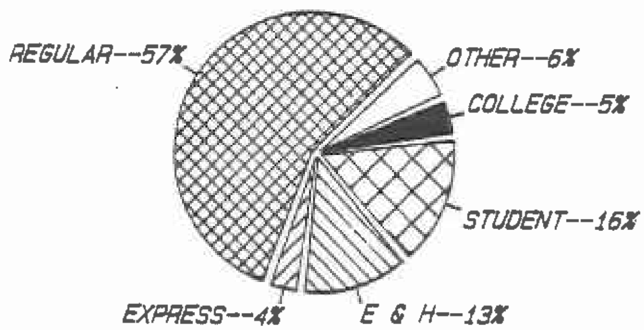
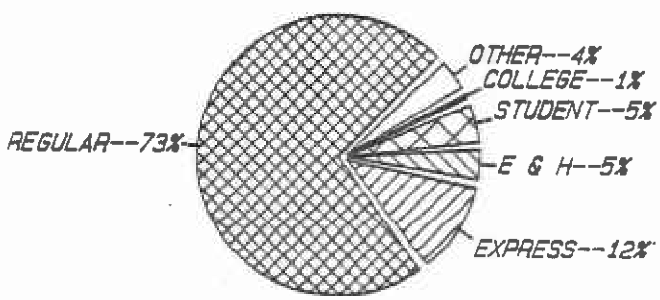
FY 1985-86 FARE POLICY STUDY

SHARE OF FY 1984-85 BOARDINGS AND REVENUE



BOARDINGS



REVENUE

RTD

Southern California Rapid Transit District

FY 1985-86 FARE POLICY STUDY DOCUMENTATION

DECEMBER, 1985

SOUTHERN CALIFORNIA RAPID TRANSIT DISTRICT

FY 1985-86 FARE POLICY STUDY DOCUMENTATION
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1.0 FY 1985-86 FARE POLICY STUDY DOCUMENTATION: INTRODUCTION

The pace of growth in transit usage in Los Angeles during the past decade has been unusually high for a city of its size. Despite fare increases in every year between 1976 and 1982, ridership on District buses continued to increase. A 30% fare increase, imposed in FY 1981-82, temporarily reversed the upward trend in ridership, promoting support for a ballot initiative (Proposition A) which, in addition to providing needed local funds to begin fixed guideway development efforts, offered three years of reduced and stable transit fares. The reduced fares, resulting from additional Proposition A operating subsidies, contributed heavily to the unprecedented growth in public transit usage realized in Los Angeles between FY 1982-83 and FY 1984-85. By the end of the three-year Proposition A Fare Reduction Program in June, 1985, District patronage approached 500 million boardings annually. This level of patronage was 42% higher than the level of patronage achieved during FY 1981-82, the year immediately preceding the Fare Reduction Program.

Rapid ridership growth has created some problems for the District. While generous subsidies have been available as a result of the Proposition A Fare Reduction Program, the District has not been able to respond to the higher patronage demand with commensurate increases in service levels. In part, equipment reliability problems limited the availability of additional buses with which to provide expanded service. A significant restructuring of the District's bus lines (the Sector Improvement Program) was implemented during the first half of the Fare Reduction Program's time frame. Program implementation diverted some personnel resources that otherwise might have been allocated to a more rapid expansion of services. Of equal importance, however, was the realization that if too much service were added during this time period and no other funding sources found, then significant service reductions would be required at such time as a portion of the Proposition A subsidy dollars began being reallocated for guideway development purposes. As a result, the District realized significant gains in productivity. Unlinked boardings per vehicle service hour increased 30% since the inception of the Fare Reduction Program, peaking at 70 boardings per vehicle service hour during FY 1984-85. The price paid for these productivity gains was increased crowding on District buses. Crowding was enough of an issue that many who spoke at the February 2, 1985 public hearing on the FY 1985-86 fare and service change proposals voiced a preference for paying higher fares, rather than seeing significant service cuts proposed.

While the validation of the Proposition A Fare Reduction Program made it possible for the District to temporarily avoid increasing fares through June, 1985, the end of the Fare Reduction Program on July 1, 1985, required that significant shifts in service and fare policies be considered. Beginning in FY 1985-86, the manner in which Proposition A dollars were allocated changed. During the first three years of Proposition A funding availability (through FY 1984-85), up to 75% of annual revenues were potentially available to Los Angeles County operators to subsidize mandated reduced fares. The District used $142.6 million in Proposition A funds during FY 1984-85 as a result of this program. However, beginning in FY 1985-86, Los Angeles County operators were required to use no more than 40% of the Proposition A revenues annually. In essence, this change in funding implied that the District would be able to receive a maximum of only $98.5 million from this source to support FY 1985-86 operations, or a reduction in funding availability of approximately $43 million. Since the reduced availability of Proposition A funds was assumed to occur regardless of any potential resolution of future federal Section 9 funding levels, the District's Board of Directors considered a combination of higher fares and reduced service levels to become effective on July 1, 1985. On February 13, 1985, the Board adopted increased fares for all categories of riders. On February 14, 1985, a program of reduced headways during the peak periods on primarily demand-based services was adopted for implementation on July 1, 1985.

To assess the various service and fare policy options available to the District for July 1, 1985 implementation, a comprehensive fare policy and service modification study was implemented in mid-FY 1983-84. The objectives of the study were to (1) identify the role which alternative pricing strategies could play in improving the efficiency and equity of transit services, (2) establish a fare level which, when combined with service changes, would compensate for the $43 million loss in Proposition A funds, and (3) strike a balance between the necessary increase in fares and the reduction in service.

The purpose of this report is to document the assumptions, sources of data, and methodologies which were developed in order to produce the staff recommended fare and service modification package. All of the analyses were drawn from the revenue, cost, and ridership characteristics of the District. Several hypotheses regarding the economic efficiency of the District's FY 1984-85 pricing policies were statistically tested by comparing fare revenues with the marginal costs of serving trips of varying distances in both peak and off-peak periods. In addition, the level of fare cross-subsidization among various socioeconomic user groups was traced in order to identify issues related to pricing equity. Based on the deficiencies identified in the analyses of existing fare policies, recommended fare policies were developed and analyzed in terms of their potential contributions to efficient and equitable transit pricing.

The following section (Section 2.0) presents the theoretical as well as empirical analyses developed to evaluate transit pricing structures based on marginal cost pricing. The procedures used to evaluate the efficiency and equity impacts associated with distance-based and time-of-day pricing structures are described. The procedures used to apportion costs and revenues to specific users (by type of service) according to time-of-day and distance traveled are also described. Generally, revenue, cost, and ridership data are merged for the purpose of analyzing the District's current "flat" fare pricing structure.

Section 3.0 presents an evaluation of the impacts associated with changes in fare levels upon ridership. This section documents the development of a discrete elasticity model calibrated from historical District-specified data. Model enhancements are described which adapt the resultant model for use with the relatively large magnitude of fare changes considered, as well as sensitize the model to the relative price differences of alternative fare payment methods available to each category of rider.

Section 4.0 assesses the District's current flat fare policies and the role which refinements of the base cash and pass fares, transfer surcharges, and discount fares can play in maximizing the District's patronage, passenger revenue, and levels of service. A discussion of the alternative fare levels which were found to be appropriate for the post-Proposition A Fare Reduction years is included.

The final section, Section 5.0, summarizes the study findings, discusses their current as well as future implications, and describes the programs which have been developed to assess the estimated versus actual changes in patronage and revenue associated with the Board-adopted July 1, 1985 fare and service modification packages.

2.0 ANALYSIS OF THE EFFICIENCY AND EQUITY IMPACTS ASSOCIATED WITH DISTANCE-BASED AND PEAK/OFF-PEAK PRICING SCENARIOS

2.1 INTRODUCTION

Many transit agencies, including the District, currently employ simple zone fare structures for special (express) services and "flat" fare structures for all other services, thereby charging essentially a constant, uniform price with respect to passenger trip distances and time-of-day. Although flat fare structures have consistently been the most widely accepted pricing alternative, questions have recently been raised concerning their efficiency in generating farebox revenues with respect to covering operating costs. Issues relating to the economic efficiency of flat fare structures, which call for prices to reflect the costs of providing services, have become a major concern. More specifically, flat fare pricing structures have been suggested as failing to collect sufficient increments of revenue from those users who impose the greatest costs on transit systems, i.e., the peak period commuters and long distance riders.

Demonstrated nationally, transit costs are relatively higher during peak periods and for long distance trips primarily because additional employees must be hired to accommodate rush hour passenger demands and because operator assignments must be extended to serve outlying areas. A uniform pricing structure which sets the fare near the average cost of serving all trips, therefore, assumes that the rider who travels short distances during an off-peak hour must offset the relatively higher costs incurred in serving the commuter who travels long distances during the rush hour. As a result, peak period and long distance riders are usually identified as being cross-subsidized. They are purchasing relatively more service for their fares than other passengers, i.e., the marginal revenues received from long distance, peak period users are less than the marginal costs of serving their trips. These losses in efficiency are made up in part through the (apparent) over-pricing of short distance trips during non-peak periods.

The equity implications of fare cross-subsidization suggest that long-distance/peak period patrons are generally from user-groups with incomes higher than the average rider. It is widely hypothesized that uniform (flat fare) pricing practices result in a regressive transfer of income from the poor to the rich. Generally, peak period service expansion (to suburban areas) tends to be associated with regressivity because transit usage by low-income patrons (who have low rates of labor force participation and high rates of transit utilization for non-work trips) is much less concentrated in the peak periods than that of other user-groups. Trips which would be economically worthwhile at a fare approximating the cost of providing service are frequently not worthwhile at the cost <u>plus</u> the price of subsidizing longer (and peak period) trips.

The primary purpose of this section is to evaluate the District's current transit fare policies and the role which distance-based and peak/off-peak pricing strategies can play in improving the efficiency and equity of the District's services during the post Proposition A Fare Reduction years. The degree to which the District's existing flat fare structure corresponds with the empirical evidence presented on uniform pricing structures is identified. An analysis of the alternative fare "levels" appropriate for the post Fare Reduction years will be presented in Section 3.0.

Summarizing the findings of this section, it was found that, contrary to the empirical evidence provided on time-variant pricing structures, the peak users of the District moderately cross-subsidize off-peak period passengers. While time-variant fares suggest that an increase in District operating efficiency is possible due to the relatively minor additional operating costs associated with implementing a peak/off-peak fare structure, differing fares by time-of-day appear to capture a higher degree of user inequity. Moreover, while distance-based fare structures appear to be more progressive than the District's current flat fare structure (with respect to family income), differentiating passenger fares by distance traveled results in a significant increase in net operating costs arising from the mechanics of administering such a structure with current technology and, thus, a decline in overall system efficiency.

2.2 SECTION ORGANIZATION

This section consists of four parts. The first part presents an overview of the methodology and framework of analysis used to evaluate the policy implications associated with implementing distance-based and peak/off-peak pricing structures. The second part describes the development of a set of operating cost models designed to estimate the marginal line-by-line operating costs of the District. A discussion of the methodology used to compute line-specific time-of-day costs and passenger-miles is included. The third part describes the procedure which was developed to compare the costs estimates of each passenger trip surveyed by the 1983 On-Board Passenger Survey with each survey respondent's estimated average cash and/or pass revenues. The procedure used to assign cash fare equivalents to passholders is also described. Levels of efficiency and equity for several distance-based and peak/off-peak pricing scenarios are identified. Finally, an analysis of the efficiency and equity impacts associated with implementing distance-based and peak/off-peak pricing scenarios is presented.

2.3 METHODOLOGY OVERVIEW

Two complementary criteria were used to assess the policy implications of several distance-based and peak/off-peak fare structures. The first criterion, efficiency, was used to assess the benefit of transit to six different types of District service-related user-groups, i.e., local policy, local demand, freeway express, local-access express, intra-community, and contract service user-groups. The question of whether each user-group should pay revenues to cover the costs of transit services in proportion to the benefits they received was evaluated. The second criterion, equity, was used to assess the impacts of various pricing strategies on those user-groups most/least dependent upon transit service. The question of whether users should contribute to the cost of service according to their ability to pay was also evaluated.

An analysis of the efficiency of the District's current pricing policies was developed by comparing the fare revenues of each service-related user-group with the marginal costs of serving trips of varying distances in both the peak and off-peak periods. An analysis of the equity implications of the District's current pricing policies was established through an evaluation of the pricing differences related to user's income, auto ownership, as well as other demographic characteristics. Based on the efficiency and equity deficiencies established in an examination of the District's existing fare policies, alternative distance-based and peak/off-peak fare policies were analyzed in terms of their potential contributions to developing higher efficiency and more equitable fare policies.

2.3.1 PRICING EFFICIENCY

Efficient transit pricing (in an economic context) requires that fares be set equal to the marginal costs of a transit property's total "social" cost production function. Transit's marginal social cost, however, falls below its direct marginal cost since public transportation provides many tangible benefits to society, such as reduced pollution, energy conservation, and improved land use patterns. These benefits accrue to everyone in a community, regardless of their use of, or contribution to, public transit. Since most transit systems do not operate on a cost-recovery basis, the difference between fare revenue and marginal operating cost (i.e., subsidies) reflects what society is willing to pay in order to appreciate the full benefits of public transit. Placing a precise monetary value on transit's full range of benefits, nevertheless, is an exceedingly difficult task, necessitating the indirect pricing of such noncommensurable benefits as reduced air pollution and travel time savings.

In recognition of the difficulties associated with measuring social costs and benefits, only direct costs and benefits as reflected by the District's expense ledgers and users' fares were considered. Pricing evaluations were not analyzed from society's point-of-view, but rather from that of the transit user and the District. Efficient transit pricing was identified with the setting of fares equal to the direct incremental costs of providing additional units of service, holding current subsidy rates constant. The efficiency criterion, therefore, was used for evaluating whether fares sufficiently offset the incremental costs of services, with production output measured according to distance and time period of travel.

2.3.2 PRICING EQUITY

Pricing equity was used to evaluate the disparities in fares and costs among various income and socio-economic groups. Whereas the efficiency criterion employs the "benefit principle", equity is assessed on the basis of a patron's ability to pay and transit dependency. When taken to an extreme, the ability-to-pay concept calls for fares to vary according to income. The intent of this study, however, was to view equity as setting fares so that the income redistribution impacts between each of the District's service "types" are virtually eliminated, neutralizing any transfers among income groups.

In terms of transit pricing, the efficiency and equity criteria appear quite consistent. From the benefit point-of-view, those who derive increments of satisfaction from transit services should be those who pay extra increments of fare. From the ability-to-pay standpoint, those least able to pay should not bear an excessive proportion of the expense burden. Since it is generally suggested that transit patrons most responsible for high-cost services are peak period and long-distance users who tend to be financially better-off than the average rider, efficient pricing could also serve to promote equity.

It is important to note that time-variant and distance-based transit fares which charge more to those most responsible for higher cost services are nondiscriminatory. Discrimination exists only when price differences charged are not equal to the differences between the costs of providing marginal units of service to customers. Since it is suggested that the fare policies which equate prices with marginal costs are efficient, equitable, and financially solvent, such pricing structures should also be considered nondiscriminatory.

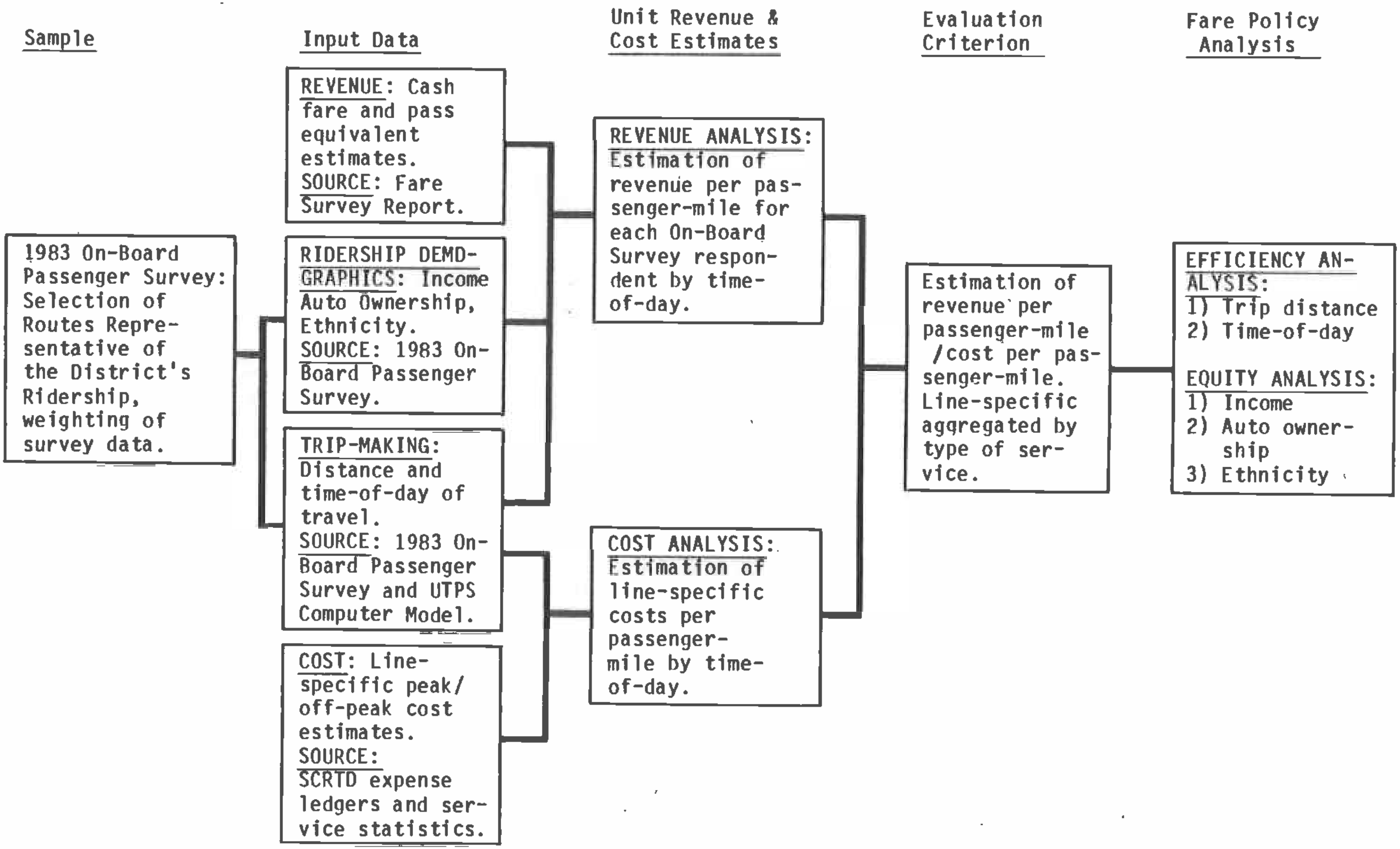
2.4 FRAMEWORK OF ANALYSIS

The procedure used to evaluate the impacts associated with distance-based and peak/off-peak pricing structures was a comparison of the revenue paid and the costs incurred in serving individual passenger trips. Efficiency evaluations of the District's current fare policies were performed by evaluating the revenue and cost differences among distinct categories of trip distances and time periods. Data were further analyzed according to the socio-economic characteristics of riders in order to ascertain the equity implications of the District's pricing policies. Figure 2-A presents a step-wise summary of the procedures used in analyzing the District's current pricing policies.

With respect to data collection, the first step involved an evaluation of the origin/destination and socio-economic characteristics of individual respondents from the 1983 On-Board Passenger Survey. Through the use of the District's Urban Transportation Planning System (UTPS) computer model, each survey respondent's trip distance was estimated from computer simulations of the transit network. Next, data was collected on the method of fare payment of individual riders. For each type of pass media, cash fare equivalents were estimated in order to assign revenue values to passholders. Finally, a set of District operating cost models was derived using a "cost-centers" unit allocation approach. The models apportioned a share of the District's total costs to each line based on such characteristics as a line's total vehicle hours, revenue miles, and number of bus "pull-outs". Costs were divided into peak and off-peak components to reflect the cost impact of the District's UTU labor agreement which limits the hiring of part-time labor and split-shift operator assignments.

