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Efficiency and Equity Implications of Alternative Transit Fare Policies

FINAL REPORT
SEPTEMBER 1980

U.S. DEPARTMENT OF TRANSPORTATION
Urban Mass Transportation Administration
Office of the Secretary

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16. Abstract

This study explores efficiency and equity implications of flat fare systems using revenue, cost, trip making, and demographic data from transit operators serving the Los Angeles, Oakland, and San Diego areas. Revenues paid by transit users for each mile of service are compared with the unit costs of their trips. The ratio of users' fares to costs per mile of travel are analyzed with respect to distance, time-of-day, and rider demographics in order to draw efficiency and equity inferences. The three case studies' fare structures were found to embody considerable inefficiencies with respect to distance and time period of travel. Short distance, off-peak patrons paid disproportionately high fares for their trips. Morning and evening peak hour passengers were also major beneficiaries of flat fare systems, on average generating revenue-to-cost ratios twenty percent below those of off-peak users. The incidence of redistributive impacts appeared less regressive among income and age groups than had been anticipated. Based upon current disparities in pricing, a range of alternative pricing scenarios was investigated. Finely graduated price structures appeared the most promising in equalizing price disparities and eliminating regressivity. More coarsely differentiated fare structures seemed best suited to improving each system's financial posture because of both their high revenue productivity and low collection costs. Fares differentiated by both distance and time-of-day appeared to provide a balance of efficiency, equity and revenue benefits.

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Efficiency and Equity Implications of Alternative Transit Fare Policies

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EXECUTIVE SUMMARY

Introduction

The financial position of American transit systems has deteriorated markedly over the past decade. The industry's operating costs nearly tripled from $1.7 billion in 1968 to $4.7 billion in 1978, while revenues during the same period increased by only 53 percent - approximately half the rate of inflation. Nationally, the gap between transit revenues and costs grew from $161 million in 1967 to $2.33 billion in 1978, an increase of 1,447 percent. These growing deficits have been covered by a variety of local, state, and federal subsidies, but the current period of fiscal stringency requires that other remedies be evaluated. Changes in transit pricing hold promise for improving the financial position of the industry, while enhancing equity and efficiency in transit operations. While the average length of a transit trip has grown and travel has become more concentrated in the peak, many operators have ironically switched from differentiated pricing systems to flat fares. Because longer trips cost more to provide than shorter ones, and peak hour trips cost more than off-peak ones, flat fares produce declining revenues compared with fares which vary with trip distance or time-of-day. Long-distance travelers and peak-hour travelers are thought to have higher incomes than short-distance and base-period travelers, so flat fares also give advantage to those with the most ability to pay while hurting those with the least ability to pay (pp. 5-8).

Research Methodology and Major Findings

This study explored efficiency and equity implications of flat fare transit pricing, and several alternative pricing policies, including charges which vary with distance traveled and time of day. Using detailed information on revenues and costs of transit trips in the Los Angeles, Oakland, and San Diego metropolitan areas, revenues paid by transit patrons for each mile of service were compared with the unit costs of their trips. The ratio of users' fares to costs per mile of service were analyzed with respect to trip length, time-of-day, and demographic characteristics of the travelers. A representative sample of bus lines was chosen for the Southern California Rapid Transit District (SCRTD), the San Diego Transit Corporation (SDTC), and the Alameda-Contra Costa Transit District (AC Transit). Disaggregate information on fare revenue, trip length, time-of-day, and socio-economic characteristics of travelers were obtained from responses to on-board surveys which had been conducted by the three companies. In addition, the cost incurred to serve each sampled traveler was estimated, using disaggregate cost accounts of the three operators. To estimate the cost of serving each passenger, a daily operating cost estimate was derived for the sample transit lines using individual cost allocation models for each transit company. These models apportioned a share of each property's total costs to specific lines based on such characteristics as vehicle miles, vehicle hours, and peak vehicles in service. Separate cost estimates were prepared for each operating division of each company in order to insure proper recognition of cost variations within transit operations as well as between them. Daily costs were divided into peak and base components to reflect the cost implications of labor agreements which prohibit part-time labor and limit split-shift work duties. Capital depreciation expenses were allocated to each route's peak and base period. Consequently, total peak and off-peak unit costs were estimated for every bus route in the sample (pp. 23-43).

So that costs could be compared with revenues at the disaggregate level of individual passengers, both costs and revenues were expressed per passenger-mile. Revenue per passenger-mile was obtained by dividing each passenger's payment by the length of his or her trip. Cost per passenger-mile was estimated for peak and base periods by dividing time-of-day cost estimates by the passenger-miles served in each time period. Hypotheses regarding efficiency and equity of pricing policies were then tested by comparing revenue per mile with cost per mile, and determining how these comparisons varied with trip length, time-of-day, and ridership characteristics such as income, age, gender, etc. Average costs per passenger-mile of service were between twenty and twenty-three cents for the three transit properties, and for all three agencies these costs declined with increasing trip length. Revenue per passenger-mile varied considerably among express, local, inner-city and suburban bus services, and with varying trip lengths for each type of service. All three operators incorporated surcharges for express or premium services, and all employed a variety of prepayment arrangements for monthly transit passes. These variations resulted in costs per passenger-mile which ranged from less than one cent for some trips to more than eight dollars for others, though these values were the extremes of the cost spectrum (pp. 45-76).

Efficient pricing would produce high positive correlations between trip costs and revenues for a variety of trip lengths and times-of-day. For all three operators, however, there were high negative correlations between unit costs and unit revenues as trip lengths varied. Riders paying the lowest fare per mile of travel were generally those whose trips had the highest unit costs; shorter trips produced higher revenues than costs, while longer trips incurred costs which exceeded revenues. Similarly, mid-day services generally returned the highest share of unit costs through the farebox, while peak period services were found to recover less than one-third of their costs through fares. Trip length and time-of-day are not independent variables, however. For all three operators average trip lengths during the peak exceeded average off-peak trip lengths by several miles, and statistical tests showed the two variables to be associated. Analysis of variance revealed that trip length explained significantly more variation in the ratio of revenue to cost per passenger-mile than did time-of-day. This finding implied that alternative fare structures incorporating distance-based pricing would contribute toward a reduction of inefficiencies and inequities with respect to time-of-day as well as distance traveled (pp. 77-97).

While inefficient and inequitable patterns of pricing were clearly established for all three operators as a function of trip length and time-of-day, variations with income, age, ethnicity, and gender were less substantial and more ambiguous. For example, for two of the three operators, current fares seemed regressive. As passenger income rose, the ratio of revenue to cost per passenger-mile fell. For one operator, however, current pricing was mildly progressive, in that a higher proportion of cost was recovered through fares from upper income than from lower income riders. For only one of the three transit operators did car owners pay a significantly higher proportion of the costs of bus trips than carless patrons, and for only one of the three operators did women pay a significantly higher share of their travel costs than men. Current pricing policies, of course, did provide senior citizens and handicapped patrons the largest subsidies in accord with national policy requiring reduced fares (pp. 97-115).

In addition to current fare policies a set of alternative fare patterns was evaluated for each of the three transit operators in an effort to identify more efficient and equitable pricing policies. Before analyzing different fare structures, however, it was important to recognize that new pricing policies would have two important impacts upon operating costs and revenues. First, fare changes would induce changes in ridership levels. These, in combination with the new fare schedules, would produce changes in revenue. To estimate the changes in patronage which would follow from new pricing policies, disaggregate estimates of fare elasticity were prepared for each company, based upon actual changes in ridership which had occurred after recent fare changes, and upon evidence from other cities. Elasticities were estimated which varied with age, income, trip length, and time-of-day, in an effort to be as precise as current data allow. In addition to changes in patronage and revenue, new fare structures would also cause changes in capital and operating cost, specifically in the cost associated with fare collection. It was assumed that pricing which varied with trip length and/or time-of-day would require new automatic fare collection machines, and estimates of their costs were obtained from their manufacturers. Capital and operating costs were revised to reflect these added costs for new fare collection policies (pp. 117-136).

Using the revised operating costs, and applying transit fare elasticities to current ridership patterns, costs and revenues were compared for all sample transit lines assuming a stage pricing system, fares graduated linearly with distance traveled, and fares which varied logarithmically with distance. Similarly, peak hour pricing differentials were tested, and some changes involving different pricing of passes were also evaluated. The analysis showed that distance-based fares appeared to offer opportunities for improving the efficiency and distributional impacts of pricing. Coarse fare strategies, such as stage pricing, have lower implementation costs but cause larger changes in ridership than do more finely graduated fare structures. On the whole, the benefits of investment in distance-monitoring fare collection systems seemed justifiable given their potential for increasing revenue and patronage, but few equity benefits would be gained by peak/off-peak differentials. Fares incorporating both distance and peak/off-peak differentials were able to most closely match unit revenues to unit costs, while improving upon some of the maldistributive effects of current pricing arrangements (pp. 137-163).

Because each of the case study transit operators had announced its intention to raise fares during the course of this research project, the techniques described above were applied to evaluate their proposed new fare schedules in comparison with existing pricing. The proposed changes were generally increases in fare which did not incorporate any major structural reorganizations of fare policy. Two of the three proposals were found to perpetuate missallocative and maldistributive effects of current pricing policies, while the third offered only minor improvements (pp. 164-170).

Summary of Major Conclusions

Five principal findings have emerged from this research which can be summarized as follows:

a. Effects of Pricing on the Industry's Financial Posture: Transit agencies are facing unprecedented financial hardships caused by spiralling costs matched with constant farebox revenues. Higher costs can be partly attributed to longer trips and an intensification of peak hour usage. While costs have escalated over the past fifteen years, prevailing practice has been to keep fares low and underwrite deficits. Not only have average fare levels declined in real terms, but price structures have generally become less and less differentiated. Consequently, today's fare structures are largely insensitive to travel and cost trends, charging constant fares regardless of when and where patrons travel (p. 171).

b. Estimates of Transit Costs: Traditional cost allocation models fail to acknowledge that transit expenses vary by time-of-day and service type. Aggregate models reinforce mispricing by allocating average rather than marginal costs to particular services. A multi-stage process was used in this research to refine cost estimates. Cost centers equations were developed which captured unique cost features of operating divisions. Costs were further divided into peak and base period components to reflect the penalizing effects of labor union restrictions on each property's wage bill. Among the three study sites, drivers' wages were effectively between 20 and 30 percent higher during the peak than the base for every hour of duty. In all three cases, over one-half of total expenses were attributable to the peak, even though the peaks' share of total ridership and revenue was less than 45 percent. On a per passenger-mile basis, peak costs were around ten percent greater than those in the base (pp. 171-172).

c. Inefficiencies in Current Pricing: Disparities between users' fares and trip costs were largest in terms of travel distance. Those traveling less than two miles were generally found to cross-subsidize other users. Short distance patrons were paying between ten and twelve times as much per mile for their trips as the average user. Beyond six miles, the gap between unit revenues and unit costs was fairly constant for all journeys. Thus, redistribution was positively skewed in terms of trip distance. Price disparities were also prevalent between peak and base periods. Off-peak patrons generally paid forty to fifty percent more revenue per unit cost than their peak period counterparts. A slightly positive association was found between peak period usage and length of travel, suggesting that distance pricing could also reduce temporal discrepancies (p. 173).

d. Inequities in Current Pricing: Overall, the redistributive effects of current fare practices appeared to be mildly regressive. Those with lower incomes were generally found to pay disproportionately higher fares, although the relationship was not as strong as one might have expected. Cross-subsidization appeared more closely related to users' transit-dependency than ability-to-pay: carless patrons generally paid higher fare rates than users owning vehicles. On average, those who were minorities, female, college-age, and making medical trips served as cross-subsidizers. However, pricing disparities were much more strongly associated with trip distance and time-of-day than with user demographics (p. 173).

e. Policy Implications of Alternative Pricing Structures: Differential fare structures offer promise for improving the industry's financial performance.

As price structures become more finely differentiated, major improvements in price efficiency and equity could be expected. Fares graduated as a linear function of distance seem particularly responsive to current pricing deficiencies. Differentiated structures also appear capable of generating appreciably higher revenue returns. Moreover, each agency's operating ratio would likely increase significantly under variable pricing, suggesting that the higher collection costs associated with fare differentials could probably be justified on a financial basis. In general, the relatively low collection costs of coarse fare structures could be expected to raise the overall fiscal performance of stage or peak-load pricing above that of graduated pricing. Under conditions of deficit constraints, stage or peak-load structures emerge as attractive pricing options. Where economic efficiency and distributional equity are primary objectives, finely graduated pricing holds considerable potential (p. 173).

The research showed that differentiated price structures seem responsive to many of the problems associated with flat fare systems. As fare structures more closely match prices to marginal costs, improvements in revenue levels, efficiency, and equity can be obtained. Although a thorough analysis of political and implementation issues was beyond the scope of this study, some of the barriers to differentiated fares were enumerated. These include political priorities which differ from economic criteria, and possible objections from organized labor where the changes imply added work responsibilities. In addition, there are potentials for fraud unless differentiated fare mechanisms are carefully designed. The findings of this study clearly indicate that potential economic benefits of differentiated pricing warrant further study of the institutional and political aspects of such pricing policies (pp. 174-178).

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CHAPTER ONE

INTRODUCTION: TRANSIT FARE POLICIES

1.1 Context of the Problem

Interest in urban transit fare policies has gained momentum in recent years. This surge of interest has paralleled dramatic financial decline in the public transit industry. With the cost of transit services growing at an unprecedented rate of seventeen percent annually since 1967 - nearly twice the general rate of inflation - transit officials have found themselves searching for sufficient revenues to halt the financial deterioration of the industry. However, revenues from the farebox have failed even to keep up with inflation much less increases in operating costs. Nationally, the result has been a staggering growth in public transit's annual deficit, reaching 2.33 billion dollars in 1978 (American Public Transit Association, 1979). With growing pressure to hold down government spending, transit managers are beginning to question the propriety of current pricing practices. Most face the challenge of restructuring fare systems so as to become more responsive to budgetary constraints and escalating costs.

Many transit operators today employ flat or simple zone fares which charge essentially a constant, uniform price regardless of when or how far a passenger travels. Moreover, the response of transit officials to sharply rising deficits has invariably been across-the-board fare increases, irrespective of which trip types are most responsible for cost increases. Although simple fare structures and uniform price changes seem to be the most palatable pricing options among politicians and certain groups of transit patrons, serious questions can be raised concerning their efficiency in generating farebox revenues adequate to cover costs. Flat fares and across-the-board price increases violate fundamental principles of economic efficiency and distributional equity which call for prices which reflect the costs of providing services. More specifically, they fail to collect sufficient increments of revenue from those users who impose the greatest costs on transit systems - primarily peak period commuters and long distance travelers.

