2. W. Cherwony. Cost Centers: A New Approach to Transit Performance. Transit Journal, Vol. 3, 1977, pp. 70-80.
3. J.H. Miller and J.C. Rea. Comparison of Cost Models for Urban Transit. HRB, Highway Research Record 435, 1973, pp. 11-19.
4. L. Alford and J. Bangs. Production Handbook. Ronald Press, New York, 1948.
5. P.A. Dierks. Financing Urban Mass Transportation: A Study of Alternative Methods to Allocate Operating Deficits. Univ. of Washington, Seattle, Ph.D. dissertation, 1975.
6. D.J. Wagon and D.A. Baggaley. Some Recent Developments in Route Costing Techniques Used in London Transport. Symposium on Cost of Bus Operations, Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1975.
7. T.E. Keeler, L.A. Merewitz, and P. Fisher. The Full Costs of Urban Transport: Parts I and II. Institute for Urban and Regional Development, Univ. of California, Berkeley, 1975.
8. J. Reilly. Transit Costs During Peak and Off-Peak Hours. TRB, Transportation Research Record 625, 1977, pp. 22-26.
9. W. Cherwony and S. Mundle. Peak-Base Cost Allocation Models. TRB, Transportation Research Record 663, 1978, pp. 52-56.
10. M. Boiteux. Peak-Load Pricing. Journal of Business, Vol. 33, 1960, pp. 157-179.
11. P.O. Steiner. Peak Loads and Efficient Pricing. Quarterly Journal of Economics, Vol. 71, pp. 585-610.
12. G.B. Parker and D.A. Blackledge. RTM Method of Bus Operations Costing Developed for the Bradford Bus Study. Proc., Symposium on Cost of Bus Operations, Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1975.
13. H. Mohring. Optimization and Scale Economies in Urban Bus Transportation. American Economic Review, Vol. 62, 1972, pp. 591-604.
14. J. Boyd, M. Asher, and R. Wetzler. Evaluation of Rail Rapid Transit and Express Bus Service in Urban Commuter Markets. Institute of Defense, Washington, DC, 1973.
15. D.B. Lee, Jr. Cost-Oriented Methodology for Short-Range Transportation Planning. TRB, Transportation Research Record 589, 1979, pp. 8-13.
16. W.W. McGlenahan and D.R. Kaye. A Method of Bus Route Costing Developed by Arthur Anderson and Company. Proc., Symposium on Cost of Bus Operations, Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1975.
17. H.S. Levinson. Peak-Off Peak Revenue and Cost Allocation Model. TRB, Transportation Research Record 662, 1978, pp. 29-33.
18. R.B. Cervero, M. Wachs, R. Berlin, and R. Gephart. Efficiency and Equity Implications of Alternative Transit Fare Policies. UMTA, 1980.


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# Transit Operating Costs and Fare Requirements Forecasting by Using Regression Modeling

JOHN W. BATES

**Because of increasing operating costs and a reduction in federal operating assistance, transit operators are faced with the reality of increasing fares over the foreseeable future. The traditional approach of holding off on any fare increase and cutting service for as long as possible, then needing to increase fares more than is politically acceptable will result in a new cycle of increasing fares, reduced services, and declining ridership. An approach to intermediate-term forecasting of fare and revenue requirements by using simple regression models is described, and examples are given for alternative fare and service questions that might be raised. Such a procedure will be useful to transit operators in planning for staged changes in fare and service levels so as to avoid drastic and unanticipated ones.**

During the decade of the 1970s, a major emphasis in public transportation policy was fare stabilization. In 1974 federal policy joined with local efforts in this regard by providing direct operating subsidy funds through Section 5 of the Urban Mass Transportation Act of 1964, as amended. By 1981, however, increasing operating costs, both real and inflationary, and an apparent reversal of federal policy intended to result in reduction and termination of Section 5 funding are forcing a rethinking of policies to maintain fares at artificially low levels. Today's environment requires transportation operators to deal with the reality of increasing fares over the foreseeable future.

The traditional approach to increasing fares is to defer any action as long as possible, reducing costs as much as possible even to the point of seriously impairing service, and in the end still facing increases that are too large to be politically acceptable. The result is frequently a fare increase that is not large enough to restore or even maintain service but that has a negative psychological effect in the community.