FIGURE 2-A

TRIP DISTANCE AND TIME-VARIANT FARE STRUCTURE EVALUATION METHDDDLDGY



In order to compare the revenues associated with each of the District's service types (disaggregated at the level of individual passengers) with costs (disaggregated at the route level on a peak/off-peak basis), it was necessary to establish a common unit of analysis. Passenger-miles was used in lieu of passenger-hours, seat-miles, and other possible unit factors for two reasons: 1) it was the only trip-making variable available from the 1983 On-Board Passenger Survey which was suited to factoring revenues; and 2) it provided a basis for conducting a marginal analysis, i.e., units of trip revenue and trip cost could be compared across categories of trip distance and between time periods. It should be noted that no data were compiled from the 1983 On-Board Passenger Survey on the duration (in hours) of each sampled trip. In addition, seat-miles were considered inappropriate because each seat-mile cost unit could not be directly associated with a particular passenger (i.e., costs allocated to empty seats would have had to be prorated among all passengers, effectively producing a passenger-mile unit cost). Other unit factors, such as vehicles, were not suited to the indexing of an individual user's payment. Accordingly, peak and off-peak revenue per passenger-mile estimates were derived for each user by dividing the rider's fare by his/her trip length in each respective time period. Cost per passenger-mile estimates were computed for each route's peak and off-peak periods by dividing time-of-day cost estimates by the passenger-miles in each respective time period. Thus, a unit cost estimate was assigned to each sampled user's trip on the basis of his/her particular bus line and time period of travel.

The criterion variable used in evaluating the efficiency and equity of the District's current fare policies was the ratio of revenue per passenger-mile to cost per passenger mile (RPM/CPM). Pricing efficiency was tested by analyzing RPM/CPM differences among distinct categories of trip distance and time-of-day. Differences in RPM/CPM were analyzed among several categories of user socio-economic characteristics to evaluate pricing equity. An implicit assumption of the analysis was that the unit costs derived for each bus line by time period were constant for all patrons of the line for the specified time-of-day. That is, it was presumed that the cost-per-mile of someone making a short trip during the "shoulder" of the peak period on a particular line was the same as someone commuting a long distance during the peak of the peak period on the same line. This amounted to an equal prorating of "unit" costs regardless of distance traveled. Of course, the "total" cost of a long distance journey was relatively higher than a short distance journey since the unit costs were expanded by trip length. The following sections provide a detailed description of the methodologies used in developing route level cost estimates, passenger revenues, and the resultant distance-based and peak/off-peak efficiency and equity evaluations.

2.5 ESTIMATION OF LINE-SPECIFIC TRIP DISTANCE AND TIME-OF-DAY OPERATING COSTS

In order to assess the efficiency and equity implications of the District's current pricing policies, it was necessary to develop line-specific trip distance and time-of-day operating cost estimates which could be merged with (1) ridership data obtained from the 1983 On-Board Passenger Survey and (2) estimates of passenger trip revenues. The goal was to develop a marginal cost allocation model which was capable of estimating line-specific peak and off-peak operating costs. Because the marginal cost of providing transit service during the peak or over long distances has been suggested to differ significantly from the average costs taken over all hours of the day on all bus runs, an allocation model which failed to account for the (apparent) higher marginal cost imposed by peak usage or long distance trips was thought to present a distorted picture of transit costs. Subsection 2.5.1, which follows, summarizes the modeling process which was developed to allocate line-by-line operating costs to the peak and off-peak periods. Subsection 2.5.2, Time-of-Day Cost Computations, describes the process used to compute line-specific peak and off-peak total costs.

2.5.1 DEVELOPMENT OF A MARGINAL OPERATING COST MODEL

In an attempt to develop a marginal operating cost model which, when summed across all time periods and days of operation for each line in the system, would also accurately estimate total annual District operating expenses, a disaggregate or "cost centers" modeling approach based on divisional expense and service data was chosen. As nearly half of the SCRTD's expenses are incurred through operator labor costs, it was decided that an appropriate modeling objective would be to accurately identify the peak versus off-peak operator payhour differentials associated with the current labor agreement of the SCRTD's United Transportation Union (UTU). Given that a cost centers approach could identify service related expenses different from the system average expense, and given that divisional operator wages played an important role in explaining these differences, increases in the accuracy of line-specific cost estimates were considered potentially significant. While it was recognized that a fully allocated marginal operating cost model based solely on variable costs could not reflect the "true" costs, in which a significant proportion are fixed and incremental, an attempt to improve the District's current method of estimating line-specific operating costs was deemed necessary. The following steps were incorporated into the modeling design.

.1 <u>Evaluation of Divisions as Cost Centers</u>

To test the degree of variation between the SCRTD's divisional unit costs, an analysis of the SCRTD's cost per vehicle mile and cost per vehicle hour was made for each of the 12 operating divisions. Total expenses incurred and accounted for by division were divided by each division's respective total vehicle miles and total vehicle hours to produce the results presented in Tables 2-1 and 2-2. Noteworthy, is the fact that the total operating expenses maintained for the 12 operating divisions, as a whole, account for approximately 55% of the SCRTD's total FY 1982-83 operating budget.

From Tables 2-1 and 2-2, significant variations in divisional costs per vehicle mile and costs per vehicle hour are apparent. Divisional costs per mile vary by as much as $0.92 (55%) per mile, whereas the divisional costs per hour vary by as much as $15.32

TABLE 2-1

SCRTD MILEAGE UNIT COSTS BY DIVISION

(FY 1982-83)

DIVISION		COST PER VEHICLE MILE
9	El Monte	$1.67
12	Long Beach	1.71
15	Sun Valley	1.79
8	Chatsworth	1.94
16	Pomona	2.02
1	Alameda	2.13
18	South Bay	2.23
5	South Central L.A.	2.25
3	Cypress Park	2.28
2	Los Angeles	2.32
6	Venice	2.46
7	West Hollywood	2.59

Mean	$2.12
Standard Deviation	$0.29

TABLE 2-2

SCRTD HOURLY UNIT COSTS BY DIVISION

(FY 1982-83)

DIVISION		COST PER VEHICLE HOUR
1	Alameda	$26.65
2	Los Angeles	27.79
5	South Central L.A.	27.88
7	West Hollywood	27.91
3	Cypress Park	27.98
9	El Monte	28.69
15	Sun Valley	29.01
6	Venice	30.21
12	Long Beach	30.39
18	South Bay	32.80
8	Chatsworth	32.90
16	Pomona	41.97

Mean $30.35

Standard Deviation $ 4.16

(58%) per hour. As expected, divisions which operate relatively greater amounts of high-speed freeway service tend to accumulate lower costs per mile but, because of the nature of their services (which are generally peak period services with relatively higher operator payhour to vehicle hour ratios), they also tend to have higher costs per hour. The statistics from Tables 2-1 and 2-2 generally illustrate that divisions furthest from the Los Angeles CBD have the lowest costs per mile and the highest costs per hour.

From a modeling perspective, the results of Tables 2-1 and 2-2 clearly show that system average unit costs do not present an accurate picture of the SCRTD's variety of services. An operating cost model based on a divisional cost centers approach, therefore, can indeed improve the accuracy of line-by-line cost estimates.

.2 Design of a System-wide Operating Cost Model

To define the service-related variables which explain the variations in the divisional unit costs noted in Tables 2-1 and 2-2, a correlation matrix between divisional expense accounts and divisional service statistics was developed. The expense accounts which were thought to have "logical" relationships with various service-related variables were statistically analyzed through the use of a Pearson Correlation Matrix. The service-related statistics which were tested include the following:

- Total Vehicle Miles
- Revenue Vehicle Miles
- In-Service Vehicle Miles
- Total Vehicle Hours
- Revenue Vehicle Hours
- In-Service Vehicle Hours
- Number of Bus Pull-Outs
- Peak Buses

An analysis of the correlation matrix indicated that of the eight service variables chosen, virtually all had relatively significant correlations with one or more of the District's expense accounts. In general, any one of the service variables would have made a "good" estimator of divisional expenses. On the other hand, various combinations of service variables appeared to provide even better explanations of divisional expenses, indicating that variations in divisional expenses can only be partially explained by one service variable. A combination of the total vehicle hours and peak bus variables, for example, indicated a better correlation with the various expense accounts than either of the variables individually. A multivariate regression analysis, therefore, was used to define which variables in tandem produced the best estimate of divisional expenses. To avoid the development of a model with high intercorrelation between the independent variables (multicolinearity), and as an aid in identifying the specific variables which explained the variations in operating expenses, a nontraditional approach to multivariate modeling design was developed.

Instead of producing one model in which all expense accounts are correlated with each service variable at the same time, three separate models were developed. The expense accounts which consistently maintained a high correlation with each of the hourly service variables (total, revenue, and in-service hours) made up the dependent variable of the first model. Individual correlations between these "hourly expenses" and each of the three hourly service variables indicated which service variable was capable of making the best estimate of hourly expenses. The same process was used to define the "best" mileage and peak service variables.

Because each of the three models estimated a unique and separate share of divisional expenses, the three models together represented the best estimate of total divisional expenses. Through simple addition of the models, a multivariate divisional operating cost model was initially developed. All remaining nondivisional operating expenses were then added to each variable's coefficient such that the resultant model was capable of estimating total system (as opposed to divisional) operating expenses. The calibrated system-wide model is represented by the following equation:

FY 1982-83 SCRTD (SYSTEM) OPERATING COSTS =
$ 28.35 (Total Vehicle Hours)
+ $ 1.12 (Revenue Miles)
+ $104.22 (Bus Pull-Outs)

.3 Differentiation Between Local and Express Service Operating Costs

The third step in the modeling process was to develop a procedure capable of differentiating the SCRTD's operating costs by type of service. Because previous studies had indicated that the variations between local and express unit costs differed significantly, separate models sensitive to these variations were thought to be useful in enhancing the overall modeling process. The objective was to split the "system" model into two distinct models; one capable of estimating local service operating costs and one capable of estimating express service operating costs. A divisional "cost centers" approach, identical to the approach previously discussed, was used as the process to identify the variations in local and express unit costs. However, in order to produce two distinct models which, when used in tandem, could also accurately estimate total system costs, individual cost center analyses were regenerated based on local and express (as opposed to system) service and expense statistics.

.4 Differentiation Between Peak and Off-Peak Operating Costs

The final step in the modeling design was to integrate the operator work rule stipulations which further explain variations in the estimates of line-by-line operating costs. Specifically, this involved an attempt to differentiate total weekday expenses between the peak and off-peak periods of service. Although the local and express models, to some extent, addressed the issue of different time-of-day costs through the use of the "bus pull-out" variable, the models did not account for the cost differences normally associated with the peak and off-peak time periods in which driver's wages represent the largest single expenditure.

To attribute a larger proportion of total hour costs to peak operations, a procedure developed by Cherwony and Mundle (1978) was used to adjust the vehicle hour coefficient in the local and express cost models upward for the peak period and downward for the off-peak period, since the weighted-average vehicle hour variable underestimates the costs of peak service and exaggerates those of the off-peak. The approach developed by Cherwony and Mundle ties together vehicle hour and operator payhour data into a time apportioned index of operating costs. The most salient feature of their approach is that the system vehicle hour coefficient is modified for the peak and off-peak periods based on two factors: an index of the relative peak and off-peak period operator productivity and an index of the relative amounts of peak and off-peak period service. The operator labor productivity index adjusts the vehicle hour unit cost coefficient by comparing the ratio of operator payhours to vehicle hours in the peak versus the off-peak. The service index simply compares the number of vehicle hours in the peak with those in the off-peak. While the operator labor productivity index functions as a measure of the penalizing features of the operator (UTU) labor agreement, the service index measures the relative amount of service offered in each peak and off-peak time period.

Integration of the Cherwony and Mundle approach into the local and express operating cost models produced four distinct SCRTD cost models: two for estimating line-by-line peak period expenses (local and express) and two for estimating line-by-line off-peak period expenses (local and express). In addition, because the variations in operator payhours to vehicle hours differed significantly between weekdays and weekends (due to the differences in the peak to base vehicle ratios between weekdays and weekends), two system average weekend models were also developed to estimate the operating costs of local and express weekend service. No attempt was made to differentiate between peak and off-peak weekend operating costs because of the relatively "flat" demand for weekend service. The final models developed as a result of the entire modeling design are presented in Table 2-3.

2.5.2 TIME-OF-DAY COST COMPUTATIONS

Since a majority (approximately 70%) of the District's FY 1982-83 passenger trips were found to be either work or school-related and, thus, relatively sensitive to the impacts associated with distance-based and time-variant pricing structures, efficiency and equity cost/revenue analyses were initially performed on weekday ridership only. Weekend distance-based and time-variant pricing evaluations were not deemed necessary unless the results of the weekday pricing evaluations demonstrated that further (weekend) studies should

TABLE 2-3

FINAL MODEL FORMATS

(FY 1982-83)

$$\text{LOCAL } TC_p = \$30.34(THR_p) + \$1.14(RM_p) + \$104.08(PO)(APB/TB)$$

$$\text{LOCAL } TC_o = \$27.16(THR_o) + \$1.14(RM_o) + \$104.08(PO)(BB/TB)$$

$$\text{LOCAL } TC_w = \$28.35(THR_w) + \$1.14(RM_w) + \$104.08(PO_w)$$

$$\text{EXPRESS } TC_p = \$33.17(THR_p) + \$0.99(RM_p) + \$134.57(PO)(APB/TB)$$

$$\text{EXPRESS } TC_o = \$29.70(THR_o) + \$0.99(RM_o) + \$134.57(PO)(BB/TB)$$

$$\text{EXPRESS } TC_w = \$31.00(THR_w) + \$0.99(RM_w) + \$134.57(PO_w)$$

where:

TC_p = Total cost of peak period weekday service, where peak period is defined as the sum of the A.M. peak (6:00 A.M. thru 8:59 A.M.) plus the P.M. peak (3:00 P.M. thru 5:59 P.M.),

TC_o = Total cost of off-peak period weekday service, where off-peak period is defined as all weekday service minus the peak period service (See TC_p),

TC_w = Total cost of weekend (24 hour) service; Saturday, Sunday, or holiday service,

THR_p = Total peak period weekday vehicle hours,

THR_o = Total off-peak period weekday vehicle hours,

THR_w = Total weekend vehicle hours,

RM_p = Peak period weekday revenue miles,

RM_o = Off-peak period weekday revenue miles,

RM_w = Total weekend revenue miles,

PO = Number of weekday bus pull-outs,

PO_w = Number of weekend bus pull-outs,

APB = Average peak period buses; A.M. peak buses plus P.M. peak buses divided by two (2),

BB = Total base period buses; 9:00 A.M. thru 2:59 P.M.,

TB = APB + BB.

be performed. Initial line-specific peak and off-peak cost computations, therefore, utilized only four of the previously mentioned six operating cost models, i.e., the local and express peak/off-peak cost models (Table 2-3).

Computation of the total peak and off-peak costs of operating each of the District's lines (routes) was accomplished by inserting appropriate input data (on vehicle hours, revenue miles, and number of bus pull-outs) into the respective local and express peak/off-peak cost allocation models. First, however, line-specific total vehicle hours, revenue miles, and number of bus pull-outs had to be apportioned between the peak and off-peak time periods. The apportioning of each line's number of bus pull-outs, defined as the sum of morning and evening peak buses, less the base volume of buses operated during the midday, was fairly straightforward. The only difficulty presented was that there was no time continuum for casually assigning "measures" of pull-outs between the peak and off-peak time periods; accordingly, there was no theoretical basis for factoring a portion of the peak-related bus pull-outs into the off-peak period. The apportionment technique chosen as the most "reasonable", therefore, was to allocate increments of pull-outs based on ratios of either (1) the average peak period to total daily bus requirements, for peak period allocations, or (2) total base period to total daily bus requirements, for off-peak period allocations (Table 2-3).

In contrast to the peak/off-peak apportionment of bus pull-outs, the allocation of vehicle hours and revenue miles between time periods was fairly complex. Generally, an aggregation of each line's scheduled vehicle hours and revenue miles by bus trip by time period was necessary. The result was a listing of the total daily vehicle hours and revenue miles for each of the District's approximately 220 lines (routes) by A.M. peak period, P.M. peak period, and all remaining off-peak period service. The programming constraints which were applied to the District's January 30, 1983 Service Data System (SDS) master file included the following:

- Variables generated:

  Total daily vehicle hours - defined as all revenue and nonrevenue hours, inclusive of time associated with bus pull-outs, bus pull-ins, within-line deadheading, between-line deadheading, and layovers.

  Total daily revenue miles - defined as all revenue and nonrevenue miles, exclusive of mileage associated with bus pull-outs and bus pull-ins.

- The A.M. peak period was defined as 6:00 A.M. to 8:59 A.M., inclusive.

- The P.M. peak period was defined as 3:00 P.M. to 5:59 P.M., inclusive.

- The off-peak period was defined as all service minus the A.M. and P.M. peak periods.

- o Schedule variations included school, non-bowl, non-race bus trips.

- o All bus "layover" hours and miles were defined as revenue hours and miles.

- o Within-line deadheading hours and miles were attributed to the origin line (route) to which the bus trip was scheduled for service.

- o Between-line deadheading hours and miles were equally apportioned between the line (route) of origin (50%) and the line (route) of destination (50%).

- o All within-line and between-line deadheading hours and miles were counted as revenue service.

- o "Foreign" line hours and miles were counted as revenue service on the foreign line (route), as opposed to the line of origin.

The method used to calculate each line's peak and off-peak vehicle hours and revenue miles incorporated a series of logical steps in order to apportion bus trip miles and hours between each time period. To identify all possible trip making variations, several definition statements were developed for both the hourly and mileage service variables. A diagram representing the various hourly and mileage bus trip possibilities is presented in Figure 2-B. The following definition statements were used to apportion line-by-line trip-specific miles and hours to either the peak or off-peak time periods:

<u>Vehicle Hour Definition Statements</u>

- o Trip Variation A or B (Figure 2-B): if a bus trip began and ended prior to the beginning of a peak period or began and ended after the end of a peak period, then zero vehicle hours were counted as peak period hours.

- o Trip Variation C (Figure 2-B): if a bus trip began before the start of a peak period and ended before the end of the same period, then the total peak period vehicle hours were calculated as the ending trip time minus the start of the peak period time, e.g., 6:30 - 6:00, or 31 minutes.

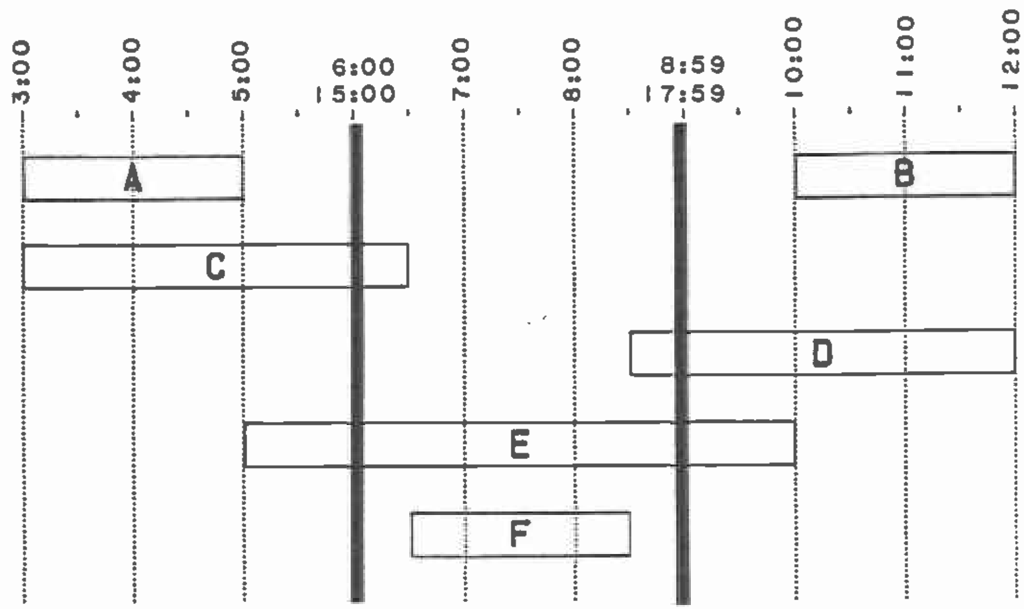
- o Trip Variation D (Figure 2-B): if a bus trip began before the end of a peak period and ended after the end of the peak period, then the total peak period vehicle hours were calculated as the end of the peak period time minus the beginning of the trip time, e.g., 8:59 - 8:30, or 30 minutes.

- o Trip Variation E (Figure 2-B): if a bus trip began before the beginning of a peak period and ended after the end of the same period, then three hours were counted as peak period vehicle hours, e.g., 8:59 - 6:00, or 180 minutes.

