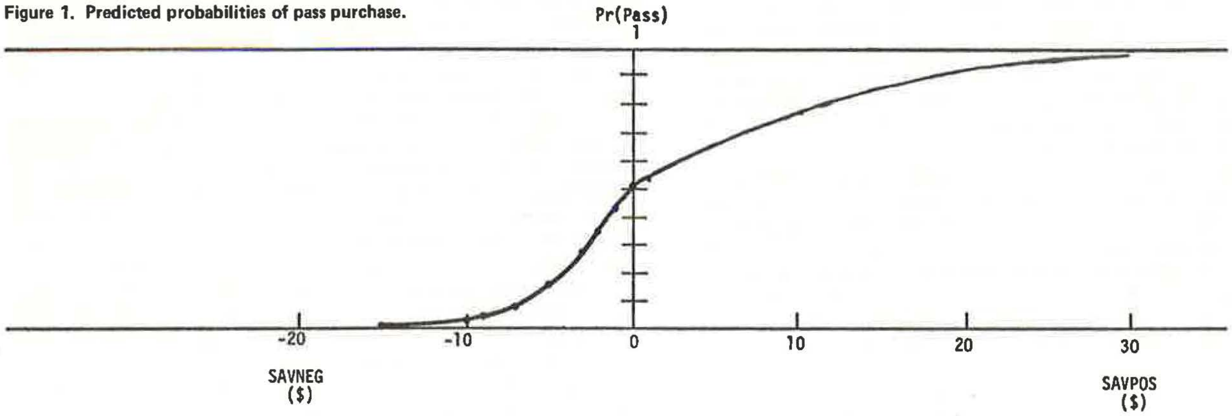

Table 3. Unrestricted fare payment choice model (binomial logit fitted by the maximum likelihood method) estimated on two income groups in Sacramento.

Independent Variable	Household Income per Year: ≤$15 000 Coefficient	≤$15 000 t-Statistic	≥$15 000 Coefficient	≥$15 000 t-Statistic
SAVPOS [monthly transit boardings times cash fare minus pass price (in cents)—positive values]	0.154	3.48	0.098	3.13
SAVNEG [monthly transit boardings times cash fare minus pass price (in cents)—negative values]	0.214	2.75	0.395	6.28
WKRATIO (monthly work trip boardings divided by total monthly boardings)	-0.122	-0.151	-0.012	-0.020
CARSPW (number of household cars divided by number of household workers)	0.131	0.475	-0.126	-0.796
MALE (1 if respondent is male, 0 if female)	-0.722	-2.14	-0.411	-1.93
CONSTANT	0.058	0.065	0.574	0.846

Notes: Log likelihood for the unrestricted model, -384.28.
Log likelihood for the restricted model, -387.15.
Likelihood ratio, 5.74, which is significant at the 95 percent confidence level.

Table 4. Elasticities at the mean for the unrestricted model.

Variable	Household Income per Year: ≤$15 000	≥$15 000
SAVPOS	0.38	0.18
SAVNEG	-0.18	-0.29
WKRATIO	-0.05	-0.01
CARSPW	0.04	-0.05
MALE	-0.19	-0.12

functions of low-income persons might differ in form from those with higher incomes, necessitating the estimation of separate models for the two groups. In particular, it was felt that low-income persons who could realize positive savings by purchasing a pass would be more responsive to small increases in savings than would other persons. Similarly, low-income persons for whom purchase of a pass is not economically practical were expected to be less responsive to small increases in savings than other persons.

To test this hypothesis, a model was estimated that relaxed the restriction that the value of the coefficients is the same for the two income groups. The model included a set of variables for low-income persons, which took on a value of 0 for high-income persons, and a set of variables for high-income persons, which took on a value of 0 for low-income persons. The results of this estimation are presented in Table 3. The elasticities of included variables, calculated at the means, are included in Table 4. The ratio of the log likelihoods for the former restricted model and this unrestricted model is significant at the 95 percent level of confidence, indicating that segmentation of the sample and estimation of separate coefficients for the two income groups contribute to the explanation of fare payment method choice.

As expected, the unrestricted model indicates that, at positive values of the savings variable, the low-income group is more than twice as responsive to changes in savings than the high-income group. At negative values of savings, the low-income group is less responsive. Coupled with the results obtained in the initial estimation, the models indicate that low-income persons are less likely to buy passes than those with higher incomes because of the high initial cost, yet they are more responsive to improvements in the cash savings that can be realized through its use. No other significant differences between the groups were revealed in the unrestricted model. The automobile-availability elasticities have opposite signs but, since the coefficients are not significantly different from zero, the elasticities should not be considered reliable.

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

The models estimated in this study provide some evidence that the initial cash outlay required to purchase a monthly pass may be a deterrent to its use by persons with limited incomes. The most important determinant of all transit rider's choices between paying cash fare and buying a pass is the relative cost of the two payment methods. Those who normally make more than the break-even number of trips in a month are more likely to buy passes than those who do not. Low-income persons in this group, even though they have a lower probability of purchasing a pass, are more responsive to improvements in the relative price of passes than are higher-income persons. Of those transit riders who do not use the bus often enough to make purchase of a monthly pass economical, the higher-income group is more responsive to improvements in the relative price of passes. Females are more likely to choose passes than males, reflecting a fundamental difference in the way the sexes value economy and convenience. It was hypothesized that transit riders who have ready access to other modes are less likely to buy passes because they perceive a greater risk of not making the anticipated number of trips and breaking even with a pass, but the models indicate that automobile ownership is not a significant factor in the payment method decision. Finally, a coefficient near zero was estimated for a variable that reflected work trips as a percentage of total trips, and it is suggested that two competing influences resulted in that outcome. Individuals who make almost exclusively work trips by bus buy passes because they can closely predict their actual transit use and savings to be realized with a pass. On the other hand, those who also use the bus for nonwork purposes buy passes because they have the potential for realizing unanticipated savings.

The insights into the fare payment method decision that were gained from the model are augmented by examining the reasons given by cash payers for their decision not to use passes. Of the study sample, 14 percent of the respondents gave reasons such as "I don't know much about them," "They are inconvenient to buy," and "I don't like to pay for transit rides that far in advance." A resounding 86 percent of the respondents stated that they do not buy passes because "I don't use the bus enough."

Closer examination of the 288 respondents who gave that reason reveals that 42 percent of them reported an average transit trip frequency higher than the break-even level. The savings over cash fare that could be realized by these 121 individuals range from $0.04 to $18.10; the mean is $2.74. Evidently a substantial number of transit riders fail to recognize that the monthly pass is the lower-cost alternative for them. To do so requires knowledge of the price of the pass, calculation of the break-even trip frequency, and comparison of the break-even level with expectations regarding future transit use.

Pass use then, could probably be increased significantly by developing marketing techniques that bridge the gaps in the transit rider's decision calculus. Instead of merely stating the price of the pass, advertising could stress that above the break-even point all rides are free. It is important to recognize, however, that raising the sophistication of riders concerning the break-even trip frequency and the savings function may have an adverse impact on system revenues.

From the standpoint of maximizing revenue, the best market in which to expand pass use is among riders who make less than the break-even number of trips and among those who will increase the frequency with which they use transit, especially during the off-peak period, in order to break even with a pass. However, increased sophistication among riders concerning the economies that can be realized with a pass should result in those who normally make more than the break-even number of trips choosing it. A loss in revenue equal to the fare times the number of trips taken above the break-even level results from each of these individuals who buys the pass. Therefore, it may not be in an operator's best interest to educate riders to make rational, well-informed decisions regarding fare payment method.

It would be of considerable interest to examine the factors that influence the demand for daily passes in Sacramento. The daily pass can be used purely as a substitute for cash, or may involve break-even considerations (with less risk involved) similar to the monthly pass. With the daily pass included in the choice set, it would be possible to properly evaluate the impact of transferring among vehicles on the fare payment method decision of a transit rider. However, in order to evaluate the relative cost of using daily passes, monthly passes, or cash it is essential to determine the number of days in a month that the bus is used. If a transit rider makes many trips in a month, but on a relatively small number of days, the daily pass may be the most economical payment medium. If the bus is used on most days in the month, the monthly pass is likely to be the low-cost alternative. A combination of methods may also be used. Thirty-two respondents in the study sample who regularly make transfers to complete their trips report that they usually pay a cash fare. Presumably, daily passes are used on days when transfers are made and cash fare is paid at other times. Proper evaluation of the choice among the three payment methods, then, requires the collection of data on transit use and payment method by a sample of respondents during every day of a month. A travel diary is suggested for this purpose.

It would be desirable to obtain information regarding pass purchasers' expected use of the pass over the coming month rather than rely on actual use. Comparison of anticipated use with actual use would permit estimation of induced trip making and would provide insight into the variance around expected frequency that is such an important determinant of choice among transit fare payment methods.

More research is needed to fully examine the impact of household income on the choice of payment method. The estimation results presented in this paper provide some weak evidence that, other factors held constant, low-income persons are less likely to purchase passes than higher-income persons. An important limitation of this data set in exploring this relationship, however, is the relatively high income of its members. Additional insight could be gained through a random sample of transit riders instead of a sample of employees who use transit.

Finally, as stated at the outset, the objective of this study was to develop sound explanatory econometric models of pass-purchasing behavior. The estimation results presented here provide significant insight into the transit payment method decision. Given an adequate data set, the models developed here could be readily adapted as tools for predicting demand for alternative payment options.

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Abridgment

Analysis of Revenue-Ridership Relationship of Selected RTA Carriers

DILIP R. JHAVERI

Revenue and ridership are the two most important indicators of transit system performance. Many management decisions are based on them. How reliable and accurate are these data? How does one affect the other? How do they compare among carriers? Using percentage changes in the time-series of revenue and ridership and ordinary least squares, it is shown that the approach provides a valuable tool to examine the consistency of data and compare structural relationship of revenue and ridership of carriers without regard to size, location, or other attributes. It is noted that, with one exception, all Regional Transportation Authority carriers showed marginal revenue productivity of riders constant but less than one for the study period. Six of the 12 carriers, most small ones, showed poor to very poor revenue-ridership relationship.

Revenue and ridership are the two important indicators of transit operation. The two indexes, however, may not move in the same direction or at the same rate. Strikes, accidents, change in fares or composition of riders, and faulty and inconsistent reporting of revenue or ridership may account for discrepancies.

This study addresses the question of reliability of joint ridership-revenue data of 12 carriers of the Regional Transportation Authority (RTA) in Chicago. The carriers include the Chicago Transit Authority's bus and rail operations, five commuter railroads, and five suburban bus systems. The management objectives include understanding of (a) the expected change in revenue given the change in ridership and vice versa and (b) the evaluation of current and past ridership-revenue data.

It is noted that many carriers, including those in the RTA system, report significant increase in ridership without comparable growth in revenue. Could this be because of the increasing number of discount riders, such as elderly, handicapped, and monthly-pass users, that allow for unlimited rides at a far lower rate than the single fares? Or, are our data suspect?

STUDY APPROACH AND METHODOLOGY

This paper attempts to determine the association between revenue and ridership through a study of linear relationships between sequential changes in the time-series of revenue and ridership. The suggested statistical approach provides confidence intervals for accepting or rejecting the data based on past relationships. The study also helps to compare the structural relationship of revenue and ridership of RTA carriers irrespective of size, location, fare levels, or other agency-specific characteristics. The method allows the measurement of changes in relationships over time.

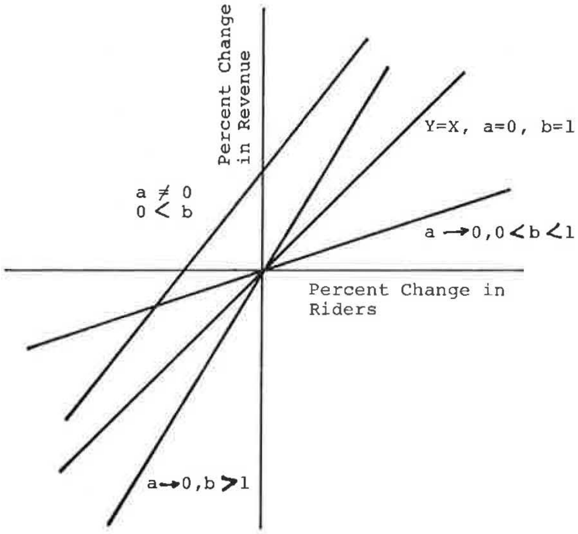
Simple revenue and ridership time-series are good descriptives of the transit systems but do not reveal their dynamic relationship. Further, seasonality and other fluctuations make them not very useful. They usually fail the statistical requirement of independence of observations. Further, because of size differences, comparison of carriers is not feasible. This is an important practical drawback that does not permit the establishment of norms against which performance of carriers may be measured.

The time-series method of percentage change in revenue and ridership overcomes these objections and provides readily interpretable criteria for inter-carrier comparisons and assessment of revenue-ridership data. Even when significant changes such as fare increase take place, the series are not affected except for the observation following the change. The study approach aids in the detection of shifts in the ridership-revenue relationship.

Regression analysis of percentage-change data has an appealing analytical and practical meaning. For instance, in the absence of subsidized and special fares, every percentage change in ridership results in an identical percentage change in revenue. Each carrier can be measured against this unit state in terms of percentage change in revenue associated with a percentage change in riders.

As illustrated in Figure 1, in unit state, the regression intercept is zero and the slope of the regression line is 1, that is, each percentage change in ridership is expected to result, on the average, in a percentage change in revenue. A consistent revenue-ridership reporting system will always suggest an intercept zero, or nearly so, while the slope may vary from zero to 1, but non-zero for all practical purposes because a zero value would indicate no relationship between revenue and ridership. The value of the slope is determined by the average fare level of new riders, if the system is growing, or riders leaving the system, in case of ridership decline, relative to the base riders and revenue. If new riders' average fare is greater than that of the base riders, the slope value ex-

Figure 1. Linear regression of percentage change in revenue (Y) and percentage change in ridership (X).



ceeds 1; if less, the slope is less than 1. Abnormal and sometimes infinite percentage changes in revenue or ridership resulting from strike, fare increase, or change in report formats are substituted by seasonally adjusted average values. For instance, if fares double, the revenue may nearly double and ridership may decline in the period following the increase. But no percentage increase in ridership or revenue may be noted in subsequent periods, all things being equal. This stability in the values of percentage changes in revenue and ridership is highly desirable for intercarrier comparative analysis of reporting performance. One must, however, allow for nonlinear revenue-ridership relationship over a short range when a system is evolving, or for kinks in the regression line as a result of sudden policy shifts.

REGRESSION ANALYSIS OF RTA CARRIER DATA

Table 1 presents important test results of regression of percentage change in revenue and ridership of 12 RTA carriers. An overall qualitiative classification of carriers' data is made based on a combination of statistical test results.

Test of Parameters

All carriers indicate value of the constant a not significantly different from zero at 95 percent confidence. For some carriers, however, this value was significantly larger than for others, such as G and F, and has affected their ratings.

The slope of regression lines of RTA carriers indicates that, on the average, percentage increase in revenue lags behind that in ridership. There is significant disparity among carriers in their expected increase in revenue from ridership growth. Carrier I had the smallest growth coefficient of 0.56, i.e., every percentage growth in riders is expected to increase, on the average, revenue by only 0.56 percent. Carrier L, an exception, has percentage revenue-growth rate exceeding ridership increase. Each percentage growth in ridership of L increases revenue by 1.056 percent, a possible indication that increasingly more new riders on L are full-fare passengers.

Test of Regression Models

The validity of regression models is largely determined by the test of residuals, i.e., the proportion of sum-of-squares of deviations around the mean unexplained, the mean-square error (MSE), and autocorrelation.

For four of the carriers, B,G,H, and I, the models explained less than one-half the sum of squares suggesting relative deviation from the regression line. For this reason, the rating of these carriers was adversely affected. For carrier B, however, the residuals are quite small in absolute value as suggested by the MSE. This helped its rating. For carriers with a higher rating, the R^2 values were mostly greater than 0.8.

Figure 2 presents the distributions of percentage changes in revenue and ridership of two carriers, D and G. Discounting the scale differences, it is apparent that the observations in D are significantly closer to the regression line than are in G. This explains the high R^2 value fo 0.814, and low for G, 0.40. The MSE for G is 97.14 compared with only 2.00 for D. These and other characteristics of the data and regression tests account for the "excellent" rating for D but "very poor" for G.

Figure 3 contrasts the distributions of residuals of carriers D and G. Discounting the scale differences, it is observed that the residuals of D are more random and significantly smaller than that of G. Residuals of G also tend to increase with changes in ridership that indicate significant variance in the period-to-period growth rates of revenue and ridership of G. Examination of data-gathering and reporting practices of carrier G confirms our evaluation that the noticeable discrepancies in growth rates of G are primarily the

Table 1. Summary of least-square regression of percentage change in revenue and ridership of selected RTA carriers.

Carriers	Intercept A	t-Statistic	Parameter B	t-Statistic	R-Square	Mean Square Error	Durbin Watson-D	Percentage of Residuals Within ± 1%	Percentage of Residuals Outside ± 2%	Autocorrelations 1st Order	Autocorrelations Annual	Assessment of Revenue-Ridership Data
A	0.5040	1.14	0.8177	7.43	0.7978	2.5573	3.0535	62.50	18.75	−0.6897	0.1273	Acceptable
B	0.2977	0.70	0.6543	3.74	0.4237	3.4034	2.1301	28.60	33.33	−0.1186	0.4807	Acceptable
C	0.4704	1.69	0.7292	4.10	0.5834	6.1729	1.4748	35.71	50.00	0.0768	0.0182	Poor
D	0.5763	1.66	0.7668	9.12	0.8140	2.0024	2.2599	47.62	4.76	−0.1766	0.0292	Excellent
E	0.4379	0.52	0.6572	4.40	0.5637	11.4554	2.4101	35.29	58.82	−0.2210	0.2332	Poor
F	−0.8884	−0.73	0.6010	9.06	0.6891	57.9349	2.1327	10.25	82.05	−0.1667	0.1205	Poor
G	1.4527	0.88	0.6881	4.83	0.4003	97.1385	2.6468	13.51	72.97	−0.3324	0.3181	Very poor
H	0.2532	0.25	0.7123	5.0	0.4100	37.7082	2.6184	13.16	71.05	−0.3205	−0.1221	Very poor
I	0.6563	0.27	0.5563	5.53	0.4593	216.3400	2.7366	5.25	81.58	−0.3761	−0.3074	Very poor
J	−0.2531	−0.39	0.8431	14.07	0.8389	18.7447	2.4574	30.00	62.50	−0.2929	0.1805	Acceptable
K	−0.1366	−0.52	0.9308	26.74	0.8584	8.3742	2.5576	47.56	24.39	−0.1505	−0.0356	Good
L	−0.0711	−0.11	1.0562	13.62	0.6988	31.2548	2.2999	65.52	20.69	−0.2819	0.2119	Good

Note: Data sets modified to remove known abnormal variations because of strike, fare increase, etc., and some extreme observations.

Figure 2. Percentage change in revenue and riders, carriers D and G.