From economic and competitive aspects, transit fares probably should be increased. However, it is important that these increases be made in a rational, well-planned manner and not in the traditional fashion: long-deferred, large-increment increases coming only after the level of operations has been reduced to the point that some segments of the transit market have been denied service at any price and other existing and potential market segments are angry and resentful. Rational and well-planned fare and service policies require anticipation of revenue requirements and a staging of fare increases in (relatively) small increments, matching fare increments to increasing costs of services provided and increased costs for alternative modes. Such policies, however, require some sort of intermediate-term forecasting capacity for both operating costs and revenues.

This paper discusses a very simple approach to intermediate-term forecasting for operating costs and fare requirements and an example of the type of analysis that might be performed. Although some of the analysis is based on data from the Metropolitan Atlanta Rapid Transit Authority (MARTA), the discussions are exemplary only and are not MARTA forecasts.

## FORECASTS OF OPERATING COSTS

For the very short run, operating costs can be forecast by using the normal budget process. This approach has the benefit of comprehensiveness and near-horizon estimating but also the disadvantage that one cannot look beyond the next few months or forecast impacts of this year's decisions on next year's requirements. Fare requirements determined during the budget process also tend to be heavily biased by short-term political and policy factors that overshadow analytical findings.

A very simple model for forecasting operating cost is the naive approach of an annual growth rate for aggregate costs or for the cost per unit of operation, such as vehicle miles. The total level of operations is a variable in the analysis for the latter case, not a given as in the budgetary approach. For one or two years into the future, the naive model is probably as good as any other. Factors that might cause drastic changes in the annual rate of change in unit costs (wages, fuel, inflation, etc.) would probably not be included in a more precise "budget-type" forecast beyond the first year either.

Beyond the naive model, cost forecasting can become as complex and as comprehensive as the analyst wishes to make it. One simple elaboration on the naive model is given here as an example, based on MARTA data for the 1973-1980 period. The average cost per vehicle mile for each calendar year is calculated and converted to "constant" 1980 dollars by using as the conversion factor the ratio of the consumer price index (CPI) for 1980 to the average CPI each year. This annual unit cost is then regressed against the actual mileage operated each year to obtain an estimator that explicitly considers the level of operations and "averages out" increases in overhead (management and supervision) that are related to the level of operation. In this example, the regression indicated a relation expressed by

$$\underset{}{CVM_{80} = 1.573 + \underset{(1.945)}{0.0158(AMILES)}} \qquad R^2 = 0.387;\ SE = 0.063;\ DF = 1, 6;\ F = 8;\ DW = 2.6 \tag{1}$$

where $CVM_{80}$ is unit operating cost (in dollars per vehicle mile) and AMILES is millions of annual vehicle miles operated.

By using a model as simple as this, as basic as a direct estimate of unit cost or as complex as desired, a rational forecast of unit and aggregate operating cost can be made for various levels of operation. This particular model is presented only as an example and without any degree of confidence. The relation may not be linear, in fact; there may be (or may not be) scale economies, and there may well be other factors that should be included. In this derivation, a time-series term and a dummy variable for the first year of a new, multiyear labor contract were also tested but were not significant in the relation, even relative to the "poorness" of the one shown. However, for the purposes of illustrating the use of a cost-estimating model, the relation given in Equation 1 will be accepted.

## FARE REQUIREMENT (REVENUE) FORECASTS

Given operating costs and estimates of revenues from all sources other than fares, the amount of aggregate fare revenue required in a given year is derived. This revenue is simply the product of average fare payment and total linked trips. There is, however, a simultaneity between fare and ridership that makes this computation cumbersome. This problem is relieved, however, if one has a model for directly estimating average fare given a total revenue requirement. Such a model can be obtained from a linear expression for total aggregate linked trips that includes explicitly the fare level to be used in the analysis. A comment should be made on the use of the term "average fare" in this discussion. There are probably very few transit operators whose published base fare is the same as the resulting average fare. Unlimited ride passes, such as those used by MARTA and others, as well as zone charges, transfer fees, and reduced fares for the elderly and the handicapped make the relation between published base fare, "standard fare", and average fare very complex. The determination of average fare value is specific for each fare structure and set of rider characteristics. If the number of linked trips is known, however, along with the total fare revenue, the average fare can be derived simply by division. In this sense, total fare revenue is the product of linked trips and average fare.