Transit costs are markedly higher during peak periods and for long trips primarily because additional employees must be hired to accommodate rush hour loads and driver tours must be extended to serve outlying areas. Thus, uniform pricing which sets the fare near the average cost of serving all trips forces the rider who travels six blocks during an off-peak hour to offset the relatively high costs incurred in serving the commuter who travels sixteen miles at rush hour. As a result, peak and long distance users are effectively being cross-subsidized. They are purchasing far more service for their fares than other passengers. In economic terms, the marginal revenues received from long distance, peak period users fall short of the marginal costs of serving their trips. These losses in efficiency are partly made up by overpricing short distance trips during non-peak periods.

The equity implications of fare cross-subsidization are important since the preponderance of long-distance trip-makers and peak period patrons are generally from groups with incomes higher than the average rider. It is widely hypothesized that transit pricing practices result in a regressive transfer of income from the poor to the rich. Altshuler (1979, p. 284) notes that "peak period service expansion (to suburban areas) tends more generally toward regressivity, because transit usage by low-income people (who have low rates of labor force participation and high rates of transit utilization for non-work trips) is much less concentrated in peak periods than that of other groups." Further, it can be postulated that ethnic minorities, females, and the socially-disadvantaged are fare cross-subsidizers under most current transit pricing policies. Not only do simple pricing systems possibly result in regressive fare cross-subsidization, but they potentially deprive short-distance and off-peak riders the opportunity to make a trip. Lisco (1970, p. 64) points out that many trips would be economically worthwhile at a fare approximating the cost of providing service, but are frequently not worthwhile at the cost plus the price of subsidizing longer (and peak period) trips. Transit operators, in turn, lose the opportunity to earn more revenue from these foregone trips and to efficiently utilize excess seating capacity during non-rush hour periods.

The primary purpose of this study is to contribute to an understanding of transit fare policies and the role which alternative pricing strategies could play in improving the efficiency and equity of transit services. Much of the analysis is drawn from the revenue and cost characteristics of three transit properties: the Southern California Rapid Transit District (SCRTD) serving the Los Angeles metropolitan area, the Alameda-Contra Costa Transit District (AC Transit) serving the Oakland area, and the San Diego Transit Corporation (SDTC). Several hypotheses regarding the economic efficiency of pricing policies are tested statistically by comparing fare revenues with marginal costs of serving trips of varying distances in both peak and off-peak periods. Also, the level of fare cross-subsidization among various socio-economic user groups is traced in order to illuminate issues related to distributional equity and to test hypotheses concerning the incidence of transit pricing practices. Based on deficiencies identified in the analysis of existing fare policies, remedial ones are presented and analyzed in terms of their potential contributions to efficient and equitable transit pricing. The intent is to shed new light on a normative approach to transit pricing - one which could improve transit's financial performance as well as its distributional impacts.

1.2 Concepts of Efficiency and Equity

Efficiency and equity are two criteria used frequently to evaluate the policy implications of public decisions. This study views efficiency in terms of what welfare economists call the "benefit" principle: users should pay revenues to cover the costs of transit services in proportion to benefits they receive. Efficiency is assessed by comparing relative differences in the costs incurred and revenues received in serving trips of varying distances and times-of-day. Thus, the efficiency criterion relates to distance and time-of-day price disparities. Equity, on the other hand, is viewed in terms of the "ability to pay" principle. Users should contribute to the cost of services according to their capacity to pay. At minimum, any redistributive impacts of pricing should not be advantageous to those most able to afford and least dependent upon transit services. Thus, equity is used in reference to price disparities related to users' incomes and other demographic characteristics. It follows that the "fairest" fare would be one which eliminated transfer effects altogether by charging users the true costs of serving them. As defined in this study, efficiency and equity are complementary criteria.

1.2.1 Pricing Efficiency

Welfare economists have laid the foundation for evaluating economic efficiency, primarily under the rubric of "marginal social cost pricing." This principle states that efficiency in the utilization of resources available to society is achieved when the price of goods and services is set equal to the marginal social[1] cost of producing them. With respect to public transit, efficient pricing requires that fares be set equal to the derivative, with respect to output, of a transit property's total social cost production function.

Transit's marginal social cost falls below its direct marginal cost since public transportation provides many tangible benefits to society: reduced pollution; energy conservation; improved land use patterns and the like. Such benefits accrue to everyone in a community, regardless of their use of, or contribution to, public transit. It is often argued that transit subsidies are justified on the grounds that transit is a "merit" good. All of society enjoys real benefits which cannot be achieved through private market mechanisms. Since most transit systems today 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 reap the full benefits of public transit. Placing a precise monetary value on transit's full range of benefits is an exceedingly difficult task, necessitating the shadow pricing of such noncommensurable benefits as reduced air pollution and travel time savings.

In recognition of the difficulties posed in measuring social costs and benefits, this study considers only those direct costs and benefits reflected by transit management's expense ledgers and users' fares. It is assumed that social marginal costs and benefits are encapsulated in the current subsidy policies of the SCRTD, AC Transit, and SDTC. Thus, pricing is analyzed not from society's point-of-view, but rather from that of the transit user and the transit operator. By addressing only direct transit costs and benefits, this research does not attempt to arrive at a socially optimal level of transit pricing, but rather to identify a more efficient and equitable structure for transit fare systems.

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[1] Social costs, vis-a-vis private costs, are those costs which accrue to all of society but not fully to the individual decision maker. Social costs include those which are secondary, external, and indirect in nature, such as air pollution or neighborhood disruption.

In sum, efficient transit pricing is to be viewed in this research as setting fares which equal the direct incremental costs of providing additional units of transit services, holding current subsidy rates constant.[2]

Accordingly, this study uses efficiency as a criterion for evaluating whether fares sufficiently offset the incremental costs of services, with production output measured according to distance and time period of travel.

1.2.2 Equity in Transit Pricing

Equity is an ethical concept denoting such virtues as "fairness," impartiality," and "social justice" (Rawls, 1971; Miller and Roby, 1970; and Altschuler, 1979). As a philosophical construct, "equity" resists attempts at precise definition, relying instead on individual perceptions and subjective interpretations. Obviously, no individual possesses the right to pass judgment on what is "fair" for everyone. Rather, democratic processes provide legislative and judicial forums for defining the parameters of equity and justice. Thus, the concept of equity falls more into the domain of politics and social policy than traditional economic theory.

This study employs the equity concept to evaluate disparities in fares and costs among income and socio-economic groups. Whereas the efficiency criterion employs the benefit principle, equity is assessed on the basis of patrons' ability to pay and transit dependency. When taken to an extreme, the ability-to-pay concept would call for fares to vary according to income capacity. As Gans (1968, p. 74) notes, however, people generally "want society to be fair, not equal." This research, therefore, views equity as setting fares so that redistributive impacts 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 posited 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 (marginal cost) pricing could also serve to promote equity.

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[2] This definition of pricing efficiency should be compared with the concepts of "efficiency" and "effectiveness" frequently used by transit managers and planners in evaluating transit system performance and productivity. The "efficiency" of transit operations indicates how well resource inputs such as labor and capital are utilized to produce varying levels of service output. Efficiency is typically measured in terms of revenue vehicle hours and miles per employee. "Effectiveness," on the other hand, indicates how well a system achieves output goals which have been set for it, and usually is expressed by service utilization measures such as revenue passengers per vehicle hour (Fielding and Glauthier, 1976; Dajani, 1978; and U.S. Department of Transportation, 1978). As performance indicators, "efficiency" serves as a measure of system management while "effectiveness" provides a measure of system utilization.

1.3 Trends in Transit's Financial Performance

1.3.1 Financial Decline of the Transit Industry

The financial posture of urban transit has deteriorated rapidly in recent years.[3] Whereas nationwide, the transit industry met operating costs through the farebox as recently as the mid-1960's, today fare revenues cover only one-half of costs. While the industry's operating costs nearly tripled from $1.7 billion in 1968 to a staggering $4.7 billion in 1978, revenues lagged far behind, increasing only 53 percent - approximately one-half the rate of inflation. The bottom line of the transit industry's balance sheet shows a startling 1,447% growth in revenue shortfall, increasing from $161 million in 1967 to $2.33 billion in 1978.

In real dollar terms over one-half of transit's cost increase can be attributed to labor compensation (Sale and Green, 1979). During the past several decades, the transit industry has generally experienced wage and fringe benefit increases which have outpaced inflation. Gomez-Ibanez and Meyer (1977) have estimated that between 1948 and 1970, the transit industry's annual wage rate increased some 15 percent more than wages in the private non-farm economy.

Associated with the rising transit wage bill are decisive productivity losses. Labor productivity - as measured in vehicle miles per employee - dropped eleven percent between 1968 and 1978. During the same period, there was a 21 percent decrease in passenger trips per employee. Since labor input accounts for about 80 percent of the industry's expense budget, the combination of rising wage rates and declining labor productivity has imposed major fiscal hardships on most transit operators.

1.3.2 Effects of Travel Distance and Peaking On Cost Escalation

In addition to labor influences, transit cost increases can be linked to changes in ridership demand with respect to travel distance and peaking. It is generally recognized that transit requires high-density urban land development to be cost effective (Meyer, Kain, and Wohl, 1965). Yet, the population outside central cities increased by 34 percent between 1960 and 1970 as opposed to 1.5 percent in central cities (U.S. Bureau of the Census, 1971). Altshuler (1979, p. 252) indicates that urbanized land area nearly tripled between 1950 and 1970 - from 12,733 to 35,081 square miles. "In consequence, there has been a 77 percent decline in the density of transit vehicle miles per square mile of urbanized area between 1950 and 1970."

Sale and Green (1979) provide some evidence that transit operations have responded to suburbanization and the dispersal of ridership by expanding routes and curtailing inner city service frequencies. Using national data, the authors found that the average number of bus route miles more than doubled from 1960

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[3] Unless indicated otherwise, most statistics presented in this section were derived from data published in the '78-'79 Transit Fact Book, American Public Transit Association.

to 1974; however, during the same period, transit firms actually reduced the total number of miles traversed by buses. In studying five metropolitan areas, they also estimated that trip lengths increased significantly over the past twenty years - ranging from a 52 percent increase in Philadelphia to a 124 percent increase in Atlanta. In approximately the same time period, however, they found a 50 percent decrease in one-way bus miles per route. Sale and Green conclude that the decentralization of urban areas has generally led to an expansion of some bus routes, a reduction of service levels on other lines, and a decline in overall labor efficiency.

The peaking of transit demand has been at least as important as the lengthening of passenger trips in the escalation of operating costs and losses of productivity. For transit service areas with populations over 100,000, approximately 60 percent of all ridership occurs during the twenty busiest hours of the week. The peaks' share of total ridership also seems to be on the rise. Oram (1979, p. 114) estimates that peak/base service ratio increased from 1.80 to 2.04 during the period 1960-1974. The cost implications of rising peak demands are severe since transit properties must hire additional workers who are needed only for a few hours of the day. Since most labor contracts prohibit hiring part-time workers or scheduling split shifts, the peaking phenomenon has also led to increased spread time and overtime work duties. Some observers have estimated that these factors have raised the cost of peak services to nearly twice that of the off-peak (Wagon and Baggaley, 1974). With wage rates outpacing inflation and miles of service remaining fairly constant, the consequences of labor expansion to serve the peak have been unmistakable: skyrocketing operating costs and declining labor productivity.

1.3.3 Trends in Fare Revenue and Transit Pricing

The willingness of local, state, and federal governments to underwrite the transit industry's swelling deficits reflects a changing philosophy toward transit pricing policies. Historically, fares were set at a level sufficient to defray operating costs and also provide a return to retire capital bonds. With the decline in transit ridership and the public take-over of most systems, there has emerged a growing nationwide political acceptance of governments' responsibilities to provide transit properties with operating assistance. According to Ortner and Wachs (1979, p. 18), "public ownership and heavy subsidation ... often reflect a desire to keep unprofitable services in operation in order to provide mobility to carless citizens, to reduce congestion on key commuter routes, to keep fares low, and to avoid confrontation with unionized public employees."

Nationally, while operating costs increased 110 percent between 1972 and 1978, from \$2.24 billion to \$4.71 billion, fare revenues rose only one-third as much, from \$1.65 billion to \$2.27 billion. In 1978 constant dollars, average transit fares actually decreased 23 percent since 1972, from 49.2 cents to 38.1 cents. As a result, transit subsidies grew from \$0.59 billion to \$2.44 billion during this period, a 413 percent jump.

Recent evidence suggests that declining fares and increasing public subsidies form a "vicious circle" - subsidies help to perpetuate lower fares which in turn lead to higher deficits. Using longitudinal data from fifteen nations including the United States, Webster and Bly (1979) report that each 10 percent increase of operating costs covered by subsidies is linked to a 5 to 7 percent fall in fare levels. It seems conceivable that if such trends continue, transit will ultimately become a free government service, subsidized wholely from public treasuries.

The decline in average (constant dollar) fares is a relatively recent phenomenon: between 1950 and 1970, average fares increased 62 percent in real terms, averaging 3 percent higher than the annual consumer price index (Peat, Marwick and Mitchell, 1974). The more recent trend toward fare stabilization and higher subsidies is attributable not only to lower fare levels but also to changes in the structure of transit pricing. While transit deficits began to grow during the late sixties, paradoxically flat fares began to gain in popularity among many transit operators. In a study of seven American cities west of the Mississippi, the Urban Mass Transportation Administration (1976) reported that all had switched from zonal pricing systems to either flat or far less graduated fare structures in the early seventies. By 1975, San Diego, Portland, and Los Angeles had eliminated 7, 11, and 318 zones respectively. Similarly, Frankena (1973) cited a renaissance of uniform fare systems in Canada, with the nation's six largest cities all abandoning multiple zone pricing in favor of flat fares by 1972. Worldwide, Gutknecht (1973) documented a dramatic changeover to flat and simple zone pricing between the early sixties and seventies in some ninety major cities; whereas graduated fare systems accounted for 55 percent of the sample in 1961, by 1972 the proportion dropped to one-quarter with flat and simple zone structures comprising the other three quarters.

Trends toward uniform fare structures suggest that transit pricing policies are fostering increasing levels of "inefficiency" and "inequity." Flat fares are insensitive to the cost impacts of changing travel behavior, including the lengthening of average trip lengths and the growth in peak hour travel. Together, the decline in (real dollar) fares and the conversion of price structures to flat systems have contributed directly to the financial deterioration of the transit industry.