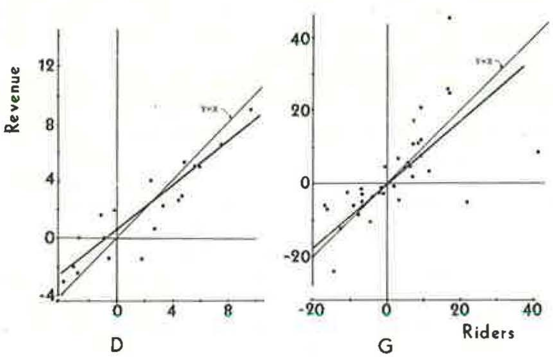
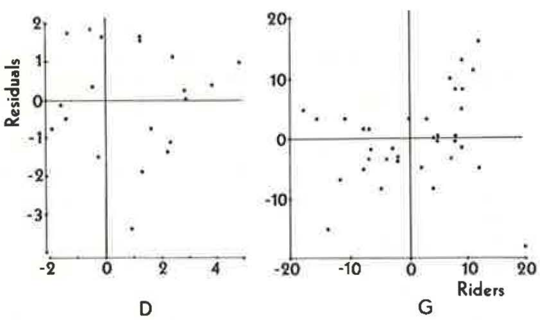


Figure 3. Plot of residuals and percentage change in riders, carriers D and G.



result of poor data quality.

The MSEs are valuable indicators of the average size of residuals even when the model may not explain a large proportion of the square deviations. A small size of deviations indicates a close grouping of observations around the regression line and small estimation errors. RTA carriers with "poor" or worse ratings exhibited MSEs in excess of 35. Carrier B with rather poor R^2 of only 0.42 but an MSE of only 3.40 was considered "acceptable" for its small deviations. Sources of its small but unexplained deviations may be found in its relatively minor error in data-gathering and reporting practices. Because MSE may be affected by a few large residuals, a visual check of residuals was made and extreme residuals were removed when justified.

Test of Seasonality

Because seasonal, systematic patterns of changes in the data could affect regression equations, all models were examined for autocorrelation in residuals, that is, seasonality in errors after linear trend is taken into account. Only carriers B and I showed statistically significant annual seasonality. Seasonal parameters for these carriers, however, failed to decrease MSE or overall evaluation of their data.

Assessment of Data Quality

No single index of data quality has been suggested since each carrier must be considered in its own unique environment. Relative values of various statistics for the carriers must be compared with caution. The MSE is perhaps the single most important index to watch in any relative test, mindful that a single large residual may affect this value.

CONCLUSION

This study demonstrated an application of ordinary linear regression analysis to evaluate the consistency and reliability of revenue and ridership data of 12 RTA-Chicago carriers. Using percentage changes over sequential periods in revenue and ridership, the simple linear models provide a useful mechanism to examine the quality of data, compare carriers in their revenue-ridership relationships irrespective of their size or location, and enable the tracking of changes in the composition of riders that affects revenue.

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Abridgment

Bus Costing Information in Short-Range Planning: Survey of Principles and Practice

MICHAEL A. KEMP, MICHAEL E. BEESLEY, AND ROBERT G. McGILLIVRAY

This paper discusses the major principles involved in the use of bus transit cost information for planning and policymaking purposes. It is argued that there is no such thing as comprehensive costing, which is immediately and uniformly applicable to all kinds of decisions. Rather, the types and treatments of the costs that should properly be considered vary with the nature of the decision being contemplated. Particular emphasis is placed on the relevance, structure, and valuation of cost items. Three major categories of decisions that require different approaches are considered. These are characterized as service changes, innovation, and the allocation of deficits and subsidies. The paper also provides a brief critical review of currently available procedures for employing cost information in short-range transit planning. A direct estimation of costs may be made by planning proposed service changes in full operational detail, but this is cumbersome and expensive. Short-cut techniques include computerized operational research models (so far, they are not well developed), simple average cost procedures, and more sophisticated causal factor allocation methods. Enhancements to the widely used causal factor approach attempt to take better

account of peak and off-peak cost differentials and to focus more closely on marginal rather than average costs.

The literature on bus transit costs often makes for confusing reading. Past studies have varied considerably in their motives, focus, depth, and relevance to planning and policy. This paper discusses some of the general principles involved in the collation and use of cost information, categorizes the practical decisions to which cost information is relevant, and reviews procedures commonly in use to appraise the costs of implemented or proposed service changes. It is a shortened version of part of a more comprehensive paper by us (1) that summarizes the applicability of current knowledge and procedures regarding bus costs for practical planning and policymaking purposes.

Much of the information in the bus costing literature is not directly relevant to practical problems of this nature. Many studies have suffered from a lack of attention to the reasons for wanting cost information and to the relation between the information and the decisions being made. It is important to establish that the types of costs that are relevant to a particular policy decision vary with the nature of the decision. Moreover, the relevant costs depend not only on the nature and level of output being sought, but they are also tied inseparably to the details of the methods chosen to achieve that output. For instance, a property wishing to expand its services (reduce headways on a particular route, perhaps) has several options open to it: (a) use existing resources more intensively, perhaps only temporarily; (b) reallocate resources internally, taking buses and drivers from other routes; (c) acquire extra resources; or (d) contract with an external company to provide the desired service increment. The actual costs of each of these approaches differ, and so do the types of costs that are relevant. The purchase price, for example, of new buses is germane to an intended fleet expansion but not to an internal reallocation of resources.

It must also be remembered that cost information is rarely of value in isolation from associated information about demand and revenues. A change in services provided is likely to lead to a change in demand as well as to a change in costs. For financial planning purposes, it is the impacts on systemwide net costs (or net revenues) that are of primary interest. A minimum cost solution to providing a given increment in service on one part of the system may well be one involving changes in revenue on some other part.

CATEGORIES OF TRANSIT MANAGEMENT DECISIONS

To exemplify and build on the principle that different management decisions require different types of cost information, it is useful to distinguish between three major categories: service changes, innovation, and allocation of support decisions.

When a planning decision considers only the types of resources and procedures currently in use by the firm, it is classed as a service change. It might involve, for example, adjustments to headways or service periods, changes in the service area or route structure, or any combination of such policies. The costs attributed to these actions vary for several reasons. First, operating conditions may differ between routes and by time of day. Operating costs are constrained by geography, traffic conditions, union agreements, and other factors. Geographical factors can lead to different costs even when the same wage rates and types and ages of buses prevail. Second, the prices paid for inputs can vary over time and across the system. For instance, a headway change might affect the average rate per driver hour because of work rules governing split shifts, spread time, and the like. Finally, costs may vary because the aggregate volume of resources employed expands or contracts. If total output is to be expanded under fixed production conditions, new assets must be purchased, personnel hired, and so on; if contracted, assets are to be sold and employees laid off. Forming new transit properties, or merging or divesting old ones, also raises the question of how costs vary with the size of the organization.

By comparison with service changes that use only procedures and types of resources already in use, innovation involves some new feature in the way output is produced. For instance, transit management might be asking whether new types of buses can be substituted for old, whether cheaper sources of labor might be used, whether a new way of organizing services might be beneficial, and so on. Bus operations face make or buy decisions; for example, they must decide whether to contract for maintenance work or provide it in-house.

These are all examples of what economists characterize as shifts in the production function or the cost function with which the decision maker is concerned. Recognizing such shifts is important because it affects the interpretation of the empirical evidence on costs. Investigators frequently assume that the conditions of production are held constant, so that the observed costs reflect attempts to make the best of a given set of circumstances. If conditions can change because of innovation, costs must be reinterpreted. Changes in the operating environment may have potentially far-reaching effects on costs, too. For example, a traffic management improvement that results in the speeding up of buses can affect labor productivity, capital productivity, maintenance, and other types of cost, as well as open the door to substitution of different equipment. The potential of innovation can be realized most efficiently if the possibilities are scanned systematically. Analysis of costs by type of function and input is a necessary step in the search for improvement: The aim is to concentrate attention where total costs stand to be changed the most.

The third major category of decisions relates to the allocation of deficit or subsidy support among jurisdictions served by a transit property. Cost measurements are significant here in that, for example, computing the avoidable costs associated with each jurisdiction's services may well show total costs to exceed the sum of the avoidable costs. The unexhausted costs are called common costs and are by definition not allocable by reference to output changes. To attribute these to jurisdictions or to specific services, one has to appeal to other considerations, notably to ideas about what is a fair basis. Costs can enter this discussion in another way, in that it is possible to make hypothetical costs a basis of agreement about what is "fair."

IDENTIFYING AND MEASURING THE RELEVANT COSTS

As a general principle, one should only count costs when they are relevant--that is, when they can affect the decision being contemplated. As shown, relevance varies with the nature of the decision. For service change and innovation decisions, the costs of past investments are irrelevant, at least from an economic efficiency point of view. Once a bus has been bought, the outlays concerned cannot be varied, and they are not relevant to any currently pending decisions about how the bus is to be used. However, if an expansion of the bus fleet is under consideration, the current price of extra buses is relevant; if a contraction is contemplated, the values of buses to be sold in the second-hand market are relevant as a credit. If a contractual obligation cannot be changed, once made it cannot affect the costs incurred. They are unavoidable and, hence, irrelevant for deciding the best course of action in a future decision. The longer the time period contemplated in a decision, the more cost elements become avoidable and, hence, relevant.

A second feature of costs that enters the decision is their structure: Costs may vary with output changes to different degrees. Outlays on bus acquisition and use are lumpy with respect to the services provided. A 50-seat bus costs roughly the same whether one or 50 people are carried, and (running costs and maintenance aside) whether 50 000 km or 80 000 km per year are run. By contrast, fuel is more variable relative to outputs, provided that it can be contracted for freely. Labor may or may not be variable with service levels over the short run.

Fixed and variable costs, as these elements of structure are sometimes called, subject the enterprise to varying degrees of risk. Fixed elements provide opportunities to lower unit costs by expanding output but involve the enterprise in a greater liability to varying financial results if planned output is not realized because of market and other fluctuations. In the case of transit bus operation, the fixed elements (and the associated economies) are of little significance in the aggregate for most bus properties. The main unit of capital, the bus, is small by comparison with the total capacity typically used. Compared with many manufacturing businesses, the opportunities to realize savings by increasing the scale of operation are few. Thus one does not expect to find economies of scale over most bus operations, and this expectation has been verified empirically.

The third important feature of costs is their valuation. Inputs such as buses and labor have prices that may or may not be affected by the property itself. One manifestation of this is in the terms negotiated with outside parties: Prices paid for buses or labor will be affected by the property's bargaining power. Costs will be affected accordingly, and these effects are usually distinguished from those arising from relevance and structure.

Another point about the valuation of costs is that the values appearing in the property's balance sheets or other financial records may or may not be relevant. For service planning and innovation decisions it is appropriate to use some measure of the opportunity costs for the resources employed--that is, the value to the enterprise of those resources in their best alternative use. Sometimes market prices may understate or overstate the opportunity costs; and sometimes the bookkeeping entries may more closely reflect accepted accounting conventions than either market prices or opportunity costs.

From this review, it should be very clear that there can be no such thing as comprehensive costing, which is suitable for all kinds of decisions. The first step is always to define the options now open; the appropriate cost calculations follow. Of course, short cuts and approximations can be made. Many different decisions will not involve different avoidable costs, but the initial questions about what are the context and content of decisions must always be asked, otherwise incorrect and misleading statements about costs are very likely to follow.

CURRENT COSTING TECHNIQUES USED FOR SERVICE CHANGE DECISIONS

The necessity of abridging this paper means that insufficient space is available to review the full range of current planning practices that use cost information in appraising bus service policies; the interested reader will find a comprehensive survey and discussion in McGillivray and others (1). Space limitations permit only a cursory categorization of techniques here.

The procedures used to estimate the costs of potential service changes can be divided broadly into two types--those that attempt a direct estimation of the costs and those that use cost formulas derived by statistical or accounting methods. For any proposed service change, particularly one that involves no innovation in operating procedures and equipment, it is possible to plan that change in maximum feasible detail--to the extent necessary if the change were to be put into effect tomorrow, for instance. With schedules in place and with specific vehicles and operators allocated to the service, it is then possible to make a quite accurate estimate of what the associated relevant costs are likely to be. Because this approach to estimating the costs of proposed changes is applicable at any level of planning sophistication, it is a procedure that has always been available to bus properties; consequently, it is widely used when major changes are being contemplated. The primary disadvantage is the level of effort required to apply it. This is particularly true where scheduling and run-cutting are handled manually, but it remains true (at least for now) even when these functions are computer-aided. The high costs involved make the technique inappropriate for sifting through many possible changes in examining the relative cost implications of each one.

One can conceive of making a fairly accurate forecast of the costs of incremental service changes without necessarily going all the way to producing crew-duty schedules. What is required for costing purposes is some estimate of the least costly method of staffing a given service timetable, given specified physical and work rule constraints. If one could predict the premium-pay work involved, it should be possible to come up with fairly accurate crew-cost estimates. This is the philosophy underlying the macro approach to transportation planning of the Urban Transportation Planning System (UTPS) (2). Although it is much more parsimonious of computer and staff time than the most widely used scheduling and run-cutting program, it has certain practical deficiencies that have thus far limited its use. Developments of this approach, however, promise to provide a flexible and accurate tool for short-range planning purposes.

Short of these direct estimation methods, transit properties obviously require some short-cut cost formula methods for appraising the likely cost implications of proposals. But accurate short-cut techniques are not easy to devise. The simplest of all approaches is to calculate a systemwide average cost, averaged over some principal unit of output, and to apply this value to proposed changes in output. For instance, companies can compute their average cost per vehicle kilometer or per vehicle hour and can assume that this value also holds for the increment of service under consideration. The deficiencies of the method are easy to see. If the total operating costs are used as the numerator, these include many cost items that are not relevant to the decision under consideration or are not measured in an appropriate way. There is also a strong assumption that the proposed increment of service is produced in a cost environment that matches the average for the rest of the system.

A simple development of the method restricts attention to the variable costs only and uses the short-run average variable costs at the current level of output. A further extension to these average cost methods is made by noting that certain variable cost accounts are highly associated with one unit of output while others are more closely associated with another unit. Thus, driver costs could be expected to be determined primarily by the vehicle hours operated (compared with other measures), while fuel costs are more closely associated with the vehicle kilometers of service. Arguing in this fashion, each variable cost account can be associated with a particular descriptor of the delivered service. The costs associated with vehicle kilometers can then be summed, as can the costs associated with each of the other descriptors of service; unit costs can be obtained by averaging in each category.

Application of the method typically involves four major steps. The first is to develop cost totals, by account, to whatever level of accounting detail it has been determined to work. It is at this stage that one should be asking whether each individual account is relevant to the decision at hand, whether it is measured appropriately, and whether it is likely to be associated linearly with any measure of output. Second, each account is allocated to one or more of the causal factors chosen. When all relevant accounts have been treated in this way, the costs allocated to each of the factors are summed and averaged over the numerical value of that factor in order to obtain a unit cost estimate. Finally, these unit cost values are applied to specific segments of the system or to proposed changes.

The original methods of this type used just two service descriptors, vehicle kilometers and vehicle hours. Further factors are frequently used nowadays: peak-hour vehicles, to which is assigned many of the fixed costs (3,4,5); a patronage measure (revenues or riders) (6,7); and the number of drivers required for peak or all-day operation (8,9). The basic approach has a number of problems. First, though many accounts can be unambiguously allocated to a particular service descriptor, it is a matter of fine judgment how several of them should be allocated. Second, the unit cost figures produced by the method are still estimates of average rather than marginal costs.

There have been several studies attempting to build on this basic causal factor method. One focus has been on categorizing costs not only by a service descriptor but also by the timescale over which operational changes will produce cost changes (10,11). This provides a wider segmentation of unit costs from which to pick the cells relevant to a particular decision. Another focus has been on identifying separate unit costs appropriate to the peak and off-peak periods (5,12). The principal problems involved in doing this are (a) that the allocation of common costs must be arbitrary from an economic efficiency point of view (although one may appeal to equity or fairness notions) and (b) that the conclusions are likely to be quite sensitive to the arbitrary definition adopted for the duration of the peak period. We tend to doubt whether the actual segmentation of peak and off-peak costs is very helpful for short-range planning purposes, with the possible exception of pricing policy. It should be possible to estimate costs that take better account of the peaking profile of the service without actually allocating costs.

Along these lines, some workers have sought to develop simple statistical relations between crew costs and the degree of service peaking (10,13). Tests of two of these methods have revealed a significant improvement in accuracy over average costing when premium pay amounts were substantial (14).

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Fare Changes and Prepaid Pass Programs: Honolulu's Experience

AKIRA FUJITA, TORU HAMAYASU, PETER HO, AND JOSEPH MAGALDI

This paper documents Honolulu's efforts to establish a prepaid bus pass program at the time of a major fare increase. It also discusses the revenue-forecasting techniques used for estimating fiscal impact of change in fare structure. A comparison of the forecasted values with the results of the actual fare structure change is also presented. In FY 1980, the Honolulu bus system carried more than 60 million passengers and used about 300 buses. The system coverage is more than 95 percent of the island population of approximately 720 000. On November 1, 1979, the basic cash fare of $0.25 was increased to $0.50. At the same time, the sale of prepaid monthly bus passes was initiated with the basic cost of $15.00; this significantly reduced the impact of the fare increase on frequent riders. As a result, the system did not experience any noticeable reduction in patronage. The average monthly revenue of $850 000 for FY 1979 has increased to a current level of $1.5 million. The system's major objective of increasing revenue was successfully accomplished without significant economic impact to the system riders. This was accomplished through the combination of fare increase and the initiation of discount prepaid passes.

On November 1, 1979, the City and County of Honolulu instituted a bus pass fare program and an increased fare schedule for its bus operation, TheBUS. The purpose of the fare program was to increase fare revenues to offset rising operating and maintenance costs. This paper documents Honolulu's efforts to establish a prepaid bus pass program at the time of a major fare increase. The paper also discusses the revenue-forecasting techniques used for estimating the fiscal impact of the fare structure change.

BACKGROUND

In 1967, the Hawaii state legislature authorized Hawaii's four counties to own, operate, and maintain mass transit systems. The City and County of Honolulu established bus service in the rural areas of Oahu not covered by private mass transit carriers in 1969. Three months following a strike by the employees of the private mass transit carrier in urban Honolulu, the city initiated urban Honolulu bus service in March 1971 with 67 buses. During a 10-month period, the 67-bus fleet carried some 17 million riders. Over the last eight years, the city's system has grown rapidly in terms of level of service and area served. In FY 1980, the Honolulu bus system carried more than 60 million passengers using about 300 scheduled buses. The system covers more than 95 percent of the island population of approximately 720 000.

Total passengers using the bus system grew from 54 300 000 in FY 1975 (July-June) to 68 800 000 in FY 1979--a 37 percent increase during this period. Revenue vehicle hours increased by only 21 percent, most of which occurred between 1975 and 1976 (1). Ridership gains were considerably greater than the increase in service provided.