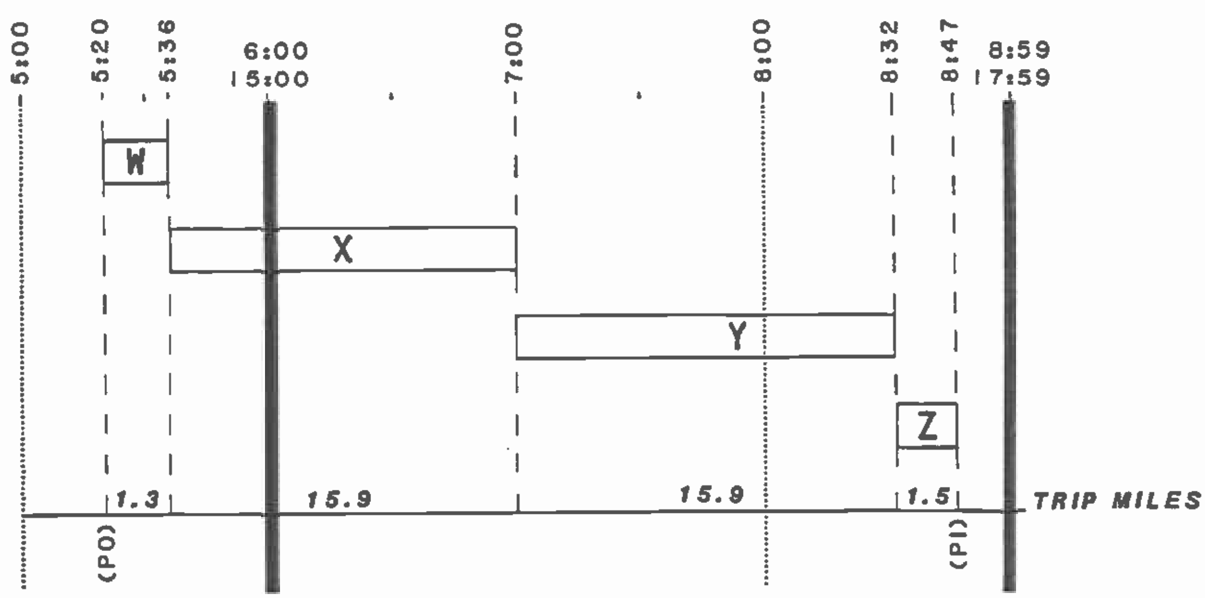
FIGURE 2-B

BUS TRIP START AND END TIME VARIATIONS AS THEY RELATE TO PEAK AND OFF-PEAK TIME PERIODS

VEHICLE HOUR VARIATIONS



REVENUE MILE VARIATIONS



- Trip Variation F (Figure 2-B): if a bus trip began after the beginning of a peak period and ended before the end of the same period, then the total peak period vehicle hours were calculated as the end if trip time minus the beginning of trip time, e.g., 8:30 - 6:30, or 121 minutes.

- All remaining vehicle hours were counted as off-peak period vehicle hours.

<u>Revenue Mile Definition Statements</u>

- Trip Variation W (Figure 2-B): if a trip involved a bus pull-out, then zero miles were counted as revenue miles because the trip (by definition) was a nonrevenue trip, e.g., the miles associated with the 5:20 A.M. pull-out (1.3 miles) were not counted as peak (or off-peak) revenue miles because they are nonrevenue (as well as off-peak) miles.

- Trip Variation X (Figure 2-B): if a trip left its near terminal prior to the beginning of the peak period, then the revenue miles associated with the peak portion of the trip equaled the proportion of peak vehicle hours associated with the trip. The revenue miles associated with the off-peak portion of the trip equaled all remaining (off-peak) trip miles. For example, in trip variation "X", the revenue miles associated with the peak period equal the proportion of peak to off-peak vehicle hours (in minutes) multiplied by the total trip revenue miles, i.e., 60 minutes/84 minutes multiplied by 15.9, or 11.4 revenue miles. The revenue miles associated with the off-peak period equal total trip miles (15.9), minus the previously calculated peak period miles (11.4), or 4.5 off-peak period revenue miles.

- Trip Variation Y (Figure 2-B): if a bus trip left its near terminal during the peak period and reached its far terminal during the same period, then the total trip miles equaled peak period revenue miles, i.e., 15.9 peak period revenue miles.

- Trip Variation Z (Figure 2-B): if a trip involved a bus pull-in, the zero miles were counted as revenue miles because the trip (by definition) was a nonrevenue trip, e.g., the miles associated with the 8:47 A.M. bus pull-in (1.5 miles) would not be counted as peak (or off-peak) revenue miles because they are nonrevenue miles, even though they are within the peak period.

- All within-line deadheading miles which "overlapped" between the peak and off-peak periods were proportionally attributed between the peak and off-peak periods based on vehicle hours (minutes).

- All between-line deadheading revenue miles, which by definition were equally split between the origin line and destination line, were attributed to the period of time in which the destination line began its service, based on vehicle hours. For example, given that a between-line deadheading trip began prior to the peak period but ended during the peak period, all miles attributed to the origin and destination lines were counted as peak revenue miles.

2.5.3 TIME-OF-DAY PASSENGER-MILE COMPUTATIONS

In order to unitize the line-specific peak and off-peak operating costs identified in the previous section, accurate estimates of line-specific peak and off-peak passenger-miles were developed next. However, to also facilitate the unitizing of passenger revenues, which were developed at the passenger trip level (Section 2.6), "trip"-specific time-of-day passenger-mile data was required. The first step in the process, therefore, was to identify the origin and destination of each passenger surveyed during the 1983 On-Board Passenger Survey and to assign each trip (based on start time) to either an A.M. peak, P.M. peak, or off-peak time period. Next, each survey respondent's trip distance was estimated through the use of the District's UTPS transit network computer model. The shortest (centroid to centroid) linked path of each trip was identified, based on total travel time. The "transit related" trip distance associated with each path was used as the estimate of passenger-miles. Travel distances associated with a respondent's access mode to or from the point of origin or destination, i.e., walk, park and ride, or kiss and ride travel distances, were excluded in the trip distance computations. Finally, each trip (and the respective passenger-miles) were factored to represent weekday boarding estimates typical of the fourth quarter of FY 1982-83, and were aggregated by line to provide line-specific time-of-day passenger-mile estimates for every line in the system.

2.5.4 PEAK AND OFF-PEAK COSTS PER PASSENGER-MILE

The final stage of the cost analysis entailed factoring of the line-specific peak and off-peak cost estimates (Section 2.5.2) by the line-specific peak and off-peak passenger-miles developed in Section 2.5.3. By dividing each line's (route's) daily peak and off-peak cost estimates by the number of passenger-miles from each time period, individual unit cost factors were derived. The factoring of cost estimates on the basis of passenger-miles yielded unit measures of expense incurred in accommodating each patron for one mile of travel during each time period. A summary of the peak and off-peak operating costs, passenger miles, and unit costs per passenger-mile, aggregated by each of the six different types of District services, is presented in Table 2-4.

Contrary to the empirical evidence typically presented on time-variant and distance-based pricing scenarios, the data shown in Table 2-4 indicate that the District's unit costs of providing service throughout the County of Los Angeles are relatively higher during the off-peak, as opposed to peak, time period. Only two of the six types of District services, i.e., freeway express and contract service, incurred higher average peak period unit operating costs. Generally, the higher "direct" costs associated with peak services were countered by relatively higher ridership levels and exceptionally long trip lengths (a user characteristic unique to Los Angeles), producing rates of cost

TABLE 2-4

AVERAGE DAILY COST CHARACTERISTICS OF THE SCRTD (FY 1982-83)

Type of Service	Peak Operating Costs	Off-Peak Operating Costs	Peak Pass. Miles	Off-Peak Pass. Miles	Peak Cost Per Pass-Mile	Off-Peak Cost Per Pass-Mile
Local Demand	$301,742	$353,469	1,331,478	1,208,769	.227¢	.292¢
Local Policy	$39,862	$52,855	235,988	186,456	.169¢	.283¢
Intra-Comm.	$6,531	$7,267	13,312	8,454	.491¢	.860¢
Local-Access Exp.	$112,674	$95,839	565,506	360,796	.199¢	.266¢
Freeway Express	$23,719	$4,261	123,281	60,215	.192¢	.071¢
Contract	$11,838	$9,039	71,178	57,738	.166¢	.157¢
System Average (peak versus off-peak unit cost differential = 31%)					.212¢	.278¢

per passenger-mile slightly less than those during the off-peak period. However, to the extent that revenues per passenger-mile were also found to be relatively lower during the peak period, i.e., differing from the system average unit cost differential of approximately 31% (Table 2-4), some degree of pricing inefficiency and inequity was thought to be possible.

It should be noted that while the peak/off-peak cost evaluation produced atypical results, prior studies of time-variant and distance-based pricing structures have not generally (1) developed analyses based on approximately 90% of an agency's line-specific service and cost data, (2) utilized an operating cost model disaggregated by service type and time-of-day, and (3) compared peak with off-peak service and cost statistics where the off-peak was defined as 18 out of 24 hours of service. The importance of this latter issue is demonstrated by the fact that of the 18 hours of off-peak service provided by the District, the 12 hours associated with evening (6:00 P.M. - 12:00 P.M.) and owl (12:01 A.M. - 5:59 A.M.) services, which are typically not included in peak versus "base" pricing studies, incurred the highest unit costs of any time period throughout the day. The intent of the following section is to test whether fare cross-subsidization exists within the District's current fare policies and, if so, to assess its severity and incidence.
Table 2-4

2.6 ANALYSIS OF THE EFFICIENCY AND EQUITY IMPACTS OF THE DISTRICT'S CURRENT FARE POLICIES

This section combines the cost data presented in the previous section with revenue and ridership data for the purpose of evaluating the District's current fare policies. The impacts associated with the implementation of peak/off-peak and distance-based pricing structures are evaluated by comparing unit cost estimates with estimates of unit revenues for distinct categories of trip distance, time-of-day, and ridership. Following the evaluation process, general assessments of the District's current fare policies are made.

A discussion of the process developed to generate line-specific time-of-day unit revenue estimates is presented first. A description of the District's current trip distance and time-of-day ridership distributions is presented next. Finally, an evaluation of alternative trip distance and time-of-day pricing scenarios is presented. The efficiency and equity impacts associated with each scenario are identified.

2.6.1 TIME-OF-DAY UNIT REVENUE COMPUTATIONS

Based on data generated from the District's FY 1982-83 quarterly Fare Survey Reports, peak and off-peak unit revenue estimates were made for each line in the system. In contrast to the unit cost estimates, which were developed from line level peak/off-peak data, unit revenue estimates were initially determined at the passenger "trip" level and then aggregated by line (and by line type) in order to establish a common unit of analysis. The frequency of use of the District's fare payment methods (by line by time-of-day) was determined from the 1983 On-Board Passenger Survey. The "base" fare associated with each of the District's range of fare payment methods is presented in Table 2-5.

For the various types of passes used by survey respondents, cash fare equivalents were estimated in order to assign revenue values to pass users. To account for the discounts offered with cash and pass transfers, an average fare per unlinked boarding was computed for each of the District's fare categories. Because there was not sufficient data to estimate an equivalent cash price for pass users within each of the five express fare categories, an aggregate average fare per unlinked boarding was computed for all express riders. The formulas used to compute the average cash and cash equivalent pass fares per unlinked boarding for each of the District's fare categories are presented in Figure 2-C. The computed average fares are presented in Table 2-6.

It should be noted that because the District already assessed a distance-based (peak period) fare for express riders, revenue as well as cost computations (and evaluations) focused on local service ridership. The average fares presented in Table 2-6, therefore, represent local service fare levels. In addition, while the District has historically set monthly pass prices at a rate of forty times the cash fare for the corresponding trip, passes are generally used more than the forty ride break-even standard, thus fares assigned to pass users were below those of cash users making the same trip (Table 2-6).

Computation of the total peak and off-peak revenues associated with each of the District's lines (routes) was accomplished by first assigning each trip surveyed by the 1983 On-Board Passenger Survey to either the peak or off-peak period based on the trip's start time. If, for example, a trip started at 7:05 a.m., it was assigned as a peak period trip. If, however, a trip started at 9:30 a.m., it was assigned as an off-peak period trip. While it was realized that trips which began at the end of any specific time period may not have (in reality) been associated with that time period, it was assumed that trips which began just prior to the same time period would adequately compensate, thus accounting for and neutralizing the inherent problems associated with identifying time-of-day trip purposes from raw data. The second step involved the factoring of each trip to represent a typical weekday unlinked boarding estimate. Trip-by-trip unlinked boarding factors were provided from the results of the 1983 On-Board Passenger Survey. The final step entailed multiplying the average fare associated with the trip's fare category by the resultant weekday unlinked boarding estimate. An aggregation of the revenues associated with each trip on a line-by-line basis produced line-specific total revenues by time-of-day.

In order to unitize the line-specific peak and off-peak revenues, estimates of aggregate trip-specific peak and off-peak passenger-miles (discussed in Section 2.5.3) were divided into the estimates of peak and off-peak revenues to produce line-by-line, time-of-day unit revenues. The factoring of revenue estimates on the basis of passenger-miles yielded unit measures of revenue collected for

TABLE 2-5

SCRTD FY 1982-83 FARE LEVELS BY FARE CATEGORY

Fare Category	CASH			PASS	
	Cash	Transfer	Zone	Pass	Stamp
Regular	50¢	10¢	0¢	$20	$0
Express 1	50¢	10¢	25¢	$20	$7
Express 2	50¢	10¢	50¢	$20	$14
Express 3	50¢	10¢	75¢	$20	$21
Express 4	50¢	10¢	$1.00	$20	$28
Express 5	50¢	10¢	$1.25	$20	$35
E & H	20¢	10¢	0¢	$4	$0
Student	20¢	10¢	0¢	$4	$0
College	50¢	10¢	0¢	$4	$0
Free	0¢	0¢	0¢	$0	$0

FIGURE 2-C

FORMULAS DEVELOPED TO COMPUTE AVERAGE FARE PER UNLINKED BOARDING

$$\text{Average Cash Fare Per Unlinked Bdg} = \frac{(CF \times LCB) + (ACTF \times (UCB - LCB))}{UCB}$$

$$\text{Average Pass Fare Per Unlinked Bdg} = (PP \times NPS) / UPB$$

Where:

CF = Cash Fare
ACTF = Average Cash Transfer Fare
LCB = Linked Cash Boardings
UCB = Unlinked Cash Boardings
PP = Pass Price
NPS = Number of Passes Sold
UPB = Unlinked Pass Boardings

TABLE 2-6

AVERAGE FARE PER UNLINKED BOARDING (FY 1982-83)

Fare Category	Average Fare Per Unlinked Boarding
Cash - Regular	$.3727
Cash - E & G	.1682
Pass - Regular	.2151
Pass - E & H	.0656
Pass - Student	.0763
Pass - College	.0699
Pass - Express*	.6859
Ticket/Token	.5619
Tourist Pass	.4133
Free	.0

*Average of all five express fare categories.

accommodating each patron one mile during each time period. A summary of the peak and off-peak revenues, passenger-miles, and unit revenues per passenger-mile, aggregated by each of the six different types of District services, is presented in Table 2-7.

Similar to the average daily unit cost characteristics presented in Table 2-4, the data shown in Table 2-7 indicate that the District's unit revenues associated with providing service throughout the County of Los Angeles are also relatively higher during the off-peak, as opposed to peak, time period. However, different from the unit cost results, the peak period unit revenues of three (as opposed to two) types of District services exceed the off-peak period unit revenues, i.e., local-access express, exclusive freeway express, and contract services. Moreover, the system average peak versus off-peak unit revenue differential approximates 3%, as opposed to the 31% computed for peak versus off-peak unit costs, indicating that (1) patrons eligible for discount fares (students, college, E&H, and children) are utilizing a significant proportion of the District's service during the off-peak periods, and (2) the District's current distance-based fare structure for express patrons appears to reflect parity with respect to peak versus off-peak fare levels. Further, while the difference between the highest and lowest off-peak unit revenues and unit costs were found to be nearly equal in terms of magnitude, the difference in magnitude between peak period unit revenues actually exceeded the difference in peak period unit costs. Although these statistics, by themselves, are not necessarily significant, their importance lies in the fact that the highest peak period unit revenues were developed by the District's "dominant" service type, i.e., the local demand service type. All other minimum and maximum unit costs and revenues were incurred by less significant service types, i.e., intra-community, freeway express, and contract services.

2.6.2 TRIP DISTANCE EFFICIENCY ANALYSIS

To fully appreciate the issues associated with fare cross-subsidization, the proportion of riders commuting a certain distance or representing a particular minority group should be recognized. This section presents descriptive statistics on the sample distribution of trip lengths and ridership demographics as well as an analysis of the efficiency and equity associated with the District's current "flat" fare structure. The ratio of revenue per passenger-mile (Section 2.6.1) to cost per passenger-mile (Section 2.5.4) formed the basis for measuring relative efficiency and equity levels across categories of trip distance. ("RPM/CPM" is employed throughout this section as an acronym for this ratio.) As a ratio of unit rates of revenue and cost, the RPM/CPM index gauges which types of trips and which user groups are paying their share and which are receiving subsidies. Conceptually, when ratios of RPM/CPM are disaggregated by increments of trip distance and time-of-day, a marginal revenue/cost analysis is approximated.

.1 Trip Distance Distributions

Figure 2-D depicts trip length distributions for the District's local, limited, and express services across 25 distance categories.

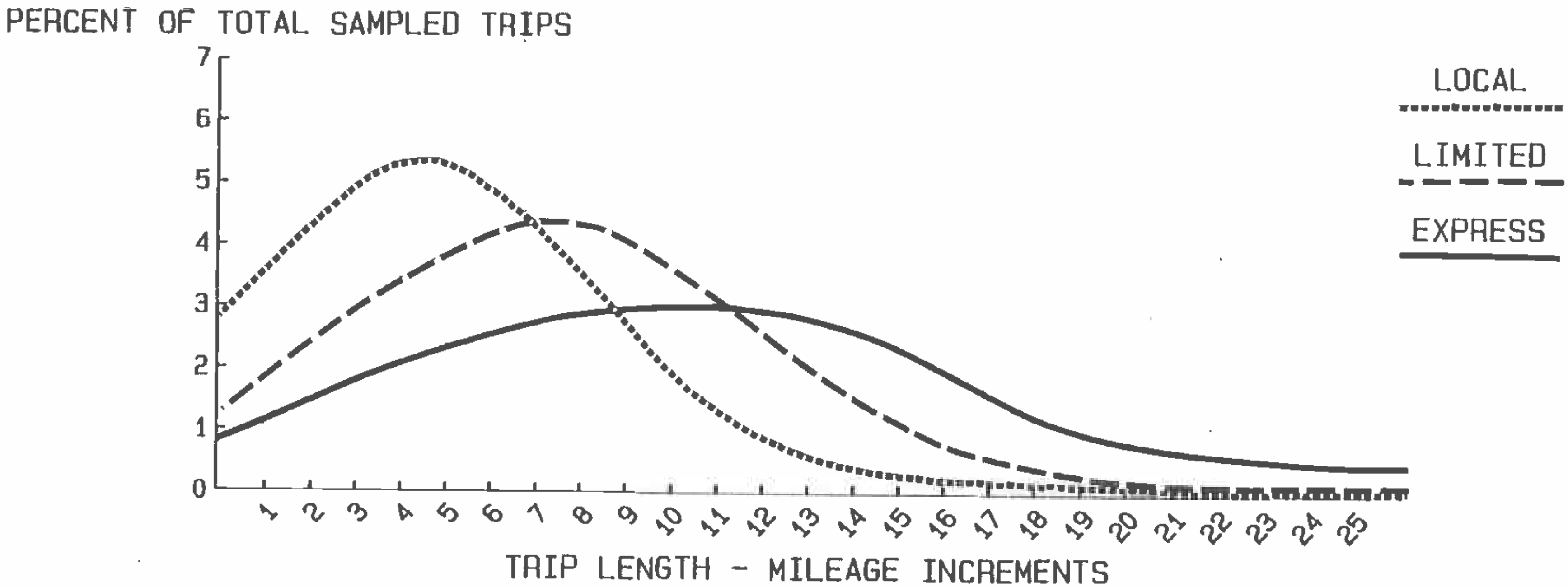
TABLE 2-7

AVERAGE DAILY REVENUE CHARACTERISTICS OF THE SCRTD (FY 1982-83)

Type of Service	Peak Revenues	Off-Peak Revenues	Peak Pass. Miles	Off-Peak Pass. Miles	Peak Rev. Per Pass-Mile	Off-Peak Rev. Per Pass-Mile
Local Demand	$110,848	$103,092	1,331,478	1,208,769	.083¢	.085¢
Local Policy	$ 8,117	$ 7,204	235,988	186,456	.034¢	.039¢
Intra-Comm.	$ 914	$ 809	13,312	8,454	.069¢	.096¢
Local-Access Exp.	$ 30,135	$ 18,313	565,506	360,796	.053¢	.051¢
Freeway Express	$ 4,745	$ 463	123,281	60,215	.038¢	.008¢
Contract	$ 1,431	$ 641	71,178	57,738	.020¢	.011¢
System Average (peak versus off-peak unit revenue differential = 3%)					.067¢	.069¢

FIGURE 2-D

SCRTD TRIP LENGTH DISTRIBUTIONS



TRIP LENGTH STATISTICS

	MEAN	MINIMUM	MAXIMUM
LOCAL	4.5	0.1	48.0
LIMITED	7.7	0.4	18.4
EXPRESS	11.0	0.7	84.5

Although not evident, approximately 50% of local riders travel less than 3.5 miles, whereas 50% of the limited and express ridership travel less than 7.0 miles and 9.3 miles, respectively. Since the distributions were positively skewed for all three service types, mean distances were higher: local - 4.5 miles; limited - 7.7 miles; and express - 11.0 miles. The largest proportion of sampled trips was under one mile for local riders, between five and six miles for limited riders, and between 13 and 14 miles for express riders. System-wide, the median, mean, and mode, skewed because of the relative amount of local as opposed to limited and express service, were 3.8 miles, 5.4 miles, and 1.0 miles, respectively.