1.3.4 Transit's Future Financial Prospects

Will transit's financial position continue to deteriorate in future years, with exponentially rising costs, faltering revenues, and perenially record-breaking deficits? One can only speculate based on recent events. With the passage of California's Proposition 13 and the growing political commitment toward fiscal austerity, there is mounting pressure on public agencies, including transit authorities, to balance their books and hold costs down. Within the transit industry, there are some positive signs that rampant cost escalation may begin to slow down. Section 15 of the 1964 Urban Mass Transportation

Act, as amended, mandates the development of uniform cost accounting procedures for the purpose of assisting transit managers in evaluating the productivity of their systems. An outgrowth of Section 15 has been the growing acceptance of annual "line-by-line analyses" which enable transit managers to identify and, if appropriate, eliminate inefficient services. Equally important have been labor concessions which allow the hiring of part-time workers in a number of cities including Seattle, Miami, and Minneapolis. Estimates of annual cost savings from the use of part-time labor in these cities range from two to nine percent (Public Technology, Inc., 1978), although Lave (1980) has challenged the potential of part-time labor as a cost-saving strategy.

Future prospects for improving transit's financial position through revenue channels appear less promising. There still appears to be a general hesitancy among most politicians to dramatically change fare levels. According to the Department of Transportation, state responses to a National Transportation Study survey revealed a common preference for fare stabilization, with the vast majority of respondents indicating either small or no fare changes in store through 1990 (McGillivray, 1976). Moreover, there are few signs that transit officials plan to reform current fare structures, with the possible exception of limited graduated pricing on selected express routes. In the case of SCRTD, the institution of 20 cent incremental surcharges on freeway express services was instrumental in raising the system's farebox revenue-to-cost ratio from 0.35 in 1977 to 0.46 in 1979 (Vandeventer and Woodhull, 1979). Based on this evidence, it seems reasonable that an even more extensive differential pricing structure could make significant progress in further reducing SCRTD's deficits. The reluctance of transit officials to reform fare structures in view of such evidence gives impetus to research on transit pricing.

1.4 Research Overview

1.4.1 General Methodology

The basic framework used for comparing the efficiency and equity impacts of alternative fare policies is a cross-sectional, cost-revenue analysis. For each of the three study sites, the pricing efficiency of existing fare policies is evaluated by comparing cost and revenue differences across various categories of trip distance and between the peak and off-peak periods. The distributional effects of current pricing practices are examined by stratifying the cost-revenue estimates according to such socio-economic variables as income, sex, age, ethnic background, and auto ownership. Following the statistical testing of hypotheses concerning the efficiency and equity levels of current pricing practices, remedial fare systems, such as distance-based and time-dependent fare structures, are evaluated. Practical considerations related to implementation problems of alternative pricing programs, technical issues, and broader national transportation policy implications are also addressed.

1.4.2 Specific Hypotheses

Six general hypotheses are presented below for testing the efficiency and equity implications of SCRTD, AC Transit, and SDTC's current fare policies. In the classical sense, hypotheses are presented as "alternatives" to the "null."

First, it is postulated that longer trips spurred by the outward expansion of urban areas have placed greater service demands on transit operators. Higher costs incurred in serving longer trips have not been offset by distance-based fares, resulting in inefficient pricing. The first hypothesis is:

> H_1: The ratio of revenue/passenger mile to cost/passenger mile is significantly lower for long trips than short ones.

The second hypothesis posits that heavy demands confined to peak periods increase transit costs far in excess of revenues, again contributing to pricing inefficiencies:

> H_2: The ratio of revenue/passenger mile to cost/passenger mile is significantly lower in the peak than the off-peak period.

The third hypothesis tests whether revenue/cost disparities related to distance and time-of-day of travel are equitable in terms of the "ability-to-pay" principle:

> H_3: The incidence of fare cross-subsidization is regressive, transferring income away from those riders who are financially less well off. Other socio-economic groups burdened with disproportionately high fares are those who own fewer cars, represent an ethnic minority, are female, and are at a non-working age.

Since longer transit trips may occur more often during peak than off-peak periods, it could be argued that time-of-day fare differentials would incorporate the distance factor into the pricing structure. Likewise, distance-dependent fares could capture some of the differentials between peak and off-peak costs. Which arrangement would be more efficient and equitable? It is hypothesized that time-differentiated fares are preferable to distance-dependant structures since, *a priori*, marginal cost differences are probably higher between the peak and base periods than between long and short trips:

> H_4: Disparities in marginal costs and marginal revenues between the peak and off-peak periods are larger than those between long and short trips.

Distance and time dependent fares may not be practical for all types of transit service. Rather, price-differentiation could be aimed at certain service types (i.e., express and inter-city operations) and specific user groups (i.e., suburban commuters). This reasoning leads to a fifth hypothesis:

> H_5: Differences in revenue/passenger mile and cost/passenger mile are significantly higher for express and inter-city services than for local and intra-city services.

It can be postulated that higher discounts for pre-paid pass users could reduce inequities inherent in flat fare structures. SCRTD (1978) planners have observed a relatively low volume of pass sales among riders on suburban lines, possibly due to infrequent off-peak usage and less accessibility to pass sales outlets. Thus, a reasonable sixth hypothesis is:

H_6: Pass users disproportionately travel short distances and during off-peak periods. Thus, differences in cost/passenger mile and revenue/passenger mile are relatively lower among pass users than non-users.

1.4.3. Study Organization

The remainder of this study consists of seven chapters. Chapter Two presents theoretical and empirical analyses of transit pricing based largely on a review of literature of marginal cost pricing and distributional equity. The chapter concludes with a survey of previous case studies on fare cross-subsidization. The third and fourth chapters describe how cost and revenues of the three transit properties were estimated and disaggregated in terms of travel distance and time-of-day. In Chapter Three, the study setting is reviewed, including a discussion of each system's current fare policies. Procedures used to select sample routes and to integrate data on passenger revenues, ridership demographics, and travel characteristics are discussed. The fourth chapter estimates unit costs associated with specific sample routes. Models are presented for apportioning costs to specific users according to time-of-day and distance of travel. Revenue, cost, and ridership data of the two chapters are merged for the purpose of analyzing current pricing policies. In Chapter Five, hypotheses described above are tested and pricing inferences are drawn. Through a comparative analysis of the three properties' fare policies, general observations on transit pricing efficiency and equity are presented. Chapter Six presents a number of issues which must be considered in the evaluation of alternative fare structures. These include the impacts of fare changes upon ridership, requirements for different fare collection equipment, and political issues which might affect implementation. Chapter Seven evaluates several pricing structures which have potential for improving the financial performance of each property. Elasticity estimates disaggregated according to distance and time period of travel are used to assess the impact on ridership of alternate fare systems. Differences in price efficiency and equity are compared under several differential fare scenarios. The final chapter is a summary of the research findings and a discussion of their implications.

CHAPTER TWO

THEORETICAL AND EMPIRICAL ASPECTS OF TRANSIT PRICING POLICIES

2.1 Introduction: Transit Pricing Theory

Many pricing principles from the public utilities field offer a theoretical framework for analyzing transit fare systems. In particular, the theory of peak-load and differential pricing, which emerged from the public utilities literature over the past several decades, provides insights for comparing uniform fare structures with time-dependent and distance-based transit pricing.

The rationale for viewing transit pricing from a public utilities perspective is derived from the characterization of the transit industry as a "natural monopoly" (Kahn, 1971; Van Tassel, 1956; Mohring, 1970). Four "natural monopoly" properties which transit may share with electric, gas, and water utilities can be identified: large fixed capital investments; nonstorable services; fluctuating demand with heavy peak loads; and inherent increasing returns to scale. There is some debate as to whether these properties characterize bus operations to the same extent as rail operations.

Though it is commonly accepted that the transit industry enjoys increasing returns to scale, evidence is inconclusive. Using national data from 1960-1969, Wells et. al. (1972) suggest tendencies toward transit scale economies by noting that cost per mile declines with increases in the total number of vehicle miles for ten of eleven systems studied. Likewise, Lee and Steedman (1970) reveal similar decreasing unit cost characteristics among larger British transit systems during the same approximate time period. More recently, however, Wabe and Coles (1975b) have argued against conventional views on transit scale economies based on 1973 findings that most British bus systems exhibit proportionally higher costs as fleet size increases. Since larger bus systems tend to operate under conditions of greater surface street congestion and stronger union pressures on driver wages, some incidences of diseconomies of scale may actually exist within the transit industry.

Economies of scale in the transit industry, like most public utilities, place the two primary function of pricing in direct conflict. One major function of pricing is revenue generation. The revenue function calls for prices which generate returns sufficient to recoup the costs of producing services. Historically, regulatory practice in the United States has been directed toward ensuring that public utilities recover total costs by setting price levels which correspond to average costs. An equally important function of pricing, however, is efficient resource allocation and rationing. Efficiency criteria require that transit and utility prices be set at marginal costs to reflect the value of real opportunities foregone in producing services. Thus prices should also serve as mechanisms for rationing society's scarce resources to those services which provide consumers with greatest satisfaction (as reflected in their willingness to pay). Since the incremental cost of producing additional transit or electricity service falls below average cost under conditions of scale economies, adherence to marginal cost pricing implies deficit-spending, typically requiring some form of public subsidization. Therefore, natural monopolies face the perverse task of achieving two conflicting objectives: cost recovery and efficient resource allocation.

Price discrimination has become an accepted component of many public utilities' pricing structures. Discrimination provides a means for more closely approaching economic efficiency while also recovering total costs. Under perfect price discrimination, charges are fashioned according to what the market will bear - that is, what electricity users or transit patrons are willing to pay (Kahn, 1971). Since most public utilities operate under monopoly powers, submarkets which place high values on services can be singled out for higher prices (in order to increase revenues and maintain price efficiency). If transit were priced according to discriminatory principles, peak users with relatively inelastic demands might be levied charges higher than the marginal costs of their trips so as to increase total system revenue. Given that peak ridership volumes would remain essentially the same and that the additional utility derived by peak users would be at least equal to the incremental value of alternative goods and services, price discrimination would increase not only total transit income but also social welfare.

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 actually <u>non</u>-discriminatory. Discrimination exists only when price differences charged are not equal to the differences between the costs of providing marginal units of service to customers (Hirschleifer, 1958). Since it is argued that fare policies which equate prices with marginal costs are efficient, equitable and financially more solvent, differential transit pricing systems should actually be considered non-discriminatory.

In its purest form, a differential fare structure based on marginal cost pricing principles would set each rider's fare exactly at the incremental cost of supplying service. The pure marginal cost pricing scheme would require each patron's fare to fluctuate continuously according to hour of the day, congestion level, exact trip length, service quality, etc. Of course, the precise marginal cost of accommodating one additional passenger would be so small as to defy measurement. As more and more passengers boarded the bus, however, capacity would eventually be exceeded and an additional vehicle would be required. Thus, the marginal cost based on a small unit of measurement would be practically zero until a vehicle reached its physical capacity whereupon the marginal cost of the next rider would rise precipitously (Van Tassel, 1956). To avoid sharp fare changes, Hotelling (1938) first suggested the use of an averaging process for computing the marginal costs of transit based on the probability of having to run another bus. Loehman and Whinston (1971) and Train (1977) have estimated the expected marginal cost of an individual passenger by combining average variable costs with the expense of adding an extra bus (pro-rated according to individual probabilities of usage).

Obviously, transit prices set according to pure marginal costs (or even an "average cost per head" index as suggested by Hotelling) would be impossible to measure with any degree of accuracy. Moreover, an elaborate system of constantly-changing fare differentials would be prohibitively expensive to implement. A more practical differential fare structure would strike a compromise between highly detailed marginal cost pricing and simple (average-cost) uniform pricing.

"Incremental costs," a term employed by accountants and business analysts, represents a more operational approach to evaluating efficient transit pricing. Larger unit measures of transit output, such as distance increments and peak/off-peak time periods, provide a pragmatic yardstick for assessing cost changes. By levying a fare commensurate with the average cost of serving all patrons traveling equal increments of distance or during the same time period, a reasonable approximation of marginal cost transit pricing can be achieved. Thus, efficient and equitable transit pricing systems such as time-based and distance-dependent fare structures are perhaps best viewed as "incremental" or "quasi-marginal."

The analysis of distance and time "increments" of transit costs can be refined further by dividing expenses into fixed and variable cost components. Fixed costs typically represent long-term capital expenses incurred for equipment and rolling stock, buildings and rents, garage facilities, and general administrative overhead.[1] Variable costs, on the other hand, represent day-to-day operating expenses for labor compensation, fuel, maintenance and the like. As the name implies, variable costs fluctuate considerably with distances traveled and intensity of usage. Fixed cost, however, are invariant over a wide range of transit service levels. In a spatial analysis of efficient transit pricing, fixed costs can be largely ignored since distances traveled do not significantly affect capital and overhead costs - basically the same amount of equipment is needed for either a short or long trip. Such is not the case, however, from a time-of-day perspective. It is essentially the morning and evening peak demand for transit which determines the number of buses which must be acquired, the size of administrative overhead, the scale of repair and maintenance facilities, and generally the entire infrastructure of the transit property. Consequently, fixed costs are an important component in measuring the incremental cost differences between the peak and base periods.

An important distinction between variable and fixed transit costs is the time horizon in which expenses are incurred. Variable costs occur over the short run. Given the current capacity and fixed investments of a transit property, it is the short run costs which are relevant in determing the appropriate amount of transit service to produce and the prices to charge riders. As Wohl (1973, p. 624) points out,

> "Once a facility exists, the best we can do is to maximize public net benefits from day to day, regardless of whether good investment decisions were made in the first place.

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[1]Many fixed transit investments are assumed to have long lives, typically 10-15 years for rolling stock such as buses, 5-15 years for administrative and maintenance equipment, and 40 years for buildings and garages. Since some transit companies operate with a relatively long-term union contract which prevents the quick discharge of some members of the labor force, it could be argued that labor costs are also fixed expenses.
Dygert, et al. (1979, p. IV.2) argued that labor costs may actually be relatively more fixed than capital since equipment is frequently leased or sold during the course of its life.

> Good pricing cannot overcome bad investment decisions ... The essence of this recognition is that pricing is a day-to-day proposition. Since fixed costs cannot be affected from day to day ... we should ignore them and concentrate only on variable costs."

Accordingly, transit fares should be set at the short run marginal cost (SRMC) of providing service, since the SRMC reflects the value of resources used in producing an additional unit of service given past investment decisions. Because the length of transit trips affect only variable expenses such as fuel and hourly wages, distance-dependent fare structures should be set solely according to the SRMC of service.