Operating expenses grew from $14 900 000 in FY 1975 to $29 500 000 in FY 1979, a gain of 98 percent. Since the system's average fare per total passenger remained nearly constant during this interval, the operating deficit went from $6 900 000 in FY 1975 to about $19 500 000 in FY 1979, an increase of 183 percent.

On November 1, 1979, the basic cash fare of $0.25 was increased to $0.50. At the same time, however, the sale of monthly bus passes was instituted; this significantly reduced the impact of the fare increase on frequent riders.

PAST FARE STRUCTURE

The fare structure for the bus system in Honolulu has traditionally been low. It is noteworthy that student fares decreased in 1971 after the city and county assumed control over the bus system.

Until March 15, 1974, Honolulu's bus system had a system of zone fares. In large part, these zones were carryovers from the private operators' policies. In 1973, the bus fares in Honolulu were as follows:

	Fare (¢)		
	City and County Buses		Leeward Bus Co.
Item	Zone 1	Zone 2	Four Zones
Adult	25	50	15-60
Student	10	25	20-35
Child	10	25	-

Leeward Bus Company operated on a four-zone system until the termination of their operation in March 1974. This zone fare structure was eliminated to provide more equitable fares and service to all residents on Oahu.

Free bus passes for senior-citizen and ambulatory handicapped riders began in February 1970 and July 1976, respectively. These users can ride the bus system at all hours of operation at no charge. This policy is currently in effect. A curb-to-curb Handi-Van service was established in June 1977. The initial one-way fare was $0.50/ride.

PROGRAM DEVELOPMENT

Several studies were made to determine feasible alternatives for obtaining additional funding and revenue to offset increased operating and maintenance costs of TheBUS. The first study was a bus passenger survey that sought to elicit bus rider's perceptions on increased bus fare options and on other funding alternatives. The second study involved an analysis of funding and fare options to determine the fiscal impact of a proposed subsidy limit considered by Honolulu's City Council.

Bus Passenger Survey

The bus passenger survey was conducted during the summer of 1978 (2). About 4000 questionnaires were distributed and collected on all the bus routes and at selected bus stops. A return of 3593 survey forms was achieved and represented 2.1 percent of the daily bus ridership (170 000 riders) at that time. Findings of the study include the following:

1. Almost one-half of the bus riders were in favor of raising fares. The express routes had the largest percentage in favor of a bus fare increase.
2. Of those in favor of raising fares, about 50 percent chose the new fare at $0.35. More than 50 percent of those people who favored an increase on the suburban and shuttle routes chose $0.35 as the new rate. About 40 percent of those passengers who favored raising fares on the express buses selected a fare increase to $0.50. The weighted average of those in favor of an increase was $0.41. About twice as many people who indicated they were in favor of an increase chose $0.50 over $0.40, probably due to the convenience of carrying fewer coins. About 29 percent of the total number surveyed were willing to pay $0.35, while 14 percent favored a $0.50 bus fare.
3. About 47 percent were in favor of reallocating taxes to help pay for operating the bus system. The results of the bus survey illustrated that just as many people were in favor of a tax reallocation as were opposed. Of those who favored using additional taxes to help pay for operating the bus system, the hotel room tax was selected by 56 percent. Gasoline and vehicle weight taxes were selected by approximately 25 percent.
4. An analysis of rider response regarding satisfaction with current bus service indicated a 3-to-1 average rate of satisfaction. People surveyed at the bus stop were more inclined to indicate dissatisfaction with the bus service, over a 3 to 1 yes/no ratio. The express riders surveyed were the least satisfied (67 percent).

Funding and Fare Options

A second study was undertaken concurrently with the bus passenger survey to investigate the feasibility of raising fares, increasing vehicle weight taxes, and gasoline and property taxes to cover growing bus deficits (3).

In addition, several fare structures were investigated by the city. After reviewing the various potential fare structures with the findings of the bus survey and the pass programs of two other transit properties, the Department of Transportation Services proposed a bus pass program (3).

Based on the review of Seattle's Metro System (4) and the Southern California Regional Transit District (5), the following advantages of a bus pass program were cited to justify such a program.

1. The pass is convenient and easy to use.
2. Riders never have to bother with having correct change.
3. The pass can easily become a bargain because it can be used as often as desired within the prescribed period (proposed Honolulu pass holders will break even with 30 rides).
4. It simplifies passenger loadings, thus increasing bus speeds especially during heavily used peak hours.
5. Daily cash accounting would be reduced.
6. Cash flow would improve by advanced monthly payments.

PATRONAGE AND REVENUE ESTIMATES

The Simpson-Curtin rule was considered for making patronage estimates resulting from fare increases. Three features of the Honolulu system, however, precluded the use of the formula:

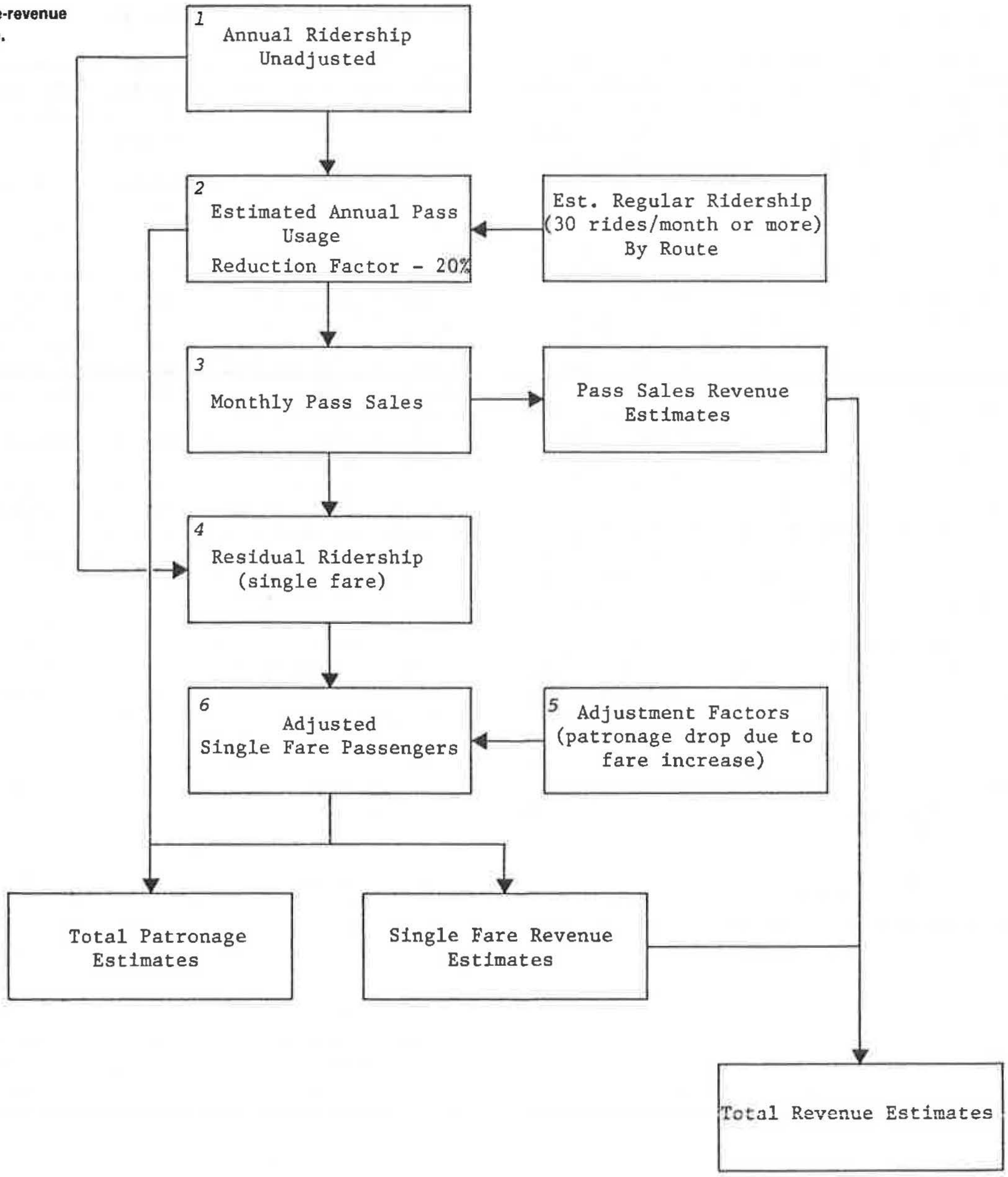
1. Captive transit riders, the elderly and handicapped, ride free at all times on the Honolulu system. Therefore, this group would not be affected by any fare changes.
2. The basic Honolulu transit fare has not been changed since 1961, while the annual average consumer price index has risen from 88.6 in 1961 to 169.4 in 1977 (base: 1967 = 100), an increase of more than 90 percent. Therefore, transit users may perceive the increase at a lower rate than the actual percentage.
3. A one-time flat fare is charged in the present and proposed system regardless of the length of a route or type of service (trip length varies from the shortest shuttle to the approximately 4-h, 90-mile around-the-island route). It is difficult to assume that the impact of a given fare increase is independent of trip length.

The general method selected was similar to a variation of the Delphi method used by Seattle (4).

The procedure used to estimate patronage and revenue under the proposed fare structure and bus pass program is charted in Figure 1. The procedure is summarized below.

1. A base ridership is established assuming current conditions (existing fare structure and no bus pass program).
2. It was assumed and agreed on by a group of transit experts that, since the monthly bus passes would require 30 rides to break even with proposed single fares, a majority (80 percent) of regular bus riders--those who use the buses more than 30 times a month--would purchase the passes. These factors of regular bus users were applied to FY 1978 patronage by route to estimate annual potential pass users. The total was then adjusted for user irregularities by a reduction factor of 20 percent to yield an annual total bus-pass usage estimate (Table 1).
3. Pass sales were estimated on the basis of an assumption of 40 rides per month or 480 rides per year: 15 302 400 annual adult pass trips = 31 880 passes/month; 7 756 500 annual student pass trips = 16 160 passes/month. An annual pass sales revenue estimate for adults was made at $15.00/pass for 12 months per year: 31 880 x ($15.00) x (12 months/year) = $5 738 400. Student pass revenue was estimated at $7.50/pass for 12 months with a seasonal adjustment factor of 90 percent: 16 160 x ($7.50) x (12 months/year) x (90 percent) = $1 308 960. Student passes would be available for the full 12 months per year to accommodate the overlapping terms of private and summer schools and to increase the mobility of youngsters seeking employment or recreation.
4. The total annual base patronage minus the estimated pass usage is considered as the potential single fare-paying passengers.
5. Transit operation consultants and other transit experts were asked for their opinions for percentage reductions (shrinkage) of the single fare-paying passengers due to the proposed fare increases. Their responses on the estimated value varied from the lowest of no shrinkage to the highest of 15 percent for adult passengers but generally agreed on a 5 percent shrinkage factor. For the impact on student riders, a consensus opinion was a 5 percent reduction. However, in

Figure 1. Patronage-revenue estimates procedure.



rural Oahu where the school bus service is available at $0.10/ride, the reduction was estimated between 40 and 50 percent.

Four patronage-revenue scenarios were made based on varying base patronage and shrinkage factors combinations. All scenarios were analyzed by using the proposed fare structure. Two base-paying patronages were used, 47.5 million and 50 million adults and students. The former represents a conservative estimate and assumes the same patronage as occurred in FY 1978. The latter represents a liberal patronage estimate. Two sets of shrinkage factors were used: (a) conservative estimate--adults, 15 percent; students, 50 percent; and other students, 5 percent; and (b) probable estimate--adults, 5 percent; students, 40 percent; and other students, 5 percent.

The four scenarios analyzed are as follows: (a) base-paying patronage, 47.5 million; shrinkage factors, conservative estimate; and bus pass program, yes; (b) base-paying patronage, 47.5 million; shrinkage factors, probable estimate; and bus pass program, yes; (c) base-paying patronage, 50 million; shrinkage factors, probable estimate; and bus pass program, no; and (d) base-paying patronage, 50 million; shrinkage factors, probable estimate; and bus pass program, yes.

6. The adjustment or shrinkage factors were applied to the nonpass riders to obtain patronage-revenue estimates for this group. These estimates reflect the decrease in single-fare patronage due to an increase in fares. The results of the four scenarios with the shrinkage factors are presented in Table 1. Under the low estimate (high shrinkage factors and low patronage figure), with the proposed fare structure and bus pass program, revenue is projected to be $15.7 million. If the most likely shrinkage factors were used with the low patronage figure, revenue is expected to increase to $16.7 million. Assuming 50 million revenue passengers, the proposed fare structure, the most likely shrinkage factor, and no bus pass program, revenue would be $19.5 million. By using a pass program, this estimate decreases to $17.6 million. The range between the four scenarios is $3.8 million.

Table 1. Patronage, revenue, and monthly-pass sales estimates for proposed fare structure.

	FY 1978				50 Million Revenue Passengers			
	Low Estimate				No Pass			
Type	Passengers	Revenue ($)	Passengers	Revenue ($)	Passengers	Revenue ($)	Passengers	Revenue ($)
Patronage[a]								
Adults	32 462 900	8 115 700	32 462 900	8 115 700	34 156 000	8 539 000	34 156 000	8 539 000
Students	15 058 800	1 505 900	15 058 800	1 505 900	15 844 000	1 584 400	15 844 000	1 584 400
Total	47 521 700	9 621 600	47 521 700	9 621 600	50 000 000	10 123 400	50 000 000	10 123 400
Pass usage								
Adults	15 302 400	5 738 400	15 302 400	5 738 400	0	0	16 100 300	6 037 600
Students	7 756 500	1 309 000	7 756 500	1 309 000	0	0	8 160 900	1 377 200
Total	23 058 900	7 047 400	23 058 900	7 047 400	0	0	24 261 200	7 414 800
Single fare[b]								
Adults	14 570 200	7 285 100	16 284 300	8 142 200	32 448 000	16 224 000	17 152 900	8 576 500
Students	5 666 000	1 416 500	5 946 500	1 486 500	12 961 000	3 240 000	6 267 700	1 566 900
Total	20 236 200	8 701 600	22 230 800	9 628 700	45 409 000	19 464 000	23 420 600	10 143 400
Total[b]								
Adults	29 872 600	13 023 500	31 586 700	13 880 600	32 448 000	16 224 000	33 253 200	14 614 100
Students	13 422 500	2 725 500	13 703 000	2 795 500	12 961 000	3 240 000	14 428 600	2 944 100
Total	43 295 100	15 749 000	45 289 700	16 676 100	45 409 000	19 464 000	47 681 800	17 558 200
Monthly-pass sales								
Adults	31 900	478 200	31 900	478 200	0	0	33 500	503 100
Students	16 200	121 200	16 200	121 200	0	0	17 000	127 500
Total	48 100	599 400	48 100	599 400	0	0	50 500	630 600

Note: Fare-patronage shrinkage factors based on four scenarios given in text: adults, 15 percent, 5 percent, 5 percent, and 5 percent, respectively; students, rural, 50 percent, 40 percent, 40 percent, and 40 percent, respectively; and students, other, 5 percent, 5 percent, 5 percent, and 5 percent, respectively.

[a] Existing fares. [b] Calculated at adults, $0.50; students, $0.25. Patronage shrinkage factors were applied.

HONOLULU CITY COUNCIL ACTIONS

On August 3, 1979, the Honolulu City Council adopted Ordinance 79-62, which established the new bus pass and fare program for TheBUS. Two additions were made to the proposed fare structure. First, a $4.00/month school discount pass was included. Second, a $1.00 family Sunday pass for unlimited rides on a given Sunday was included.

On November 1, 1979, the city and county began a monthly prepaid bus program and simultaneously increased the cash fare for passengers. The fare structure was changed to the following:

Type of Fare	Cost ($)
Bus Passes	
Adult	15.00/month
Student	7.50/month
School discount	4.00/month (school days)
Family Sunday pass	1.00/Sunday
Senior citizen and handicapped	Free
Cash Fares	
Adult	0.50
Student	0.25
Transfers	Free

The bus pass program was modified, effective July 1980. The school discount pass and family Sunday pass were discontinued. A fare increase for the curb-to-curb Handi-Van service was enacted in April 1980, and the fare was raised from $0.50/ride to $1.00/ride.

BUS PASS SALES PROGRAM

Honolulu uses an outlet system to sell bus passes to the public. Selected companies who sell the passes enter into contract with the city specifying the methods for distribution and cash accounting. A total of 66 pass outlets include the state's largest bank (30 offices), a supermarket chain (17 stores), university campus center (1 outlet), Honolulu satellite city halls (9 districts), city bus information center (1 outlet), and, since August 1980, a savings and loan company (8 offices). A distinguishing feature of Honolulu's program is that there is no commission for the sales. Sales by noncity outlets are made as a public service and as an opportunity to use the cash received as a "float" for almost a month. The pass sales procedure involves the following steps:

1. Printed passes are prepared by a private printer under contract with the city and county of Honolulu.
2. Passes for a given month are distributed to the main office of the various outlets. This is done on the first of the prior month. The passes are then distributed by the main office to the respective outlets.
3. Pass sales begin on the 16th of the previous month. Sales continue until the 15th of the month in question.
4. Funds are held by the commercial outlets in special accounts. These funds are transferred to the bus company, MTL, Inc., which consolidates the accounts for the city and county. The funds are transferred on the first business day after the 15th of the month, thus allowing the vendors a "float" for nearly one month. To maximize the cash advance, all sales are cash only and sales adjustments are made only at the main bus office. No refunds are made for lost or stolen passes.

There is a minimal amount of advertising for the bus pass program at this time. Television advertisements are provided free by the supermarkert chain as a public service.

Two major advantages accrue to the city and the county in this procedure. First, the interest revenue lost by letting the outlets hold the pass sales receipts is less than the typical 3 to 5 percent sales commissions used elsewhere (4,5). The sales procedure also minimizes city accounting efforts since accounting is necessary only once a month.

RESULTS

Total revenues for TheBUS system increased from $10 million in FY 1979 to $14.75 million in FY 1980. This increase is based on the result of the fare increase and prepaid pass sales for an eight-month period in FY 1980. Estimated revenues for FY 1980 were $17 million given the fare increase and pass program for the entire fiscal year (3). By assuming the revenues for the first four months of FY 1980 identical to those in FY 1979 and by factoring the $17 million figure for eight months, the revised figure of $14.53 million was obtained. This compares favorably with the actual revenue of $14.75 million.

Table 2 indicates the monthly pass sales trend from November 1979 through June 1980. Pass sales have generally increased with the exception of December 1979. During December, Hawaii experienced a statewide public worker's strike lasting nearly six weeks. Honolulu was also faced with the prospect of a sympathy strike by the Bus Operator's Union, which was negotiating a new contract at the time. However, there was an increase of $50 000 in cash receipts for December over November 1979. In comparison, December 1978 cash revenues were $10 000 less than November 1978 revenues (see Table 3).

Table 4 summarizes monthly patronage for FY 1979 and FY 1980. No patronage reduction was noted in November or December 1979 except for a traditional holiday season dip in patronage. In January 1980, the system recorded the highest monthly patronage since the city initiated the service in 1971. Historically, the month of February records a lower patronage than in January. However, in February 1980, there was an increase of patronage over that in January 1980. It is apparent that ridership did not decrease due to the increase in cash fares and the introduction of the bus pass program.