Longer trips were generally associated with higher income patrons commuting to or from work during the peak period. In addition, a higher proportion of long distance travel was found among non-minority users who owned one or more automobiles. Table 2-8 contrasts the differences in trip length among several bipolar user groups.

.2 Trip Distance Efficiency Evaluation

As mentioned earlier, longer trips spurred by the outward expansion of urban areas have placed greater service demands on the District. To test whether the higher costs incurred in serving longer trips have been offset by the District's current fare structure, an evaluation of RPM/CPM ratios across one mile trip distance increments was performed. Results of the RPM/CPM computations are presented in Table 2-9. To facilitate the comparison, the results shown in Table 2-9 were also standardized, i.e., each RPM/CPM estimate was expressed as a percentage of the average RPM/CPM. The same information is displayed in Figure 2-E. The horizontal line in the "Standardized RPM/CPM" column of Table 2-9, as well as the horizontal line drawn in Figure 2-E, serve as "subsidy thresholds" - those traveling distances with RPM/CPM estimates about it are, in effect, cross-subsidizing those riders within the distance categories below the line. As can be noted, the five mile trip distance separated trips into subsidizer versus subsidizee categories.

It is evident that the District's current "flat" fare structure redistributes resources with respect to travel distances. Short journeys produced revenues in excess of costs, whereas losses were sustained in serving longer trips. Moreover, a correlation ratio between trip length and RPM/CPM, representing the proportion of total sum of squares explained, indicated that the relationship was highly non-linear. Price inefficiencies were most prominent between trips below one mile and all others. Those riding less than one mile paid over twice as much per mile of service as those traveling two miles.

In order to ascertain the structure of RPM/CPM differences as a function of trip distance, a statistical "range test" was conducted. The Tukey(a) method was used to segregate distance categories into homogeneous subsets for which the difference

TABLE 2-8

AVERAGE TRIP LENGTHS (IN MILES)

Family Income <$10,000	= 4.75
Family Income ≥$25,000	= 5.39
Off-Peak Period	= 4.85
Peak Period	= 4.99
Minority (Ethnicity)	= 4.97
Nonminority	= 5.07
No Auto Ownership	= 4.71
Auto Ownership ≥1	= 5.23

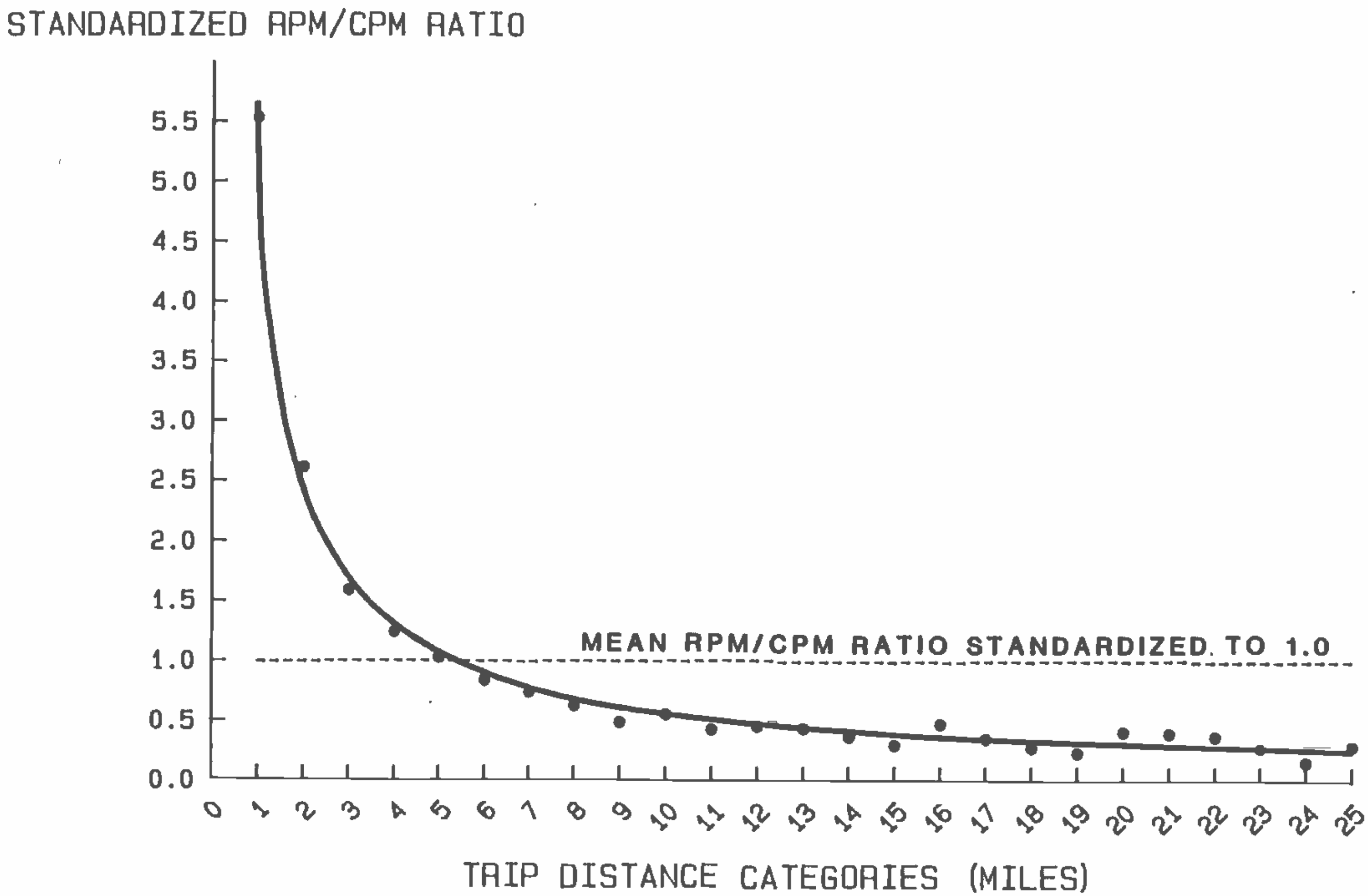
TABLE 2-9

MEAN RPM/CPM ESTIMATES BY TRIP DISTANCE CATEGORIES

Miles	RPM	CPM	RPM/CPM	Standardized RPM/CPM
< 1	.308	.301	1.023	5.530
1-2	.141	.292	.483	2.611
2-3	.086	.293	.294	1.589
3-4	.068	.296	.230	1.243
4-5	.055	.289	.190	1.027
5-6	.043	.275	.156	.843
6-7	.037	.269	.138	.746
7-8	.033	.284	.116	.627
8-9	.025	.282	.089	.481
9-10	.028	.269	.104	.562
10-11	.023	.292	.079	.427
11-12	.020	.234	.085	.459
12-13	.022	.270	.081	.438
13-14	.017	.248	.069	.373
14-15	.015	.270	.056	.303
15-16	.021	.240	.088	.476
16-17	.019	.284	.067	.362
17-18	.012	.229	.052	.281
18-19	.010	.227	.044	.238
19-20	.016	.205	.078	.422
20-21	.018	.243	.074	.400
21-22	.017	.239	.071	.384
22-23	.013	.253	.051	.276
23-24	.007	.241	.029	.157
24-25	.015	.269	.056	.303
			M = .185	

FIGURE 2-E

STANDARDIZED RPM/CPM RATIOS BY TRIP DISTANCE CATEGORIES



between any two groups was not significant at the 0.05 level. The test results in Table 2-10 show the structure of "mis-pricing" with respect to travel distance, and provide a basis for conceptualizing representation of the standardized "curve" displayed in Figure 2-E. As can be noted, very short trips appear to play a large role in cross-subsidizing longer journeys. Trips up to two miles in length seem relatively efficiently priced while those between two and five miles receive only moderate cross-subsidies. Beyond ten miles, however, the range test found little difference in RPM/CPM among distance categories. Essentially, a ten-mile trip was as highly subsidized as a twenty-five mile trip.

The functional relationship between RPM/CPM estimates and distance categories can be described as hyperbolic. The standardized curve of Figure 2-E shows quite vividly that the high productivity associated with short trips declines markedly with distance, although at a decreasing rate. It follows, therefore, that an efficient distance-based price structure for District operations would have a low base fare and perhaps three or four more stages with the largest step levied against trips beyond ten miles.

2.6.3 TIME-OF-DAY EFFICIENCY ANALYSIS

Whether peak services return a higher proportion of their costs through the farebox than off-peak services has been the subject of many discussions throughout the public transit industry. Numerous research findings have suggested that higher peak period revenues are overshadowed by comparatively higher peak costs. Other findings, however, have asserted that the peak's revenue "effect" exceeds the cost effect. That is, peak service has better financial performance, in terms of the ratio of <u>unit</u> revenue to costs, than off-peak service. It has also been suggested that agencies view the peak's financial performance favorably because of the long-standing industry practice of apportioning expenses on an average cost basis, i.e., whenever the "true" cost of peak demand is overlooked, the peak usually does show more favorable revenue-to-cost ratios than the off-peak periods, and is fully exploited as the high-yield market. To the extent that the procedures discussed in Section 2.5, "Estimation of Line-Specific Trip Distance and Time-of-Day Operating Costs", capture the true marginal costs of peak services, the following evaluation should provide a reasonable basis for analyzing the incidence of fare cross-subsidization between time periods.

As was discussed earlier, and presented in Table 2-4, the off-peak unit costs of four of the District's six service types are relatively higher than the peak period unit costs. System-wide, off-peak unit costs exceeded peak period unit costs by 31%. Although off-peak unit revenues also exceeded peak period unit revenues for three of the six District service types (Table 2-7), the system-wide (as well as service type) differential was considerably less, i.e., approximately 3%, indicating that peak period fares are proportionally greater than peak costs when compared to off-peak fares versus off-peak costs. The peak and off-peak RPM/CPM estimates presented in Table 2-11 clearly demonstrate this point.

TABLE 2-10

HOMOGENEOUS SUBSETS OF DISTANCE CATEGORIES*

Subsets	Miles	RPM/CPM
Highly Subsidizing	< 1	1.023
Lightly Subsidizing	1-2	.483
Lightly to Moderately Subsidized	2-3	.294
	3-4	.230
	4-5	.190
Moderately to Highly Subsidized	5-6	.156
	6-7	.138
	7-8	.116
	8-9	.089
	9-10	.104
Highly Subsidized	10-11	.079
	11-12	.085
	12-13	.081
	13-14	.069
	14-15	.056
	15-16	.088
	16-17	.067
	17-18	.052
	18-19	.044
	19-20	.078
	20-21	.074
	21-22	.071
	22-23	.051
	23-24	.029
	24-25	.056

*Based on Tukey(a) statistical range test.

TABLE 2-11

COMPARISON OF MEAN RPM/CPM ESTIMATES AMONG TIME PERIODS

Type of Service	Peak RPM/CPM	Off-Peak RPM/CPM
Local Demand	.367	.292
Local Policy	.204	.136
Intra-Comm.	.140	.111
Local-Access Exp.	.267	.192
Freeway Express	.200	.109
Contract	.121	.071
System Average	.316	.248

From Table 2-11, it can be noted that each of the District's six service types returns the highest share of unit operating costs through peak fares. Approximately 36.7% of the District's local demand peak period unit costs, for example, are returned through peak period fares, as opposed to approximately 29.2% of the local demand off-peak period unit costs returned through off-peak period fares. While all remaining service types returned significantly less revenue than the local demand service, most notably intra-community and contract services, the proportion of peak versus off-peak revenue returned for each remaining service type actually exceeded that of the local demand service. The peak versus off-peak revenue return differential for local demand services approximates 20.4%, whereas the peak versus off-peak revenue returned differential for local policy, intra-community, local access express, freeway express, and contract services approximates 33.3%, 20.7%, 28.5%, 45.5% and 41.3%, respectively. The system-wide peak versus off-peak revenue return differential is 21. 5%.

The higher net revenue of peak services reflect several factors. Although average revenue receipts were somewhat higher during the off-peak than peak period, higher off-peak unit costs overcompensated for the relatively efficient off-peak fare levels. In addition, peak period trips were found to be only slightly longer (approximately 3%) than off-peak period trips. Moreover, the District's costs per passenger-mile were considerably lower during the peak period, primarily due to the inefficiencies associated with evening and owl off-peak services. Consequently, the substantially lower costs of trips during the peak hours were paired with only slightly lower revenues, rendering peak services as comparatively high-yield operations.

In summary, the findings of this section indicate that, contrary to the empirical evidence provided on time-variant pricing structures, the peak users of the District moderately cross-subsidize off-peak period passengers. The slightly lower unit revenues received from peak customers were found to be sufficient to offset the decisively lower unit costs of their trips. The current pricing structure of the District's local services, therefore, appears to result in a net transfer from peak users to off-peak users. Although RPM/CPM estimates generally differed among the five time periods, a peak/off-peak dichotomy of fares does not appear to be justified.

2.6.4 EQUITY ANALYSIS

The concept of equity was used in this study to evaluate disparities (if any) in fares and costs among various income user-groups. Whereas the efficiency criterion employed the "benefit principle" to distance-based (Section 2.6.2) and time-variant (Section 2.6.3) pricing structures, equity was assessed on the basis of a patron's "ability-to-pay". Equity was viewed as setting fares so that the cross-subsidization impacts associated with a patron's income versus trip length were as closely neutralized as possible.

Longer trips are generally associated with higher income patrons commuting to or from work during the peak period (Table 2-8). Specifically, the average trip lengths of patrons with family incomes greater than or equal to $25,000 (5.39 miles) are 13% longer than the average trip lengths of patrons with family incomes less than or equal to $10,000 (4.75 miles). This is portrayed graphically in Figure 2-F, where it is evident that a greater proportion of short trips are taken by patrons from "lower" income families. Consistent with the empirical evidence typically presented on income versus trip length distributions, the difference between trip length distributions was found statistically significant. Results of the application of the Kolmogorov-Smirnov statistical procedure (a nonparametric statistical test designed to evaluate the difference in continuous distributions) indicated that a statistical difference was present at the 0.05 level. However, with respect to fare cross-subsidization, data generated on the average revenue per boarding of each income group (Figure 2-G) indicated that the District's current fare structure appeared to be mildly progressive. As shown in Figure 2-G, the average revenue per boarding collected from lower income patrons is consistently three to four cents less than that collected from higher income patrons. Due to the predominance of riders eligible for discount fares in lower income groups, it was found that lower income riders generally pay between 8% and 20% less than higher income patrons for trips shorter than average.

An evaluation of RPM/CPM estimates (based on family income, Figure 2-H) demonstrated that the distributive effects of the District's current flat fare structure are indeed mildly progressive. The District's more affluent patrons tend to cross-subsidize some of the costs incurred in serving lower income riders. Accordingly, the null hypothesis that the incidence of fare cross-subsidization is progressive, was accepted, i.e., the net transfer effect of the District's current fare structure was found to favor lower income patrons.

2.7. EFFICIENCY, EQUITY, AND RIDERSHIP IMPACTS OF ALTERNATIVE FARE POLICIES

In establishing fare policy, the District's Board of Directors often faces conflicting objectives. Goals which call for higher revenue and service efficiency, for example, may mean sacrificing other important objectives such as increased ridership and "simplified fare collection". Revenue and efficiency can be maximized by charging each user a unique fare while ridership and simplified fare collection goals can be most easily achieved by eliminating fares altogether. Realistically, however, the District must choose fare structures somewhere between the extremes of pure marginal cost pricing and free services. Differentiating fares according to distance and time-of-day represent possible compromises.

2.7.1 IMPLEMENTATION OF WEEKDAY OFF-PEAK DISCOUNTS

The implementation of a peak/off-peak pricing structure, which would lower fares for all riders during off-peak periods and, thus, provide a disincentive for peak period riders, would enable the District to lower the ratio of peak to base service requirements, thereby contributing to