From the long run perspective, an important decision facing transit officials is the proper scale of operations necessary to accommodate peak demand levels. Long run costs become particularly relevant to transit pricing whenever high levels of ridership require capacity expansion. At some point, new capital expenses become a cheaper substitute for high variable costs which would have to be incurred if service output were to be expanded to satisfy ridership demands. The appropriate pricing rule to apply whenever demand levels approach capacity is the equation of fares with long run marginal costs (LRMC); that is, fares should equal the addition to total transit costs necessary to expand capacity sufficiently to produce one more unit of service. Accordingly, the efficient transit company would expand service to the output level where the SRMC of accommodating peak riders just equals the LRMC of additional capacity. Accordingly, a peak user's fare should capture both the SRMC of his or her trip plus the incremental cost of capacity on which he or she draws.

To the extent that the wear and tear of transit equipment varies with use, it can be argued that the annual depreciation of fixed capital is actually a variable rather than fixed cost. Since most transit managers maintain cost estimates (including those for capital debt service payments) on an annual basis, it follows that short-run expenses actually serve as the basis for most transit pricing decisions. Therefore, it seems appropriate that time-of-day transit pricing also be viewed with reference to SRMC under the assumption that all capital depreciation varies directly with service utilization.

The foregoing discussion has argued that an efficient system of transit pricing would set all fares at the short run marginal cost of service. It is the SRMC which accurately reflects the value of alternative resources consumed in the production of an extra unit of transit service. To the extent that transit behaves as a "natural monopoly" with increasing returns to scale, however, pricing at the SRMC leads to revenue shortfalls. Differential pricing represents a non-discriminatory approach recovering costs through the farebox while also ensuring a more economic utilization of transit resources. Given the obvious complexities of measuring the precise SRMC of accommodating every transit patron, the average costs of serving equal "increments" of trip distances and the average costs of peak versus off-peak service emerge as pragmatic approaches to efficient differential pricing.

2.2 Alternative Approaches to Transit Pricing

2.2.1 Introduction to Alternative Pricing Concepts

Transit fare policies which are based on marginal cost pricing rules are not necessarily appropriate for all transit agencies in all instances. The efficient pricing principles discussed previously must often be tempered by other objectives which transit policymakers are striving to achieve. One such objective might be to limit operating deficits which, under conditions of scale economies, would call for fares to systematically deviate from marginal cost prices in inverse proportion to price elasticities of demand. Other considerations could warrant an even greater departure. For example, whenever market imperfections or competitive distortions exist for close substitutes such as the automobile, it can be argued that transit fare structures should be designed to redress price imbalances. Also, officials may wish to price transit so as to reflect the quality of service, to improve distributional equity, or to increase overall ridership levels in order to reap the full benefits of transit's external economies.

This section reviews a number of transit pricing approaches which represent alternative fare structures. The following three alternative pricing rationales are considered: 1) Responses to Highway Underpricing; 2) Time-Valued Fares; and 3) Quality-Based Fares.

2.2.2 Responses to Highway Underpricing

The existence of pervasive imperfections in the economy may warrant a conversion from "optimal" to "second-best" pricing. In the case of transportation, misallocative effects result when motorists face only the private rather than marginal social costs of travel. This cannot be overlooked in an analysis of transit fare policies. Highway congestion, excessive fuel consumption, and high pollutant concentrations are all symptoms of the failure to price highway use at a true marginal cost. Abe (1973) and others have suggested the application of "second-best" pricing principles which would set transit fares considerably below marginal costs to partly compensate for the resource misallocations resulting from the historical underpricing of the automobile. Vickrey (1973, p. 252) notes that even if transit services were completely free, "the annual subsidy per passenger for the peak hour ... or suburban transit rider would (still) be far below that being offered the private-car commuter."

Whenever rush hour congestion is dependent on the relative price of transit and auto travel and the two modes are close substitutes for one another, it can be argued that peak-load transit pricing reduces overall social welfare. If peak riders are charged a fare corresponding to their full marginal costs while motorists face only their average private costs, the resulting increase in highway congestion could cost society more than is saved from a reduction in peak demand for transit (Vickrey, 1973; Glaister, 1974). Thus, any revenue gains received from increased peak prices must be balanced against the efficiency losses sustained from the marginal congestion imposed by transit users switching to the auto mode. In an analysis of bus and rail fare structures and their mutual influences on road congestion in London, England, Glaister and Lewis estimated that "second best" transit fares would be 8 and 18 cents per passenger mile in the off-peak and peak periods respectively, approximately one-half the level of "first best" marginal cost fares. The implication, therefore, is that peak-load pricing should be modified by depressing fares for both times of day below marginal costs so as to attract peak auto and transit users to off-peak buses and to attract rush hour motorists to the transit mode.

Some observers have further argued that certain situations merit the lowering of peak hour fares below those in the off-peak as a second-best congestion-minimizing solution to the mispricing of highway usage. Ponsonby (1958) proposed the raising of fares during non-peak periods in order to expand rush hour transit services beyond what peak users could afford so as to reduce overall road congestion. More recently, Sherman (1971; 1972) suggested that in the presence of congestion interdependence between the auto and transit modes, circumstances may arise when off-peak riders should be charged an optimal fare at their corresponding marginal costs while peak users should pay a "second-best" fare below their average costs. Since during peak periods average costs are less than marginal costs, "second best" pricing practices could result in peak fares which actually fall below "first-best" off-peak ones.[2]

The second-best pricing of transit services in response to highway misallocations relates closely in concept to another possible fare policy objective: ridership maximization. This argues that transit's "effectiveness" can only be maximized by exploiting the potential external economies which transit offers, such as energy savings and improved urban development patterns. Taken to the extreme, the objective of ridership maximization would call for either a free or negative fare in order to lure auto users over to the transit mode. In the more usual situation of limitations on deficits, however, fares would be reduced to attract new customers only to the point where the marginal subsidy per additional rider would be relatively low.

Proposals for pricing transit services on the basis of either "second best" compensatory principles or ridership maximization objectives have not escaped criticism. One counter-argument maintains that "two wrongs don"t make a right." Opponents to subsidized fares point out that the underpricing of transit only serves to worsen the resource misallocations already existing in the transportation sector. By pricing transit below marginal social cost, it is argued, scarce resources which have higher utility in alternative activities would be wasted, thereby leading to greater urban sprawl and excessive energy consumption. Meyer, Kain, and Wohl (1965) recommend correcting highway misallocations through direct measures (i.e., congestion tolls) which charge

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[2]Sherman implies that a bifurcation of possible first and second best pricing policies are available between peak and off-peak periods depending on whether highway motorists pay input taxes. In the more common case of no input taxes on rush hour travel, marginal cost pricing can be applied to off-peak usage since there is excess capacity available. Moreover, the second-best peak solution falls below average costs, with the size of the peak subsidy increasing as the ratio of cost elasticities with respect to auto and transit passenger miles becomes smaller than the ratio of expenditure elasticities. Accordingly, as the marginal social cost of highway travel becomes exceedingly high, peak fares may actually drop below those in the off-peak.

motorists their true social costs on the grounds that fare subsidization only exacerbates existing distortions.

Frankena (1979) has criticized ridership maximization objectives also on economic efficiency grounds. He argues that any attempt to maximize ridership, even when operators face deficit constraints, would result in the accommodation of customers who are only willing to pay a fare below the opportunity cost of their services. According to Glaister and Collings (1978), London Transport's efforts to maximize passenger miles has led to a 30 percent decline in aggregate welfare (measured in excess total public transit expenditures).

Probably the strongest argument against the "second best" underpricing of transit relates to the practical difficulties in making it work. For one, it would be impossible to accurately measure the market distortions imposed by excessive highway use in order to gauge how far below marginal costs bus fares should be set. Secondly, there is little evidence to suggest that lower fares could entice sufficient numbers of motorists to switch modes. Moses and Williamson's (1963) seminal research on transit subsidization revealed that substantial negative fares would be necessary to bring about a 50 percent shift in Chicago's mode choice.

The position is taken in this research that problems of highway underpricing are better dealt with by more direct remedial measures such as parking surcharges and congestion tolls. Since the SCRTD, AC Transit, and SDTC all have operating ratios[3] below 50 percent, it can be inferred that elements of "second best" and externality pricing are already captured in their respective fare policies. Again, this research assumes optimal systemwide subsidy levels are embodied in the three agencies' current price systems, thus narrowing the scope of analysis to structural aspects of fare policies.

2.2.3 Time-Valued Fares

Turvey and Mohring (1975), Wohl (1973), and Frankena (1979) recommend using the value of time rather than the value of factors of production as the primary basis for pricing transit services. The authors contend that the marginal social cost of an extra transit passenger trip consists of: 1) the value of a passenger's own travel time, plus 2) the marginal congestion costs each additional passenger imposes on all other transit riders as well as highway users.

Time costs of transit trips depend upon bus travel speeds which in turn reflect surface street traffic flow, stopping frequency, rates of deceleration and acceleration, and boarding and alighting volumes. The time cost of each passenger is the summed value of his or her time spent waiting for the bus, the accumulated dwell time for other passengers to board and alight, and the travel time to traverse the length of the trip. The marginal congestion cost to others can be measured by the in-vehicle wait time of accommodating the extra passenger, additional delays to other vehicles sharing the road, and the added discomfort

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[3]Operating ratios measure the proportion of total operating expenditures covered by farebox revenue.

imposed on others when the bus is full. Turvey and Mohring conclude that bus fares should therefore rise as the expected frequency of boarding and alighting movements increase and as the probability becomes greater that a bus is full whenever people wish to get on it.

In terms of time-of-day pricing, it can be inferred that peak fares should be greater than base fares not only because the marginal cost of labor and capital per vehicle hour is highest during rush hour periods, but also because the average speed of buses is slower. That is, as more and more customers ride the bus during the rush hour, the probability increases that greater numbers of transit and road users will be delayed, with congestion costs increasing in some proportion to the frequency of vehicle stops. Turvey and Mohring suggest, however, that marginal congestion costs increase logarithmically, thus warranting declining rates of step increases for additional peak-load volumes.

Time-valued transit pricing seems to have the most far-reaching implications on distance-based fare policies. Turvey and Mohring (1975, p. 284) suggest that "fares should be positively related to distance only when the probability of buses being full is non-negligible along the whole route." Frankena adds that distance-based pricing seems appropriate only when the marginal congestion cost imposed by an extra rider would be greater for longer than shorter trips. Accordingly, lengthy trips would increase congestion costs to the extent that the longer an additional rider remains on a vehicle which is full, the greater the chance someone will be forced to wait for another bus. Frankena (1979, p. 11) concludes that fare structures should be "positively related to distance in the peak direction during rush hour but not under other circumstances."

Time-valued pricing proponents make the point that it isn't the distance traveled which is important to the marginal congestion pricing of transit but rather how full buses are for various types of trips. If a bus traversing a long distance is relatively empty while an inner-city operation serving shorter trips is at capacity, proponents argue in favor of low marginal fares for the long haul transit commuter. Since each extra inner city passenger places a relatively greater burden on others, short trips would bear a disproportionately larger share of operating expenses. Consequently, the time-value argument lends further support for tapering distance-based fares at a significantly declining rate.

The major difficulty in operationalizing a fare system based on time-costs is that passenger's waiting, delay, and travel times would all have to be "valued." Another practial problem is that time-valued pricing would require elaborate fare collection systems to monitor the congestion effects of boarding passengers, thus further increasing dwell time and waiting delays. For these reasons, this research does not attempt to directly apply time-valued concepts to the efficiency and equity analysis of fare policies. Rather, it is assumed that user's fares reflect their willingness to endure delay and indirectly the value they place on the time spent travelling by bus.

2.2.4 Quality-Based Fares

Turvey, Mohring and Frankena's arguments in support of time-valued pricing relate closely to the concept of "quality-based" fares which is gaining increasing acceptance.[4] Applying basic principles of marketing, quality-based fare advocates view transit as a "bundle of services;" fare policies should therefore be geared toward pricing according to whatever people are willing to pay for a set of travel "characteristics." Quality-based pricing proponents argue that market segments must first be defined in terms of travel needs. Appropriate transit services should then be provided at fares which are equal to the valuation users place on them. Pricing policy should therefore be subsumed by the larger goal of providing whatever services are necessary to meet the distinct demand characteristics of different ridership groups. Advocates point out that the only transit services in the nation that are breaking even today are club buses, subscription services and taxi operations; each set prices according to the type of service characteristics people are willing to pay for - reduced travel time, air conditioning, or guaranteed seats.

The concept of quality-based pricing seems to be at variance with traditional efficiency approaches to distance-dependent and peak-load pricing. Middendorf (1979) notes that although distance-based fares are related to the higher cost of serving longer trips, they do not necessarily mean that one receives better quality service. Quality-based pricing advocates join time-based fare proponents in arguing that riders perceive service quality in terms of time-savings. Because long-haul commuters experience longer travel times and since express services are usually cheaper on a per-mile basis, proponents of quality based pricing suggest that the current price level of longer trips should be relatively low. Similarly, because peak period users are often burdened with slow travel speeds and overcrowded surroundings, the quality-based pricing concept implies that peak fares should be lower than base fares. It is argued that giving beneficiaries of uncrowded and more comfortable transit service a discount while levying a premium surcharge on peak users would be piling insult onto injury. As Vickrey (1955, p. 606) admonished, peak-load pricing proposals are "likely to be considered inequitable by many if not most of the lay population on such grounds that rush hour riding is less comfortable, is more of a necessity, (and) is more heavily concentrated among ... working people."

Probably the strongest argument in support of using service quality rather than marginal costs as the basis for transit pricing lies in the potential for increasing ridership levels and perhaps even system revenues. A number of empirical studies have shown that ridership is considerably more responsive to changes in service (e.g., reduced travel time and improved coverage) than changes in fare levels (Kraft and Domencich, 1972; Kemp, 1974). Mullen (1975) reveals that service elasticities are on average double the size of fare elasticities, with the margin of difference increasing as a function of income.

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[4]The discussion in this section is drawn largely from the workshop on price and service innovations which was held at the UMTA-sponsored Transit Pricing Forum, Virginia Beach, March 28-29, 1979.

In sum, current transit pricing policies can be criticized on the grounds that too much emphasis has historically been placed on keeping fares low rather than improving service. Under uniform price systems, transit properties are usually discouraged from offering premium service that is often desired by longer-distance or peak period commuters. On the other hand, differential pricing systems seem to be in congruence with concepts of "quality-based" and "service-related" fares since the additional prices many users are willing to pay could be funneled into the finance of service improvements. Consequently, marginal cost transit pricing appears to offer not only considerable efficiency and equity advantages, but potentially also a number of quality and service-related benefits.

2.3 Empirical Research on Transit Pricing Efficiency and Equity

Findings from a number of studies seem to lend empirical support to many of the theoretical points discussed in this chapter. This section summarizes the findings of previous research on price efficiency and equity.

2.3.1 Time-of-Day Cost and Equity Differentials

Past studies have generally found both the average and marginal costs of peak period transit services to be higher than those in the base, providing justification for peak-load pricing. However, estimates have ranged from relatively minor variations in time-of-day costs to substantial differences.