Initial pass sales of 34 000 were about 70 percent of the projected low estimate of 48 100 monthly passes (3). After six months, pass sales of 40 652 were nearly 85 percent of the projected low estimate. It is interesting to note that the student and school discount pass sales are quite close to the low estimate--15 190 to 16 200, respectively. Adult pass sales are lower than projected--25 800 to the projected number of 31 900.

Table 4 summarizes monthly fare revenues for FY 1979 and FY 1980. During this time period, service has remained nearly constant. Changes in revenue are thus a function of the change in fare structure and increased patronage growth on a stable system. Bus pass revenues approximate $450 000 monthly as compared with the low estimate of $599 400 (3). About 23 percent of the $149 400 difference is due to the $4.00 school discount pass, which was discontinued, effective July 1980. Cash revenues from the fare box have increased $130 000 to $170 000 per month as compared with FY 1979 monthly revenues.

In justifying the implementation of the prepaid bus pass program, a number of advantages were cited. The following discussion reflects Honolulu's experience with respect to the list of advantages.

1. The pass is convenient and easy to use. The success of the pass program indicates its overall acceptance by the community. Sales of the passes are good. The distribution system appears to be effective with pass sales at the bank outlets ($200 000 monthly) and supermarket chain ($220 000 monthly). These facts are indicative of the dispersed distribution of sales on Oahu.

Returns and exchanges of the prepaid passes have been minimal after the first two months of operation. There was some confusion on the use of the student pass and the school discount pass in November. Also, the strike situation in December 1979 resulted in some requests for reimbursements

There has been some abuse of the pass program, in particular the $4.00 school discount pass and the $1.00 Sunday family pass. Bus drivers reported youths were using the school discount pass on weekends, particularly at heavily used boarding areas. Sunday family passes were never successful with low sales after its initial start-up in January 1980. There were instances of large "families" boarding city buses by using a single $1.00 pass. Both of these passes were dropped from use, effective July 1980.

2. Riders never have to bother with having correct change. The prepaid pass program is useful to riders who now can use their pass for unlimited rides in a given month. The cash-paying riders, however, are now confronted with a minimum two-coin fare ($0.50), compared with the original one-coin fare ($0.25). At the beginning of the pass and fare increase program, fareboxes on buses serving Waikiki were being jammed with paper bills due to the lack of change. This problem has since diminished.

3. The pass can be a bargain to regular users. While current statistics are not conclusive, the high pass sales indicate that purchasers are using passes for savings as well as for convenience. The City Department of Transportation Services will be undertaking ridership surveys in FY 1981 to verify pass usage in more detail. These surveys will be part of an ongoing bus system planning program for Honolulu funded by the Urban Mass Transportation Administration.

4. Bus passes simplify passenger loadings and increase bus speeds (by reducing loading times). Preliminary observations in Honolulu indicate that the pass program has simplified passenger loadings and faster load times are occurring. A before-and-after dwell time survey analysis is currently under way to develop regression equations for predicting loading times with and without a pass program.

5. Daily cash accounting would be reduced. The accounting system for fare and pass revenues was revised at about the time of the bus pass program implemenatation. There is no evidence that the accounting has been improved as a result of the pass program.

6. Cash flow would improve by advanced monthly payments. Under the Honolulu pass program, vendors hold the cash receipts until the middle of the current pass month. As such, the city experiences no gain from advanced monthly payments. The absence of pass sales commissions, however, results in a saving of nearly $150 000 annually. The increase in cash fares has resulted in an improved daily cash flow.

CONCLUSIONS AND RECOMMENDATIONS

The Honolulu program was successful in raising the additional revenue needed to offset increased operating and maintenance costs without a reduction in ridership. The success of the program rested heavily upon the community acceptance of TheBUS and the willingness of private companies to undertake the pass sales at no cost to the city. The approach used to project pass sales and system revenues is a feasible one and may be of use in the transit industry.

Honolulu's experiences with its prepaid pass program and fare increase can serve as a guide to other cities and transit properties who are planning to implement a transit pass program.

The following recommendations are intended to serve as guidelines and to identify appropriate areas for future research:

Table 2. Number of prepaid passes sold.

Month	Adult	Student	School Discount	Family	Total
1979					
November	22 287	4398	7 267	0	33 952
December	20 797	4496	6 226	0	31 519
1980					
January	22 028	4642	7 693	149	34 512
February	25 296	5046	9 046	136	39 524
March	25 743	5299	9 254	40	40 336
April	25 805	5224	9 547	76	40 652
May	24 923	5105	10 086	79	40 193
June	25 079	4343	2 858	0	32 280

1. Transit prepaid pass programs are viable programs for the transit industry. These pass programs should be introduced when there are general fare increases. The passes should offer a financial incentive for riders to use the pass. In Honolulu's case, 30 rides are the break-even level for a pass.

2. The transit pass program should be kept as simple as possible. The fare structure should be simple with a minimal number of pass types. Care should be taken to minimize the enforcement problems encountered by bus operators.

3. Community acceptance and involvement are extremely useful in advancing a transit pass program. The use of surveys to inform the public of problem

Table 3. System patronage: FY 1979 and 1980.

	Cash			Passes[a]					
Month	Adult	Student	Total	Adult	Student	School Discount	Free	Total	Grand Total
1978									
July	2780	1261	4041				632	632	4673
August	2773	1254	4027				618	618	4645
September	2662	1289	3951				609	609	4560
October	2769	1318	4087				634	634	4721
November	2688	1275	3963				617	617	4580
December	2658	1257	3915				600	600	4515
1979									
January	2903	1346	4249				651	651	4900
February	2767	1281	4048				624	624	4672
March	3063	1447	4510				693	693	5203
April	2814	1349	4163				644	644	4807
May	2739	1350	4089				632	632	4721
June	2669	1279	3948				610	610	4558
July	2874	1340	4214				656	656	4870
August	2890	1349	4239				650	650	4889
September	2729	1323	4052				630	630	4682
October	2877	1397	4274				656	656	4930
November	1514	712	2226	1244	253	366	709	2572	4798
December	1598	752	2350	1199	268	324	717	2508	4858
1980									
January	1704	802	2506	1270	276	401	773	2720	5226
February	1642	773	2415	1364	281	441	780	2866	5281
March	1660	781	2441	1484	315	482	818	3099	5540
April	1573	741	2314	1440	301	481	786	3008	5322
May	1549	729	2278	1437	304	525	788	3054	5332
June	1561	735	2296	1399	250	144	709	2502	4798

[a]Family Sunday pass usage was less than 1700/month.

Table 4. Revenue trends: FY 1979 and 1980.

	Cash			Passes[a]				
Month	Adult	Student	Total	Adult	Student	School Discount	Total	Grand Total
1978								
July	695	126	821					821
August	693	125	818					818
September	665	128	793					793
October	692	132	824					824
November	672	127	799					799
December	664	126	790					790
1979								
January	726	135	861					861
February	692	128	820					820
March	766	145	911					911
April	704	136	840					840
May	685	135	820					820
June	667	128	795					795
July	718	134	852					852
August	721	135	856					856
September	682	132	814					814
October	719	140	859					859
November	757	178	935	334	33	29	396	1331
December	799	188	987	312	34	25	371	1358
1980								
January	852	201	1053	330	35	31	396	1449
February	821	193	1014	379	38	36	453	1467
March	830	195	1025	386	40	37	463	1488
April	787	185	972	387	39	38	464	1436
May	775	182	957	374	38	40	452	1409
June	780	184	964	376	33	11	420	1384

[a]Less than 150 family Sunday passes were sold in any one month.

areas as well as to collect data regarding those areas is helpful.

4. There is a need to update and expand the Simpson-Curtin formula to account for inflationary effects on transit fare increases. There is also a need to include variables that account for travel cost changes in competing modes of travel.

5. There is a need to examine transit pass usage patterns. Delineating "convenience" users from "financial savings" users and obtaining information on their usage frequency would be helpful for marketing analyses and predicting revenue trends.

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Abridgment

Measured Fare Elasticity: The 1975 BART Fare Change

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By using the measured response of San Francisco Bay Area Rapid Transit (BART) patrons to a fare structure change in 1975, this paper shows that variance in empirical demand elasticities can be strongly and inversely related to the level of patronage aggregation considered and the relative change in fare. The 1975 fare structure change affords a unique opportunity to observe such variance with both increases and decreases in fare occurring for cases at different fare and patronage levels. Two levels of aggregation are considered. One is the systemwide total response aggregate; the other treats each origin-destination data element as a separate case. Different values are computed for elasticity and are found to be related to the level of aggregation. Elasticity functions are also derived from the cases for use in BART forecasting procedures. Analysis for the correct weighting factors to use in fitting the elasticity functions indicates that variance of the measured elasticities is related to the case patronage levels and the square of the difference in logarithms of the fares before and after the change. The fitted elasticity functions also demonstrate that divergences in values of elasticity can be a function of both model specification and the operating point selected for the calculation of elasticity from the function.

The objective of this study was to more accurately represent the varying response of San Francisco Bay Area Rapid Transit (BART) patrons from different market areas to fare changes through derived elasticity functions. Elasticity functions aid in the prediction of responses to fare structure changes at a more refined level of critical system screenlines. They also provide potential controls for studying level-of-service impacts during simultaneous fare and level-of-service changes on BART in mid-1980.

This paper presents results for both calculated constant aggregate elasticities and acceptably fitted elasticity functions that quantitatively demonstrate how much divergence can occur with such computations. An important reason for this divergence is the high variance in the response of trip making to a fare change that appears to be inversely related to the level of patronage. Variance may provide an additional explanation for controversial inconsistencies in elasticity estimates (1,2).

FACTORS IN DIVERGENT ESTIMATES

Depending on the level of aggregation used in computation, the data in this study yielded different values for average elasticity. This was not unexpected since Chan and Ou (1) had hypothesized that aggregate empirical elasticities based on coarse demand data would tend to underestimate the response while disaggregate calibrated elasticities, mostly based on zonal and household data, would overestimate. Thus the absolute value of the aggregate elasticity would be less than that of the disaggregate elasticity. The calculated aggregate elasticity did demonstrate this relation with respect to the average elasticity for the set of origin-to-destination cases that is a more disaggregated level of data. In this case, such differences appear to be an artifact of the method of computation and the aggregation of data.

Gomez-Ibanez and Fauth (2) offer three other explanations for such differences: variations in data accuracy, failure to capture characteristics differentiating markets, and different variables included in model specifications. Model specification does appear to be a significant factor for elasticity functions derived from mathematical models of demand. Ruiter (3) provides an excellent summary of many travel demand models along with derived elasticity functions. In most of the forms summarized, elasticity is not a constant. It is, instead, a function of the variables in the model, most often of the cost variable. Different sensitivities are thus implied for the value of elasticity. A departure from base values for the variables in the function results in a divergence in values computed for elasticity. If results in this paper can be extrapolated, differences on the order of 30 to several hundred percent can easily occur.

Measured elasticities attempt to describe the response of demand to a change in cost directly. An increase in trip cost can be expected to reduce trip making. Adjustments can be made for seasonality, trip purpose, accessibility to alternative stations, and perceived value of cost and its change with time. But adjustments cannot be made for all factors. Thus, erratic values for elasticity can be expected. The extent of the erratic behavior can be surprising. For example, elasticity for daily demand in the 793 selected cases ranged in value from

13.3 to -17.3 with a standard deviation of 2.129 about a mean of -0.781. Morning peak-period elasticity showed a greater range from 21.1 to -34.4 with a standard deviation of 4.121 about a mean of -0.710. Since the square of the deviation from the mean is strongly related to the inverse of the level of patronage, the greater variation in the peak may be related to the lower levels of patronage in the sample cases.

DEFINITION OF ELASTICITY

The method used in this paper for computing elasticity (η) from a measured response to a change in fare is the log difference ratio evolved directly from the differential formulation for elasticity (4, p. 169): $\eta = (\log D_2 - \log D_1)/(\log F_2 - \log F_1)$ where D = demand, F = fare, and the subscripts represent before and after.

Elasticity functions are derived from commonly used demand model forms. Table 1 lists a selected set of demand models and the corresponding elasticity functions. Both case dependent and case independent variables are identified. K and S are intercept and coefficient scaling constants that may be functions of variables not represented by F. The trip cost F may represent fare or the ratio of fare to average annual income. Fitting most of the elasticity functions of Table 1 requires the assumption of a zero intercept. This is a serious and not always justified assumption (5, p. 13). Mixed-model functions are possible alternatives and are listed in Table 2. The corresponding implied-demand models shown were determined from the differential equations based on the elasticity function.

DESCRIPTION OF DATA

Each element of the origin-to-destination trip matrices for 33 BART stations based on daily and 2-h peak-period averages for representative weekdays in October and November 1975 is considered as a "case." Cases with no fare change, such as the round-trip cases representing system touring trips that enter and exit at the same station, and cases with zero patronage in any one of the time periods were rejected. These criteria left 793 acceptable cases. Table 3 provides selected statistics on total daily and morning peak data. Statistics for the afternoon peak were similar to the morning peak statistics.

The BART fare structure is distance-related with minimum fares for the central business district and among neighboring stations and with a decreasing marginal cost with distance. Surcharges are added to transbay fares, and adjustments are made for relative speed and required transfers (6). The new fare structure introduced on November 3, 1975, reduced some fares but increased most. The minimum fare changed from \$0.30 to \$0.25 and the maximum fare increased from \$1.25 to \$1.45.

BART patronage exhibits seasonality and a growth trend. Extensive analysis had been done on five years of monthly average patronage since the start of transbay service (7,8). Though statistically significant growth trends of more than 5.6 percent per year were identified for daily patronage, data used for elasticity functions were not detrended since, in addition to much lower regional population and employment growth rates, a possible explanation for the trend can be real dollar fare elasticity. Relative seasonal factors (8 p. 11) were used. Income and trip purpose data were available for each station as origin or destination from the May 1976 passenger profile survey.

Table 1. Alternative mathematical forms of demand models with corresponding elasticity functions with fare as independent variable.

Demand Model Form	Elasticity Function for D with respect to F	Function Ref. No.
Logarithmic or product		
$D = K F^{-a}$	$\eta = -a$	1.1
Exponential		
$D = K e^{-bF}$	$\eta = -bF$	1.2
Linear		
$D = K - bSF$	$\eta = -bS(F/D)$	1.3
Half-bell		
$D = K e^{-bF^2/2}$	$\eta = -bF^2$	1.4
Linear log		
$D = K - bS \log F$	$\eta = -bS(1/D)$	1.5
Log linear		
$\log D = K + bS(1/F)$	$\eta = -bS(1/F)$	1.6

Notes: Case dependent factors– D = demand; F = cost variable, fare or fare divided by income; K = scaling factor or intercept; and S = slope-scaling factor (for this analysis assume S = 1). Case independent parameters–a, b = constants.

Table 2. Mixed-model fitted elasticity functions.

Function Ref. No.	Fitted Elasticity Function	Implied Demand Model Form
2.1	$\eta = -a - bF$	$D = K F^{-a} e^{-bF}$
2.2	$\eta = -a - b(F/D)$	$D = K F^{-a} - [b/(a+1)]^F$
2.3	$\eta = -a - b F^2$	$D = K F^{-a} e^{-bF^2/2}$
2.4	$\eta = -a - (b/D)$	$D = K F^{-a} - (b/a)$
2.5	$\eta = -a - (b/F)$	$\log D = \log K - a \log F + b(1/F)$ or, $D = K F^{-a} e^{b/F}$

Notes: Case dependent factors–D = demand; F = cost variable, fare or fare divided by income; K = scaling factor or intercept; and S = slope-scaling factor (for this analysis assume S = 1). Case independent factors–a, b = constants.

Table 3. Selected statistics for October and November 1975 representative sample averages.

	Total Day		A.M. Peak Period	
Patronage	October	November	October	November
Total	124 942	118 090	33 848	31 447
Total patronage[a]	123 822	117 276	33 820	31 415
Average extracted fare (\$)	0.632	0.753	0.657	0.778
Average trip distance (km)	21.1	20.9	22.3	22.0
Average time in BART (min)	27.6	27.3	28.3	27.9
Total 793-case sample patronage	97 685	90 335	27 302	24 686
Average extracted fare (\$)	0.709	0.872	0.732	0.899

Note: Trip distance is on-board BART trip distance. Time in BART includes average waiting and transfer time plus nominal on-board travel time.

[a]Exclusive of round trips.

METHODOLOGY FOR DEVELOPING ELASTICITY FUNCTIONS

The elasticity functions were developed by fitting the curves of Table 2 with least squares regression. Patronage and trip cost variables were computed from data for each month and from averages for both months. Income, trip time, distance, work trip purpose, and BART system segment indicator variables were also considered. Best fits were obtained with patronage and both trip cost variables for October, the "before" month. Distance and trip time, which correlated with fare, provided good initial fits; other variables tested seemed to be irrelevant. The multiple correlation coefficients for the fits were very low despite very satisfactory F-values. An analysis of residuals revealed that the residuals were not normally distributed and were strongly related to the values of patronage, fare, and the abso- lute difference in the logarithm of fares. Weighted least squares was indicated.

The appropriate weighting factor to use is one that inversely relates the residual variance to some constant variance (5, p. 80; 9, p. 326). Of the various weighting schemes tried, three had some theoretical merit. The first used the square of the log difference in fares; this could be justified by considering measured elasticity to be a stochastic demand response divided by a constant that is the log difference in fares. The second used the level of patronage; this could be justified by considering it as a sample size for the measured response of individual trip makers. The third used a factor based on the proportion of trips changed; this would be applicable for the output of a Bernoulli process where 1 is a change in trip making and 0 is no change. All three reduced variance and produced better multiple regression coefficients, but the last yielded unsatisfactory distributions of residuals. Best results were obtained through a combination of the first two in the weighting factor (w_i), $w_i = D_{i1}$ (log F_{i2} - $F_{i1})^2$ where D_{i1} is the level of patronage of case i in the "before" month and F_{ik} is the fare for case i in month k.

Table 4. Average measured elasticities of BART daily systemwide patronage related to fare change in November 1975.

Method of Computation	Type of Demand Adjustment: Unadjusted	Seasonality	Seasonality and Trend
Linear mean ratio			
Unweighted	-0.682	-0.773	-0.803
Log difference ratio			
Unweighted	-0.689	-0.781	-0.811
Weighted by -			
ADLF[a]	-0.559	0.621	-0.641
D[b]	-0.368	-0.443	-0.468
$D(ADLF)^2$	-0.348	-0.392	-0.406
Aggregated -			
793 cases	-0.377	-0.454	-0.479
Totals	-0.310	-0.399	-0.429

[a]ADLF = Absolute value of the difference in log fares. [b]D = Demand.

Table 5. Selected weighted regression results for fitted measured elasticity function.