A simple linear regression model has been derived for monthly aggregate transit ridership in Atlanta for a 120-month period beginning in January 1970. This model included terms for total vehicle miles, average fare, the price of gasoline, and special adjustment factors for the number of nonholiday weekdays each month and the number of weeks of special school service operations each month. The model is given as

$$\begin{aligned} TRIPS = &\underset{(-4.32)}{-0.015(FARE)} + \underset{(3.89)}{0.798(MILES)} + \underset{(3.32)}{0.013(GAS)} \\ &+ 0.111(WKDY) + 0.100(SCH) - 0.081 \\ &R^2 = 0.919;\ SE = 0.219;\ DF = 5{,}114;\ F = 218.6;\ DW = 1.42 \end{aligned} \tag{2}$$

where

TRIPS = monthly linked trips (000 000s);
FARE = average fare during the month (¢);
MILES = total vehicle miles operated during the month (000 000s);
GAS = average price per gallon for gasoline during the month (¢);
WKDY = number of nonholiday weekdays during the month; and
SCH = number of weeks special school services are provided during the month.

This model was applied to MARTA monthly operating data for the period January-December 1980, the 12-month period following the 10-year "calibration" period. The calendar-year total number of linked trips estimated by the model was 72.903 million compared with a reported figure of 72.911 million.

Linear models of this type have been used by others in analysis of factors that cause changes in transit ridership. A few of these analyses have also included automobile costs, particularly gasoline price, in the relation. Although there may be some opinion that the linear form is not appropriate, for any or all of the variables included, and that constant-elasticity formulations rather than the direct-value form used here are "better", such discussions are suited to a paper specifically on demand modeling. This paper presents a discussion of use of demand models and uses the relation expressed in Equation 2 for the exemplary purpose.

Since revenue is the product of average fare and linked trips, revenue for any given month is

$$R = FARE * TRIPS \tag{3}$$

or

$$R = -0.015FARE^2 + (0.798MILES + 0.013GAS + 0.111WKDY + 0.100SCH - 0.081)FARE \tag{4}$$

Note that R must be expressed in dollars * 100 to maintain continuity of fare expressed in cents.

This expression can be restated as

$$(FARE)^2 - (53.3MILES + 0.867GAS + 7.4WKDY + 6.667SCH - 5.4)FARE + 66.67R = 0 \tag{5}$$

which may be solved by the quadratic formula to give the average fare necessary given the revenue required for the month and service level, gasoline price, number of weekdays, and number of weeks of school services. For an annual forecast, the computation can be made for the "average month" during the period, times 12, or by using 1/12 annual figures for revenue, service, miles, weekdays, and school weeks and annual average price of gasoline and fare.

The presence of the term for special school services requires some explanation. Until the 1980-1981 school term, City of Atlanta schools did not provide school bus services and public school trips were made on MARTA services. This was a special situation and required the specific term in the regression. Beginning in September 1980, free bus services were initiated by the City of Atlanta schools for trips more than 1 mile in length and there was a substantial reduction in MARTA ridership. For projections, the value of the SCH term is zero, and the term is removed from the model in the examples that follow.

All of the variables in the model shown are "controllable" by the transit operator except the price of gasoline. Values for this variable in projections must themselves be forecast. One way to deal with the "weakness" this causes is to do ranging-type projections, by changing the values for gasoline price used in the analysis to estimate the sensitivity of the forecasts to variations in actual future gasoline prices versus predicted ones.

Note again that the models presented here for linked trips and fare/revenue--Equations 2 and 5, respectively--were developed for MARTA by using MARTA and Atlanta data. Although other researchers have done similar analyses and obtained similar results, there have been published results that were quite different. This model is presented only as part of a discussion of how such models can be used in transit management, not as a specific model for general use.

## INTEGRATING COST AND REVENUE MODELS

If one takes the operating cost model from Equation 1, or

$$CVM = k^* (1.573 + 0.0158AMILES) \tag{6}$$

where k is an escalation factor or percentage increase in unit cost over the base year and AMILES is the total annual service level, as distinguished from MILES, which denotes average monthly mileage, then average monthly operating cost can be calculated by

$$COST = k(1.573 + 0.0158AMILES) * MILES \tag{7}$$

and average monthly revenue required from fares by

$$REV = k(1.573 + 0.0158AMILES) * MILES - INC \tag{8}$$

where INC is the average monthly income from sources other than fare (including subsidy).

Given these relations, one can substitute into Equation 5 and state a comprehensive cost/revenue model:

$$FARE^2 - (53.3MILES + 0.867GAS + 154.9)FARE + 66.67[k(1.573 + 0.0158AMILES) * MILES - INC] * 100 = 0 \tag{9}$$

which is simplified by deleting the term for special school services and assuming 21.7 weekdays/average month. Having established this relation, one can solve the equation for any one of the variables when all of the others are known (or when values are assigned).