On the lower range of average cost estimates, Reilly (1977) found a 9.5 percent difference between peak and base vehicle-hour related costs for Albany's transit operations. Reilly's differential rose to 12.5 percent when the effects of a larger labor force on driver's wages were accounted for. Cherwony and Mundle (1978) found a similarly low differential of 15 percent in vehicle hour related costs using data from the Metropolitan Transit Commission in Minneapolis. Keeler et al. (1975) cite a 1974 study by Goldstein where AC Transit's hourly costs for the peak (due to labor pressures on higher pay-hour rates) were estimated to be approximately one-fifth above those incurred during the non-peak period.

On the high end of peak/off-peak cost differential estimates are the following works. Mohring (1972), in a 1972 study of the Twin Cities, rather subjectively estimated operator's wages during the peak to be double those of off-peak periods, implying that labor agreement penalties exert strong pressures on cost escalation. Ostensibly following Mohring's precedent, Boyd et al. (1973) also estimated peak operators' costs to be twice those of the base (using national data). Abroad, Wagon and Baggaley (1975) estimated that London Transport's crew wages per bus minute of operation during the peak were nearly twice the rate of the base period. Regressing crew costs as a function of the number of bus minutes throughout the day, the authors found a statistically valid model which actually allocated 2.3 times more costs to the peak period under two-man bus operations.

Peak/off-peak cost differential estimates have been even larger in marginal terms. Pignataro et. al. (1970) estimated that only six percent of the peak ridership volume would be necessary to cover the marginal costs of off-peak services. In a cross-sectional study of British bus systems, Wabe and Cole (1975) estimated that marginal costs in the peak were 3-1/2 times as high as those in the off-peak.

There have been relatively few empirical studies which have traced the equity implications of peak/off-peak cost differentials. In a study of the Albany Capital District Transit Agency's flat fare policy, Leutze and Ugolik (1978) found that the revenue per mile paid by the midday transit user was one cent and seven cents higher than the fare rates paid by morning and evening riders respectively. Reilly's findings that peak vehicle hour costs were higher than those in the base for the same Albany system would seem to suggest that CDTA's operations have fostered a degree of cross-subsidization between time periods. Pucher (1978) provides the strongest evidence to date that temporal fare cross-subsidization is regressive. Using data from the 1970 Nationwide Personal Transportation Survey, he disclosed that low-income households accounted for only one-quarter of peak bus patronage but for 41 percent of off-peak ridership. Households with incomes above $15,000, in contrast, were found to constitute 16 and 9 percent of peak and off-peak ridership respectively.

2.3.2 Travel Distance Revenue, Cost, and Equity Differentials

Results from a number of studies suggest that the efficiency and equity impacts of flat fare pricing are particularly significant in terms of passenger trip distances. Empirical findings from five studies are summarized below.

In a study of two small-to-medium size transit systems in western Pennsylvania, Wilson and Kurgan (1974) revealed that short trips taken at higher per-mile fares were cross-subsidizing longer, lower-priced trips. The authors found that 3.4 miles was the breakeven point in service cost recovery; revenues from trips less than 3.4 miles were used to offset deficits incurred in serving longer trips above the breakeven threshold. They also found statistically significant relationships between route length and deficits: the longer the route, the larger the revenue shortfall. Their observations seem to verify the contention that flat fare systems yield considerable variations in the price paid per mile.

A similar investigation conducted by Frankena (1973) of Canadian transit fare policies showed that inner-city services earned profits which were used to cover losses on longer routes in low-density suburbs. In Regina, for instance, the author found that most inner-city routes broke even while several outlying routes recovered as little as 20 percent of their direct costs. In Toronto, Frankena documented that the 1972 elimination of an additional 15 cents per trip zone charge in favor of a flat price provided an income transfer of $95.00 a year to suburban residents who commuted daily to the central city. He also found a positive correlation between subsidy per trip and income. Frankena concluded that almost 100 percent of all subsidies levied in five Canadian cities were for the exclusive purpose of serving long-distance commuter trips (which constituted less than one-quarter of all trips).

Leutze and Ugolik's study of Albany's transit system support the conventional wisdom that the short trip, inner-city rider tends to pay considerably more per mile for his or her bus trip than the longer distance, suburban commuter. Based on data gathered from passenger surveys on trip duration, they found that riders traveling ten minutes or less were paying an average of 32 cents per mile compared to the system wide average of 17.9 cents per mile. On the other hand, users traveling an hour or so paid only 3.9 cents per mile.

The authors added that the structure of distance inequalities was found to be highly correlated with ridership demographics.

In a comparative study on the relative fare per mile of New York City's bus and subway services, Weiss et. al. (1974) also found evidence of distance inequities in transit pricing. They calculated that the average New York City bus rider traveled two miles whereas his or her subway counterpart averaged 7.2 miles per trip. The authors noted that if both the bus and subway services were priced at the statewide average of 11.7 cents per mile, bus riders would pay 23 cents per trip while subway users would pay 85 cents per trip. They concluded that the inequities emanating from New York City's fare policies are particularly glaring in view of the fact that the average mean income of subway users was found to be nearly twice that of the average bus rider.

In a study of commuting patterns of workers from the Detroit area during the sixties, Kain (1965) provided indirect evidence that black bus commuters cross-subsidized predominantly white, suburban transit travelers. Based on traditional locational theory, Kain argued that suburban residents balanced their relatively high transportation costs with housing purchases which are cheaper on a per unit basis than what inner-city residents pay. Rock (1975) suggested that to the extent white CBD workers patronize flat fare transit services, they would spend approximately the same on transportation services as black transit commuters. Thus, predominately white suburban households could possibly enjoy lower unit costs of both housing and transit commuting. Using Kain's theory on commuting patterns and residential decisions, Rock found that the Chicago Transit Authority's fare structures provided a redistribution of income from blacks to whites due largely to distance price inequities.

With these findings as background, the remainder of this report presents the empirical findings from the analysis of three case studies.

CHAPTER THREE

REVENUE AND RIDERSHIP CHARACTERISTICS OF THE SCRTD, AC TRANSIT, AND SDTC

3.1 Introduction

Revenue, cost, and ridership of the three case study sites are analyzed in this chapter and the following one as a prelude to the testing of hypotheses on price efficiency and equity. In particular, procedures used to compare fare revenues with the costs of serving trips of varying travel distances and time periods are presented.

3.1.1 Study Sites

The operating characteristics, ridership composition, and pricing structure of each transit property are unique. This section compares study sites using the latest data available. In the case of SCRTD, data represent the period between May-March, 1979, while for AC Transit and SDTC the analysis time frames are fiscal years 1978-79 and 1977-78, respectively.[1]

3.1.1.1 Southern California Rapid Transit District (SCRTD). The SCRTD provides fixed-route bus transportation service to most of Los Angeles County as well as contiguous urban areas in surrounding Orange, San Bernardino, Riverside, and Ventura Counties. The district serves a region of over eight (8) million people within a service area of 2,280 square miles (see Figure 3-1). In fiscal year 1979, the SCRTD accommodated 330 million passengers on 220 local and express routes, making it the third largest transit operator in the country.[2] During the same period, the District received \$91.4 million in revenues while facing costs of approximately \$237 million, leaving an operating deficit of \$145.6 million. As a result, the system's revenue covered 39 percent of its costs.

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[1] All data presented in this section were obtained from either internal records of the three transit properties or reports prepared by their planning staffs. For the SCRTD, much of the operating and socio-economic background data was acquired from monthly Statistical Digests and internal documents prepared by the District's staff. AC Transit data were secured from either the 5 Year Plan: FY 1980-1984, Title VI Compliance Report, or the AC Transit On-Board Survey. Information on the SDTC was gathered largely from either the San Diego Transit Five Year Plan Update: 1980-1984, or the Transit Ridership Survey.

[2] The terms "route" and "line" are used interchangeably in this research. Although the industry's nomenclature is by no means standard, a "line" generally refers to a bus service between an origin and terminus which operates on a unique combination of roadways while a "route" connotes any given portion of operations on a specific line.

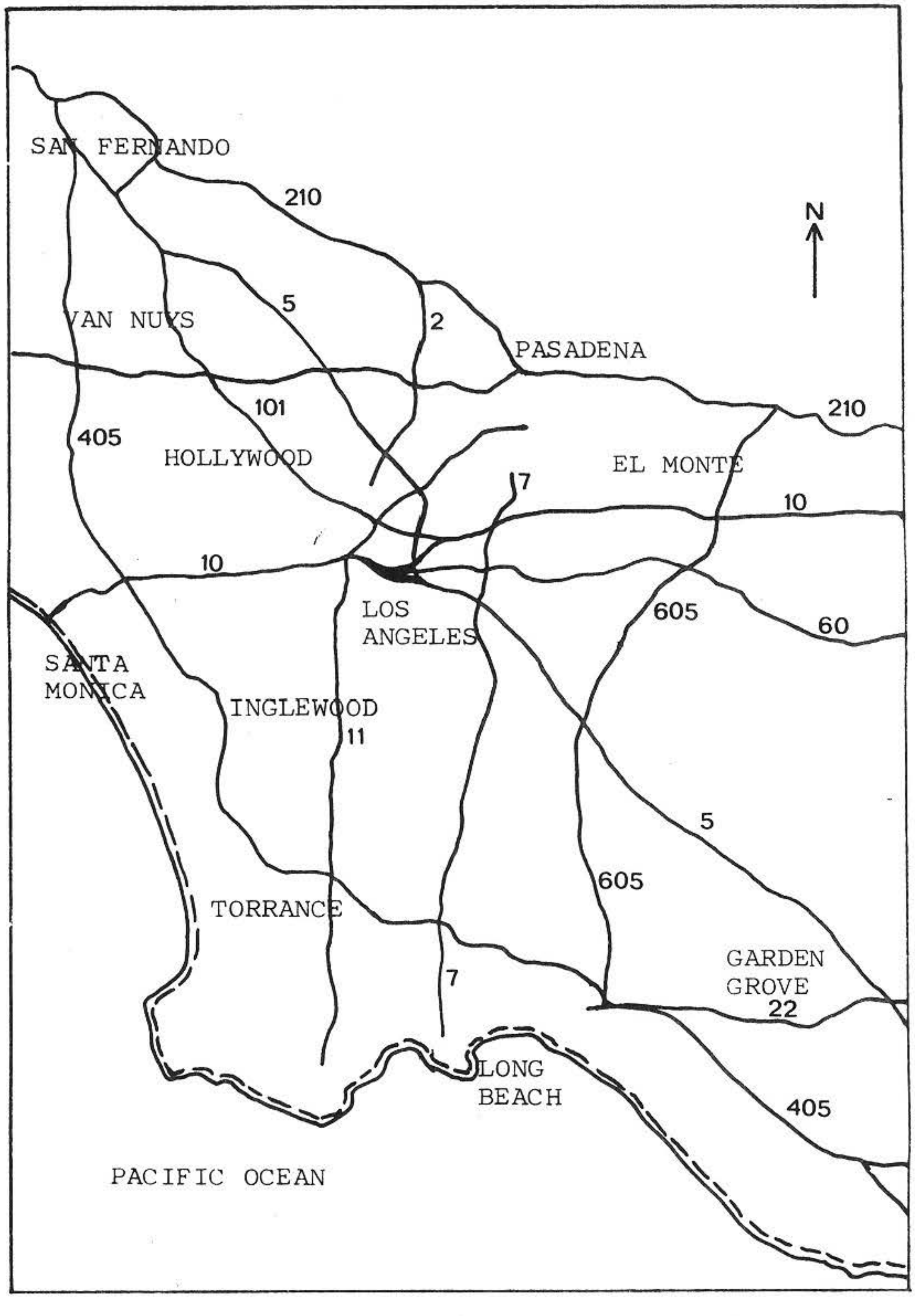

FIGURE 3-1. SCRTD SERVICE AREA

The SCRTD is governed by an eleven member appointed Board which has the authority to supervise and regulate all transit facilities and services owned and operated by the District. The Board is empowered to issue general obligation bonds, tax property with the consent of District voters, and set fare levels and price structures for all SCRTD services. Until early 1974, the SCRTD had a rather intricate fare structure encompassing 318 zones. The base fare was 36 cents and zonal stages were 8 cents each. Following the oil embargo of 1973, the District instituted a flat fare system with the base fare set at 25 cents. Over the past six years, there have been a number of fare adjustments. Between July 1, 1977 and June 30, 1978, the base cash fare was 40 cents for regular customers and a dime for seniors, supplemented by 10 cent transfers and 20 cents express service surcharges. On July 1, 1978, the regular base and senior citizens price was raised a nickel, with most other fare components remaining unchanged.

Results from ridership surveys conducted in both 1978 and 1979 indicated that many of the SCRTD's patrons were transit-dependent. Over 75 percent of the district's users were from households with incomes below $15,000. Also, many were either young or old - riders under 21 and above 62 years of age comprised 46 percent of sampled riders. Approximately 36 percent of all users lived in households with no cars; nearly 60 percent of SCRTD's riders cited the unavailability of a car as their main reason for traveling by bus. About half of all journeys were to and from work, 43 percent of all trips occurred during the five hour morning and evening peak period, and the average ride was 3.8 miles in length.

3.1.1.2 <u>Alameda-Contra Costa Transit District (AC Transit)</u>. The AC Transit system provides a variety of bus transit services for a large area stretching along the eastern shore of the San Francisco Bay. AC Transit's total service area incorporates the most populous parts of Contra Costa and Alameda Counties, in all providing bus service to some 1.43 million residents of the East Bay area. The AC Transit system operates in two separate Districts (see Figure 3-2). Approximately 95 percent of AC Transit's 247,000 average daily users ride the local, express, and transbay services operating in District I. District II is contained within the cities of Fremont and Newark where primarily mini-fixed route and dial-a-ride services are provided. In addition, AC Transit provides special contract services to several suburban communities as well as to the BART system. In total, AC Transit operates 108 routes in both districts (or 193 routes when peak period supplements and line variations are included).

AC Transit is governed by a seven member elected Board in which are vested the powers to impose taxes on properties within the district, incur indebtedness, exercise eminent domain, establish routes and service levels, and fix fare rates. Since AC Transit's inception in 1958 until two decades later, the Board of Directors had maintained a 25 cent basic fare policy. Between 1960 and 1975, zonal charges augmented the basic fare, increasing the average fare to 30 cents. With the elimination of zonal surcharges, the average fare fell to 27 cents in 1978, forcing the Board to re-examine its long-standing policy of a quarter basic fare. In July of 1978, the basic fare was raised to 35 cents for local service to adult customers, 25 cents for passengers under 18, and a dime for senior citizens. Fares for express and transbay services were raised above $1.25, depending on the distance traveled.