Table 2 Ref. No.	Independent Variable	Coefficient	t-Statistic	Intercept	Coefficient of Determination (r^2)
2.1	F/I	-11.294	-11.25	0.027 6	0.1380
2.5	I/F	0.015 67	12.27	-0.879 0	0.1598
2.3	$(F/I)^2$	-112.17	-9.78	-0.213 1	0.1079
2.2	(F/I)/D	-158.08	-6.49	-0.348 6	0.0506
2.1	F	-0.612 5	-8.58	-0.057 15	0.0851
2.5	1/F	0.216 7	10.39	-0.844 5	0.1202
2.3	F^2	-0.367 5	-6.75	-0.265 6	0 0545
2.2	F/D	-10.62	-5.97	-0.351 7	0.0431
2.4	1/D	-6.880 6	-5.56	-0.350 2	0.0376
-	T	-0.015 96	-9.12	-0.002 3	0.0952
-	L	-0.014 65	-7.84	-0.134 4	0.0721
-	F/I	-10.459	-6.30	0.040 1	0.1384
	T	0.001 783	-0.63		

Notes: F = October fare ($); I = income ($000s); D = October demand (trips); T = in-BART travel time (min), including wait and transfer time; L = on-board station-to-station travel distance (km).
Weighting factor is demand times the square of the difference in log fares.

FINDINGS AND DISCUSSION

Average Values for Elasticity

Selected averages for daily systemwide measured elasticities are given in Table 4. Except for the aggregated totals without round trips, averages are for 793 cases. The weighted averages are less in absolute value than the unweighted since the weight factors were heavier for cases with measured elasticities with smaller deviations from the mean value. The range of these estimates is noteworthy. In other results, morning peak elasticities varied less but indicated a more elastic aggregate response; afternoon peak elasticities varied more and were less elastic.

Selected Elasticity Functions

Selected fitted elasticity functions are shown in Table 5. High t-statistic values show that the independent variables are significant explanatory variables for measured elasticity even though coefficients of determination (r^2) are not large. Adding another variable did not improve the fit significantly in most cases. The functions listed are all preferable to a constant elasticity by regression criteria.

Some insight into the divergence of elasticity estimates given by differently specified models can be gained from the plots of elasticity functions against fare divided by income in Figures 1 and 2. Figure 1 shows functions that were directly fitted to the independent variable while Figure 2 shows those that were related to demand and had to be transformed by substitution of the appropriate demand function from Tables 1 and 2. The zero intercept functions are plotted to illustrate the implication of that constraining assumption. For example, curves 2.5 and 1.6 represent the same inverse cost independent variable of the log linear model but are different because curve 2.5 includes a significant intercept that shows the dominant influence of the product model. The null hypothesis is not supported for the plotted zero intercept cases and is rejected at the 0.01 significance level. On the other hand, the fitted straight-line function (2.1) derived from the exponential demand model effectively has a zero intercept. The null hypothesis that the intercept of this function is zero is maintained at 95 percent confidence.

The functions fitted directly and inversely to the cost variables yield the best and almost equivalent figures of merit. October fare divided by income is more efficient than fare itself and is preferred. The inverse cost function (2.5) produces behavior contrary to that implied by a log linear model and the regression coefficient would be rejected under a one-tailed test. The linear function (2.1) with its near zero intercept is the most acceptable with respect to its consistency with the postulated behavior of demand related to cost in an exponential model.

CONCLUSION

The measured elasticities and elasticity functions presented were all computed using acceptable methods from the same data base. Yet they give diverse values for elasticity. Variance in the response to fare change is one factor influencing this diversity. Also, the often used assumption of constant elasticity is not necessarily correct. Fare level or fare related to income are acceptable explanatory variables for the variation in measured elasticity.

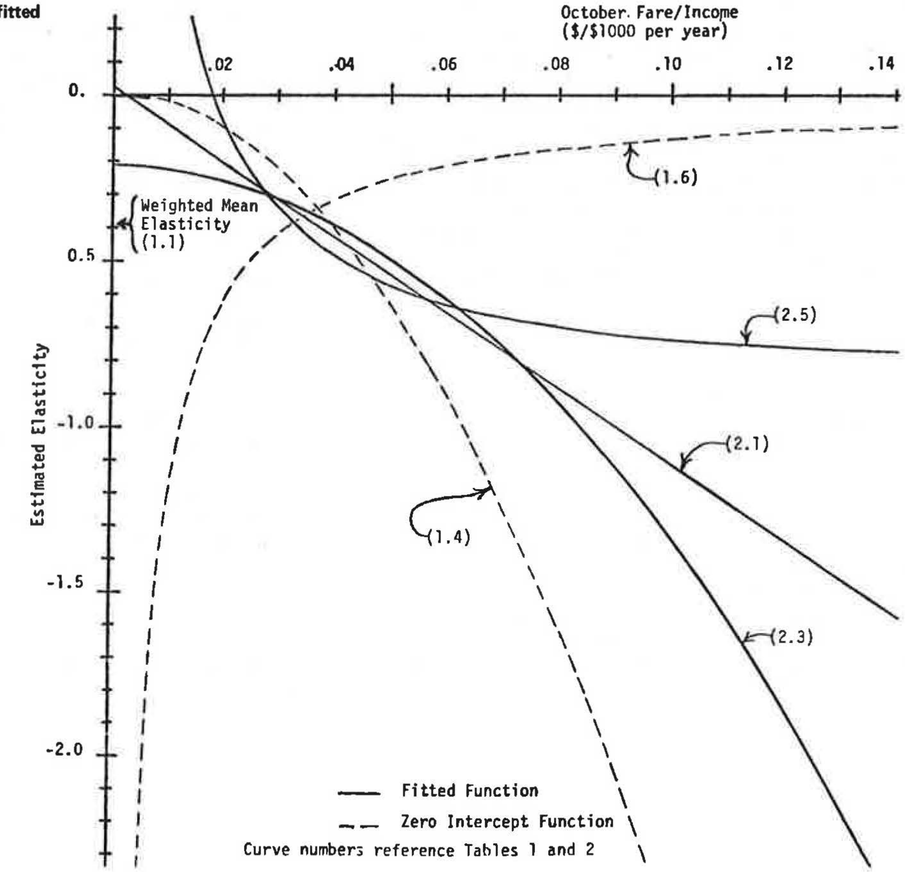

Figure 1. Elasticity functions directly fitted to October fare divided by income.

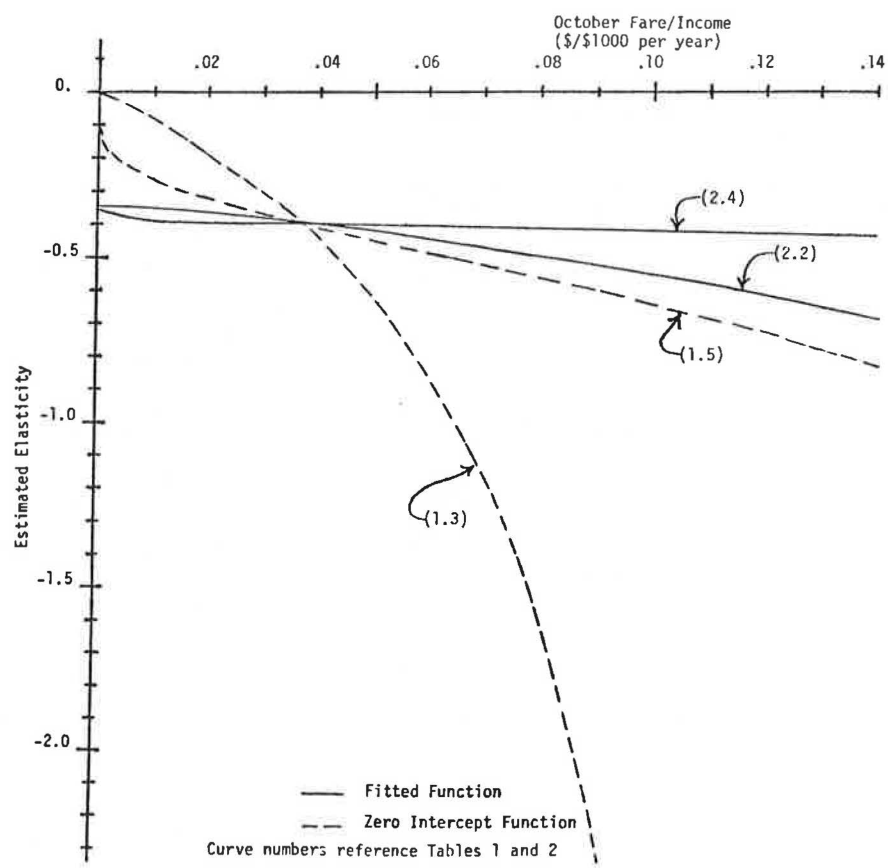

Figure 2. Elasticity functions derived from functions fitted to inverse demand or fare divided by income and by demand.

Elasticities derived from some demand models, including the disaggregate models, do consider such cost variables. Transferability of results would be affected by the specification of these and other possibly important variables not yet identified.

The variation in elasticity data is large relative to the mean value and inversely related to the demand level and the square of the log difference in fares. The indications are that the demand weighted mean value of the cases approaches the aggregate elasticity, which may provide a better estimate of the expected response if a single value for change in demand is sought.

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Further Evidence on Aggregate and Disaggregate Transit Fare Elasticities

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This paper presents new evidence on transit fare elasticities from experimental demonstrations and demand models. Mean values and standard deviations of fare elasticities are analyzed for both aggregate and disaggregate ridership categories. Aggregate fare elasticities for fare-free, fare prepayment versus cash payment, and promotional fare reductions are presented. Fare elasticities are also disaggregated by mode, trip length, route type, period of the day, and income and age groups. A review of the methods used in elasticities estimation is also presented.

Over the past few decades, transit operators have relied on the Simpson and Curtin formula (1) for predicting the impact of fare changes on transit ridership. The Simpson and Curtin formula, which predicts the percentage decrease in ridership as a function of the percentage increase in fares, has reverted to the rule of thumb that transit ridership will decrease (increase) 0.3 percent for every 1 percent increase (decrease) in transit fares.

Although the Simpson and Curtin rule of thumb is generally correct in highlighting the fact that transit ridership is inelastic, its indiscriminate use can lead to serious miscalculations of the ridership impacts of fare changes. This problem was brought out by two American Transit Association (ATA) studies of losses in passenger traffic due to transit fare increases between 1950 and 1967 (2,3). Both studies, while finding an average shrinkage ratio of -0.33, showed wide variances in the range of elasticities estimated, ranging from -0.004 to -0.97. Dygert, Holec, and Hill (4) have shown that in slightly more than half the cases the shrinkage ratio estimated by ATA was below Simpson and Curtin's rule of thumb.

The existence of such a wide variation in transit fare elasticities has prompted many transportation analysts to present evidence of disaggregate ridership response to fare changes (5-7). This paper presents new information on the size of aggregate and disaggregate transit fare elasticities obtained from demonstrations and demand models. In addition, this paper cautions the reader in interpreting the demand elasticity estimates from data containing no fare change.

APPROACHES TO ESTIMATING TRANSIT FARE ELASTICITIES

Nature of Approaches to Demand Estimation

Two broad approaches to estimating fare elasticities may be distinguished. These approaches include (a) monitoring fare changes or demonstration studies, or those that rely on data generated either by a practical demonstration of an actual change or by monitoring an actual change in current fares; and (b) nonexperimental approaches, or those that rely on a data base either devoid of an actual change in current fares or where actual changes are part of historical trends.

Approaches in the first category include the monitoring of transit fare demonstrations and individual fare changes such as those using monthly data series (8,9). These approaches estimate fare elasticities in current dollars. The nonexperimental approaches generally include (a) the conventional time-series analysis of annual transit operating statistics; (b) aggregate direct-demand and modal-split models based on cross-sectional data; and (c) disaggregate behavioral mode-choice models based on cross-sectional data. These last two approaches estimate fare elasticities in constant dollars. All the nonexperimental approaches have in common the facts that the data base does not contain an actual fare change in current or money terms and also that the data base is not generated with the objective of controlling for nonfare changes.

Methodological Note on Special Problems of Cross-Sectional Models

In interpreting transit demand elasticities, some problems are posed by over-reliance on elasticity estimates developed from a cross-sectional data base containing no fare change. One cannot rely on elasticity estimates from cross-sectional studies to provide accurate estimates of annual changes in patronage in response to fare changes because they reflect a different type of behavior from that implicit in time-series analysis. This difference between time-series and cross-sectional models arises because the residuals from both models cannot be assumed to belong to the same underlying population. In general, cross-sectional estimates represent behavior that, for lack of better terms, economists have labeled "long-run structural adjustments" (10-12), although it is possible that cross sections taken at a time of rapid growth or of cyclical change could also reflect short-run annual adjustments such as those characterized by time-series relations. Although cross-sectional models have advantages in forecasting structural changes in demand, dynamic annual-change-type responses cannot be estimated with any degree of confidence unless supporting time-series information is available to establish a systematic relation.

Another problem is that some recent work on disaggregate behavioral models has departed from McFadden's (13) original contribution and as a consequence, as shown by Oum (14), some of these models (a) impose many rigid a priori conditions on the elasticities and cross-elasticities of demand, (b) result in estimates of elasticities that are not invariant to the choice of the "base" or modal denominators, and (c) possess severely irregular and inconsistent underlying preference or utility structures. Moreover, an estimation problem arises whenever simultaneous mode choices concern more than two modes. Both Theil (15) and Nerlove and Press (16) argue that biased coefficients result when simultaneous choices--such as the choices involving more than two transport modes--are estimated via single-equation estimation techniques such as the maximum likelihood approaches currently used by transportation mode-choice modelers.

In spite of the alleged superiority of calibrated models relying on cross-sectional data, some studies (6,17) have shown that the approaches that rely on data generated by monitoring actual changes in current fares result in more stable elasticity estimates. The reader is therefore urged to use caution when interpreting and using elasticity estimates from calibrated cross-sectional models unless the models have been calibrated from a data base where actual fare changes have occurred.

Variable-Elasticity Models

The research and implementation issues of disaggregate behavioral models have been reviewed elsewhere (18,19) and do not have to be repeated here. One area, however, that has been overlooked concerns the need for more analysis of the interaction effects of fare and service levels. Whether from demonstrations or sophisticated mode-choice models, most demand-analysis approaches explicitly ignore the possibility of analyzing fare and service interactions by assuming constant-elasticity models (i.e., assume the interactions to be zero). These constant-elasticity models should be deemphasized in favor of variable-elasticity models with interaction effects, such as the translog models (20).

Aggregate Fare Elasticities

From an analysis of more than 60 studies of transit fare demand (6), the following aggregate fare elasticity means and standard deviations have been estimated:

Factor	Mean	SD	No. of Cases
Monitoring fare changes, demonstration studies	-0.28	±0.16	67
Nonexperimental time-series	-0.42	±0.24	28
Nonexperimental cross-sectional	-0.53	±0.35	28

The results from demonstrations and other fare-change-monitoring studies are not appreciably different from Simpson and Curtin's rule of thumb. However, the fare elasticities developed from nonexperimental direct-demand and mode-choice models are appreciably higher, especially for those models using cross-sectional data. It has been shown that the calibrated elasticities from models are almost twice as large as the empirical elasticities estimated from actual fare changes (17). The aggregate values presented in an Ecosometrics study (6) show the elasticities from studies that use cross-sectional data to be 1.89 times the elasticity values from demonstrations and studies of fare changes that use before-and-after data.

Fare-Free Elasticities

The fare-free demonstrations and case studies conducted under the sponsorship of the Urban Mass Transportation Administration (UMTA) provide information on the ridership responsiveness to maximum reductions in fare to fare-free service. The following table (6) summarizes the fare elasticities calculated from the results of these demonstrations:

	Time Period	
Service Restrictions	Off-Peak	All Hours
CBD only	-0.61 ± 0.14 (3 cases)	-0.52 ± 0.13 (3 cases)
Senior citizens	-0.33 (1 case)	NA
Students only	NA	-0.38 (1 case)
No restrictions	-0.28 ± 0.05 (4 cases)	-0.36 ± 0.28 (2 cases)

As seen from this table, the highest fare-free elasticities apply to central business district (CBD) travel where the result of the free fare is to divert a substantial number of walking trips to the free bus service. Except for the CBD fare elasticities, the fare-free elasticities are generally lower than the elasticities observed for fare increases and decreases at comparable initial fare levels. This is confirmed by the low elasticities of -0.29 and -0.19 estimated from the off-peak fare-free demonstrations in Denver and Trenton. The relatively low fare-free elasticities throw doubt on the theoretical hypothesis that the greater the relative change in fares the greater the elasticity value.

Fare Prepayment Versus Cash Payment

The knowledge of fare elasticities of demand for transit fare prepayment is limited. The scant information available from Europe shows pass riders to be more fare-inelastic than cash-fare or ticket riders, reflecting the fact that pass users are frequent riders who, like commuters, exhibit low fare elasticities. In Paris, the fare elasticity of demand for passes is -0.14 in contrast to -0.20 for single-ride tickets (21). The Midland Red Bus Company in Warwickshire County, England, shows fare elasticities of -0.10 for passes and -0.32 for single-ride tickets (21).

There have only been a few attempts to calculate fare prepayment demand elasticities by using U.S. data. In Jacksonville, Florida, the adult cash fare elasticity of -0.31 is lower than the demand elasticity for passes (-0.36) (22). The systemwide fare elasticity is -0.38. Demand elasticities for pass users participating in the employer-promoted fare prepayment demonstration in Sacramento (23) were calculated by Ecosometrics to be -0.41 for work trips, -0.27 for nonwork trips, and -0.39 overall. The higher fare elasticity for work trips compared with that for nonwork trips is indicative of the limitations on nonwork travel for individuals working every day.

By using a maximum-likelihood disaggregate choice model, Page (24) estimated fare elasticities of the probability of purchasing a pass ranging from -0.18 to -0.38 for the Sacramento employer-promoted monthly-pass program. Although the elasticity estimates are reasonable, the econometric-demand work conducted here and elsewhere on pass programs has failed to analyze passes as rate structures. The result of this improper reflection of the econometrics of rate structures is to confuse the price-and-income effects of passes on demand (25).

Fare Elasticities from Promotional Fare Reductions

Although transit properties across the country are continuously offering "bargain fares", "Sunday specials", and "fare-free days," few of these programs are monitored closely for their short-term and long-term ridership and revenue impacts. Caruolo and Roess (26), however, have identified two fare-free projects from which fare elasticities could be calculated.

An Auburn, New York, experiment involved the all-day elimination of a 25-cent fare for one month. Although ridership increased more than 300 percent during the fare-free month (fare elasticity of -0.63), there is no mention of the level-of-ridership attrition after the experiment. In Madison, Wisconsin, fares were abolished during off-peak hours for one week. Total weekly ridership increased 93.5 percent, resulting in a fare elasticity of -0.32.