## EXAMPLE APPLICATIONS OF THE MODEL

The following examples demonstrate how a model of this type might be used for fare policy analysis and financial planning. Imagine a transit operation that for the current year has the following values for the pertinent parameters:

| Parameter | Value |
|---|---|
| FARE (¢) | 50.0 |
| MILES (000 000s) | 18.0 |
| GAS (¢) | 135.0 |
| TRIPS (000 000s) | 54.4 |
| REV ($000 000s) | 27.2 |
| COST ($000 000s) | 33.4 |
| INC ($000 000s) | 6.2 |

The operator would like to estimate the average fare required (and the resulting number of linked trips) if the following conditions occur over the next three years:

1. Unit operating costs increase at 10 percent/year,
2. The service level is increased at 1.0 million miles/year,
3. There is an annual growth in the price of gasoline of 10 percent/year, and
4. There is no income available other than that from fares (i.e., no subsidy, advertising, etc.).

With these assumptions or assignments of values to the parameters in the model for each of the three projection years, the average fare payment required and resulting annual ridership can be obtained from the model. The results are given in Table 1. Equation 8 is used to derive the average fare value. Then Equation 2 provides the number of linked trips, which can be multiplied by average fare to yield passenger revenue; or Equation 5 can be used to derive revenue, divided by average fare, to yield linked trips. Operating cost is derived from Equation 6. All of these computations were made for an "average" month and then multiplied by 12 for the annual figure. The process provides the additional benefit of allowing for an analysis of the sensitivity of the required fare to each of the parameters whose values must be assigned. For example, what would be the result if the unit cost increased at a rate of 11 percent instead of 10 percent, or what would happen if gasoline prices stabilized at current levels?

The increases in average fare given in Table 1 are substantial. The imaginary operator may well believe that these are too much for the community to accept and may then try alternatives, such as determining the fare required if the current level of subsidy and other nonfare revenues is continued. The result under this condition is given in Table 2.

Table 1. Fare required when unit costs and service levels increase and nonfare revenue is reduced to zero.

| Parameter | Value by Year 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Average fare (¢) | 50.0 | (73.8) | (84.3) | (96.0) |
| Service miles operated (000 000s) | 18.0 | 19.0 | 20.0 | 21.0 |
| Area gasoline price ($/gal) | 1.350 | 1.485 | 1.634 | 1.797 |
| Annual linked trips (000 000s) | 54.4 | (53.0) | (54.2) | (55.4) |
| Fare revenue ($000 000s) | 27.2 | (32.1) | (45.7) | (53.2) |
| Operating cost ($000 000s) | 33.4 | (39.1) | (45.7) | (53.2) |
| Nonfare revenue ($000 000s) | 6.2 | 0 | 0 | 0 |

Note: Values not in parentheses are assigned; values in parentheses are calculated.

Table 2. Fare required when unit costs and service levels increase and nonfare revenue is held constant.

| Parameter | Value by Year 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Average fare (¢) | 50.0 | (59.2) | (69.5) | (80.8) |
| Service miles operated (000 000s) | 18.0 | 19.0 | 20.0 | 21.0 |
| Area gasoline price ($/gal) | 1.350 | 1.485 | 1.634 | 1.797 |
| Annual linked trips (000 000s) | 54.4 | (55.6) | (56.9) | (58.2) |
| Fare revenue ($000 000s) | 27.2 | (32.9) | (39.5) | (47.0) |
| Operating cost ($000 000s) | 33.4 | (39.1) | (45.7) | (53.2) |
| Nonfare revenue ($000 000s) | 6.2 | 6.2 | 6.2 | 6.2 |

Note: Values not in parentheses are assigned; values in parentheses are calculated.

Table 3. Nonfare revenue required when unit costs increase and fare and service levels are held constant.

| Parameter | Value by Year 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Average fare (¢) | 50.0 | 50.0 | 50.0 | 50.0 |
| Service miles operated (000 000s) | 18.0 | 18.0 | 18.0 | 18.0 |
| Area gasoline price ($/gal) | 1.350 | 1.485 | 1.634 | 1 797 |
| Annual linked trips (000 000s) | 54.4 | (55.6) | (58.8) | (61.3) |
| Fare revenue ($000 000s) | 27.2 | (28.2) | (29.4) | (30.7) |
| Nonfare revenue ($000 000s) | 6.2 | (8.5) | (11.0) | (13.8) |

Note: Values not in parentheses are assigned; values in parentheses are calculated.