FIGURE 2-F

TRIP LENGTH FREQUENCY DISTRIBUTIONS

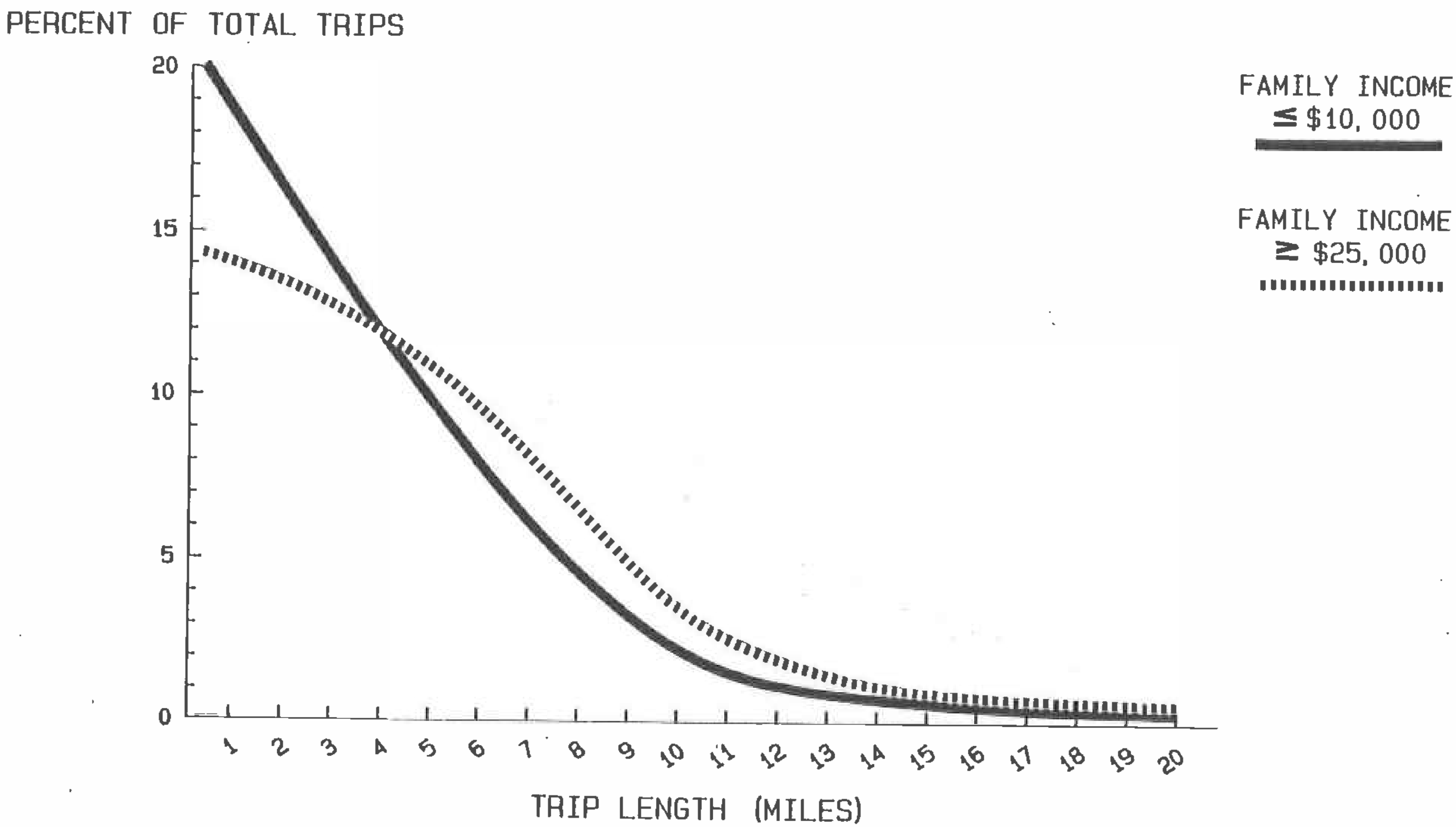


FIGURE 2-G

AVERAGE REVENUE PER BOARDING

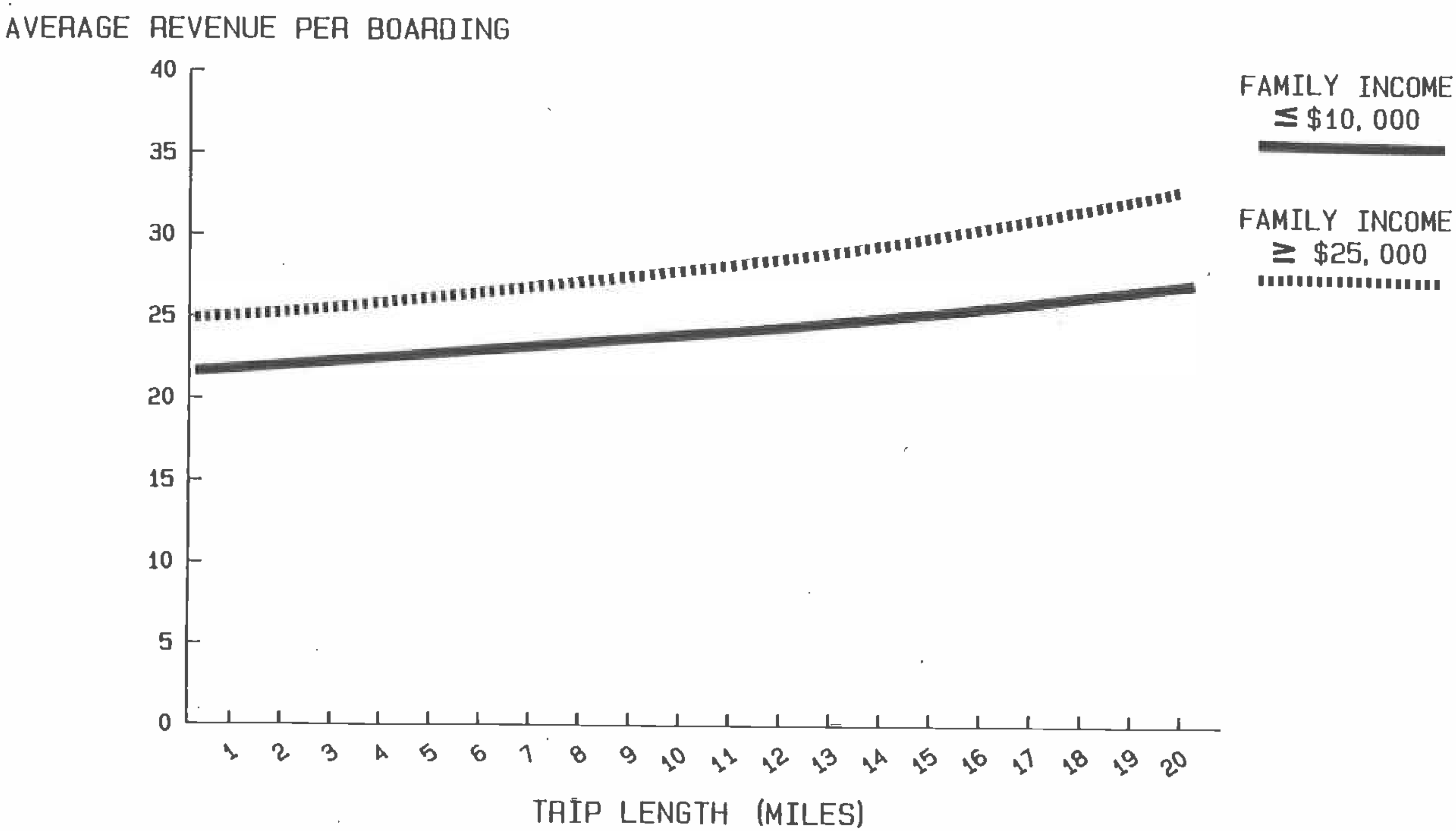
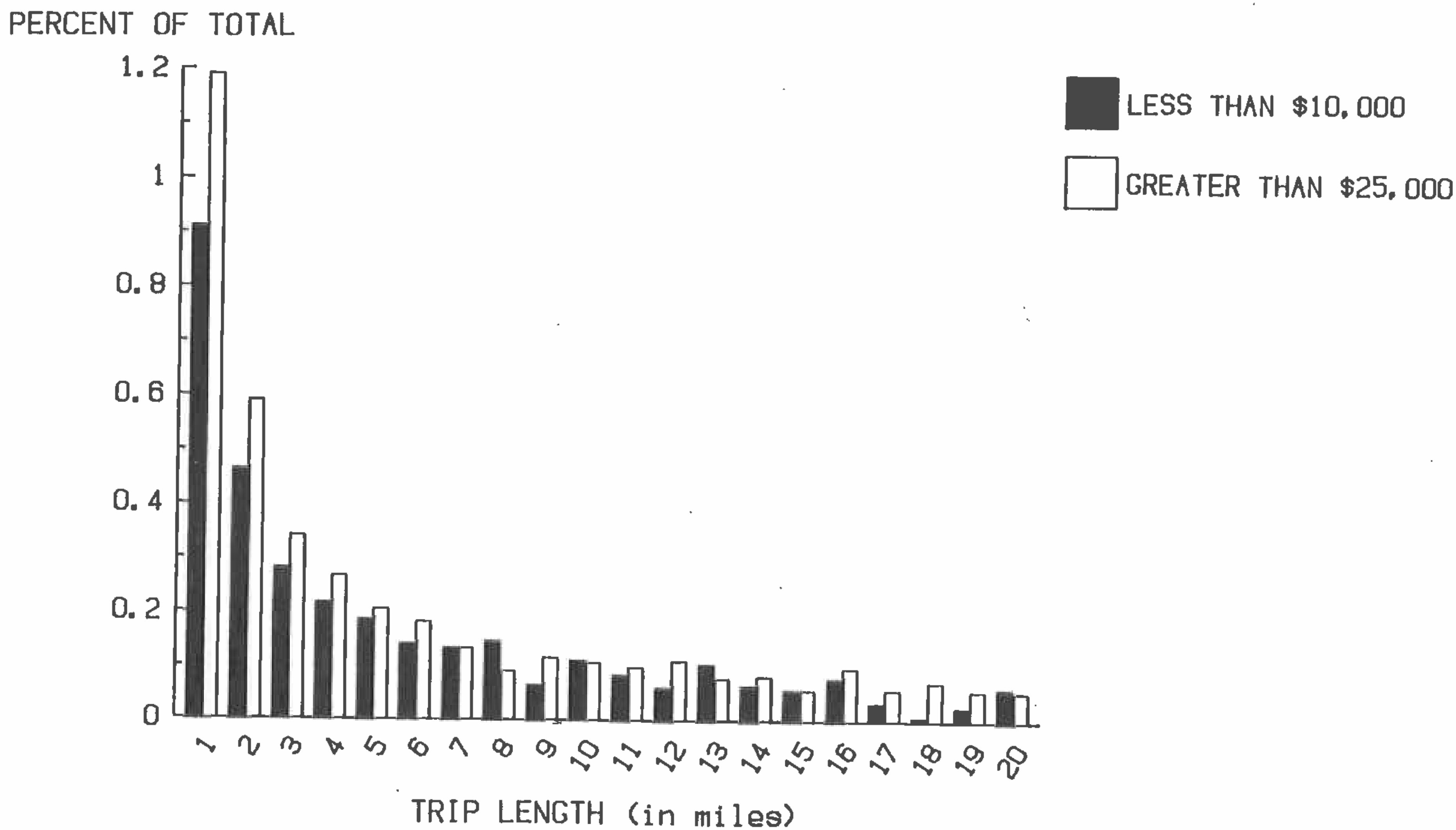


FIGURE 2-H
RPM/CPM COMPARISONS



improved operating economies. As discussed in Section 2.6.3, however, these economies would be achieved at the expense of discriminating against peak riders who already generate revenues which represent a higher share of peak operating costs (31.6%) than the share of off-peak operating costs presently supported by off-peak revenues (24.8%). Further evaluations associated with the cost of implementing a time-variant pricing structure, therefore, were not developed. The current pricing structure of the District, which results in a "progressive" net transfer from peak users to off-peak users, was thought to be relatively efficient as well as equitable.

2.7.2 IMPLEMENTATION OF DISTANCE-BASED PRICING

Proponents of distance-based pricing claim that flat fares discriminate against riders making shorter than average trips and, conversely, riders who travel significantly further than average are subsidized, in part, by the fares paid by shorter distance riders. It is further claimed that this perceived inequity is made worse because poor and minority riders are more likely to take shorter trips as a result of their presumed greater transit dependence.

As was discussed in Section 2.6.2, low family income (less than $10,000 per year) local service riders in Los Angeles do tend to travel shorter distances than higher family income riders (more than $25,000 per year). The trip lengths for low income riders averaged 4.75 miles compared to a 5.39 mile average for higher income riders (the difference is statistically significant at a .05 level of confidence). However, due to the predominance of riders eligible for discount fares in the lower income groups, it was found that lower income riders generally pay a lower average fare than higher income riders (between 8% and 20% less for trips shorter than average).

Since these findings indicated the likelihood of some benefit to lower income riders associated with a distance-based fare structure, an evaluation was conducted of a distance-based fare structure having line-specific zones spaced four miles apart. The initial zone fare, and subsequent additional zone surcharges, were set at a level which would result in the same fare being paid for a trip of average length as the fare applicable under the existing fare structure. Application of current fare elasticity models to the distance-based fare structure demonstrated that the number of riders traveling shorter than average distances would increase somewhat. However, the overall loss of riders due to higher fares for longer than average trips resulted in a net loss of 1% of total boardings. Revenues from shorter than average trip length boardings declined more than 13%, but were more than offset by increased revenues from longer distance riders. Total passenger revenues increased 4%, representing additional annual revenues of $5.4 million resulting from a distance-based fare structure having prices comparable to the existing flat fare structure.

Unfortunately, the imposition of a distance-based fare structure results in additional operating costs arising from the mechanics of administering distance-based fares with current technology. Fare verification requires that buses stop at each fare zone boundary in order for the driver to determine whether all passengers onboard have paid the requisite zone surcharge for the zone to be entered. Each of these fare checks may require from one to five minutes, depending on the extent to which the bus is loaded. In the aggregate, these fare checks contribute additional running time to each bus trip, resulting in a need for additional buses in order to maintain existing schedules. The cost associated with these additional bus requirements was found to be extremely significant. If each fare check required only one minute, system average daily bus hours would increase approximately 5%, and the number of additional buses required to maintain existing schedules would increase by 100-120 buses daily. The annual operating cost associated with these additional bus requirements would increase by $22.7 million at present costs with no increase in productivity. In order to generate sufficient additional revenue to offset higher revenue collection costs, it was determined that distance-based fares would need to be increased to the point where no rider would be paying less than the fare for all riders with a comparable flat fare system.

While there is the promise of future improvements in fare collection technology, the reliability of the equipment needed to implement mechanized fare collection was not deemed sufficient to warrant conversion from the District's existing farebox-based methods. Ideally, collection technology is called for which will accept payment, control entry, and issue tickets, thus speeding the egress and exit of passengers while keeping passenger-driver interaction to a minimum. In addition to capital overhead, the following factors should be considered when evaluating fare collection systems: 1) cost of installation, operation, and maintenance; 2) effect on passenger boarding and departing times; 3) revenue security (i.e., likelihood of fraud versus receipt of full fare); 4) reliability of equipment; 5) effects on drivers' workloads and responsibilities; and 6) impact on passenger convenience.

2.8 SUMMARY

Differentiated fare structures appear to be responsive to some of the problems associated with the District's current flat fare structure and nonresponsive to others. Clearly, as fare structures become closer approximations to marginal cost pricing, efficiency levels increase. By setting fares in line with the true cost of user's trip lengths, those most in need of transit also stand to gain. Differentiated peak/off-peak pricing structures, however, do not seem warranted in view of the fact that the District's current flat fare structure appears to incorporate a significant degree of progressivity. Moreover, in terms of revenue yield, it is not clear that either distance-based or time-variant pricing structures hold promise, given the current technology associated with fare collection mechanisms. The degree to which alternative flat fare pricing levels can reduce price inefficiencies and also enhance the District's current distributional inequities is explored in the following section.

3.0 FARE ELASTICITIES

This section documents the development of the elasticity model used to evaluate potential impacts of the District's July, 1985 fare change. Proceeding from a discussion of available modeling techniques, a discrete model form was developed and calibrated from historical District-specific data. Model enhancements are described which adapt the resultant model for use with the relatively large magnitude fare changes considered, as well as sensitizing the model to the relative price differences of alternative fare payment methods available to each category of rider.

3.1 ELASTICITY CONCEPTS

In simplest terms, fare elasticity is a means of expressing the proportional change in the demand for transit as a function of the proportional change in transit pricing. While capable of elegant mathematical expression in concept, the actual determination of fare elasticities for a particular transit property at a specific point in time can be quite speculative. The existence of historical data illustrating local demand responses to prior fare changes is often of limited value to the analyst who is attempting to estimate the likely ridership response to a future proposed fare change because the exact nature of the underlying factors that influence changes in ridership demand is unknown.

Numerous studies of transit fare elasticity have been conducted. These studies have considered the influence of a wide variety of potential causal variables, several hypothesized model forms, aggregate and disaggregate data, and variable and invariant fare experience. Collectively, this body of research provides some basic observations regarding ridership response to fare changes:

- <u>Transit demand is relatively inelastic with respect to fare changes</u>

  Evidence compiled from 67 case studies[1] found fare elasticities varying between -0.04 and -0.87 with a mean of -0.28 ± 0.16. This means that the proportional change in ridership is usually considerably less than, and inversely related to, the proportional change in fares for observed instances. By comparison, a rule of thumb in the transit industry, attributed to the work of Simpson and Curtin, is that the proportional change in aggregate ridership approximates -0.3 times the proportional change in average fares.

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[1]<u>Patronage Impacts of Changes in Transit Fares and Services</u>; P. Mayworm, A. Lago & J. McEnroe; Ecosometrics, Inc.; prepared for UMTA Office of Service and Methods Demonstrations; Washington, D.C.; September, 1980.

- Elasticities for fare increases do not differ from elasticities for fare decreases.

- Small cities have larger fare elasticities than large cities.

- Off-peak fare elasticities are double the size of peak fare elasticities. It has also been observed that weekend fare elasticities are comparable to off-peak weekday elasticities.

- Short-distance trips are more elastic than long-distance trips.

- Intra-suburban trips are as much as four times more elastic than radial trips on arterials.

- Fare elasticities rise with income and fall with age.

- Of all trip purposes, the work trip is the most inelastic. Shopping and school trips, for example, have been observed to be two to three times as elastic as work trips.

3.2 MODEL SELECTION

The specific manner in which fare elasticities are modeled is subject to consideration of the purposes of the study being conducted. In this study, the District was concerned with evaluating the near-term (one year) impacts of a variety of possible fares on District ridership and revenues. This permitted exclusion of a wide variety of factors which might otherwise have an influence on ridership response, such as changes in land use and development patterns, employment fluctuations, availability of modal alternatives, etc. Other factors which might have near-term influence, such as service level changes and annual demand changes resulting from population change, could then be either accounted for in the model estimation process (for example, population change) or controlled exogenously by the District (for example, service levels). These assumptions allowed modeling of the ridership change essentially as a function of fare change, a traditional approach.

Given the choice of a traditional approach, the next consideration is the selection of specific model form. Studies of fare elasticity have historically employed one of three distinct mathematical relationships as hypothetical models of transit demand/price interaction. While a large variety of alternatives are available, these three have achieved the greatest degree of acceptance because of ease of estimation of model parameters, and theoretical appropriateness to the purpose for which they are designed.

Shrinkage Ratio

By far the most prevalent model form, the shrinkage ratio (or line elasticity) is easily calibrated, simple to comprehend, and easy to use. It represents the proportional change in ridership as a linear function of the proportional change in average fare, as follows:

$$\frac{Trips_{future} - Trips_{base}}{Trips_{base}} = E_{sr} \left[\frac{Fare_{future} - Fare_{base}}{Fare_{base}} \right]$$

Because of its form, it provides a simple tool for evaluating the impacts of relatively small changes in fare with reasonable accuracy. For larger fare changes, it has been shown to be a less reliable predictor. Furthermore, it suffers from two theoretical weaknesses: (1) since the function is unbounded, with very large increases (greater than 333% for an elasticity of -0.3), it would project the loss of more than 100% of all riders; and (2) theoretically, the demand response to a fare increase from F_1 to F_2 should be the same as the response to a fare decrease from F_2 to F_1, but this is not the case with this model form as demand changes are calculated as a percentage of the ridership base corresponding to each fare level. Given these limitations, this model form is most appropriate for the evaluation of relatively small fare changes.

Midpoint Elasticity

The shrinkage ratio's limitation with respect to differing elasticities for fare increases and decreases can be overcome by measuring the elasticity relative to the midpoint between the base and future ridership demand levels. The midpoint elasticity model form can be expressed as:

$$\frac{Trips_{future} - Trips_{base}}{1/2(Trips_{future} + Trips_{base})} = E_{mid} \left[\frac{Fare_{future} - Fare_{base}}{1/2(Fare_{future} + Fare_{base})} \right]$$

This modification of the shrinkage ratio formula corrects most of the theoretical limitations associated with that model form. Since the midpoint elasticity provides for a non-linear relationship between demand and price at a given value of elasticity, it is not affected by boundary limitations (such as large fare increases projecting negative ridership) as is the case with the shrinkage ratio. Its behavior tends to be more conservative than the shrinkage ratio when considering fare increases, though it is more volatile when considering fare decreases. For example, at an elasticity of -0.3, a fare increase of 100% would contribute to a loss of ridership of 30%, but the midpoint elasticity formula would project an increase of 85.7%. One additional point of note is that the shrinkage ratio does not permit analysis of the impact of increasing the fare from a free fare base (it is undefined in this situation), while the midpoint elasticity is always defined. Because of these features, the midpoint elasticity formulation has become widely accepted as the traditional model form of choice for consideration of large fare changes.

Arc Elasticity

A third, less commonly used, model form is the arc elasticity formulation. It can be expressed as:

$$\log(Trips_{future}) - \log(Trips_{base}) = E_{arc}\left[\log(Fare_{future}) - \log(Fare_{base})\right]$$

The mathematical behavior of this function is quite similar to the behavior of the midpoint elasticity formulation. In fact, several analysts have improperly referred to the midpoint elasticity as the arc elasticity, even though they are distinctively different. As is the case with the midpoint elasticity, the arc elasticity assumes a non-linear relationship between demand and price for any given elasticity. It is also useful for analysis of both large and small fare changes. Its only theoretical limitation is that it is undefined in those instances where a free fare is being considered. Arc elasticity projected impacts for a given elasticity are slightly less conservative than the projections provided by the midpoint elasticity formula for fare increases and slightly less volatile for fare decreases. Using the example offered previously in the discussion of the midpoint elasticity formula, the arc elasticity formula (assuming an elasticity of -0.3) projects a loss of 18.8% of riders with a 100% fare increase, but is incapable of evaluating a 100% fare decrease.

Consideration of these traditional model forms led to the rejection of them for the purposes of this study. The shrinkage ratio (or line elasticity) formulation is clearly inappropriate for analysis of the large fare changes considered in the present analyses. While the midpoint and arc elasticity formulae are more appropriate for this purpose, historical District ridership response to previous fare changes suggested that these model forms might be too conservative in estimating the loss of patronage associated with very large fare changes on the order of 300%-500%. Furthermore, the behavior of the midpoint and arc elasticity formulae in the instance of fare decreases (though not immediately relevant to this study) while theoretically appropriate, were considered to be unrealistic for a large urban area such as Los Angeles, which attracts a small share (less than 5%) of all trips to transit.

The desired model form would be expected to exhibit the following properties:

- For large fare decreases (say -50% to -100%) ridership growth should be relatively inelastic. This implies that the expected proportional change in patronage should be significantly less than the proportional change in fares, perhaps no more than one half as large. Among the traditional model forms, only the shrinkage ratio, or line elasticity, exhibits this property;

- For modest fare changes (say -50% to +50%) the proportional change in ridership should remain relatively inelastic. For purposes of conservative revenue projection, it would be desirable to assume that ridership change would be directly proportional to the size of the fare change (a property exhibited by the line elasticity model form). Within this range, all of the traditional model forms behave similarly; and

- For large fare increases (say greater than +50%), ridership change should become increasingly less elastic with increasing fares. This property is exhibited by both the midpoint and arc elasticity model forms. Recent experience with a modest fare change in FY 1981-82 (fare increases varying between 30%-40% for all fare categories) suggested that the traditional arc and midpoint elasticity formulae might be optimistic in predicting ridership retention with larger fare changes. Therefore, while the desired model form should behave similarly to these models for large fare changes, it should consistently predict lower ridership retention in order to provide conservative estimates of expected revenue for budget purposes.