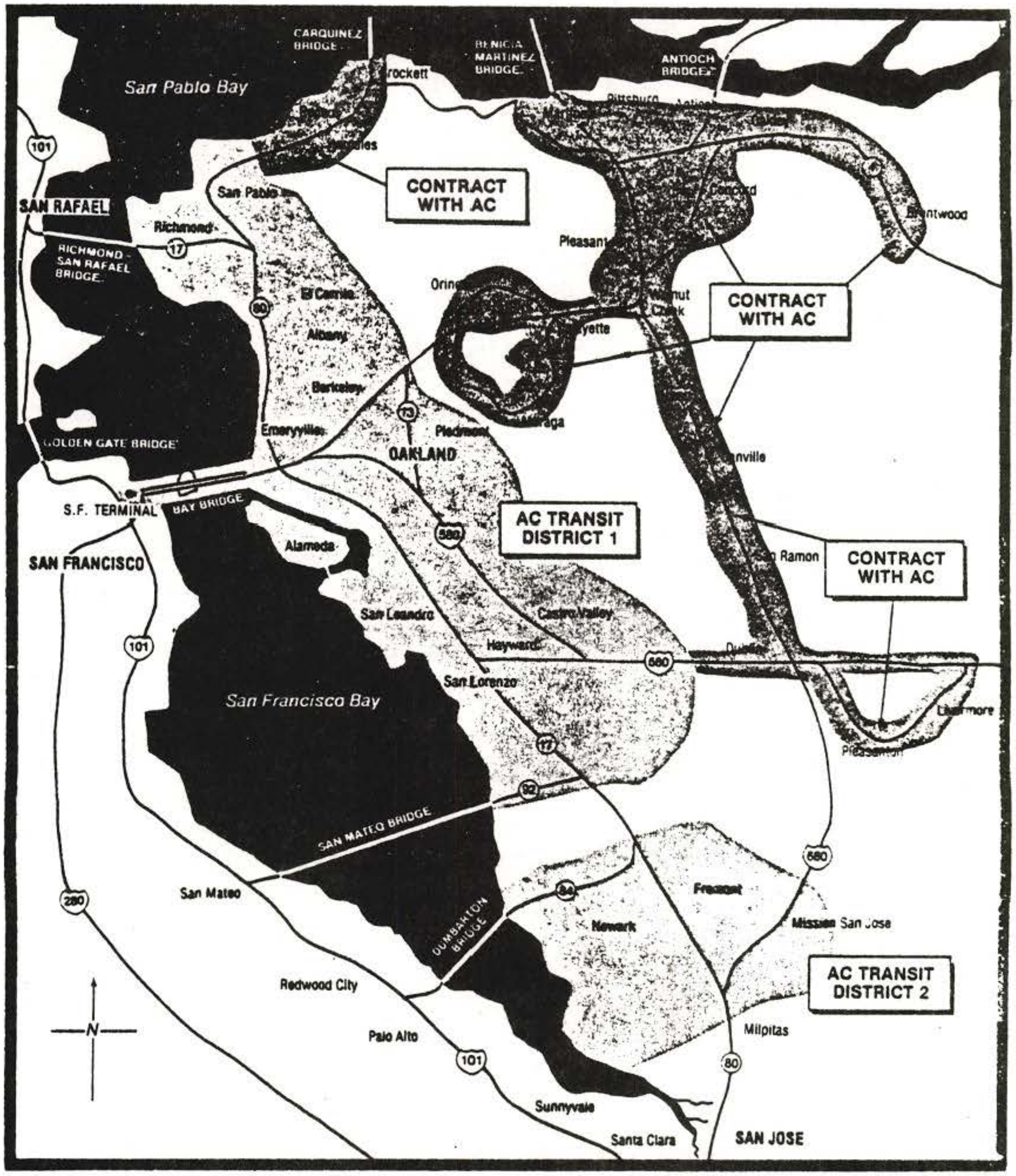

FIGURE 3-2. AC TRANSIT SERVICE AREA

Like SCRTD's, much of AC Transit's ridership can be characterized as captive. A 1978 ridership survey revealed that 75 percent of all users had no cars available for their trip. In addition, approximately 68 percent of AC Transit's patrons were from households with incomes below $15,000. Blacks and Hispanics comprised around 36 percent of the total ridership. Nearly one-third of all trips were to and from work, with the average journey length around 4 miles.

3.1.1.3 San Diego Transit Corporation (SDTC). The SDTC provides local, express, and shuttle fixed-route bus service to 1.2 million residents of the 385 square mile service area of the San Diego metropolitan region. Figure 3-3 shows the 1978 coverage of SDTC's 43 routes over 695 oneway miles. During fiscal year 1977-78, the District returned around 33 percent of its $25.2 million operating costs through the farebox. The average subsidy for each of the District's 120,000 weekly passengers was 56 cents per ride.

The passage of California's Proposition 13 in June of 1978 has curtailed SDTC services. Since the District relied on a local property tax to finance many of its services, the nine member elected Board of Directors was forced to cancel nine unproductive routes and transfer seven others to the jurisdiction of the North County Transit District (NCTD). Currently, the District operates 27 bus lines over 487 route miles serving a population of one (1) million. These service reductions have resulted in a decline of nearly ten percent in annual ridership, from 36.6 to 33.1 million passengers between fiscal years 1977-78 and 1978-79.

For a decade following the 1967 public takeover of the bus system, SDTC management followed a general policy of simplifying and reducing fares. In 1972, the system's base fare was reduced from 40 cents to 25 cents and all zonal surcharges were eliminated. For some riders, previous fares of 90 cents were reduced to a quarter. In 1975, base fares were raised to 35 cents and two years later a 15 cent surcharge was placed on the system's seven express routes. Between 1975 and 1978, senior citizens' local service fares were 15 cents, youth fares were 20 cents, and regular monthly saverpasses sold for $14.00. In August of 1978, regular, senior and youth fares were increased by a nickel and monthly saverpasses were raised to $20.00.

Findings from SDTC's 1977 on-board survey revealed the following: 24 percent were either above 60 or below 16 years of age; 46 percent lived in households with annual income below $7,000; 42 percent had no access to a car in running condition; and 56 percent were female. In comparison, 29 percent of San Diego's regional population was either above 60 or below 16 years of age, 11 percent of all families owned no car, 30 percent of the area's households had annual incomes below $7,000, and 50.4 percent of the region's residents were female. Further, homebased work trips accounted for 39 percent of the system's journeys and 52 percent of all trips fell within a six hour span of peak period travel.

3.1.2 Summary Comparisons of the Three Transit Properties

The SCRTD, AC Transit, and SDTC were chosen as three case study sites due primarily to the availability of cost and revenue data suited to the needs of this research. Equally important, however, was the fact that the three complemented one another. As the second largest metropolitan area in

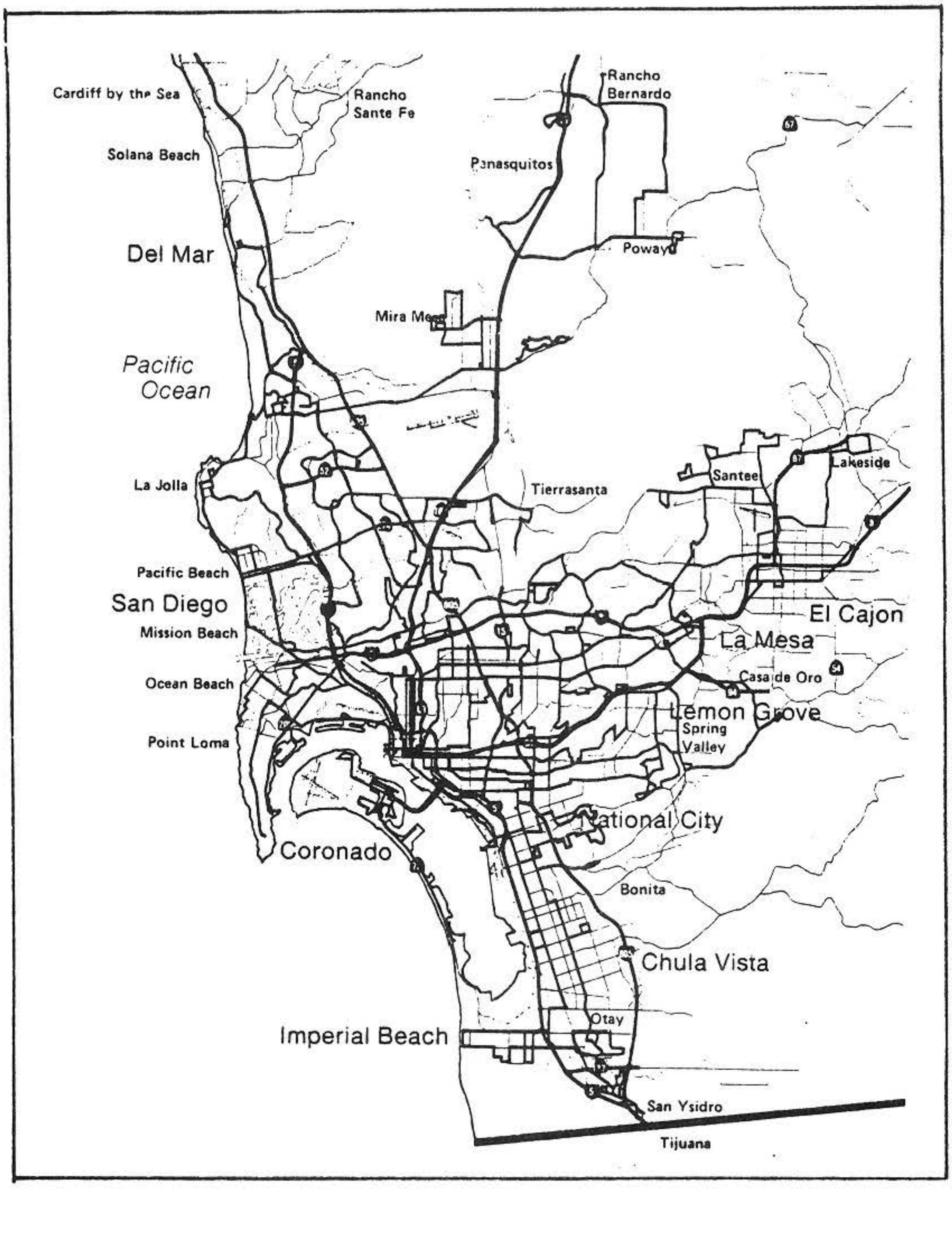

FIGURE 3-3. SDTC ROUTE COVERAGE

the nation with the third largest transit operation, the Los Angeles area and SCRTD system provide a unique setting for analyzing fare policy of large operators. The AC Transit system, on the other hand, is more representative of medium scale operations throughout the nation. Several distinguishing features of the AC Transit system are the variety of services offered (e.g., local, express, transbay and dial-a-ride), existence of coordinated service and fare programs with the regional rail system (BART), and the relatively high subsidization of transit travel within the District. Compared to the other two properties, the SDTC's operations are of a modest scale, serving a medium-size urban region. The San Diego area's demographic and travel characteristics are generally quite similar to those of the Los Angeles area, except for the relatively large concentration of tourists and military personnel in the area.

Tables 3-1 through 3-3 highlight operating, financial, pricing, socio-economic, and trip-making characteristics of the three transit properties. In Table 3-1, the magnitude of differences in the scale of each property's operations is shown. The SCRTD operated five times as many routes, over seven times as many miles, using eight times as many employees, to serve nine times as many riders as the SDTC. The SCRTD also returned substantially more revenue per passenger mile than the other two properties, probably due to the higher average fares and higher load factors. In terms of cost efficiency and effectiveness, the SDTC stands out as a relatively productive service with an average cost per passenger of $.71 and an average cost per service hour of $23.59 compared to an average of $27.24 per hour for all three operators. For the three separate analysis periods, SCRTD had the lowest subsidy rate and highest operating ratio.

The price levels and fare structures of the transit properties are displayed in Table 3-2. Generally, AC Transit and SDTC priced basic services at 35 cents per ride while SCRTD charged 40 or 45 cents, depending on the particular analysis date. Each system had a senior citizen and handicapped fare discount program and also charged users an additional amount for express service. Only AC Transit and SDTC offered school-age customers a cash discount, although SCRTD had a special pass arrangement for young passengers. Pass programs were integral components of both SCRTD's and SDTC's fare system, providing frequent users a bargain rate. AC Transit limited pass usage to mid-day shopping trips and Sunday (or holiday) travel. Only SCRTD charged for transfers, although all three properties levied a surcharge on those switching from local to express services.

Table 3-3 compares demographic and travel characteristics of the three properties. The high proportion of low income, carless, and minority users of each property's service suggests that many patrons were dependent upon transit because they had no other travel options. Work and school journeys constituted the largest share of each property's trips. The average trip length was about four miles for all three properties and between forty and fifty percent of all transit trips occurred during the peak.