Table 4. Level of service possible when unit costs increase and fare and nonfare revenue are held constant.

| Parameter | Value by Year 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Average fare (¢) | 50.0 | 50.0 | 50.0 | 50.0 |
| Service miles operated (000 000s) | 18.0 | (16.8) | (15.7) | (14.8) |
| Area gasoline price ($/gal) | 1.350 | 1.485 | 1.634 | 1.797 |
| Annual linked trips (000 000s) | 54.4 | (55.5) | (57.0) | (58.8) |
| Fare revenue ($000 000s) | 27.2 | (27.8) | (28.5) | (29.4) |
| Operating cost ($000 000s) | 33.4 | (34.0) | (35.7) | (35.6) |
| Nonfare revenue ($000 000s) | 6.2 | 6.2 | 6.2 | 6.2 |

Note: Values not in parentheses are assigned; values in parentheses are calculated.

Certainly, this type of analysis might be useful in discussing whether an existing subsidy payment might be continued.

Another type of analysis possible from the model is given in Table 3. Here the service level is held constant along with the fare, and the amount of subsidy and other nonfare revenue required to maintain the operation is computed. Table 4 reflects nearly the same situation, but the level of subsidy and other nonfare revenue is held constant along with the fare while the total level of operations is decreased to the level that can be supported with the funds thus available.

Table 5. Level of service possible when unit costs increase, nonfare is held constant, and fare is increased 5¢/year.

| Parameter | Value by Year 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Average fare (¢) | 50.0 | 55.0 | 60.0 | 65.0 |
| Service miles operated (000 000s) | 18.0 | (18.0) | (18.0) | (17.9) |
| Area gasoline price ($/gal) | 1.350 | 1.485 | 1.634 | 1.797 |
| Annual linked trips (000 000s) | 54.4 | (55.5) | (57.0) | (58.6) |
| Fare revenue ($000 000s) | 27.2 | (30.5) | (34.2) | (38.1) |
| Operating cost ($000 000s) | 33.4 | (36.7) | (40.4) | (44.3) |
| Nonfare revenue ($000 000s) | 6.2 | 6.2 | 6.2 | 6.2 |

Note: Values not in parentheses are assigned; values in parentheses are calculated.

Table 6. Nonfare revenue required when unit costs increase, level of service is held constant, and fare is increased 5¢/year.

| Parameter | Value by Year 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Average fare (¢) | 50.0 | 50.0 | 60.0 | 65.0 |
| Service miles operated (000 000s) | 18.0 | 18.0 | 18.0 | 18.0 |
| Area gasoline price ($/gal) | 1.350 | 1.485 | 1.634 | 1 797 |
| Annual linked trips (000 000s) | 54.4 | (55.6) | (57.0) | (58.6) |
| Fare revenue ($000 000s) | 27.2 | (30.6) | (34.2) | (38.1) |
| Operating cost ($000 000s) | 33.4 | (36.7) | (40.4) | (44.5) |
| Nonfare revenue ($000 000s) | 6.2 | (6.1) | (6.2) | (6.4) |

Note: Values not in parentheses are assigned; values in parentheses are calculated.

Finally, Tables 5 and 6 demonstrate the cases in which fare is increased at the rate of 5¢/year. In Table 5 the level of nonfare revenue is held constant and mileage is set at the resulting affordable level, and in Table 6 mileage is held constant and nonfare revenue is changed as appropriate. Note that the "alternatives" in Tables 4-6 show increased annual volumes for linked trips, even when service level is decreased and/or fare is increased. This is due to the impact of the assumed increase in gasoline price, which overrides negative impacts of fare increases and service decreases in the ridership model (Equation 2).

## CONCLUSIONS

The model used in these discussions is based on work done for MARTA and is not suggested as a general model for any other transit system. However, the values of the coefficients for the variables in the basic regression of linked trips are in the same general ranges as those of models derived for other areas. What is suggested here is that a relatively simple research process can be applied to provide transit operators with an analytical tool that might be very useful in deriving fare policies and financial plans that look beyond the immediate budget year and allow for more rational decisions and consideration of longer-term impacts of fare decisions.