In 1975, Madison conducted a demonstration project to test the effects of reduced fares and more frequent headways on weekend ridership (27). Although some data discrepancies exist, the demonstration is one of the only documented efforts in the United States to sequentially vary transit fares and headways. The results of the short-term weekend fare reduction and subsequent fare increase are presented below (6,27):

Fare Change	Date of Fare Change	Fare Elasticities Saturday	Fare Elasticities Sunday
Decrease	January 18, 1975	-0.28	-0.20
Increase	May 10, 1975	-0.51	-0.64

Caruolo and Roess (26) also reviewed the 1974 "Save-on-Sunday" program sponsored by the Metropolitan Transit Authority in New York City. Under the two-rides-for-the-price-of-one program, ridership increased by approximately 37 percent overall. The Sunday price promotion lasted six months and resulted in an overall fare elasticity of -0.47 (6). As in Auburn and Madison, the price promotion in New York City resulted in a net revenue loss for the operator.

DISAGGREGATE FARE ELASTICITIES

Recently, transit operators have begun to target fare programs to meet the needs of specific user groups, and aggregate fare elasticities do not provide reliable estimates of the ridership and revenue impacts of individual programs. This section presents evidence of disaggregate fare elasticities for different types of trips and user groups.

Fare Elasticities by Mode

Several studies have confirmed that bus fare elasticities (8 cases) are two times greater than rapid-rail fare elasticities (8 cases), as shown below (6,21,28,29):

City	Bus Service	Rapid-Rail Service
New York	-0.32 ± 0.11	-0.16 ± 0.04
London	-0.33	-0.16
Paris	-0.20	-0.12
Mean and SD	-0.30 ± 0.10	-0.15 ± 0.13

For six independent fare changes in New York City between 1948 and 1977, the mean bus fare elasticity is -0.32 ± 0.011 while the value for subway service is -0.16 ± 0.004. This larger elasticity for bus transit than for rapid rail can be explained by the more numerous substitutes for bus transit. Automobile, taxi, and even walking modes of travel share the same right-of-way and serve the same routes as buses. In contrast, rail transit has fewer modal substitutes, is faster than bus transit operating on surface streets, and occupies its own right-of-way.

Although it can be said for certain that bus fare elasticities are, on the average, twice as large as rapid-rail elasticities, the relation between bus and commuter-rail fare elasticities is inconclusive. Although it is our belief that commuter-rail fare elasticities are lower than those for buses, the few observations available show inconsistencies that make it impossible to formulate definite conclusions. The most reliable of the fare-elasticity estimates are those from London (30) and from the Boston 1963 demonstration (31), which show commuter-rail elasticities lower than bus fare elasticities (6).

Long- and Short-Distance Fare Elasticities

The demand for very short transit trips appears to be more elastic with respect to fares than is the demand for long trips. The London Transport Review Board's 1968 mathematical analysis (32) shows that bus trips of less than 1 mile exhibit higher fare elasticities (-0.55) than trips of 1-3 miles (-0.29). Bly (21) reports that in Essen, Germany, the fare elasticity for short- and long-distance trips was found to be -0.32 and -0.12, respectively.

Fare Elasticities by Route Type

Differences in fare elasticities have been observed for various types of transit services and routes in urban areas. The general consensus has been that on routes in which the preponderance of travel is for work purposes, such as radial arterials and express routes, the fare elasticities are lower than those observed on routes with a large proportion of discretionary travel, such as on intrasuburban and local routes.

Table 1 presents data from the London Transport experience that tends to support this. The results show that weekday intrasuburban trips are more elastic than radial trips between central London and the suburbs. The relatively large intrasuburban fare elasticities suggest that the intrasuburban trips are either less important or have more modal substitutes than radial trips.

Peak and Off-Peak Fare Elasticities

In nearly every study where peak and off-peak fare elasticities have been estimated, off-peak elasticities are two to three times larger than the values observed for peak travel. The off-peak fare elasticities for New York and London presented in Table 2 (6) are 2.5 times larger than corresponding peak-period values. Moreover, this factor applies equally to bus and rapid-rail travel. For subway service in New York City and bus service in St. Louis, afternoon peak-period ridership is more elastic than morning peak-hour ridership indicating that a greater degree of nonwork or nonessential travel takes place during the evening rush hour.

Table 1. Fare elasticities by route type and transport mode.

Transport Mode	Route Type: Radial Arterial	Intrasuburban	All
Bus	-0.09	-0.38	-0.32
Rapid rail	-0.11	-0.28	-0.26
Commuter rail	-0.06	-0.26	-0.13
Mean	-0.09	-0.31	-0.24

Note: Because own-price elasticities were not presented in Fairhurst and Smith (30) and could not be estimated, the elasticity values presented in this table were calculated from simulations of a 10 percent fare increase across all public transportation modes.

Evening, late night, and weekend fare elasticities are not much different from the values observed for midday services, although the results obtained from a 1968 study for New York City (28) show Sunday ridership to be less elastic than Saturday ridership (6).

There are scant data available on accurate estimates of the cross-elasticity between peak and off-peak periods. Ecosometrics (6) presented evidence that showed the mean elasticity of peak demand to off-peak fare changes to be +0.15 ± 0.14 (6 cases) and the mean elasticity of off-peak demand to peak period fare adjustments to be +0.03 ± 0.01 (2 cases). Clearly, the reason for the extremely low peak demand cross-elasticities is that workers have little choice in deciding their home-to-work travel time. In cities with differential time-of-day pricing and well-organized variable work hours programs (such as in Duluth, Minnesota), peak to off-peak fare cross-elasticities may be larger.

Fare Elasticities by Income and Age

One would expect high-income groups to have a larger fare elasticity than low-income groups. The analyses of both the Denver and Trenton off-peak fare-free demonstrations provide partial support for this general hypothesis, as shown in the table below (33,34):

Household Income ($)	Off-Peak Fare Elasticities: Denver	Trenton
Under 5 000	-0.28	-0.09
5 000-9 999	-0.24	-0.10
10 000-14 999	-0.25	-0.41
15 000-24 999	-0.28	-0.08
25 000 or more	-0.31	-0.43

Although the Denver demonstration shows only slight differences in off-peak elasticities by income group, Trenton's fare elasticities generally rise as household incomes increase. The elasticities calculated in these demonstrations refer to off-peak hours when most nonwork trips are taken. Whereas most of the new transit trips in the Denver case came from the more-affluent groups, the largest increase in temporal shifts from the peak came from the lowest-income groups.

The Denver and Trenton off-peak fare-free demonstrations have provided some evidence to suggest that there is an inverse relation between age and ridership response during the off-peak hours. In both demonstrations, young people were most responsive to the off-peak fare elimination, as shown in the following table:

Age Category (years)	Demonstration: Denver	Trenton	Mean Value
1-16	-0.32	-0.31	-0.32

Table 2. Disaggregated fare elasticities by time of day and week.

City	Peak Period: A.M.	P.M.	Average	Off-Peak Period	Midday	Evening	Late Night	Saturday	Sunday	All Hours
New York										
Rapid rail	-0.03	-0.06		-0.11	-0.10	-0.18	-0.04	-0.15	-0.04	-0.09
St. Louis	-0.13	-0.17			-0.40	-0.38				-0.24
Madison				-0.32				-0.28	-0.20	
								-0.51	-0.64	
Denver				-0.29	-0.28			-0.28	-0.45	
Trenton				-0.19	-0.18	-0.22		-0.13	-0.26	
London										
Bus		-0.27	-0.27	-0.37						-0.33
Rapid rail		-0.10	-0.10	-0.25						-0.16
Stevenage, England		-0.32	-0.32	-0.84						-0.67

Age Category (years)	Demonstration Denver	Demonstration Trenton	Mean Value
17-24	-0.30	-0.24	-0.27
25-44	-0.28	-0.08	-0.18
45-64	-0.18	-0.12	-0.15
65 or older	-0.16	-0.12	-0.14

CONCLUSION

The principal focus of this paper has been on identifying the differences in fare elasticities of transit demand among market groups. Although systemwide elasticity values, such as the Simpson and Curtin formula, have been useful for predicting aggregate ridership changes resulting from changes in fares, these values do not provide reliable estimates of the ridership and revenue impacts of individually targeted fare programs. Thus, the evidence currently available on disaggregated fare elasticities of demand was presented.

Also, the differences in fare elasticities noted in this paper highlight the futility of using flat-fare systems as revenue-producing agents. Not only do flat fares provide more subsidy to the more-affluent suburbanites and other long-distance riders, but they also result in significant losses of opportunities for increasing ridership and revenues. If U.S. transit companies are going to take advantage of the increased revenue and ridership opportunities afforded by the differences in fare elasticities across transit markets, the reliance on flat fares will have to be abandoned.

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Abridgment

Free-Fare Transit: Some Empirical Findings

LAWRENCE B. DOXSEY AND BRUCE D. SPEAR

This paper presents comparative results from two free transit demonstrations funded by the Urban Mass Transportation Administration. In Denver and Trenton, one-year experiments with off-peak free transit began early in 1977. The analysis here is based on survey and ridership-count data collected as part of the demonstration evaluation process. Aggregate ridership increases of about 50 percent were observed at both sites following the elimination of fares. The majority of the additional trips would have otherwise been made by non-bus modes, though roughly 15-25 percent would not have been made at all without free fare. Transit-dependent groups, including the elderly, the poor, and the carless, were less responsive to fare elimination than were nondependent groups. Neither demonstration had a measurable impact on automobile use. At both sites increased ridership led to modest and generally localized deteriorations in service quality.

This paper summarizes the results of two off-peak free-fare demonstrations sponsored by the Office of Service and Methods Demonstrations, Urban Mass Transportation Administration (UMTA). One took place in Denver and the other in Trenton. Each lasted for one year. Restriction of free fare to off-peak periods served to reduce the overall cost of the demonstrations since peak-period ridership continued to generate revenue. Furthermore, continued collection of peak-period fares focused ridership gains on the excess capacity of the off-peak periods.

Although the basic approach to fare elimination was identical in Denver and Trenton, the two demonstrations had several important contextual differences. These included predemonstration site-and-transit service characteristics, underlying local objectives for the demonstration, the manner in which fare elimination was implemented, and external events that influenced the observed impacts of the demonstrations. Perhaps the most significant differences between the two demonstrations were in the circumstances under which they originated. Whereas the Trenton demonstration was planned from the beginning as a one-year experiment, the Denver demonstration evolved out of what was initially planned as a one-month, locally sponsored transit promotion effort. One consequence of the more spontaneous origin of the Denver demonstration is that there was little opportunity to develop either a comprehensive implementation procedure or an evaluation plan.

Also, during the course of the demonstration Denver restructured its bus routes from a radial pattern, focused on Denver's central business district (CBD), to a grid pattern. The route restructuring probably had both temporary and longer-term negative impacts on free-fare ridership levels (1).

AGGREGATE CHANGES IN TRANSIT RIDERSHIP

With the introduction of off-peak free fares, each site experienced a large increase in aggregate system ridership that was sustained throughout the demonstration period. In Trenton, average weekly off-peak ridership rose by 46 percent; in Denver, the increase was 52 percent. Figure 1 presents monthly ridership estimates for the two sites from January 1977 through June 1979.

Although ridership peaked early in each demonstration, it is evident from the figures that much of these ridership gains were sustained throughout the year of free fare. This suggests that even after the novelty of free bus service wore off, free fare continued to make transit an attractive travel alternative. Following the reinstitution of off-peak fares early in 1979, ridership remained above projections based on predemonstration levels, suggesting that some of the ridership induced by the free fares was retained after fares were reimposed. However, several exogenous events also influenced post-demonstration ridership in ways that were probably significant but cannot be easily quantified. Perhaps the most significant influence came from the nationwide gasoline crisis that occurred in 1979. The long-term impacts of the free-fare promotion are therefore uncertain at best, but are probably not of sufficient magnitude to offset the revenue loss associated with the year-long free-fare promotion.

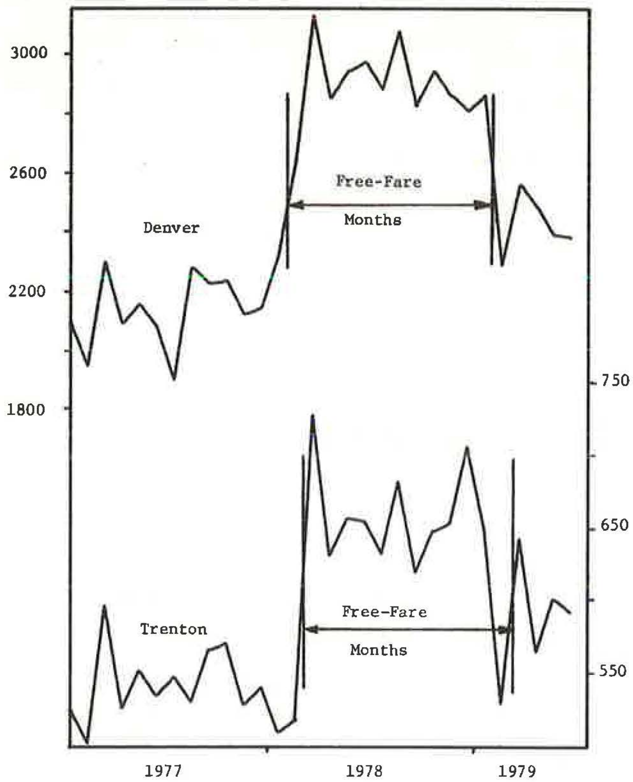
TRAVEL-RELATED BENEFITS

The benefits ascribed to free-fare-induced transit derive from three sources: (a) increased mobility for transit dependents, (b) reduction of car travel through diversion of car trips to transit, and (c) economic stimulation of commercial areas through increased trip making for shopping.

One of the principal benefits attributed to free-fare transit is an increase in the mobility of transit-dependent segments of the population. By eliminating cost as a barrier to travel, proponents argue (2,3) that such groups as the poor, the elderly, or the young will have greater access to activities and opportunities throughout the urban area.

It was found that 12 percent of all free-fare trips in Trenton and 7 percent of those in Denver

Figure 1. Monthly ridership (000s).



would not have been made had fares been charged, according to the trip makers. At each site, a major share of the free-fare-induced trips was made by people with household incomes below $10 000, and by people in the 17-to-24 age group. Note, however, that these age and income groups were heavy bus users prior to free fare. As a consequence, despite large absolute shares of all induced trips, their induced trips were relatively few in comparison to their total bus trips prior to free fare. In Trenton, the share of free-fare-induced trips relative to base-period trips was greatest among people in the $10 000-$15 000 income bracket, while in Denver, people with incomes of more than $15 000 were most readily induced to take new trips by free fare. Among age groups, young people at both sites were most induced to make trips during free fare. In Denver, however, the single greatest increase occurred among people in the 17-24 age group. The share of induced trips among the elderly was low relative to their prior level of trip making at both sites.

Together, these findings suggest that no particular sociodemographic group can be identified as an overwhelming beneficiary of off-peak, systemwide free fare. Young people in general seemed to take advantage of free fare to make more trips, while the elderly took fewer free-fare-induced trips than might have been expected. Beyond these observations, the relative increases or decreases among sociodemographic groups and trip purposes were site specific.

Because of the importance of impacts on transit dependents in assessing free fare, the full set of travel changes, including not only induced travel but modal shifts as well, was separately evaluated for the poor, the elderly, and the carless. The shares of off-peak transit trips attributable to each of these groups declined during the free-fare demonstration at each site. Because of the overall increases in system ridership, these lower shares do translate into modest absolute increases in the number of trips made by these groups. However, it would appear that transit dependents were generally less responsive to the free-fare incentive than were other segments of the population. One explanation for this phenomenon is that transit dependents have fewer travel alternatives from which to switch, and are therefore less responsive in terms of mode change.

Free fare had relatively little impact on the trip purposes of the three groups. There were small decreases in the shares of home-based trips and shopping trips among the nonelderly. These were offset by small increases in the shares of social-recreational and other trip purposes. Free fare also seemed to result in modest increases in the share of work trips by the low-income and the carless groups.

In considering the travel behavior changes of these three groups, free fare did not significantly improve the overall mobility of the transit-dependent rider relative to that of other transit travelers. Based on the above findings, it does not appear that systemwide free fare represents a well-focused policy tool for the provision of mobility to specific population segments.

IMPACTS OF FREE FARE ON VMT

A considerable volume of the general press literature advocating free-fare transit focused on its potential for diverting car trips to transit with consequent reductions in car-based vehicle miles of travel (VMT) and the traffic congestion, air and noise pollution, and energy consumption associated with car VMT (4-6). Realistically, transit's relatively small share of total urban travel leaves it underleveraged for substantially reducing car use. In a city with a 5 percent transit mode share, for example, doubling transit use, even if all additional trips were diverted from the car, would induce slightly more than a 5 percent reduction in car travel.

Indeed, the findings from Denver and Trenton confirm the relative ineffectiveness of free fare in reducing car VMT. Approximately 9 percent of the free-fare trips in Trenton and 15 percent of the Denver trips would have been made by car. At the outside, free fare reduced weekly car VMT in Denver by less than 0.5 of 1 percent and in Trenton by slightly more than 0.1 of 1 percent. These changes are so small as to be unobservable within total VMT.

Although the impact of free fare on car travel seems insignificant in the aggregate, it is still useful to examine the sociodemographic characteristics of those individuals who switched from car to transit. In both Denver and Trenton, those who were diverted from the car were younger and had higher incomes than the typical transit user. The association between income and car use is not unexpected. However, the fact that these people switched to transit suggests that price sensitivity exists at all income levels. More importantly, it appears that a potential market of transit riders exists among the younger, middle- to upper-middle income car traveler.

IMPACTS OF FREE FARE ON CBD VITALITY

The ability of free fare to improve the economic health of a city's CBD depends on its influence on CBD attractiveness and accessibility relative to that of alternative destinations. Free fare enhances mobility within the CBD. Moreover, systemwide free fare, in contrast to CBD free-fare zones, reduces the cost of travel to the CBD. However, as systemwide free fare similarly reduces the cost of travel to alternative destinations, the CBD's relative gain is less than it would be with a geographically restricted free-fare policy.

Neither demonstration site provides very strong evidence of the impacts of free fare on CBD commercial activity. In Trenton, inbound bus trips with a shopping destination and outbound trips with a shopping origin showed greater increase than did the reverse travel. In Denver, between 0.5 and 1 percent of free-fare travel involved additional shopping trips to the CBD. This represents approximately 0.5 percent of all CBD shopping travel. On the other hand, roughly equal shares of respondents reported decreasing their CBD travel due to free fare as reported increasing their trips.

FINANCIAL IMPACTS OF FREE FARE

Financial consequences are free fare's greatest disadvantage. The major impact is the direct loss of revenue from previous fare-paying riders. With off-peak free fare there is also loss of revenues as patrons are drawn from peak to off-peak ridership. There may as well be an increase in operating cost if additional service is required to accommodate the new ridership. The revenue loss and cost increase contribute to an increase in the required operating subsidy.

In Trenton, the combined revenue losses both from off-peak trips that would have been made even if a fare had been charged and from diverted peak period trips amounted to $343 000. Additional operating costs attributable to free-fare service added another $22 500 for a total increase in transit subsidy of $365 500. In Denver, the lost revenues from off-peak trips were partially offset by an increase in fare-paying peak trips. Estimated net revenue losses during 1978 amounted to $3.94 million. Increased operating costs attributable to free fare added another $407 000, bringing the total cost of free fare in Denver to $4.347 million. At each site, free fare required about an 11 percent increase in operating subsidy.