3.3 MODEL DEVELOPMENT

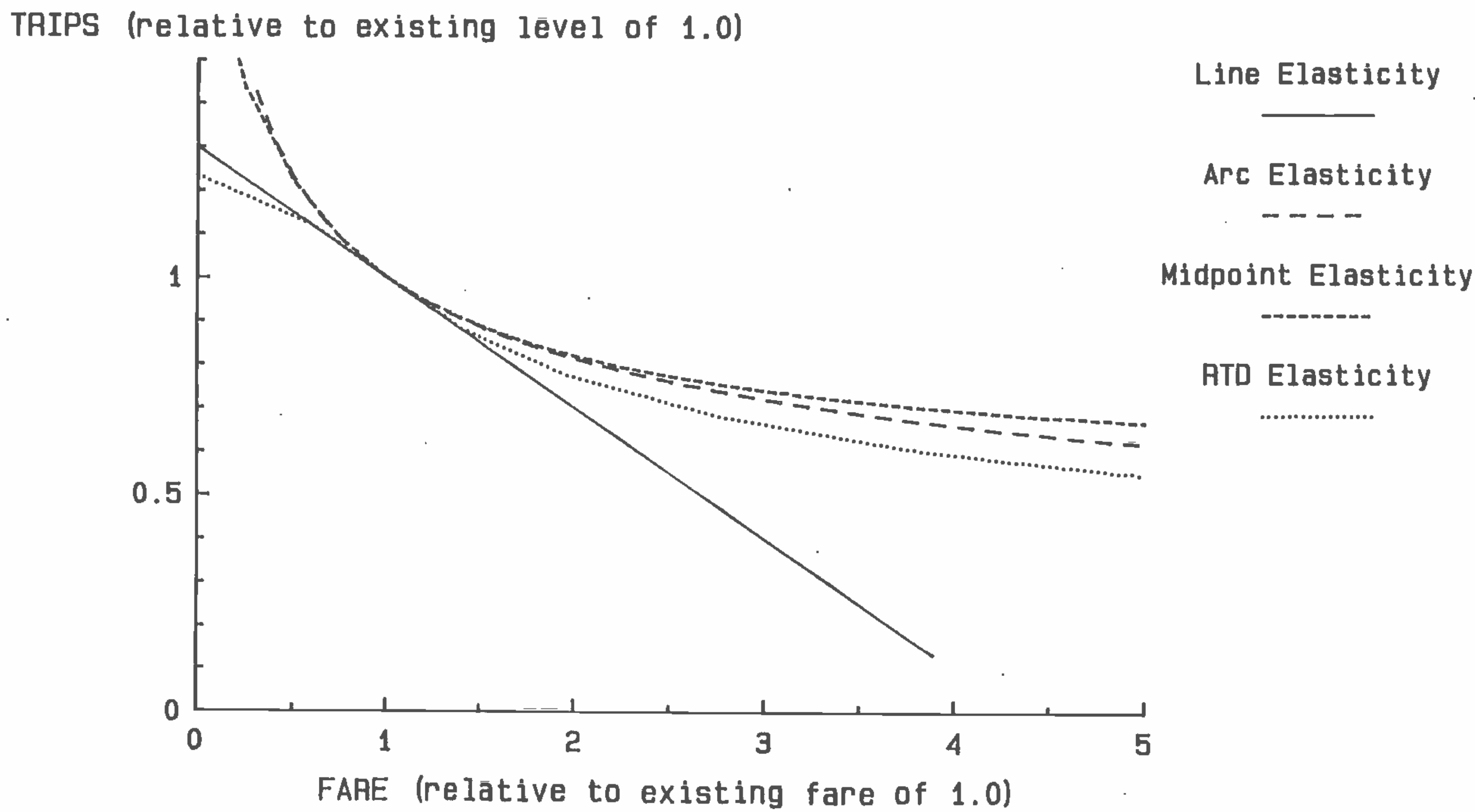
The model form developed for this study satisfied all of the criteria presented in the previous section as exhibited in Figure 3-A. Conceptually, it was developed from subjective analysis of attempts to model recent District demand/price interactions by fare category using the traditional line elasticity formulation. The data base for this analysis consisted of five fiscal years (FY 1980-81 through FY 1984-85) of annualized District linked trips and average fares stratified by fare category (see Appendix A). From this data, four annual change datum were established for linked trips and average fares for each fare category. The first two datum corresponded to a fare increase and a fare decrease, respectively. The last two datum represented a period of unchanged fares (although minor fluctuations in the average fare occurred for each fare category as pass use multiples, and the distribution of cash and pass ridership varied). The analysis data is provided in Table 3-1.

A variation of the traditional line elasticity formula (incorporating a constant term to account for natural growth not otherwise attributable to fare changes) was calibrated for each fare category using standard unvariate regression techniques. This model is represented as

$$\frac{Trips_{future} - Trips_{base}}{Trips_{base}} = C + E \left[\frac{Fare_{future} - Fare_{base}}{Fare_{base}} \right]$$

FIGURE 3-A

COMPARISON OF ELASTICITY RELATIONSHIPS FOR ELASTICITY COEFFICIENT OF -0.3



RTD function assumes no natural patronage growth

TABLE 3-1

HISTORICAL DATA BASE
FOR ANALYSIS OF DISTRICT FARE ELASTICITIES

Fare Category	Datum[1]	Change in Linked Trips[2]	Change in Average Fare[3]
Regular	FY81-82	-.1445	.3169
	FY82-83	.0915	-.3967
	FY83-84	.1072	.0216
	FY84-85	.0831	-.0274
Express	FY81-82	-.2292	.4171
	FY82-83	.1605	-.3247
	FY83-84	.1402	.0165
	FY84-85	.0824	-.0033
Elderly & Handicapped	FY81-82	-.1001	.3588
	FY82-83	.0955	-.4849
	FY83-84	-.0005	.0127
	FY84-85	.0824	.0002
Student	FY81-82	-.0672	.3341
	FY82-83	.7760	-.7078
	FY83-84	.4426	.0511
	FY84-85	.0819	.0000
College	FY81-82	.0386	.3180
	FY82-83	1.2022	-.7961
	FY83-84	-.0092	-.0880
	FY84-85	.0825	.0007

[1]Datum represents the change from first fiscal year shown to second fiscal year shown.

[2]Change in Linked Trips defined as $\frac{Trips_{year\ 2} - Trips_{year\ 1}}{Trips_{year\ 1}}$

[3]Change in Average Fare defined as $\frac{Fare_{year\ 2} - Fare_{year\ 1}}{Fare_{year\ 1}}$

Source: SCRTD Planning Department

where "Trips" represents annualized linked trips, and "Fare" represents annualized average fare per linked trip. The calibration outputs are provided in Table 3-2.

These results confirmed the earlier hypothesis regarding the unreasonable behavior of the line elasticity model form for large fare changes. The three fare categories experiencing fare variations at 50% or less annually (Regular, Express, and Elderly and Handicapped) exhibited elasticities that were intuitively reasonable with relatively small predictive error. The two fare categories subject to larger fare variation (Student and College) exhibited larger predictive errors, and unexpectedly large elasticity coefficients. These findings led to the acceptance of the linear models for Regular, Express, and Elderly and Handicapped fare categories for purposes of evaluating relatively modest variations in average fare (less than 50%). It was decided, on purely subjective grounds, to employ the Elderly and Handicapped elasticity relationship for evaluation of Student ridership response to fare changes, and the Regular elasticity relationship for evaluation of the College fare category.

3.4 IMPACT OF LARGE FARE CHANGES ON MODEL FORM

Since the fare changes being considered in the course of this study were, in some cases, as large as 300% the calibrated elasticity relationships established at this point were not useful for further analysis. In order to extend the range of fare variation to which the models could be applied, it was necessary to develop a means by which larger fare variations could be accommodated.

An algebraic restatement of the line elasticity model form which is more useful for direct application of a calibrated model is:

$$\frac{Trips_{future}}{Trips_{base}} = 1+C+E \left[\frac{Fare_{future}-Fare_{base}}{Fare_{base}}\right]$$

Since all of the terms on the right-hand side of this equation are defined in a calibrated model, it is a straightforward exercise to calculate the ratio of future-year trips to base-year trips for any contemplated fare change. Keeping in mind the earlier assumptions, this model is applicable only within a defined range of possible fare changes; the magnitude of this variation limit is called "L". Then, the above relationship is valid only within the range:

$$-L \leq \frac{Fare_{future}-Fare_{base}}{Fare_{base}} \leq L$$

Within the context of the data at hand, it is appropriate to define L as follows (for each fare category - Regular, Express, and Elderly & Handicapped):

TABLE 3-2

LINEAR FARE ELASTICITY COEFFICIENTS
FOR ANNUALIZED DISTRICT HISTORICAL DATA

Fare Category	Constant (C)	Elasticity (E)	Magnitude of Highest Observed Fare Change	Standard Error of Regression
Regular	.028	-.308	39.7%	.096
Express	.053	-.541	41.7%	.094
Elderly & Handicapped	.013	-.222	48.5%	.058
Student	.247	-.763	70.8%	.207
College	.167	-1.144	79.6%	.278

Source: SCRTD Planning Department

$$L = \left| \text{Max} \left(\frac{Fare_{future} - Fare_{base}}{Fare_{base}} \right) \right|$$

Then, if it is assumed for each increment between L^n and L^{n+1} that the elasticity response to fare variation is linear, successive fare change increments of L can be represented by the product of successive applications of the calibrated linear elasticity model (though successive applications of the linear elasticity model after the first one should exclude the growth coefficient, C, in order to provide for a continuous function).

An example of this hypothetical construct best serves to demonstrate how it would be applied in practice. Consider the following:

$$\frac{Fare_{future} - Fare_{base}}{Fare_{base}} = 70\%$$

Assume C =.028 and E= -.308 (the calibration values for the Regular fare category from the present study). The limit of linearity, L, for this fare category is 39.7%.

A 70% fare increase will require the application of two successive increments of the linear model since:

$$\frac{Fare_{future}}{Fare_{base}} = 1.70 = (1.397)(1.217)$$

This means that:

$$\frac{Trips_{future}}{Trips_{base}} = \left[(1+C)+E(\text{Increment \#1})\right]\left[(1)+E(\text{Increment \#2})\right]$$

$$\frac{Trips_{future}}{Trips_{base}} = \left[(1+.028)+(-.308)(.397)\right]\left[1+(-.308)(.217)\right]$$

$$\frac{Trips_{future}}{Trips_{base}} = (1.028-.122)(1-.067) = (.906)(.933) = .845$$

Thus, the model would project a 15.5% loss of ridership associated with a 70% fare increase (note that the line elasticity model having the same values for C and E would have projected an 18.8% ridership loss for the same fare increase). The reader is referred again to Figure 3-A which graphically portrays the behavior of this model construct compared with the behavior of other traditional model forms for the same elasticity (the SCRTD elasticity function graphed in Figure 3-A assumes C=0, E= -.3 and L=40%).

3.5 IMPACT OF FARE PAYMENT ALTERNATIVES

In many cases projection of future year ridership in response to a fare change may be modeled simply by the application of a fare elasticity model. However, when the fare category being evaluated provides for more than one form of fare payment (such as cash and pass), an additional consideration exists when one form of fare payment is offered at a discount from the other(s) available. This is the case with the District's fare structure for each of the five major categories considered in this study.

The fare structure for the Regular fare category will be used as a basis for discussion. The pre-existing (FY 1984-85) fare structure afforded a 50¢ fare for a single ride (60¢ if one or more transfers were necessary), or a patron could purchase a monthly pass (good for unlimited use within a calendar month) priced at 40 times the price of a single ride or $20 (transfers accommodated without charge). Since the average number of actual linked trips per pass approached 60 per month, then the cash-paying rider paid a different average fare per boarding from the pass-using rider. In this instance, the average fare for a cash rider was $.50 + ($.10)(.93)(.48) or $.545 per linked trip (adjusting for multiple transfer uses and the share of cash riders purchasing a transfer, respectively). The average fare for a pass user was $20/59.6 or $.336 per linked trip. Therefore, the average pass user paid only 61.7% as much as the average cash rider for each linked trip.

The adopted fare structure (FY 1985-86) contains a cash fare of 85¢ per initial boarding, 10¢ for each transfer boarding, and a monthly pass priced at 37.6 times the single ride price, or $32. This means that the cash rider would pay $.85 + ($.10)(.48) or $.898 per linked trip, while the pass user would pay $32/59.6 or $.537 per linked trip, which is 59.8% as much as the average cash rider pays for each trip. Furthermore, since some riders would ultimately benefit from the availability of pass price subsidies offered by their local communities (effectively maintaining the former monthly pass price of $20), these riders would continue to pay only $.336 per linked trip, which is only 37.4% of the average cash fare per linked trip.

With the availability of a lower per trip cost afforded by purchasing a pass as opposed to continuing to pay a significantly higher cash fare, it would seem that some riders, rather than be deflected by the higher cash fare would, instead, purchase a pass, thereby altering the patronage decline that might otherwise be indicated by elasticity analysis. Consideration of this factor is important because any shifts in the proportion of riders who pay cash as opposed to buying a pass will influence the determination of the overall future year average fare for the fare category under study.

Douglas Wentworth, in A Simple Technique For Calculating Changes in Fare Category Distribution (Tri-County Metropolitan Transportation Commission, APTA and USDOT; paper presented at APTA Western Conference; Portland, Oregon; April, 1984), suggests a method for approximating fare category distributional shifts occurring as the result of differential changes in the price of the available fare media. His approach hypothesizes that the ratio of cash riders to pass riders is inversely proportional to the average fare for cash and pass riders, respectively. In other words:

$$\frac{Trips_{cash}}{Trips_{pass}} = K \left[\frac{Fare_{pass}}{Fare_{cash}} \right]$$

Since only limited data was apparently available to him, Mr. Wentworth assumed that K (the constant of proportionality) is time-invariant. In the District's analysis of this concept, historical data suggested that this assumption may not be valid. District historical data is presented in Table 3-3. The evidence suggests that the propensity to pay cash as opposed to purchasing a pass may not only be a function of the relative price of the media (as measured by K), but may also be influenced by the magnitude of the cash fare (inversely).

Given the concern that other factors may influence the proportionality constant in Mr. Wentworth's model, it was decided to employ an average value of K for the most recent three years (a period of stable fares) when applying this model to determination of each fare category distribution. With this modification to the determination of the future year average fare for a given fare structure, all of the elements of the District's fare impact evaluation model are presented.

An example application of the fare impact evaluation model process for Regular fare riders illustrates the manner in which this study's impacts were derived. The first step in the process is the preparation of disaggregate base year data stratified by analysis group. Using District data, the following establishes the base year parameters for our analysis.

FY 1984-85	Eligible for Subsidy in FY 1985-86	Not Eligible for Subsidy in FY 1985-86
Regular Cash Boardings	1,949,700	190,409,800
Regular Cash Trips	1,316,400	128,560,400
Regular Pass Boardings	543,400	95,104,100
Regular Pass Trips	345,100	60,390,400
Number of Passes Sold	5,792	1,013,691
Cash Revenue	$717,097	$70,032,194
Pass Revenue	$115,840	$20,273,820

Calculation of Average Fare for Riders Eligible for Subsidy in FY 1985-86

FY 1984-85 Average Cash Fare/Trip

$$= \frac{(1,316,400)(\$.50)+(1,949,700-1,316,400)(\$.093)}{1,316,400} = \$.537$$

TABLE 3-3

ANALYSIS OF CASH VERSUS PASS USE FOR REGULAR FARE RIDERS

Fiscal Year	Share of Linked Trips Using Pass	Average* Cash Fare	Average* Pass Fare	K**
1980-81	.3874	$.733	$.382	3.034
1981-82	.3747	$.917	$.567	2.699
1982-83	.3360	$.544	$.337	3.190
1983-84	.3182	$.545	$.357	3.271
1984-85	.3186	$.545	$.336	3.469

*Per linked trip

**Defined as $\left(\frac{Trips_{cash}}{Trips_{pass}}\right)\left(\frac{Fare_{cash}}{Fare_{pass}}\right)$

Source: SCRTD Planning Department

FY 1984-85 Average Pass Fare/Trip

$$= \frac{(5,792)(\$20)}{345,100} = \$.336$$

Weighted Average Fare FY 1984-85

$$= (\$.537)(.7923)+(\$.336)(.2077) = \$.495$$

<u>Calculation of Average Fare for Riders not Eligible for Subsidy in FY 1985-86</u>

FY 1984-85 Average Cash Fare/Trip

$$= \frac{(128,560,400)(\$.50)+(190,409,800-128,560,400)(\$.093)}{128,560,400} = \$.545$$

FY 1984-85 Average Pass Fare/Trip

$$= \frac{(1,013,691)(\$20)}{60,390,400} = \$.336$$

Weighted Average Fare FY 1984-85

$$= (\$.545)(.6804)+(\$.336)(.3196) = \$.478$$

<u>Calculation of Fare Category Distribution Constants</u>

Note: The lack of adequate historical data permits calculating the value of K for each analysis group based on only one year's data.

Riders Eligible for Subsidy: $K = \left[\frac{.7923}{.2077}\right]\left[\frac{\$.537}{\$.336}\right] = 6.097$

Riders not Eligible for Subsidy: $K = \left[\frac{.6804}{.3196}\right]\left[\frac{\$.545}{\$.336}\right] = 3.453$

<u>Calculation of Projected Fare Category Distributions</u>

Riders Eligible for Subsidy:

FY 1985-86 Average Cash Fare/Trip = $.85+(.481*)($.10) = $.898

---

*Transfer Rate FY 1984-85

FY 1985-86 Average Pass Fare/Trip = $20/59.6** = $.336

$$\frac{\$.336}{\$.898} \quad 6.097 = \frac{\text{Cash Share}}{\text{Pass Share}} = 2.281$$

Cash Share = .6952
Pass Share = .3048

Weighted Average Fare FY 1985-86
= ($.898)(.6952)+($.336)(.3048) = $.727

Riders Not Eligible for Subsidy:

FY 1985-86 Average Cash Fare/Trip = $.85+(.481)($.10) = $.898

FY 1985-86 Average Pass Fare/Trip = $32/59.6 = $.537

$$\left[\frac{\$.537}{\$.898}\right] (3.453) = \frac{\text{Cash Share}}{\text{Pass Share}} = 2.065$$

Cash Share = .6737
Pass Share = .3263

Weighted Average Fare FY 1985-86
= ($.898)(.6737)+($.537)(.3263) = $.780

<u>Calculation of Fare Elasticity Response</u>

Riders Eligible for Subsidy:

$$\frac{Trips_{86}}{Trips_{85}} = 1.028-.308\left[\frac{Fare_{86}-Fare_{85}}{Fare_{85}}\right]$$ Calculated in increments limited to 39.7% per increment

$$\frac{Fare_{86}}{Fare_{85}} = \frac{\$.727}{\$.495} = 1.469 = (1.397)(1.052) \text{ or 2 increments}$$

$$\frac{Trips_{86}}{Trips_{85}} = \left[1.028-.308(.397)\right]\left[1-.308(.052)\right] = .891$$

**FY 1984-85 Average Linked Trips/Pass

Riders Not Eligible for Subsidy:

$$\frac{Fare_{86}}{Fare_{85}} = \frac{\$.780}{\$.478} = 1.632 = (1.397)(1.168) \text{ or 2 increments}$$

$$\frac{Trips_{86}}{Trips_{85}} = \left[1.028-.308(.397)\right]\left[1-.308(.168)\right] = .859$$

Calculation of FY 1985-86 Ridership and Revenue

Riders Eligible for Subsidy:

$$\text{FY 1985-86 Trips} = (\text{FY85 Trips})\left[\frac{Trips_{86}}{Trips_{85}}\right] = (1,661,500)(.891) = 1,480,400$$

Cash Trips = (FY86 Trips)(Cash Share) = (1,480,400)(.6952) = 1,029,200

Pass Trips = 1,480,400-1,029,200 = 451,200

Cash Boardings = (Cash Trips)+(.481)(Cash Trips) = 1,524,200

Passes Sold = (Pass Trips)/(Linked Trips per Pass) = 451,200/59.6 = 7,570

Pass Boardings = (Pass Trips)+(.575*)(Pass Trips) = 710,600

Cash Revenue = (1,029,200)($.85)+(1,524,200-1,029,200)($.10) = $924,320

Pass Revenue = (7,570)($20) = $151,400

Pass Subsidy Revenue = (7,570)($12) = $91,840

Riders Not Eligible for Subsidy:

FY 1985-86 Trips = (188,950,800)(.859) = 162,308,700

Cash Trips = (162,308,700)(.6737) = 109,347,400

Pass Trips = 162,308,700-109,347,400 = 52,961,300

Cash Boardings = 109,347,400+(.481)(109,347,400) = 161,943,500

*FY 1984-85 Pass Transfer Rate

Passes Sold = 52,961,300/59.6 = 888,612

Pass Boardings = 52,961,300+(.575)(52,961,300) = 83,414,000

Cash Revenue = (109,347,400)($.85)+(52,596,100)($.10) = $98,604,900

Pass Revenue = (888,612)($32) = $28,435,584

Summary of Impacts (Regular Fare Category)

	FY 1984-85	FY 1985-86
Cash Base Fare	50¢	85¢
Transfer Surcharge	10¢ (Unlimited Use)	10¢ (per use)
Monthly Pass Price	$20	$32($20 to subsidized patrons)
Cash Boardings	192,359,500	163,467,700
Cash Trips	129,876,800	110,376,600
Pass Boardings	95,647,500	84,124,600
Pass Trips	60,735,500	53,412,500
Number of Passes	1,019,483	896,182
Cash Revenue	$70,749,291	$99,529,220
Pass Revenue	$20,389,660	$28,586,984 + $91,840 subsidy
Total Boardings	288,007,000	247,592,300
Total Revenue	$91,138,951	$128,116,204 + $91,840 subsidy

3.6 IMPACTS OF STUDIED FARE CHANGES

The fare elasticity model, discussed in the preceding sections, is the principal analysis tool used in this study. Rather than presenting analyses of all of the fare structure alternatives investigated during this study, this discussion will focus on the application of the fare elasticity model to the adopted fare structure for FY 1985-86.