TABLE 3-1. COMPARISON OF OPERATING AND FINANCIAL CHARACTERISTICS

	SCRTD	AC TRANSIT	SDTC
Analysis Period	5/1/78-4/30/79	1/1/78-12/31/78	7/1/77-6/30/78
No. of Routes	220	109	43
Service Area (miles^2)	2,280	1,466	385
Service Area Population	7,600,000	1,430,000	1,200,000
Oneway Daily Route Miles	4,511	2,146	695
Annual Vehicle Miles	103,500,000	24,700,000	15,200,000
No. of Buses	2,600	839	350
No. of Employees	7,000	2,100	879
Average Operating Speed (m.p.h.)	14.2	14.9	14.1
Annual Total Passengers	334,000,000	52,600,000	36,600,000
Average Passengers/Mile	3.23	2.15	2.40
Annual Revenue ($)	94,400,000	13,300,000	8,400,000
Average Revenue/Mile($)	.91	.54	.52
Average Fare/Passenger ($)	.29	.26	.28
Annual Total Cost ($)	237,000,000	42,200,000	26,000,000
Average Cost/Passenger($)	.71	.80	.71
Average Cost/Mile($)	2.14	1.71	1.66
Average Cost/Hour($)	30.66	27.48	23.59
Average Subsidy/Ride($)	.42	.56	.48
Operating Ratio (Revenue/Cost)	.40	.32	.32

TABLE 3-2. COMPARISON OF FARE SYSTEMS

(All figures in $'s)

	SCRTD				AC TRANSIT			SDTC	
Analysis Dates	5/78		9/78-3/79		9/78-10/78			11/77	
Service Type	Local	Express	Local	Express	Local	Express	Transbay	Local	Express
Base Fare	.40	.60-1.40[a]	.45	.65-1.45[a]	.35	.35-60[b]	.75-1.25[b]	.35	.50
Senior/Handicapped Fare[c]	.10	.10	.15	.15	.10	.10	.30-.40	.15[e]	.35
Youth Fare[d]	.40	.60-1.4[a]	.45	.65-1.45[a]	.25	.25	.30-.40	.25	.30
Park/Ride Fare	-	.80-1.40	-	.85-1.45	-	-	-	-	-
Monthly Pass	18	24-48[e]	20	26-50[e]	-	-	-	14	20
Monthly Senior/Handicapped Pass[c]	4	4	4	4	-	-	-	6	10
Monthly Youth Pass[d]	12	12	14	14	-	-	-	10	14
Daily Shoppers Pass	-	-	-	-	.35[f]	-	-	-	-
Sunday Passes[g]	1	-	1	-	.75	-	-	-	-
Park/Ride Pass	-	38-48[e]	-	32-50[e]	-	-	-	-	-
Transfer[h]	.10	-	.10	-	0	0	0	0	0

a SCRTD's express increments are $.20 per step.

b AC Transit's express increments range from $.05 to $.10 per step.

c The minimum eligible age for a senior citizen's monthly fare and pass is: SCRTD-62; AC Transit-65; SDTC-60. AC Transit's discounts are effective only during the non-peak and its senior express increments are 0-$.05 per step. Blind SCRTD customers ride free.

d The maximum eligible age for a student discount is: SCRTD-21; AC Transit-17; SDTC-18. Persons under 5 ride free on the AC Transit system.

e SCRTD's monthly pass express increments are $6 per step.

f Available for unlimited riding only during the hours of 9:00 a.m. to 3:00 p.m., Monday through Saturday.

g Sunday passes are available for unlimited travel for any one Sunday (or in the case of AC Transit, any holiday).

h SCRTD's transfers are $.10 for all groups. AC Transit and SDTC have no transfer charges for local services. For transfers from local to express services, SCRTD and AC Transit patrons must pay the full express fare whereas SDTC's senior, youth, and regular customers pay $.05, .10, .15 respectively. For transfers from express to local services, AC Transit and SDTC users pay no charge while SCRTD riders pay $.10.

TABLE 3-3. COMPARISON OF SOCIO-ECONOMIC AND TRIP-MAKING CHARACTERISTICS

	SCRTD	AC TRANSIT	SDTC
Survey Date	9/78	9/78	11/77
% Below $15,000 Family Income	75.8	66.1	73.8
% No Auto Available	61.3	73.2	46.4
% Youth or Senior Citizen	33.7	24.3	24.0
% Hispanic Speaking	14.4	6.3	14.0
% Female	57.2	56.3	56.3
% Work Trip	49.2	31.2	36.5
% School Trip	27.8	22.0	13.4
% Riding 4 or More Days/Week	80.6	74.8	72.0
% Paying Cash Fare	70.4	72.8	62.0
% Transfers of Total Riders	20.5	24.3	19
Average Trip Length	4.2	3.8	4.9
% of Trips in Peak	42.0	50.0	52.0

3.2 Framework of Analysis

The primary mode of analysis used to test the hypotheses presented in the first chapter was a comparison of the revenue paid with the costs incurred in serving individual passenger trips. Efficiency evaluations of current fare policies were performed by statistically testing revenue and cost differences among distinct categories of trip distances and time periods. Data were further analyzed according to socio-economic characteristics of users in order to ascertain the equity implications of pricing policies.

Figure 3-4 presents a step-wise summary of the procedures used in analyzing current pricing practices. First, a representative sample of each agency's bus lines was chosen. For the sample lines, data on the fare revenue, trip length, time period of travel, and socio-economic characteristics of individual passengers were obtained from responses to on-board ridership surveys conducted by each agency. Steps taken to assign equivalent cash fare values to passes and to estimate individual trip lengths are discussed further in this chapter.

The estimation of the total cost incurred in serving each sampled user was a fairly complex task. For this reason, cost allocation procedures are discussed separately in the next chapter. Briefly, a daily operating cost estimate was derived for each sample line using "cost-centers" unit allocation models. These models apportioned a share of each transit property's total costs to specific lines based on such characteristics as the line's daily vehicle hours, daily vehicle miles, and peak vehicles in service. Next, daily costs were divided into peak and base components to reflect the cost impact of labor agreements which prohibit hiring part-time labor and limit split-shift work duties. Also, capital depreciation expenses were allocated to each route's peak and base period. Consequently, a total peak and off-peak daily cost estimate was derived for each sample route.

In order to compare revenues (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 chosen to factor data into comparable units. "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 on-board surveys which was suited to factoring revenues;[3] 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. Accordingly, a "revenue per passenger-mile" estimate was derived for each user by dividing the rider's fare by his or her

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[3]No data were compiled on the duration in hours of each sampled trip. Also, "seat miles" was considered inappropriate because each "seat mile" cost unit could not be directly associated with a particular passenger (i.e., costs allocated to empty seat would have to be pro-rated among all passengers, effectively producing a "passenger-mile" unit). Other unit factors, such as "employees" and "vehicles," were not suited to the indexing of an individual user's payment.

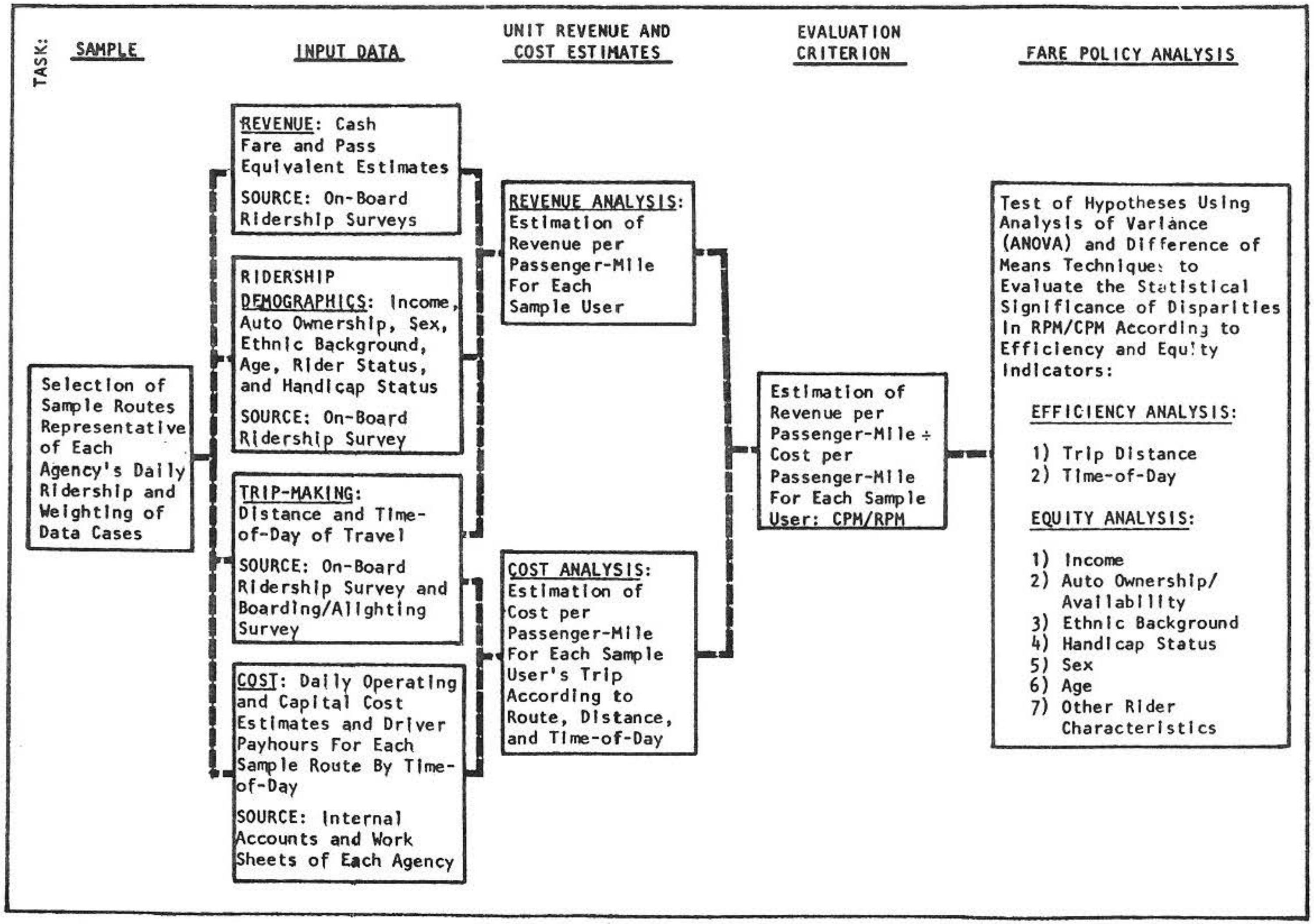

FIGURE 3-4. RESEARCH METHODOLOGY

trip length. Also, "cost per passenger-mile" estimates were computed for each route's peak and base periods by dividing daily time-of-day cost estimates by the daily 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 or her particular bus line and time period of travel.[4]

The criterion variable used in testing fare policy hypotheses was the ratio of "revenue per passenger-mile" to "cost per passenger-mile" (RPM/CPM). Hypotheses on price efficiency and equity were tested by analyzing RPM/CPM differences among distinct categories of trip distance, time-of-day, and rider demographics. Both analysis of variance (ANOVA) and difference of means (DOM) techniques were used to draw statistical inferences regarding current policies. Differences in RPM/CPM were also analyzed among categories of service, fare payment type, trip purpose, and user attitudes to supplement the efficiency and equity analysis.[5]

In sum, each property's fare policies were evaluated by estimating disparities in the revenue and cost of specific groups of sampled users. Though each level of revenue and cost refinement introduced additional assumptions and possible estimation errors, as Dajani, et al. (1975, p. 21) note, "only highly disaggregated studies can provide a clear, reliable picture of the costs and benefits of a transit system." The remainder of this chapter discusses procedures employed in sampling users and merging revenue and ridership data into the analysis.

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[4]An implicit assumption was that unit costs derived for each transit 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 on a particular line was the same as someone commuting a long distance, during the heaviest peak time on the same line. This amounted to an equal pro-rating of <u>unit</u> costs regardless of distance traveled. Of course, the <u>total</u> cost of a long distance journey would be much higher than a shorter distance one since cost units would be expanded by trip length.

[5]All revenue, cost, trip-making and socio-economic data used in testing fare policy hypotheses were placed in computer files. Each survey response represented a sample record which was stored on computer tapes and disks for the purpose of statistical hypothesis testing. In several cases, separate files were sorted and merged to compute passenger trip lengths and to integrate cost data. Standard computer statistical routines were then employed to perform the hypothesis tests presented in Chapter 5.

3.3 Selection of Sample Routes

An overriding objective in the selection of sample routes was to obtain an accurate data base representing each transit property's range of service types (i.e., express, local, shuttle), travel patterns (i.e., short and long trips), fare payments (i.e., regular fares, discounts, passes), cost profiles (i.e., high and low operating costs), and passenger socio-economic characteristics (in terms of race, income, age).

A multi-stage stratified sampling approach seemed best suited to attaining a representative mix of bus routes and users. First, routes were stratified into homogenous groups on the basis of service type and ridership. The selection of representative lines from each stratum then followed.[6] The final sampling stage entailed either randomly selecting cases (i.e., survey responses) or analyzing all samples from each route chosen.

3.3.1 Selection Methodology

The route selection process varied somewhat among the three transit properties. Appendix A describes the actual process followed in selecting each property's sample routes, and lists those routes chosen.

The general route selection procedure employed for all three properties involved several common steps. Summary results of on-board passenger surveys and other data sources were initially scanned for the purposes of categorizing routes.[7] Bus lines were generally stratified into one of the following

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[6]A selection procedure was followed in lieu of randomly sampling routes from each stratum because ridership and operating data from some routes seemed unrepresentatitive of the riding population (due to either data biases, spurious sampling techniques, or small response rates). Rather than risk the possibility of randomly choosing routes displaying ridership patterns uncharacteristic of a particular stratum, it seemed more appropriate to select representative routes by comparing trip-making data (i.e., distributions of socio-economic groups and trip length) and line performance measures (i.e., farebox ratios, cost per mile, etc.).

[7]The types of summary passenger statistics used for reviewing and stratifying routes were: daily passenger counts; average trip length; sample rate; percent express operations; fare payment breakdowns; auto ownership rates; and distributions of sex, age, income, trip types and ethnic groups.

Other resources generally used to compare and categorize routes included each property's five year transit plan, regional short and long range transportation plans, census data, and Title VI Compliance reports. The five-year plans contained a wealth of line performance and system productivity data such as passengers per revenue hour, operating ratio, peak load factors, vehicle mile per employee, and composite route evaluation scores. Census data provided geographic breakdowns on the socio-economic composition of various transit service areas and route corridors. Title VI reports, prepared in compliance with UMTA's Circular 1160-1 Interim Guidelines, displayed useful information on each district's route service to minority and disadvantaged areas.

categories to reflect the dominant attributes of each route's service operations and ridership profiles: express/commuter; local/transit-dependents; inter-city/mixed; shuttle/shopper; local/mixed; and inter-city/transit-dependent.[8] Next, several measures were taken to improve the statistical reliability of the sample base. Routes with outlier data points and extremely unrepresentative ridership characteristics were purged from the data set. In addition, routes with small survey response rates and obvious data biases were deleted. Data biases stemmed from procedural problems in administering surveys on certain routes including surveyor absenteeism during certain time periods, culturally-related misinterpretations between surveyors and riders resulting in selective sampling, and general errors and oversights (CPO, 1978; Crain and Associates, 1979; Johnson, 1979).

Other sampling biases which could potentially denegrate the reliability of each property's ridership data were identified. One source of bias was the considerable variation in response rates among user groups. Differing response rates tended to weight results to give user groups with the highest response rates more than proportional influence. In general, there was an undersampling of short-distance passengers on those routes with crowded buses and considerable on/off activity. In addition, each property's survey results revealed that certain age, ethnic and occupational groups refused questionnaires more often than others. In the case of AC Transit, the very young, elderly, women, minority, and short haul patrons were all somewhat underrepresented, with the proportional magnitude of bias around ±2.5 percent. Consequently, some routes were selected within certain strata with ridership distributions skewed in favor of short trips, females, senior citizens, and minorities to partly compensate for inherent biases of on-board passenger surveys.[9] A final step involved an attempt to screen out extremely congested routes by examining load factor data since the likelihood of obtaining non-biased survey results under conditions of standing-room-only was small.