IMPACTS ON TRANSIT OPERATIONS

Two aspects of service quality were adversely affected by free fare: onboard crowding and the level of schedule adherence. Both impacts occurred as the direct result of very sharp increases in ridership.

With little increase in the number of buses serving off-peak free-fare trips, all buses became more crowded. In Denver, load counts conducted at the CBD fringe in August 1978 showed the average load for the 51-seat buses to be 45 passengers, an increase of roughly 50 percent during the period prior to free fare. CBD boundary load counts were made in Trenton both before and during the fare-free period. For off-peak vehicles alone, the average load increased by nearly 60 percent. Furthermore, the share of off-peak buses arriving downtown with standees rose from 1 or 2 percent to between 15 and 20 percent. At both sites, the most severe crowding was concentrated in or near the downtown.

Schedule adherence can be influenced by increased demand in at least three ways: (a) Larger numbers of boardings and alightings will increase dwell times; (b) a higher overall level of ridership increases the average number of boarding and alighting stops made per run; and (c) as on-board crowding becomes more severe, more time is typically required during each boarding or alighting. At both sites, schedule checks of buses arriving at the boundaries of the CBD were conducted during the demonstrations in accordance with normal transit administrative procedures. The share of buses arriving ahead of schedule declined in both Denver and Trenton, although the change was more dramatic in Denver. On-time arrivals (buses arriving less than 5 min behind schedule) declined in Trenton but increased slightly in Denver. Late arrivals increased significantly at both sites. Free fare thus appears to have resulted in a fairly distinct pattern of vehicle delay, although the average amount of delay was modest.

CONCLUSION

Off-peak systemwide free fare will probably not be an attractive long-term pricing policy for local transit operators. Because of a substantial overflow of benefits to untargeted groups, it would appear that more restrictive pricing policies such as targeted transit subsidies could achieve similar social benefits at less cost than systemwide free fares.

ACKNOWLEDGMENT

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Trip-Distance and Fare-Paying Characteristics of BART Patrons in May 1978

WARD D. BELDING, JR. AND THADDEUS W. USOWICZ

Average on-board trip distance and average fares paid for the San Francisco Bay Area Rapid Transit (BART) are tabulated for the 1978 passenger profile survey sample by income class, age group, special fare category, and market segment. On-board trip distance was found to vary significantly with income class. It also varied with age group insofar as the middle-aged group took longer trips. Trip distance did not vary significantly with special fare category. The trip-distance frequency distribution of systemwide trips has a lumpy, multimodal shape. The shape is considerably smoother if the suburban commuter trips and the local intraurban transit trips are partitioned into separate distributions indicating that the BART system should not be considered as a pure example of an urban rapid transit system.

On June 30, 1980, fares on the San Francisco Bay Area Rapid Transit (BART) system increased for the first time since November 1975. The research reported here was conducted prior to this change in order to assess the potential impacts of alternative fare structures on various classes of patrons. BART fares are based on a complex formula with a variety of options similar to those discussed in an earlier study (1). An important feature of the formula relevant to this research is that fares beyond 9.6 km (6 miles) are directly related to distance; that is, most fares increase with increasing distance, usually with a decreasing marginal rate. Given the basic relationship of fare with distance, the BART staff desired to gain a better understanding of the relationship of trip distances among patrons in different income classes, age groups, and the special fare categories of senior citizens and handicapped.

Analyses conducted by us confirmed relationships of trip distance with income and, to a lesser extent, with age. However, no significant relationship was found to exist with the special fare categories. We are reporting the results here because the actual data are of interest to the transportation planning community, as well as to correct errors in the presentation of similar data (2, Table 2, p. 52) based probably on the misinterpretation of badly labeled data in an intermediate source.

We also found that the trip-distance distribution for intra-BART trips is characterized by a lumpy bimodal pattern. We expected the large market area served by the 121-km (72.6-mile) BART system to exhibit a unimodal gamma-curve-like distribution for trip distances. The actual lumpy pattern has remained remarkably consistent since the start of transbay service in 1974. One interpretation of this unusual pattern is that there are at least two kinds of BART markets. The first is analogous to a suburban rail commuter market and the other to an urban area rapid transit market. Partitioning trips into those associated with 14 suburban stations and those solely between pairs of the remaining 20 urban area stations produces two trip-distance distributions exhibiting the expected unimodal characteristic. Indeed, partitioning out trips associated with only the five Contra Costa County Line (C-line) stations from Orinda to Concord has a similar effect on the pattern. These stations are major generators of transbay trips and are distinguishable by higher-than-average mean household income of BART patrons and a greater proportion of work trips.

We do not address the issue of what are appropriate factors for discriminating among multiple markets. However, multiple markets seem to exist. We have attempted to partition the markets by seeking to identify separate trip-distance distributions that resemble the expected distribution. No claim is made that this is the best approach to partitioning markets, but it was the most convenient given the information and resources at hand. A need for more research is clearly indicated.

BART 1978 PASSENGER PROFILE STUDY DATA

The most recent data set on passenger incomes and ages available prior to the 1980 fare change was the May 1978 on-board passenger survey. At that time, a random sample of BART passengers returned 10 220 self-completed questionnaires dealing with their usage behavior, travel pattern, and demographic information (3). The questionnaires were coded and the data for each case computerized and stored on magnetic tape. The results were tabulated and reported (4) but were not related to station-to-station distances and fares until this study.

Several aspects of the data are relevant. First, not all of the questions were answered by the respondents. Cases where an applicable question had no valid answer were excluded from this analysis. In addition, round-trip cases were excluded since these were either tourist trips or, as we noted by reviewing a sample of ambiguous questionnaires, cases where origin or destination stations were unclearly identified or were not given and could not be coded. The exclusion of cases for these reasons created various sample sizes for each category analyzed; for example, only 9051 cases were valid for income-class analysis for the total study sample. Other sample sizes are noted as encountered below.

Second, under the survey-weighting scheme, each case is weighted by a factor related to the station of origin. The rationale for the weighting is that the sampling was effectively stratified by handing out questionnaires at each station of origin in proportion to the expected rate of arrival of patrons. The weight is related to the ratio of the proportion of actual daily trips originating at a station to the proportion of cases in the sample originating at a given station. Interestingly, the effect of the weighting has been to weight the middle-income categories slightly higher than either the lower- and upper-income categories. This effect, however, is insignificant.

Third, the questionnaires were not handed out to youths below high-school age. Thus, the youngest age category is underrepresented in the sample.

Finally, the questionnaire was rather lengthy. It covered approximately 30 questions and should have taken less than 5 min to complete on-board the train. Yet, it seems reasonable that fewer questionnaires would tend to be answered on shorter trips, as well as over those system links experiencing crush loads during the peak.

These aspects are expected to introduce some bias in the results toward longer trip lengths in all categories but not to affect the general relationships greatly.

SURVEY TRIP DISTANCES AND FARES PAID

The average trip distances computed in this study are based on station-to-station line distances taken from BART construction drawings. Thus any distances referred to in this report are effectively on-board trip distances and do not include the system access and egress portions of the trips.

The average fares are based on the fare structure in effect from November 1975 through June 29, 1980. Either full or discounted fares paid can be computed given information on the kind of ticket used. Normally, this information is not available from the automated fare-collection equipment. Discounted special fare tickets may be purchased at banks by senior citizens, preteens, and handicapped persons. A 90 percent discount applied for senior citizens and a 75 percent discount for handicapped or youth.

Table 1. Average on-board trip distances and fares, by time period, for 1978 survey sample and patronage report.

Sample Time Period	Sample Size	Trip Distance (km) Arithmetic Mean	Trip Distance (km) Geometric Mean	Average Fare ($) Extracted[a]	Average Fare ($) Paid[b]
Day (600-2400)	9 051	22.4	17.4	0.810	0.772
a.m. (600-900)	3 503	22.8	18.1	0.817	0.791
p.m. (1530-1830)	2 923	24.1	19.2	0.856	0.828
May average weekday	144 413	20.5	NA	0.750	NA

Notes: 1 km = 0.62 mile.
NA = not available.
[a]Full value. [b]Discounted.

The full value is magnetically encoded on all tickets and, when the patron exits, the automated fare equipment extracts the normal fare based on the station where the patron entered the system. During fare collection, information about the type of ticket is irrelevant and is not acquired and kept. Therefore, the BART patronage-reporting system can only report statistics on the extracted or normal fare for each trip. The actual fare paid, on the other hand, includes the discount and is of greater interest since it represents the actual out-of-pocket cost for the patron. Since the survey included a question asking the type of ticket being used for the trip, the actual fare paid could be computed for this study.

Table 1 shows average trip distances and fares for the survey sample covering the whole day and the a.m. and p.m. peak periods. Both the arithmetic mean and the geometric mean of trip distance are shown, since the latter is closer to the most likely value of a heavily skewed distribution of trip distances. Figure 1 shows a histogram of the daily trip-distance distribution in 5-km (3.1-mile) intervals. The bimodal characteristic alluded to above is apparent; it is more pronounced in histograms with intervals of 3-4 km (1.9-2.5 miles). The trip-distance distributions for the a.m. and p.m. peak periods remain very similar to the daily trip-distance distribution, while the averages are slightly greater than the daily average. Although an analysis by trip purpose was not performed, we would hypothesize that this difference is likely as a result of longer-commute work trips. Interestingly enough, the trip-distance distributions and the average distances traveled seem to have remained quite similar and constant since the start of trans-

Figure 1. Distribution of daily trip distances for 1978 passenger profile survey.

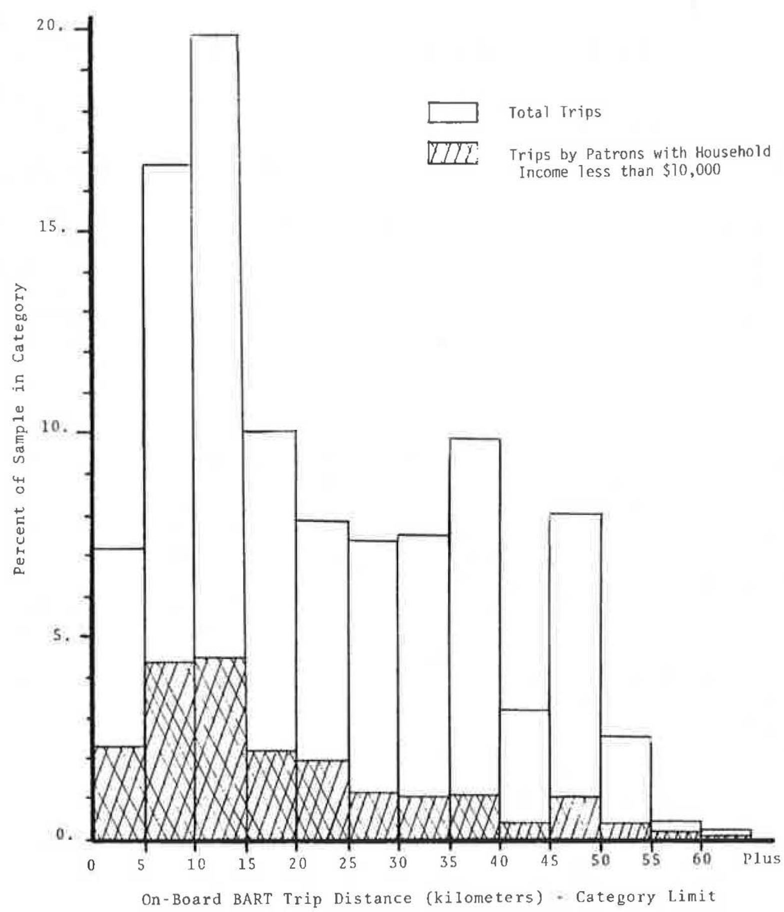


Figure 2. Distribution of discounted actual fares paid for 1978 passenger profile survey.

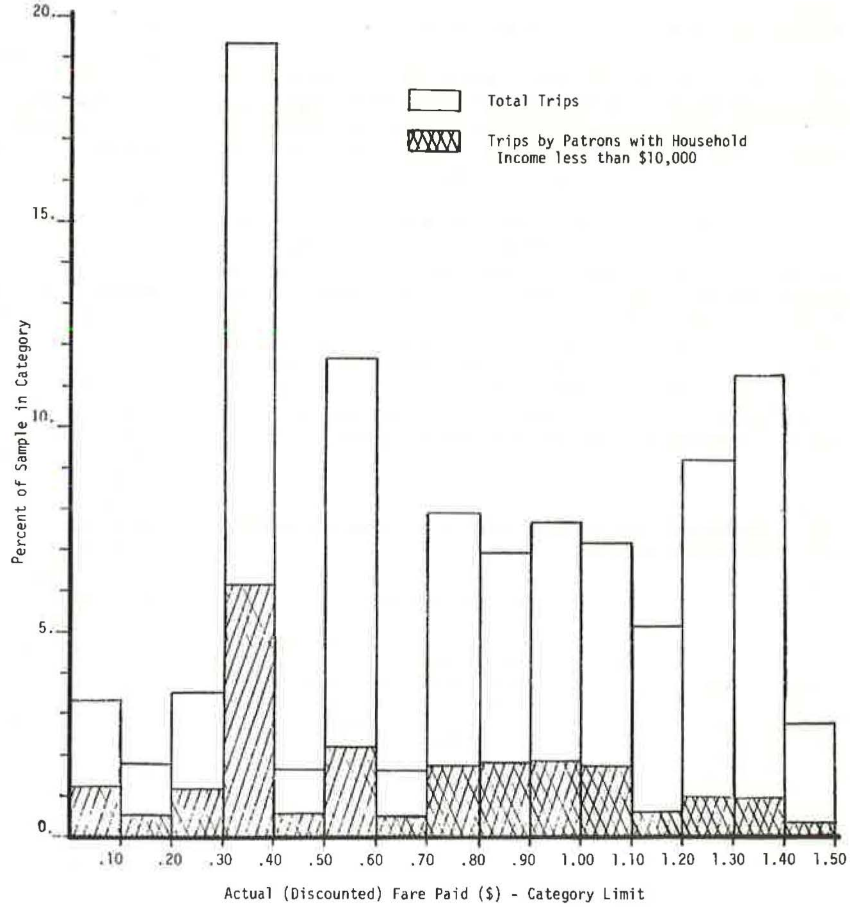


Table 2. Average on-board trip distances and fares paid, by household income.

Income Class ($)	Percentage of Weighted Sample	Trip Distance (km) Arithmetic Mean	Trip Distance (km) Geometric Mean	Average Fare Paid[a] ($)
<7000	12.1	17.9	13.4	0.603
7000-9999	9.8	18.3	14.0	0.635
10 000-14 999	17.1	19.9	15.3	0.694
15 000-19 999	13.6	21.7	16.7	0.737
20 000-24 999	15.0	24.2	19.0	0.823
25 000-49 999	28.5	26.4	21.4	0.910
≥50 000	4.0	24.5	20.2	0.892

Note: 1 km = 0.62 mile.
[a]Discounted.

bay service even though studies (5,6) have shown daily patronage to be growing at more than 5.6 percent per year. Table 1 also shows the average distance traveled as calculated from representative total weekday data for May 1978 (7). The average distance traveled of 20.5 km (12.76 miles) for the full day is slightly lower than the sample average of 22.4 km (13.93 miles). This may result from proportionally fewer questionnaires being answered on short trips. Indeed, the cases in the sample with incomplete answers had an arithmetic mean of 19.7 km (12.24 miles). Though these cases alone would be insufficient to lower the sample average, in conjunction with total nonresponses, they represent the probable explanation for the difference.

Both average extracted fare (at full value) and average fare paid (discounted for special fares) are also shown in Table 1. The average fare exhibits a behavior with time period similar to that of trip distance; i.e., it is greater for the peak periods than for the whole day. A histogram of the distribution of average fare paid with intervals of $0.10 is shown in Figure 2.

Relationship with Income

Table 2 shows the average trip distances and average fares paid by the income classes from the survey. An analysis-of-variance test supported the existence of a statistically significant difference among the classes with respect to both the distance traveled and the fare paid at the $p \leq 0.001$ significance level. Figure 1 includes a histogram of the trip distances for passengers with household incomes of less than $10 000. This distribution differs from the total daily one with a larger proportion of shorter trips.

Figure 3 illustrates the relationship of average trip distance with income for all trips and those of selected geographic market segments. This figure shows that the longest trip lengths occur among the middle-income groups. Figure 4 shows a similar tendency for average fare paid.

The comparison of fares paid to distance traveled is an interesting one to make. Figure 5 shows the behavior of two ratios with income. The lower curve represents arithmetic mean fare divided by the arithmetic mean distance; the other is the geometric mean fare divided by the geometric mean distance. Since this is a ratio, we would like to remind the reader that a ratio of arithmetic means of such skewed distributions is unlikely to yield a good estimate of the arithmetic mean of the ratio. On the other hand, the ratio of geometric means should yield the geometric mean of the ratios as an esti-

Figure 3. Mean trip distance by market segment related to household income.

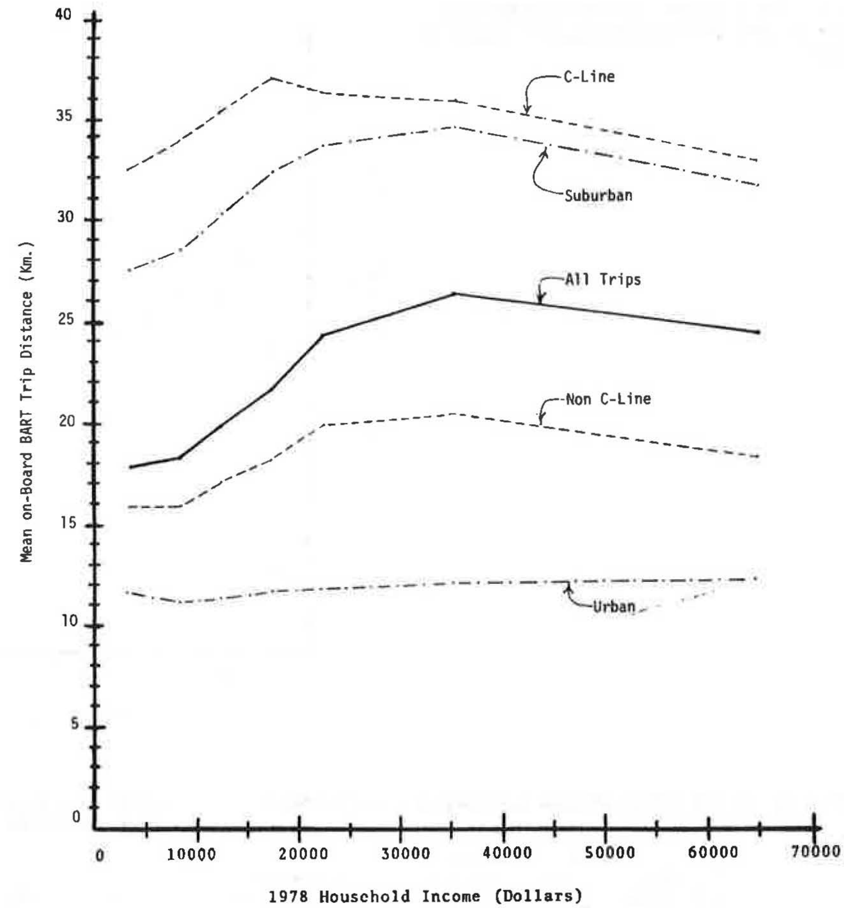


Figure 4. Discounted average actual fare paid by market segment related to household income.