A comparison of the FY 1985-86 fare structure with its predecessor is provided in Table 3-4. Details of the process by which these fares were determined are presented elsewhere in this report. A significant element affecting the impacts of the FY 1985-86 fare structure is the availability of pass price subsidies to many riders. Table 3-5 identifies the subsidies known at this time.

Due to the influence of subsidy availability, this report documents two projections of FY 1985-86 ridership and revenues; (1) the effect of available subsidies, and (2) the effect of no subsidy availability. Table 3-6 summarizes these impacts by fare category. An evaluation of actual experience in light of these projections will be conducted during FY 1985-86.

TABLE 3-4

COMPARISON OF FY 1984-85 AND
FY 1985-86 ADOPTED FARE STRUCTURES

Fare Category	Fare Media	FY1984-85	FY1985-86
Regular	Cash[1]	50¢	85¢
	Transfer[2]	10¢	10¢
	Pass[4]	$20	$32 ($20 to eligible riders)
Express	Cash[1]	50¢	85¢
	Transfer[2]	10¢	10¢
	Cash Increment[3]	25¢	35¢
	Pass[4]	$20	$32 ($20 to eligible riders)
	Pass Stamp[5]	$7	$12
Elderly & Handicapped	Cash[1]	20¢	40¢
	Transfer[2]	10¢	10¢
	Pass[4]	$4	$7 ($0-$4 to eligible riders)
Student	Cash[1]	20¢	85¢
	Transfer[2]	10¢	10¢
	Cash Increment[3]	Free	35¢
	Pass[4]	$4	$12 ($4 to eligible riders)
College	Cash[1]	50¢	85¢
	Transfer[2]	10¢	10¢
	Cash Increment[3]	Free	35¢
	Pass[4]	$4	$15 ($4-$7 to eligible riders)

[1]Base cash fare for an initial boarding.

[2]Surcharge assessed for successive cash boardings - paid once for unlimited use in FY 1984-85; paid each time in FY 1985-86.

[3]Surcharge assessed to cash riders for each express increment travelled.

[4]Cost per month for unlimited use.

[5]Cost per month per express zone for unlimited use.

6Cash fares may also be paid with tickets and/or tokens (sold without a discount) - this group of riders is analyzed separately.

[7]Selected riders pay no fare (children under 5, blind, SCRTD employees, and City of Los Angeles Traffic Control Officers within the Los Angeles CBD) - this group of riders is analyzed separately.

[8]Selected Special Services charge unique fares - those services are analyzed individually.

[9]Table 3.5 describes pass subsidies provided to eligible riders.

Source: SCRTD Planning Department

TABLE 3-5

FY 1985-86 PASS PRICE SUBSIDY AVAILABILITY

Fare Category	Community	Amount of Subsidy/Pass	Est. Share of FY85 Passes	Est. FY86 Cost of Subsidy
Regular ($32 monthly pass)	South Gate	$12	.0046	$72,948
	South Pasadena	$12	.0006	$ 9,672
	Temple City	$12	.0005	$ 7,728
			.0057	$90,348
Express ($32 monthly pass plus $7 per stamp)	South Gate	$12	---	---
	South Pasadena	$12	.0021	$4,584
	Temple City	$12	.0007	$1,224
			.0028	$5,808
Elderly & Handicapped ($7 monthly pass)	Alhambra	$3	.0083	$ 22,869
	Baldwin Park	$3	.0008	2,184
	Bell	$3	.0011	3,198
	Burbank	$3	.0075	20,811
	Covina	$3	.0007	2,097
	El Monte	$3	.0083	22,344
	Glendale	$3	.0199	55,578
	Hawthorne	$3	.0020	5,835
	Huntington Park	$3	.0086	23,460
	Inglewood	$3	.0069	19,377
	La Puente	$6	.0004	3,396
	La Verne	$7	.0003	4,067
	Los Angeles	$3	.7670	2,069,799
	County (Districts 2-5)	$3	.0395	110,454
	Monterey Park	$3	.0068	18,651
	Pico Rivera	$3	.0011	3,084
	San Fernando	$3	.0011	3,306
	South Gate	$3	.0031	8,802
	South Pasadena	$3	.0010	2,778
	Temple City	$3	.0007	1,986
	West Hollywood	$3	.0212	56,304
			.9063	$2,460,380
Student ($12 Monthly Pass)	La Puente	$8	.0003	$ 3,968
	County (Districts 2-5)	$8	.0683	860,624
	Monterey Park	$8	.0076	92,256
	Pico Rivera	$8	.0004	4,968
	South Gate	$8	.0055	69,968
	South Pasadena	$8	.0005	6,912
	Temple City	$8	.0009	11,344
			.0835	$1,050,040

Fare Category	Community	Amount of Subsidy/Pass	Est. Share of FY85 Passes	Est. FY86 Cost of Subsidy
College ($15 Monthly Pass)	La Puente	$11	.0003	$ 946
	County (Districts 2-5)	$11	.0683	224,785
	South Gate	$8	.0055	10,152
	South Pasadena	$11	.0005	1,738
	Temple City	$11	.0009	3,036
			.0755	$240,657

Est. Share of All FY85 Passes Subsidized	Est. FY86 Total Cost of Subsidies
.2418	$3,847,233

Source: SCRTD Planning Department

TABLE 3-6

PROJECTED IMPACTS OF FY 1985-86 FARE ALTERNATIVES

Fare Category		FY 1984-85	FY 1985-86 w/o Subsidy Availability	FY 1985-86 with Subsidy Availability
Regular	Cash Boardings	192,359,500	162,060,700	161,936,600
	Pass Boardings	95,647,500	85,721,300	85,950,200
	Number of Passes	1,022,255	913,678	916,118
	Cash Revenue*	$70,749,300	$98,270,400	$98,199,200
	Pass Revenue	$20,445,100	$29,237,700	$29,315,800
Express	Cash Boardings	10,349,100	7,865,700	7,864,400
	Pass Boardings	9,414,400	7,496,300	7,501,700
	Number of Passes	171,454	135,751	135,860
	Cash Revenue*	$8,304,100	$9,568,500	$9,567,300
	Pass Revenue	$6,689,200	$8,782,300	$8,787,300
Elderly & Handicapped	Cash Boardings	12,259,700	10,275,200	7,037,300
	Pass Boardings	53,224,700	46,407,300	56,437,400
	Number of Passes	838,219	729,216	886,832
	Cash Revenue	$2,025,700	$3,108,400	$2,371,100
	Pass Revenue	$3,352,900	$5,104,500	$6,207,800
Student	Cash Boardings	8,508,700	4,005,700	3,727,300
	Pass Boardings	66,806,300	52,144,600	54,058,800
	Number of Passes	1,430,161	1,115,872	1,156,831
	Cash Revenue*	$1,423,400	$2,447,100	$2,277,000
	Pass Revenue	$5,720,600	$13,390,500	$13,882,000
College	Cash Boardings	1,171,000	1,949,000	1,843,800
	Pass Boardings	16,419,000	9,077,300	9,680,100
	Number of Passes	282,895	158,861	169,410
	Cash Revenue*	$431,800	$1,203,700	$1,138,700
	Pass Revenue	$1,131,600	$2,382,900	$2,541,200
Free, Ticket & Special Services	Free Boardings	20,807,300	21,383,800	21,383,800
	Cash Boardings	1,338,600	1,355,500	1,355,500
	Pass Boardings	84,800	83,500	83,500
	Ticket Boardings	5,588,100	4,725,200	4,725,200
	Cash Revenue	$530,900	$566,800	$566,800
	Ticket Revenue	$2,852,000	$4,087,800	$4,087,900
	Total Boardings	493,978,700	414,551,100	424,385,600
	Total Revenue	$123,656,600	$178,150,700	$178,942,100

*Includes subsidies

Source: SCRTD Planning Department

4.0 PRICING EVALUATION

Based on the results of the distance-based and time-variant structural analyses presented in Section 2, which, in effect, suggest that the District's current flat fare structure is relatively efficient as well as equitable, a range of alternative "flat" fare pricing structures was analyzed in terms of the likely impacts on disaggregate as well as system ridership and fiscal performance. In order to evaluate effectively the impacts of each alternative flat fare structure, the fare elasticity models developed in Section 3 were integrated into the evaluation process. The primary purpose of this section is to assess the District's current flat fare policies and the role in which refinements of the base cash and pass fares, transfer surcharges, and discount fares can play in maximizing the District's patronage, passenger revenue, and levels of service. A discussion of the alternative fare "levels" which were found to be appropriate for the post-Proposition A Fare Reduction years is included.

4.1 IMPACTS OF ALTERNATIVE FLAT FARE PRICING STRUCTURES

Although distance-based fare structures appear to be more progressive than the District's current flat fare structure (with respect to family income), differentiating passenger fares by distance traveled results in a significant increase in net operating costs arising from the mechanics of administering such a structure with current technology and, thus, a decline in overall system efficiency. Moreover, while time-variant fares suggest that an increase in District operating efficiency is possible due to the relatively minor additional operating costs associated with implementing a peak/off-peak fare structure, differentiating fares by time-of-day appear to capture a higher degree of user inequity. As a result, a variety of refinements to the District's current flat fare structure were considered.

To evaluate the impacts of each alternative flat fare structure, disaggregate as well as system evaluations of the change in patronage associated with seven alternative flat fare pricing scenarios were developed. The impacts of fare cross-subsidization were analyzed. A brief summary of the more important results associated with each scenario, including each scenario's tradeoffs, is presented below:

(1) Retention of Proposition A fare structure - This alternative provided for equal proportional increases in all fares for all categories of riders. It retained the existing heavy cross-subsidization of discount riders by full-fare riders. The drawback to this alternative, however, was the recognition that student and college ridership was continuing to grow at a faster rate than regular ridership, thereby resulting in a need for larger and more frequent fare increases over time since student and college fares were subsidized by full-fare paying riders.

(2) Implementation of service-based pricing - This alternative (also known as quality-based pricing) provided for different base fares for each type of service, presumably related to

the differential costs associated with operating different service types. Services considered for higher base fares included limited local, intra-community, and local services operating on policy-based headways.

In the case of limited services, a higher fare was believed to be justified based on travel time savings in comparison to a parallel local service. In most instances, however, the travel time savings were found to be marginal because limited service lines are usually operated in the most congested corridors. Intra-community services and policy-based headway local services, on the other hand, are typified by relatively low boarding to bus hour ratios which result in higher net costs of operation. While in theory this suggested that a higher fare was warranted in order to recover a greater proportion of operating costs, in practice, the higher fare was believed to discourage a significant amount of patronage. This was contrary to the basic objective of providing such services, which is to encourage greater utilization of transit through maintenance of a convenient level of regional services.

(3) <u>Implementation of additional restrictions on eligibility for free fares</u> - This alternative sought to increase revenues by requiring fare payment from some riders who are presently entitled to free boardings. Specific actions considered included (1) charging student fares to children under 5 who are not carried aboard; (2) charging full fare to children under 5; and (3) charging handicapped fares to blind riders.

Because none of the revenue options considered produced significant revenue gains (collectively they added less than 1% to existing passenger revenues), and because the reasons for maintaining existing free boarding privileges and restrictions were thought to be as much a matter of public policy as they were a matter for consideration of any revenue impacts associated with such privileges, this alternative was not considered feasible.

(4) <u>Implementation of time-based pricing system-wide</u> - The implementation of time-based pricing was designed to distribute fares more equitably, based on the quantity of service consumed. The concept is analogous to the concept underlying distance-based fares except that passengers would purchase time on the system rather than distance. Similarly, time-based fare collection awaits the development of reliable technological improvements in fare collection equipment before it may be considered economically feasible.

(5) <u>Adjustment of monthly pass pricing multiples</u> - In FY 1984-85, regular monthly passes were priced at 40 times the base fare for a single ride. This alternative increased the pricing multiple from 40 to 45. Analysis of the average

number of linked trips made on each type of monthly pass (regular, express, E&H, student, and college) during FY 1983-84 showed that, with the exception of regular passes, all other passes were used for 43 linked trips or fewer per month. Regular full-fare monthly passes show an average use of 56 linked trips per month. This high rate of utilization meant that the average regular monthly pass user saves approximately 30% of the full cash fare value of the trips taken. A higher pass pricing multiple (45, for example) generated a higher return for the District toward the full value of the trips. At the same time, a 45 multiple yielded an approximate 20% discount for the average pass user. While it was recognized that some pass users who utilize passes only on weekdays to commute to and from work might feel that a higher priced pass would no longer be economical (marketing estimates that as many as 30% of current pass users probably use the pass in this manner), the monthly pass priced at 45 times the base fare was believed to be, at worst, a break-even proposition for any of these riders who transfer at least once per trip.

(6) Reduction of discounts for elderly, handicapped, student and college riders - The FY 1984-85 fare discounts for these ridership groups were as follows:

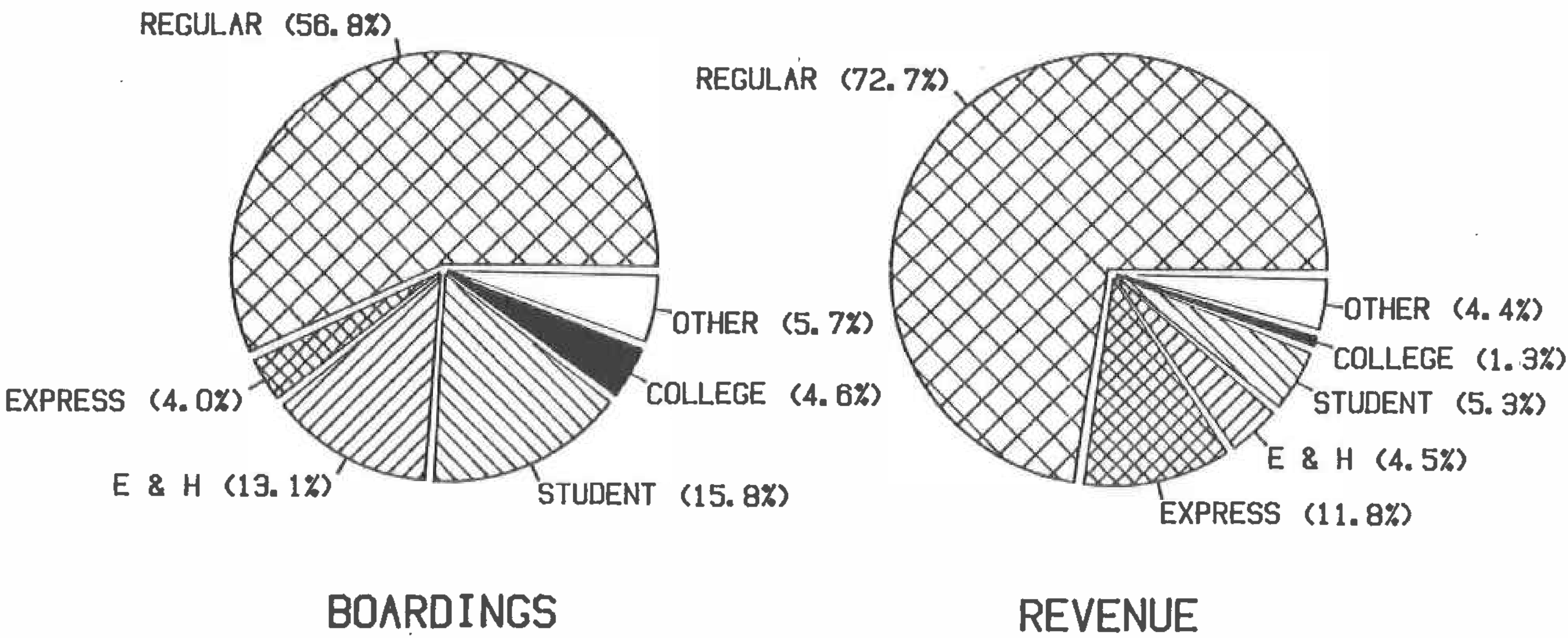
	Cash Discount	Monthly Pass Discount
Elderly & Handicapped	60%*	80%*
Student	60%*	80%*
College	None	80%*

*Note - No cash zone increments or pass stamps are required, which represent an additional discount available to express riders in these ridership groups.

Analyses of the current fare levels for the above user groups indicated that large discounts have produced significant increases in ridership by these groups during the Proposition A Fare Reduction Program. Discount riders now account for more than one of every three riders. The large numbers of discount riders mean higher fares for full-fare riders in order to subsidize the revenue losses attributable to each discount boarding. In FY 1984-85, full-fare (non-express) riders comprised 57% of all boardings while contributing 73% of all passenger fare revenues (Figure 4-A). This means that about $.14 out of each $.50 full-fare is used to subsidize the lower fares of all discount riders. Clearly, one way to minimize fare increases for the majority of riders, who pay full fare, is to reduce the size of the discounts offered to discount riders.

FIGURE 4-A

SHARE OF FY1984-85 BOARDINGS AND REVENUE ($.50 BASE FARE, PROP A FARE STRUCTURE)



The only institutional requirement affecting discount fares is a federal and state mandate that elderly and disabled riders cannot be charged more than 50% of the base fare during off-peak periods. Local political considerations and historical precedent suggest that some discount should be offered to handicapped, student, and college riders, as well. Since the implementation of Proposition A, local communities in Los Angeles County have an additional source of funding available in the form of 25% Local Return share of Proposition A sales tax revenues. These monies must be used for a transit-related purpose. Subsidization of some or all of the cost of discount monthly passes is a legitimate transit-related purpose. It was felt, therefore, that the willingness of communities to use these funds would afford an opportunity for the District to reduce the subsidy of discount fares by full-fare riders since lower discounts (i.e. higher discount pass prices) need not be entirely passed through to the transit rider.

(7) Imposition of additional transfer restrictions - Transfers provide a means of identification, for those who require more than one bus to complete a trip, so that drivers of subsequent buses will know that a base fare has already been paid. At present, transfers provide for an unlimited number of boardings subject to time and directional limits on their validity. Pass riders do not need to use transfers, as their passes permit subsequent boardings automatically.

Higher base fares, however, attach a higher value to a transfer, particularly if multiple boardings are permitted with a single transfer. Without some reasonable restriction on the ultimate value of such a fare media, it was believed that an expanded market for the resale of transfers would result. A simple means of limiting the value of transfers was to restrict them to a single use. In this manner, the transfer's ultimate value would be no more than the full-cash base fare.

4.2 SERVICE MODIFICATION IMPACTS

While the primary goal of this study was to maximize patronage and service levels, most of the District's sources of revenue to support operating costs were found to be determined by "existing" legislation (i.e., Federal Section 9, State Transit Assistance - STA, and local, including TDA and Proposition A funds). Therefore, beyond increasing revenues from these sources, only two principal actions were available to balance revenues and expenses: (1) increase farebox revenues by raising fares, and (2) reduce operating costs through service reductions and increased productivity. These two actions are highly inter-related. A review of recent historical relationships between District fare and service changes illustrates the nature of this interaction and provided guidance for the FY 1985-86 alternative fare and policy recommendations.

Action	Transition Period	Change in Boardings	Change in Service Hours	Ratio of Boardings to Service Changes
Fare Increase	FY1980 - FY1981	+12.5%	+3.0%	4.2 to 1
Fare Increase	FY1981 - FY1982	-11.1%	-2.4%	4.6 to 1
Fare Decrease	FY1982 - FY1985 (Proposition A Fare Reduction Program)	+42.2%	+8.8%	4.8 to 1

Recognizing the above service to patronage relationship, a number of fare-related policy decisions were made in the process of developing an alternative fare policy and fare structure. The following nine policies were recommended to the District's Board of Directors for consideration as the basis for determining a fare structure (note: underline denotes change from present policy). These policies were used in formulating the Study-recommended fare levels and fare structure presented in Table 4-1.

(1) All local and limited bus service should be subject to a flat fare for initial boardings.

(2) All express bus service should be subject to an express surcharge varying with increments of freeway distance traveled. Express zones should remain as defined in present tariffs.

(3) All special and contract services should be subject to individual pricing apart from the proposed fare policy.

(4) Fare payment should be by means of exact change, pass, tickets, transfers or tokens. <u>Cash riders should be subject to a transfer surcharge for each transfer boarding</u>.