The sensitivity of ridership to the price of gasoline in the models used here calls for further comment. In the alternatives in Tables 4-6 discussed above, as noted, increases in annual ridership are projected even with increases in fare and/or decreases in service level. This is because of the projected increase in gasoline price. The potential impacts of this condition must be considered. The increase in fare and/or decrease in service level causes some previous transit trips to be lost, while the increase in gasoline prices generates a net gain in total transit trips. The increase in trips, however, more than likely represents diversions from the automobile and may well occur principally during the peak periods. The overall result is an increased burden on current transit-dependent riders and a relative increase in peak-period transit use, which might cause operating costs to increase more rapidly. The social as well as the financial implications of this condition should be carefully considered.

Rational fare policy is essential if the competitive position that transit has established over the past several years is to be maintained and, it is hoped, improved. The 1970s saw a recapitalization of transit systems that strengthened the competitive position. Increasing gasoline price alone is a major factor that favors transit, as are increasing costs for dispersed housing and automobiles. The situation is much different from that in the postwar era when the combination of release from shortages, increasing real incomes, subsidized suburban housing, cheap gasoline, and deteriorated capital structure of transit was overwhelming in its bias for increased automobile travel and decreased transit travel. Pricing the improved transit product in line with the competition will allow increasing fares to match increasing costs. However, the fare increases imposed must be incrementally small, regularly instituted, and anticipated. Planning for fare changes, operating costs, and service levels must extend beyond the current budget year if this is to be accomplished. The process described here is one approach to doing this.

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# Examining Likely Consequences of a New Transit Fare Policy

ROBERT CERVERO

**An evaluation model is presented for examining the likely consequences of implementing alternative transit fare policies. The model weights responses to on-board ridership survey responses based on disaggregate fare elasticity estimates in projecting future patronage levels and revenue income. Revenue and cost data associated with specific users' trips are also combined in comparing the farebox recovery levels among various categories of trip distance, time of day, and user demographics. The functional components of the model are described and its use is demonstrated. Fare, cost, and travel data from the Southern California Rapid Transit District are used to examine the current fare policy of the system. Uniform fares are found to be both inequitable and inefficient. Both distance-based and time-of-day fare scenarios are designed and tested in terms of their ability to correct some of the problems associated with flat fares. Finely graduated fares are found to be best suited for mitigating inequities, and stage fares seem to be a more cost-effective pricing strategy. As transit funding sources continue to shrink, it is imperative that analytic tools be developed for examining the full range of impacts of alternative fare systems.**

The American transit industry today finds itself in a financial stranglehold. The nationwide transit deficit stood at $4 billion in 1980, the product of precipitous cost increases and declining real dollar fares during the 1970s (1). The Reagan Administration's planned phase-out of federal operating subsidies portends a future of major fare increases and service cutbacks. As the going rate for a bus ride threatens to reach the $1 mark in Los Angeles, Chicago, and other major cities in the not-too-distant future, transit managers are scrutinizing current fare practices and pricing rationales more closely. More finely graduated, distance-based pricing and peak/off-peak fares, in particular, may become prevalent during the 1980s as operators attempt to capture some of the differential costs of providing services. During the past several years, more than 20 American transit properties have introduced some form of time-of-day pricing; Tri-Met in Portland, Oregon, and several other operators have recently expanded their zonal fare systems (2).

Understanding the likely effects of alternative transit fare systems is essential to effective ongoing transit planning. Not only is it necesssry to examine the likely ridership and fiscal impacts of a proposed fare change, but one must also be able to discern the distributional consequences. Citizens' groups and minority organizations are increasingly becoming outspoken and militant in their opposition to unilateral fare hikes, as demonstrated by recent court challenges charging violation of Title VI requirements of the Civil Rights Act of 1964 in such places as Dallas, Pittsburgh, and Memphis. Recent evidence suggests that today's reliance on predominantly flat fares is grossly inequitable in that short-distance, midday, and lower-income users typically cross subsidize the long-distance, usually more affluent, rush-hour commuter (3,4). Mitigating any maldistributive effects of a fare change is particularly important because of transit's universally accepted role in providing mobility opportunities to disadvantaged persons.

This paper presents a model originally used in examining the likely consequences of proposed fare changes for three California transit properties (5). In addition to estimating the revenue and ridership impacts of a fare change, equity consequences were assessed. The criterion variable used in evaluating equity impacts was a farebox recovery ratio disaggregated at the level of the individual user (i.e., a ratio of what share of a user's trip costs is met through the farebox). Trip costs were estimated by using a multistage cost allocation technique that is described in detail in a companion paper in this Record and elsewhere (6). Fare revenue and patronage information was gathered from on-board ridership survey responses. The use of passenger-level data enabled the analysis of distributional