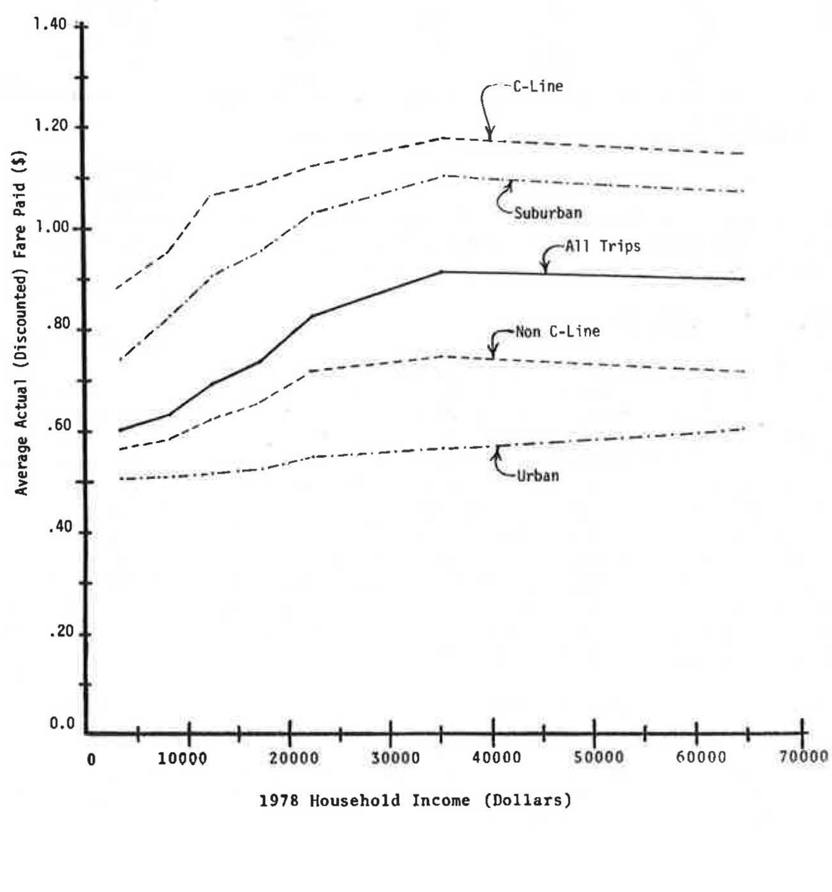


Figure 5. Ratios of mean discounted actual fares paid to mean on-board BART trip distance related to household income.

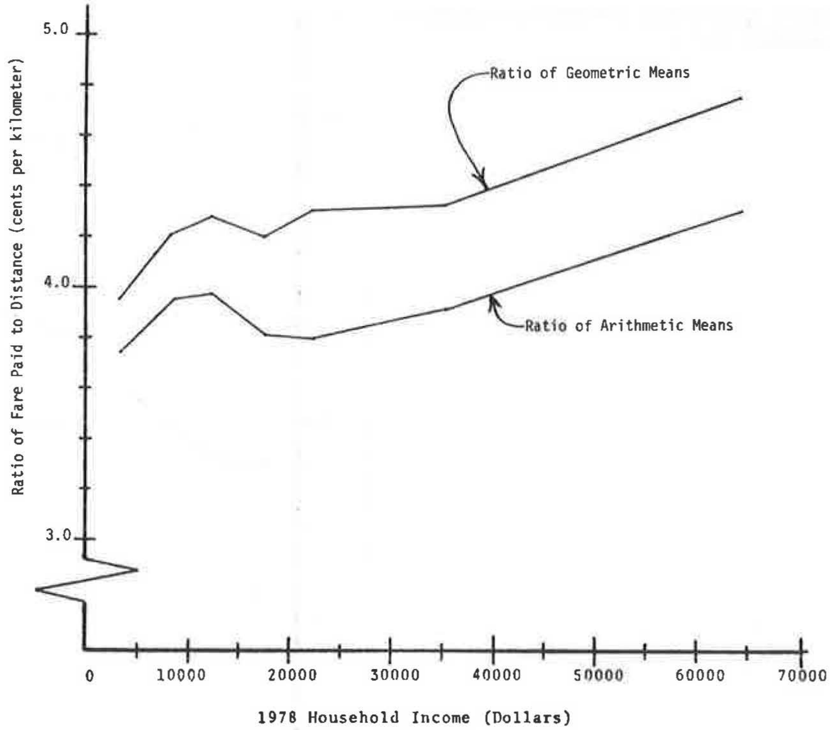


Table 3. Average on-board trips distance and fares paid, by age (N = 9603).

Age Group	Percentage of Weighted Sample	Trip Distance (km) Arithmetic Mean	Geometric Mean	Discounted Average Fare Paid ($)
<18	2.1	16.6	12.8	0.546
18-24	20.2	19.7	15.2	0.711
25-34	34.2	22.1	16.9	0.797
35-44	18.1	24.8	19.6	0.872
45-54	12.8	24.7	19.8	0.866
55-64	8.0	22.2	17.4	0.777
≥65	4.6	22.0	17.2	0.170

Notes: 1 km = 0.62 mile.
Youths were not normally surveyed and are underrepresented in this table.

Table 4. Average on-board trip distance and fares paid, by special fare category (N = 9538).

Special Fare Category	Percentage of Weighted Sample	Trip Distance (km) Arithmetic Mean	Geometric Mean	Discounted Average Fare Paid ($)
Regular fare	94.1	22.3	17.2	0.805
Handicapped, youth	1.3	21.6	17.2	0.193
Senior citizen	4.6	22.3	17.3	0.081

Notes: 1 km = 0.62 mile.
Youths were not normally surveyed and are underrepresented in this table.

mate of the most likely value of that ratio. Both behave similarly with the actual fare paid per kilometer generally increasing with income.

Relationship with Age

Table 3 shows the average trip distance and average fare paid by age group. Again, an analysis-of-variance test indicates that differences among the groups are statistically significant at the $p \leq 0.001$ level. Middle-aged passengers tend to travel greater distances than younger or older passengers, so trip distance does not relate directly with age; rather, it relates to whether or not the passenger is middle-aged, probably with a family living in the suburbs. Though an analysis by trip purpose was not done, these differences too are likely to be the result of longer-commute work trips. Fares paid, of course, correlate with trip distance.

Relationship with Special Fares

Table 4 shows the average trip distance and discounted average fare paid by the fare category of the ticket used. Trip distance does not differ significantly among the categories and the frequency distributions of trip distances for all three categories remain very similar to the total trip-distance frequency distribution. Analysis of variance supports the null hypothesis of no difference among the special fare categories with respect to trip distance.

Relationship with Market Segments

The practice at BART has been to report patronage behavior and statistics by three major markets that follow the geographic partitioning of the bay area. There are the Westbay market, which includes trips within and between San Francisco and Daly City; the Eastbay market, which includes trips within and among Oakland, Berkeley, and other portions of Alameda and Contra Costa Counties; and the Transbay market, which links the two areas. The partitioning of systemwide patronage into these three market segments, however, did not provide an immediately appealing explanation of the unusual shape of the total trip-distance distribution. By its nature, the Westbay market was constrained to a maximum on-board BART trip length of 12.7 km (7.6 miles), which is the distance from the Daly City terminal to the Embarcadero Station just about a block from the bay in downtown San Francisco. Of course, it is possible conceptually to merge the Eastbay and

Table 5. Average on-board trip distances and fares paid, by market segment (N = 9838).

Market Partitioning	Percentage of Weighted Sample	Trip Distance (km) Arithmetic Mean	Geometric Mean	Discounted Average Fare Paid ($)
C-line versus system				
All C-line	24.0	35.3	33.2	1.106
Non-C-line	76.0	18.1	13.9	0.654
Suburban versus urban				
Intrasuburban	3.5	22.3	16.1	0.534
Suburban-urban	48.4	32.7	29.7	1.011
All suburban	51.9	31.9	28.5	0.978
Intraurban	48.1	11.7	9.9	0.529
Major market				
Transbay	49.5	30.6	27.6	1.046
Eastbay	26.6	19.0	15.1	0.573
Westbay	23.3	8.4	7.3	0.386
Non-transbay	50.5	14.0	10.7	0.484
Total sample	100.0	22.2	17.1	0.762

Note: 1 km = 0.62 mile.

Westbay markets into a single nontransbay local-serving market. Regardless, the distribution of transbay trip distances is very lumpy, reflecting a shape similar to the systemwide distribution with fewer short trips.

Though the partition by the three major markets is perhaps the simplest to implement, a more intellectually appealing partition would be to break out the suburban commuters. The largest group of the suburban commuters enters through the C-line stations--Orinda east through Concord--that lie beyond the Berkeley Hills.

Partitioning by the C-line stations is one viable alternative, since the areas served by these stations feature the lowest residential density of all areas served by the rail portion of the BART system. Another viable partition is to include these stations among a larger set of suburban stations as informally classified for access planning. The other stations in this set are San Leandro south through Fremont along the Alameda county line (A-line) and El Cerrito Plaza north through Richmond (R-line) and further along the R-line. All of these stations are in the Eastbay. They also neatly partition a ranked list of stations based on worker density per net residential acre in the service area at a threshold value of 27 workers/hm^2 (11 workers/acre) based on the 1970 census (8). (Rockridge and MacArthur stations would also fall into the category by the density criteria, but their service areas are parts of Oakland and Berkeley and, therefore, they are considered urban area stations.)

Average trip distances and fares paid are tabulated in Table 5 for all of the market partitions discussed above, as well as several of the markets merged where it may make sense. For example, intrasuburban market trips may be merged with trips between the suburban and the urban markets; i.e., suburban-urban, into a category which includes all suburban-related trips. The intrasuburban mean trip distance is as long as it is because about one-third of the intrasuburban trips are between different lines; thus they are not truly local trips. As for the intra C-line, they are included in the all-C-line-related trip category simply because there were too few of them to consider separately. Figures 3 and 4 show how these averages do vary with income for most of these markets.

Histograms showing distributions of the C-line versus non-C-line and the suburban versus intraurban market partitions are given in Figures 6 and 7. Both of these partitions yield distributions with shapes that, at first glance, look like the expected gamma distribution.

Gamma parameters were derived by using the compu-

Figure 6. Distribution of daily trip distances partitioned by C-line market segments.

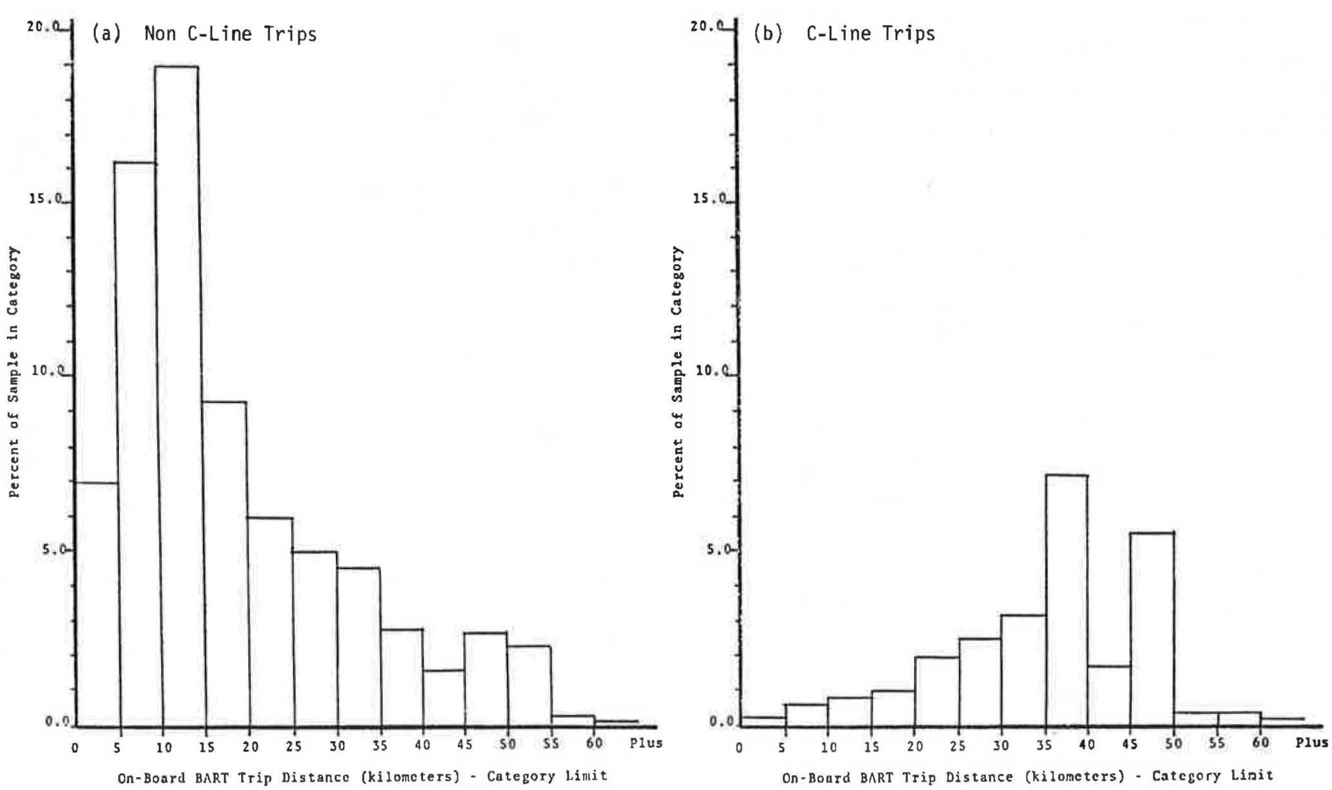
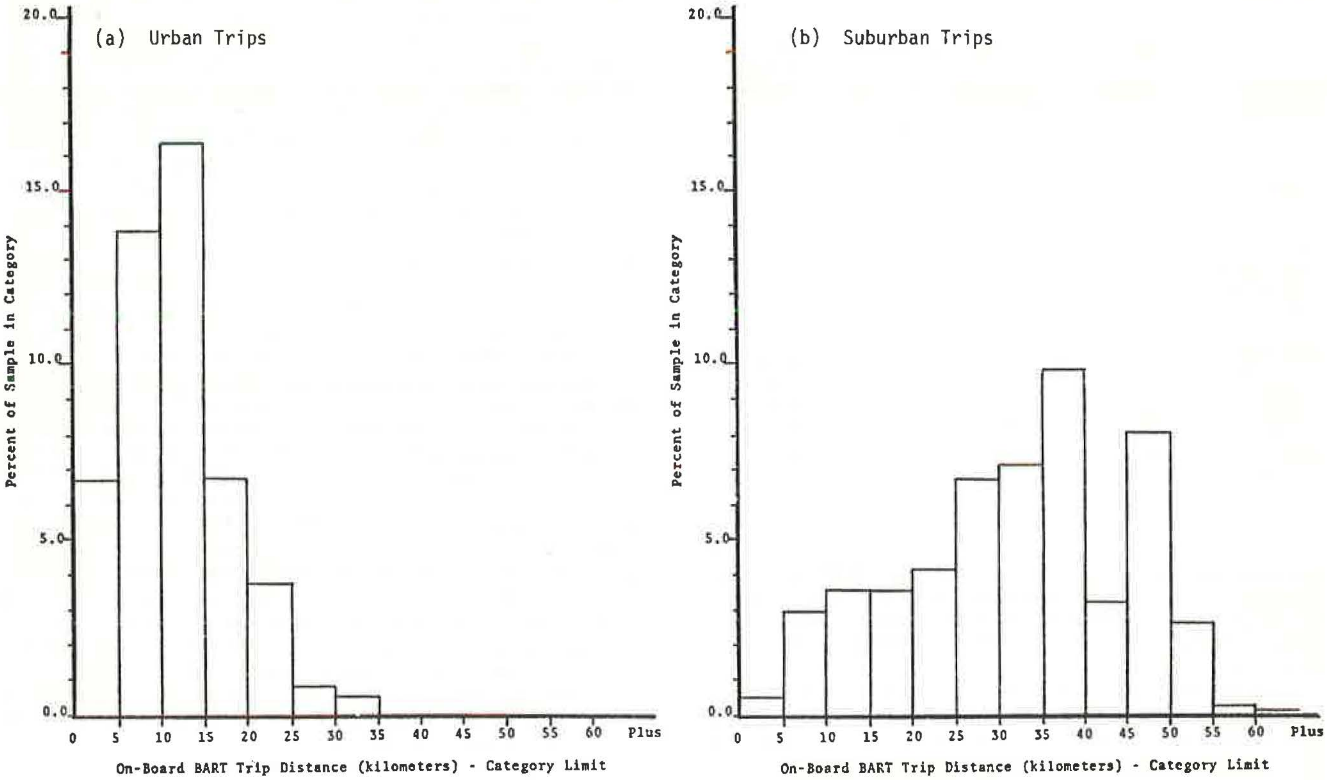


Figure 7. Distribution of daily trip distances partitioned by urban-suburban market segments.



tation procedure for the maximum likelihood estimator approach described by Voorhees (9) and taken from Greenwood and Durand (10). Application of chi-squared goodness-of-fit criteria demonstrated that none of the actual distributions fit gamma distributions well. The exclusion of the access and egress portions of the trips may account for some of this lack of fit. Though the distributions resulting from the partitioning described here do not have quite the kinds of shape sought, we believe much of the lumpiness of the systemwide trip-distance distribution of Figure 1 can be removed and explained by the partitioning of suburban and urban markets.

CONCLUSION

It is hoped that the information reported here can contribute to further studies of the equity of public transit. We recognize equity to be an extremely complex issue that cannot be completely resolved with only these data. First, the data dealing with fares paid are good only for the fare structure that existed from November 1975 until June 1980. Information on both the BART passenger-income distribution in 1980 and the response to the fare change was not available at the time this paper was written. Second, significant other information is needed, such as (a) accurate measures of the incidence of various taxes that are used to fund the system, (b) additional appropriate measures (other than merely trip distance) of the broader spectrum of benefits derived from a rail transit system especially for members of lower-income groups who tend to live closer to urban centers and thus to major transportation routes, (c) correct measures of the amount of subsidy provided for each trip by location since this is clearly related to the varying costs of constructing and operating different portions of the system, and (d) similar data on how and by which alternative mode such trips would take place without the given system and the degree of subsidy provided. Finally, the concept of equity itself seems to have multiple meanings dependent on its supporter. Lee (2) discusses a number of these issues evenhandedly if any readers would wish to pursue them further.

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