(5) Elderly and handicapped riders should receive at least a 50% base fare discount and should not be subject to express surcharges.

(6) <u>Student (age 5-18 years) and college (full-time students) riders should not be offered any cash fare discounts</u>.

(7) <u>Monthly passes should be sold to full-fare paying riders at a price multiple of 45 times the base fare plus 40 times the applicable distance surcharge, if any.</u> Elderly and handicapped, student, and college passes should provide an exemption from express surcharges. Elderly and handicapped passes should be discounted at least 50% from the price of a full-fare monthly pass. <u>Student passes should be discounted no more than 50% from the price of a full-fare monthly pass.</u> College passes should be discounted no more than one-third of the price of a full-fare monthly pass.

TABLE 4-1

RECOMMENDED/ADOPTED FARE STRUCTURE: FY 1985-86

Fare Category	FY 1983 - FY 1985 Proposition A	(Recommended) FY 1985-86	(Adopted) FY 1985-86
CASH			
Regular	50¢	75¢	85¢
Express (per zone)	25¢ (E&H, Student exempt)	30¢ (E&H exempt)	35¢ (E&H exempt)
E&H	20¢	35¢	40¢
Student	20¢	75¢	85¢
College	50¢	75¢	85¢
Transfer	10¢	10¢ (per use)	10¢ (per use)
Tickets	Face Value	Face Value	Face Value
Tokens	50¢	75¢	85¢
PASS			
Regular	$20 (40 multiple)	$34 (45 multiple)	$32 (37.7 multiple)
Express Stamp	$7 (Regular only)	$12 (Regular only)	$12 (Regular only)
E&H	$4	$12	$7
Student (ages 5-18)	$4	$18	$12
College	$4	$24	$15

Note: Transfers include time and directional restrictions. Free boardings include children under five, SCRTD employees and their dependents, SCRTD Board members, uniformed police officers, City of LA TPO's within downtown LA, and the blind.

(8) Free boardings should be permitted for all children under five, SCRTD employees and their dependents, SCRTD Board Members, law enforcement officers in uniform, and uniformed City of Los Angeles Traffic Control Officers within the limits of downtown Los Angeles. All such riders should not occupy a seat to the exclusion of a fare-paying passenger. Blind persons should ride free without restriction.

(9) Transfers should be restricted with regard to direction of travel and time of expiration in accord with existing tariffs.

(10) Outstanding tickets should be honored at face value for cash fare payment. Outstanding tokens should be honored at a value equivalent to the base fare, exclusive of surcharges.

As a result of the District's Board of Directors consideration of the Study-recommended fare levels, and in recognition of the public's response to a change in the current fare levels, the Board adopted a modified version of the recommended fare structure to be implemented on July 1, 1985 (Table 4-1). While the general structure of the Study-recommended ($.75 base) fare scenario was adopted by the Board, the following differences, as well as similarities, should be noted:

- To encourage greater pass utilization by the general public, the adopted regular pass price ($32) was discounted to a greater extent than the recommended pass price ($34) through a reduction in the pass price multiple from 45 (as recommended) to 37.7.

- Because the Board adopted an increase in the express cash price per zone of $.05 over the recommended $.30 cash price, while retaining the recommended express stamp price of $12 per zone, a significant discount was afforded to express pass users who purchase one or more express stamps. The express stamp price was effectively reduced through a decrease in the express stamp multiple from the recommended 40 uses per month to the adopted 34.3 uses per month.

- In response to the public's concerns voiced at the February 2, 1985, public hearing, the Board reduced the pass prices for the elderly & handicapped, student, and college user groups from the recommended levels of $12, $18, and $24, respectively, to $7, $12, and $15, respectively.

- Similar to the study recommendations, the Board-adopted fare structure retained the concepts of (1) not discounting the cash fares for the student and college user-groups and (2) limiting transfers to one use per transfer.

5.0 CONCLUSIONS

This report has documented the range of analyses performed in support of the fare structure changes implemented by the District on July 1, 1985. In the course of this evaluation, several tools were developed (a cost model and a fare impact prediction model) to assist with District-specific analyses. Both fare policy alternatives and fare structure modifications were assessed. Future monitoring of the effects of the most recently implemented fare changes will allow further model refinements leading to improved predictive capabilities for future fare changes.

5.1 COST MODEL ASSESSMENT

The cost model developed in this study was specifically designed to assist in the evaluation of modal pricing, distance-based equity, and peak versus off-peak cost recovery. As it is a cost-allocation model, rather than a marginal cost model, it joins a variety of other such models previously developed by the District. Its development has contributed to improved understanding of District cost drivers, and served the purposes for which it was intended. The District is continuing research into cost model development in an effort to support a broader range of analyses with a unified model form.

5.2 FARE POLICY EVALUATION

Pure and incremental distance (and time) based pricing, peak versus off-peak pricing, and flat fare alternatives were evaluated. It was concluded that a continuation of the existing hybrid fare policy (flat fare on local buses, and incremental distance-based fares on express buses) provides the best balance of equity versus administrative considerations at the present time. Pure distance-based pricing requires the development of more reliable technology. Incremental distance-based pricing on local buses entails significant revenue collection costs which offsets any pricing advantage to all but a small minority of riders. Differential peak/off-peak pricing was found to be inequitable since peak riders were observed to return a larger share of costs through the farebox with the existing fare structure in spite of higher peak unit operation.

5.3 FARE STRUCTURE CONSIDERATIONS

Principal areas of investigation included the relative attractiveness of appropriate discount fares to selected classes of riders, transfer pricing mechanisms, and promotion of user-side subsidy programs. While study findings suggested lesser discounts for regular passes because of high usage rates for pass holders, the District Board of Directors adopted a higher price discount in an effort to promote the use of passes by a greater share of the District's riders. This policy is designed to promote improved operating efficiency (through reduced boarding delays) at the expense of slightly reduced fare revenues. All other study recommendations were supported in the Board-adopted fare structure. Cash discounts for student and college riders were eliminated. Pass discounts for these riders were significantly reduced. Transfer surcharges were imposed on a per use basis in contrast with previous policies that provided an unlimited number of rides per transfer (time and directional restrictions were continued). Finally, an outreach program was initiated to encourage local communities to provide pass price subsidies with Proposition A Local Return Funds. Many communities have since responded by providing such subsidies.

5.4 FARE IMPACT DETERMINATION

A detailed fare elasticity model was developed which is sensitive to differing classes of riders, relative price differences between cash and pass fares, and the availability of pass price subsidies. During its developmental stage, the model was used to provide preliminary impact assessments for a wide variety of fare structures which were under consideration. Initial projections of a 17.5% loss of ridership with the Board-adopted fare structure were developed at a time when the sensitivity to cash/pass price differences and subsidy availability was not yet incorporated into the model. The refined model form, documented in this report, projects a 14% patronage loss with the newly implemented fare structure. Further refinement of this model is anticipated as impact data on the most recent fare change becomes available.

Appendix A

DEVELOPMENT OF ELASTICITY MODEL HISTORICAL CALIBRATION DATA

The historical data used to calibrate the District's fare category-based elasticity models for this study was developed from historical annualized District ridership and revenue data. This appendix documents the procedures employed to pre-process the data into a form useful for calibration purposes.

1. Quarterly District patronage was accumulated from Statistical Digests (FY 1981 and FY 1982) and monthly Patronage Reports (FY 1983, FY 1984 and FY 1985). The accumulated data was stratified by type of service day (weekday, Saturday, and Sunday and Holiday) in the source documents, and this stratification was preserved for quarterly aggregations.

2. Quarterly revenues were compiled from Statistical Digests, monthly Patronage Reports, a historical file of Farebox Cash Revenue, and monthly pass sales data. Farebox cash revenue (including revenue from tickets and tokens) was accumulated by type of service day for each quarter. Pass sales were accumulated quarterly by fare category, and pass sales revenue was calculated by multiplying historical pass prices by quarterly sales.

3. Weekday, Saturday, and Sunday and Holiday quarterly patronage was then disaggregated to boardings by fare category using ridership shares determined from historical Fare Surveys. Fare Surveys have been conducted in 13 of the 20 quarters from FY 1980-81 through FY 1984-85. Ridership shares for quarters in which no Fare Survey was conducted were estimated by proportioning the relative changes observed for corresponding quarters in years where Fare Survey data were available.

4. Transfer rates for cash and pass riders were developed initially for FY 1983-84 data based on responses to the District-wide On-Board Survey conducted in May, 1984. Cash transfer rates were adjusted in relative proportion to each other in order to match calculated farebox cash revenue with actual receipts on an annualized basis. Adjusted pass transfer rates were then established by direct proportional adjustment of initial estimates obtained from the On-Board Survey. Cash transfer rates for all other years in the data base were estimated by proportionally adjusting FY 1983-84 rates in order to match calculated with actual farebox receipts for each fiscal year. Finally, pass transfer rates for all other years in the data base were calculated by proportionally adjusting FY 1983-84 pass transfer rates in direct proportion to the calculated change in cash transfer rates from year to year.

5. For analysis purposes, premium fare Special Services patronage, obtained separately, was disaggregated by assuming the same distribution of cash versus pass boardings as observed for Regular fare riders. Similarly, pass and cash transfer rates were also assumed comparable to the rates observed for Regular fare riders.

Outputs of this procedure consisted of quarterly data, by fare category by type of service day (weekday, Saturday, or Sunday and Holiday) for the following:

Cash Boardings
Cash Linked Trips
Pass Boardings
Pass Linked Trips
Farebox Cash Revenue

Additionally, quarterly pass sales and pass revenues by fare category were compiled.

Appendix B

DETAILED MODEL SPECIFICATION

Model Calibration

Given historical annualized data on the following by fare category:

T_{cy}, T_{py} = Linked Trips by cash and pass riders, respectively, in year y

B_{cy}, B_{py} = Total boardings by cash and pass riders, respectively, in year y

F_{cy}, F_{py}, F_{ty} = Fare for cash riders (initial boarding), monthly pass price, and transfer surcharge, respectively, in year y

P_y = Number of Passes Sold in year y

Calculate the following:

Average Cash Fare in year y = $F_{ycash} = F_c + \left[\frac{B_{cy} - T_{cy}}{T_{cy}}\right] F_{ty}$[1]
(per linked cash trip)

Average Pass Fare in year y = $F_{ypass} = F_{py} \quad T_{py}$

Average Fare per Linked Trip in year y = F_y

$$= \left[\frac{T_{cy}}{T_{cy}+T_{py}}\right] F_{ycash} + \left[\frac{T_{py}}{T_{cy}+T_{py}}\right] F_{ypass}$$

Cash Propensity in year y = $K_y = \left[\frac{T_{cy}}{T_{py}}\right] \left[\frac{F_{ycash}}{F_{ypass}}\right]$

[1]Adjust F_{ty} to account for multiple transfer trips if transfer surcharge is assessed less frequently than once per transfer boarding.

Then for all years y through y+t-1, where t represents the number of years of data, estimate the coefficients (C and E) of the following relationship:

$$\left(\frac{T_{y+1}-T_y}{T_y}\right) = C+E \left(\frac{F_{y+1}-F_y}{F_y}\right)$$

The estimators, C* and E*, will be based on (t-3) degrees of freedom, and will not usually be significant unless t is large. In most instances, the decision of whether or not C* and E* are appropriate for application to determination of future year patronage variation (resulting from fare changes) must be based on the predictive error of the resulting estimated relationship. A low standard error of the regression (less than 0.1), and a negative signed E* are believed to be appropriate conditions for acceptance.

A final step in the calibration process is the determination of an appropriate value for K (the typical propensity to pay cash as opposed to buying a pass). If fare variation has been small during the most recent years in the data base, then K may be estimated as the average value of the K_y's for those years. Otherwise, the value of K_y for the most recent year may be more appropriate.

Model Application

Given the following base year data, and forecast fares, for a particular fare category;

B_{cb}, B_{pb} = Total cash and pass boardings, respectively, in base year b

T_{cb}, T_{pb} = Linked cash and pass trips, respectively, in base year b

F_{cb}, F_{tb}, F_{pb} = Cash base fare (initial boarding), transfer surcharge (adjusted for multiple transfer boardings if surcharge is applied less often than once per transfer boarding), and monthly pass price, respectively, in base year b

F_{cf}, F_{tf}, F_{pf} = Analogous fares for future year f where f = b+1

Determine the following:

Average base year cash fare = $F_{bcash} = F_{cb} + \left[\frac{B_{cb}-T_{cb}}{T_{cb}}\right] F_{tb}$
(per linked cash trip)

Average base year pass fare = $F_{bpass} = F_{pb} / T_{pb}$

Average base year fare per Linked Trip

$$= F_b = \left[\frac{T_{cb}}{T_{cb}+T_{pb}}\right] F_{bcash} + \left[\frac{T_{pb}}{T_{cb}+T_{pb}}\right] F_{bpass}$$

Average future year cash fare = $F_{fcash} = F_{cf} + \left[\frac{B_{cb}-T_{cb}}{T_{cb}}\right] F_{tf}$

Average future year pass fare = $F_{fpass} = F_{pf} / T_{pb}$

Future year cash share $= \left(\frac{T_{cf}}{T_{cf}+T_{pf}}\right) = \frac{K(F_{fpass})}{F_{fcash}+K(F_{fpass})}$

Future year pass share $= \left(\frac{T_{pf}}{T_{cf}+T_{pf}}\right) = \frac{F_{fcash}}{F_{fcash}+K(F_{fpass})}$

Average future year fare per Linked Trip

$$= \left[\frac{T_{cf}}{T_{cf}+T_{pf}}\right] F_{fcash} + \left[\frac{T_{pf}}{T_{cf}+T_{pf}}\right] F_{fpass}$$

Then calculate the fare elasticity response of ridership as follows:

Define $L = \left| \text{Max} \left(\frac{F_{y+1}-F_y}{F_y}\right) \right|$ for the historical data base

Define N as the minimum natural number (positive integers including 0) for which

$$(1+L)^N \geq 1+\left[\frac{F_f-F_b}{F_y}\right]$$

If N<2, then

$$\frac{T_f}{T_b} = (1+C^*)+E^* \left(\frac{F_f-F_b}{F_b}\right)$$

where $T_f = T_{cf}+T_{pf}$ and $T_b = T_{cb}+T_{pb}$

Otherwise $(N \geq 2)$

Let $F = \left(\frac{F_f - F_b}{F_b}\right)$

and

$$\frac{T_f}{T_b} = \left[(1+C^*)+E^*\left(\frac{F}{|F|}\right)(L)\right]\left[1+E^*\left(\frac{F}{|F|}\right)(L)\right]^{N-2}$$

$$\left[(1+E^*)\left(\frac{F}{|F|}\right)\left(\frac{1+|F|}{(1+L)^{N-1}}-1\right)\right]$$

Finally determine the following:

$$T_{cf} = T_f \left(\frac{T_{cf}}{T_{cf}+T_{pf}}\right)$$

$$T_{pf} = T_f \left(\frac{T_{pf}}{T_{cf}+T_{pf}}\right)$$

$$B_{cf} = T_{cf}\left(1 + \frac{B_{cb}-T_{cb}}{T_{cb}}\right)$$

Passes Sold in future year $= P_f = P_b\left(\frac{T_{pf}}{T_{pb}}\right)$

$$B_{pf} = P_f\left(\frac{B_{pb}}{P_b}\right)$$

Future year farebox cash revenue $= R_{cf} = (T_{cf})(F_{bcash})$

Future year pass revenue $= R_{pf} = (P_f)(F_{pf})$

Example Application

This example utilizes data for the District Elderly and Handicapped fare category.

Calibration Data:

	FY1980-81	FY1981-82	FY1982-83	FY1983-84	FY1984-85
B_{cy}	14,141,300	11,664,100	12,388,400	12,001,300	12,259,700
T_{cy}	9,779,600	7,886,500	8,393,200	8,114,500	8,275,800
B_{py}	46,418,400	45,328,600	49,329,400	48,948,800	53,224,700
T_{py}	30,821,800	29,418,300	31,965,500	31,620,900	34,905,800
P_y	741,992	757,571	808,822	829,404	838,219
F_{cy}	30¢	41.55¢[2]	20¢	20¢	20¢
F_{ty}[1]	9.3¢	4.65¢	9.3¢	9.3¢	9.3¢
F_{py}	$6	$7.9754[2]	$4	$4	$4

[1] Adjusted for multiple transfer boardings at no additional surcharge.
[2] Adjusted for portion of trips assessed additional express surcharges.

Calculated Historical Data:

	FY1980-81	FY1981-82	FY1982-83	FY1983-84	FY1984-85
F_{ycash}	$.3415	$.4378	$.2443	$2445	$2447
F_{ypass}	$.1444	$.2054	$.1012	$.1049	$.0961
Cash Share	.2409	.2114	.2080	.2042	.1917
Pass Share	.7591	.7886	.7920	.7958	.8083
F_y	$.1919	$.2545	$.1310	$.1334	$.1246
K_y	0.751	0.571	0.634	0.598	0.604
Cash Transfer Rate	.446	.479	.476	.479	.481

Pass Transfer Rate	.506	.541	.543	.548	.525
Linked Trips Per Pass	41.54	38.83	39.52	38.12	41.64
Boardings Per Pass	62.56	59.84	60.99	59.02	63.50

Model Estimation:

	$\left(\frac{T_{y+1}-T_y}{T_y}\right)$	$\left(\frac{F_{y+1}-F_y}{F_y}\right)$
FY 1980-81 to FY 1981-82	-.0812	.3262
FY 1981-82 to FY 1982-83	.0819	-.4853
FY 1982-83 to FY 1983-84	-.0154	.0183
FY 1983-84 to FY 1984-85	.0867	-.0660

$$\left(\frac{T_{y+1}-T_y}{T_y}\right) = .0075 - .204 \left(\frac{F_{y+1}-F_y}{F_y}\right)$$

Standard Error of Regression = .0538

Forecast Data (Forecast Year = FY 1985-86):

F_{cf} = 40¢

F_{tf} = 10¢

F_{pf} = \$7 for 10% of patrons
\$4 for 90% of patrons

Projection:

F_{bcash} = \$.2447 F_{bpass} = \$.0961 F_b = \$.1246

F_{fcash} = \$.40+(.481)(\$.10) = \$.4481

F_{fpass} = (\$7)(.10)+(\$4)(.90) / 41.64 = \$.1033

F_{fpass} for non-subsidized = \$.1681

F_{fpass} for subsidized = \$.0961

$$\text{Future year cash share (non-subsidized)} = \frac{(0.612)(\$.1681)}{\$.4481+(0.612)(\$.1681)} = .1867$$

$$\text{Future year cash share} = \frac{(0.612)(\$.0961)}{\$.4481+(0.612)(\$.0961)} = .1160$$

Average future year fare per linked trip = F_f(non-subsidized) = (.1867)(\$.4481)+(.8133)(\$.1681) = \$.2204 (non-subsidized)

Average future year fare per linked trip = F_f(subsidized) = (.1160)(\$.4481)+(.8840)(\$.0961) = \$.1369 (subsidized)

<u>Non-Subsidized(10%)</u>

L = .4853

$$(1+.4853)^N \geq 1+\left(\frac{\$.2204-\$.1246}{\$.1246}\right)$$

N = 2

$$\frac{T_f}{T_b} = [1.0075-.204(.4853)]\ [1-.204(.1909)] = .873$$

T_{cf} = (.873) [(.10)(43,181,600)] (.1867) = 703,800

T_{pf} = (.873) [(.10)(43,181,600)] (.8133) = 3,066,000

B_{cf} = (703,800)(1.481) = 1,042,300

P_f = [(.10)(838,219)] (.873) = 73,177

B_{pf} = (73,177) [(.10)(53,224,700)]/[(.10)(838,219)] = 4,646,500

R_{cf} = (703,800)(\$.4481) = \$315,373

R_{pf} = (73,177)(\$7) = \$512,239

Subsidized(90%)

$$L = .4853$$

$$(1+.4853)^N \geq 1+ \left(\frac{\$.1369-\$.1246}{\$.1246}\right)$$

$$N = 1$$

$$\frac{T_f}{T_b} = 1.0075-.204(.0987) = .987$$

$$T_{cf} = (.987)\left[(.90)(43,181,600)\right](.1160) = 4,449,600$$

$$T_{pf} = (.987)\left[(.90)(43,181,600)\right](.8840) = 33,908,600$$

$$B_{cf} = (4,449,600)(1.481) = 6,589,900$$

$$P_f = \left[(.90)(838,219)\right](.987) = 744,590$$

$$B_{pf} = (744,590)\left[(.90)(53,224,700)\right]/\left[(.90)(838,219)\right] = 47,279,500$$

$$R_{cf} = (4,449,600)(\$.4481) = \$1,993,866$$

$$R_{pf} = (744,590)(\$4) = \$2,978,360$$

Subsidy = (744,590)($3) = $2,233,770