3.3.2 Sample Size

The sample size for this research was constricted by both the response level of each property's on-board ridership survey and the confidence requirements of statistical procedures used to test hypotheses. Passenger sample sizes differed significantly among the three properties with the high extreme represented by SDTC's 33 percent sampling of average daily ridership while SCRTD sampled slightly over three (3) percent of its daily riders. AC Transit

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[8]The mixed classification denoted a balance of user groups including both choice and captive riders.

[9]To the extent the non-respondents among short-haul, young, old, female, and minority patrons are similar to the actual respondents of the same groups, such compensation adjustments seem intuitively reasonable. However, non-respondents more than likely represented the extremes of the undersampled groups - the very young, the very old, and the very poor.

fell in-between, sampling approximately 17 percent of daily users. To balance sample size among the three case study sites commensurate with each operator's relative ridership level, thirty (30), twenty (20), and ten (10) routes were chosen respectively for the SCRTD, AC Transit, and SDTC systems. Listings of the chosen routes appear in Appendix A. Comparing Columns (3) and (8) of Table 3-4 indicates that the 30-20-10 route breakdown provided a fairly even pro-rated share of each property's average daily ridership.[10] Columns (7) and (9), however, indicate that the 10 and 20 routes selected for the SDTC and AC Transit yielded a substantially larger proportional sample than that generated from SCRTD's 30 routes. These sample size discrepancies were partially corrected by weighting techniques described in Appendix B. Weighting enlarged Column (9) of Table 3-4 as follows: SCRTD - 0.8 percent to 2.2 percent; AC Transit - 6.0 percent to 14.7 percent; and SDTC - 7.2 percent to 13.4 percent. Thus, weighting led to a marginal equalization of relative sample sizes among the three properties, although SCRTD's sampling rate remained considerably smaller than the other two agencies.

3.4 Integration of Revenue, Demographic, and Trip-Making Data

3.4.1 On-Board Ridership Surveys

Most of the data on fare revenues, demographic characteristics of patrons, trip distance, and time-of-day of travel were collected from user responses to each case study's on-board ridership survey. Appendix C describes the procedures used by each property in conducting surveys and also displays the English version of self-administered questionnaires.

Generally, each agency's questionnaire elicited responses on a range of socio-economic variables, trip-related characteristics, and attitudinal indicators. Also, all three properties recorded the approximate age, sex, and apparent ethnic background of refusals and non-respondents in order to make weighting adjustments to reduce the incidence of sample bias.

Since surveys were conducted on only a portion of each sample route's bus runs,[11] the scope of this research was constrained as follows:

1. All the data inputs reflected trips made during the following periods: non-holidays, school days, and weekdays;

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[10] That is, while Column (3) shows the choice of 30, 20, and 10 routes gave SDTC the largest route sample, when viewed in terms of ridership represented by the 30, 20, and 10 routes, Column (8) reveals the chosen sample routes resulted in a reasonably proportional representation of each property's total ridership.

[11] A bus run refers to a continuous tour of duty assigned to a specific driver in which a sequence of services are provided over a specific route, except for split shifts where the line of operation sometimes changes.

TABLE 3-4. COMPARISON OF SELECTED ROUTE SAMPLE SIZES WITH EACH SYSTEMWIDE RIDERSHIP

Transit Property:	(1) Total # of Sample Routes Selected	(2) Total # of System Routes	(3) Sample Routes as a % of Total Routes	(4) Total Sample Size of Selected Routes	(5) Average Daily Ridership of Selected Routes	(6) Average Daily System Ridership	(7) Selected Routes Sample Size as a % of Route's Daily Ridership	(8) Selected Routes Ridership as a % of Daily System Ridership	(9) Selected Routes Sample Size as a % of Daily System Ridership
SCRTD	30	219	13.7%	8,610	323,100	1,028,100	2.6%	31.4%	0.8%
AC Transit	20	109	17.2%	14,870	69,270	247,000	21.4%	28.0%	6.0%
SDTC	10	43	23.3%	8,137	27,574	113,387	29.5%	24.3%	7.2%

2. Only the surveyed segment of bus trips were included as sample cases. Accordingly, if a patron transferred onto a surveyed bus route, only a portion of his or her one-way linked trip was actually accounted for in this research (unless the original route from which he or she transferred was also surveyed). Thus, trip length estimates pertained only to the particular segment surveyed and not to the total linked trip distance;

3. Since all survey data were collected anonymously, any repeated sampling of the same patron (i.e., persons surveyed in both the morning and evening peaks or on two segments of a linked one-way trip) could not be prevented; and

4. Both SCRTD and AC Transit's sample cases included data from transfer patrons while SDTC's did not. In the case of SDTC, transfer patrons were not surveyed and therefore could not be included in the analysis.

3.4.2 Revenue Data

Data inputs on the method of fare payment and the actual fare amount paid were collected from rider responses to on-board surveys. The fare amount associated with each agency's range of fare payment methods were presented in Table 3-2.

For the various types of passes used by survey respondents, cash fare equivalents were estimated in order to assign revenue values to passholders. These were derived by dividing the total monthly revenue collected under each pass arrangement by the number of monthly users of the corresponding type of pass. SDTC's passholders were assigned revenue values identical to the cash fare associated with their particular trips while SCRTD pass users' fares were discounted below corresponding cash levels.[12] The revenue values assigned to SCRTD's users boarding with a pass during the May, 1978 survey were: regular pass - 21 cents; student pass - 15.8 cents; and senior/handicap pass - 10.4 cents. For SCRTD's September, 1978 and March, 1979 survey dates, the following were used: regular pass - 22.2 cents; student pass - 18.6 cents; and senior/handicap pass - 10.6 cents. And for the five SCRTD express lines studied, estimates of express pass users' fares ranged from 52 to 82 cents, depending on the distance which the passenger traveled.

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[12] The SCRTD has historically set monthly pass prices at a rate of forty times the cash fare for the corresponding trip. Generally, however, passes are used more than the forty monthly ride breakeven standard. Therefore, fares assigned to SCRTD's passholders were below those of cash users making the same trip. SCRTD officials take the position that passes should be priced at a rate below the average cash fare of a particular type of trip as a reward to those who ride the system frequently.

In contrast, SDTC's pass fares were set equal to cash ones since passholders tend to travel at a rate in which monthly passes are priced (i.e., forty times per month). Several SDTC surveys, for example, have indicated that regular passholders consistently travel between 38 and 40 times per month, with senior and youth pass users traveling slightly more often.

Since the equivalent cash fare estimates represented mean values, there was a degree of error introduced into the revenue values assigned to some pass users. The size of the total error was related to the degree of variance around the mean value of pass usage. This variability was found to be less than ten percent for all pass types, due primarily to the similar pattern of usage among passholders.[13]

Finally, AC Transit's transfer users boarding a surveyed bus run were assigned a zero fare while SCRTD's transferers were assigned a dime fare.[14] In contrast, transfer cases were eliminated from the SDTC analysis since transferers did not receive questionnaires.

3.4.3 Demographic Data

Indicators of the socio-economic status of bus passengers were compiled from each agency's on-board survey. Demographic data collected from surveys were generally sufficient to allow an inter-agency comparison of the "equity" repercussions of price structures.

Socio-economic indicators were divided into two groups: those directly reflecting users' "transit-dependency" and those which help to illuminate the equity picture, but which by themselves provide no strong indication of users' "ability-to-pay" or "need." Included in the former group were indicators of household income, vehicle ownership and availability, language and ethnic background, and handicap status. Secondary measures of equity were age, gender, and occupational status.

The "household income" variable provides the most direct measure of users' "ability to pay." To the extent that current fare structures result in variable ratios of revenue/cost across income categories, the incidence of fare cross-subsidization can be viewed as either progressive, regressive or neutral. The vehicle ownership and availability variables, on the other hand,

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[13]Since a characteristic common to all passholders is frequent riding, the variance in the rate of usage was relatively small. SCRTD planners have estimated the variability of mean fare equivalents to be less than ten percent by tabulating monthly counts of pass usage for a significant sample of passholders and computing the relative dispersion around the mean for each pass type.

[14]This research analyzes only the segment of a trip in which passengers were surveyed. Although patrons transferring onto surveyed bus runs paid a full fare on a previous link of their trip, they nonetheless were assigned a zero or a dime fare for the segment surveyed. No attempt was made to pro-rate the initial bus fare paid to the particular transfer link under study since there was no means of determining exactly what fare the user originally paid. Thus, an argument could be lodged that the zero fares assigned to transfer patrons understate the true revenue contribution they make to the trip segment surveyed since they paid a full fare on a previous trip link. On the other hand, the assignment of zero revenue to transfer patrons does reflect the relative discount which current fare policies offer to those users who are forced to change routes to complete a one-way trip.

directly reflect the relative transit-dependency of survey respondents. The former measure is more indicative of the relative affluence of a rider, while the latter generally reflects the degree to which he or she relies on transit services. For example, the survey respondent could be a student from a three-car household, yet could be totally dependent upon transit for a school trip. Accordingly, the user would respond to the vehicle ownership and vehicle availability questions quite differently. Finally, ethnicity and language provide insight into the equity impacts of fare structures upon different social groups. In the case of the SCRTD and SDTC, ethnic backgrounds were revealed only by respondents' language whereas AC Transit solicited specific responses on users' ethnicity.

3.4.4 Trip-Making Data

The spatial and temporal analyses of transit price structures were conducted by comparing revenue/cost differentials across categories of trip distance and time-of-day. Estimates of trip length were derived by computing the route mileage between each user's bus stop of origin and destination.

The analysis of pricing with respect to time-of-day was performed by assigning revenue and cost data to one of the following five time periods: 1) Morning Peak; 2) Midday; 3) Afternoon Peak; 4) Evening; and 5) Owl. Table 3-5 presents the hour intervals which fall into each property's time period categories.

The assignment of hour intervals to particular time periods was dependent on both the structure of peak demand loads and the judgment of each property's transit managers.[15] System demand levels were analyzed at fifteen minute intervals in order to delineate at which times demand profiles exhibited pronounced peaking. Although the peak time intervals differed among the transit properties, for all three cases the morning peak centered on 7:30 a.m., while the evening one centered on 4:30 p.m.

The ridership and revenue data presented in this chapter are an important component of this research. An equally important input, however, is cost information. The next chapter presents a model used in allocating each property's total costs at the passenger level.

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15 Alternately, the peak periods could have been determined with respect to supply as opposed to demand. Since supply levels of buses closely matched demand levels of passengers, no attempt was made to tie the supply criterion into the decision calculus.

TABLE 3-5. TIME INTERVALS FOR EACH TRANSIT PROPERTY'S TIME-OF-DAY CATEGORIES

TIME PERIOD	SCRTD	AC TRANSIT	SDTC
Morning Peak	6:15 - 8:45 AM	6:30- 8:30 AM	6:00- 9:00 AM
Midday	8:45 AM- 3:15 PM	8:30 AM- 4:00 PM	9:00 AM- 3:00 PM
Afternoon Peak	3:15 - 5:45 PM	4:00 - 6:00 PM	3:00 - 6:00 PM
Evening	5:45 - 11:00 PM	6:00 - 12:00 PM	6:00 - 11:00 PM
Owl	11:00 PM- 6:15 AM	12:00 6:30 AM	11:00 PM- 6:00 AM

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CHAPTER 4

COST CHARACTERISTICS OF THE SCRTD, AC TRANSIT, AND SDTC

4.1 Introduction

In order to assess the efficiency and equity repercussions of current transit pricing policies, it is necessary to merge the revenue and ridership data presented in the previous chapter with estimates of costs to serve trips of varying lengths and times-of-day. This chapter describes methods, assumptions, and models employed to allocate operating and capital costs to peak and base periods and among various categories of trip distance.

As discussed in Chapter Two, the marginal cost of providing transit service during the peak or over long distances differs significantly from average costs taken over all hours of the day or all bus runs. Any allocation model which fails to account for the higher marginal cost imposed by peak usage or long distance trips presents a distorted picture of transit costs.

A logical approach would be to develop a cost allocation process attributing each and every operating and capital expense to the specific unit of bus service which caused it. Daily cost estimates reflecting individual characteristics of each line could then be divided further into time-of-day components. By pro-rating the resultant peak and off-peak cost estimates among each route's users (on the basis of, say, passenger-miles traveled), a reasonable approximation of incremental cost incurred in serving each patron could be derived. Several factors, however, impair the use of such an approach. For one, few expense items can be linked directly to a specific bus route much less to a particular time-of-day. Most transit cost records are kept at either a systemwide or divisional level, thus precluding precise disaggregation. Moreover, detailed records of such important cost factors as drivers' wages, equipment, and general overhead expenses are not always maintained on a time-of-day basis. Even when such information is available, one is faced with the arduous task of "attributing" the effects of such factors as part-time work prohibitions and spreadtime penalties to the costs of serving peak and base period users.[1] Just as important, however, is the fact that peak/off-peak cost allocation theory remains partial and equivocal. Although a growing body of literature has evolved over recent years offering insights into the transit cost allocation problem, no widely applicable or universally accepted approaches have yet emerged.

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[1] These factors are discussed in subsection 4.4. Briefly, most labor agreements prohibit the hiring of part-time workers and impose premium pay penalties on work performed beyond an eight hour period. Since labor must serve both morning and evening peak periods, these stipulations translate into more payhours per vehicle hour in the peak than the base.

This chapter focuses on the procedures used to calculate the direct costs of serving sampled trips, presents peak and base period cost estimates for each route studied, and analyzes cost characteristics of the three properties. The method employed in estimating direct costs can be characterized as a multi-stage allocation process. Each stage seeks to refine original cost estimates to better reflect the expense characteristics of each bus run studied. First, a systemwide unit cost allocation formula is presented for each transit property. Next, a "cost centers" approach to refining the systemwide allocation formula is described. The "cost centers" model is then used to estimate the daily cost of operating each route studied and to analyze the effects of travel distance on unit cost. Each route's daily cost is further divided between the peak and base periods employing attribution procedures which account for the effects of labor prohibitions and peak load demands on total costs. Finally, each route's peak and base daily costs are expressed on a per passenger-mile basis for the purpose of estimating the unit cost of serving different mileage increments of travel.

4.2 Unit Cost Allocation Models

Cost allocation models estimate operating expenses by associating costs with output factors which are most responsible for causing them. Although these models typically account for only variable costs (i.e., exclusive of capital depreciation), Miller and Rea (1973, p. 11) point out that this is not a serious drawback since most systems' "operating costs constitute 90 percent or more of total costs."

Two commonly used methods for attributing operating costs to various causal factors are: 1) the unit cost method; and 2) the regression method. Under the unit cost method, expense items are segregated into subcategories - such as labor, vehicle maintenance, fuel and so on. The subcategories are then stratified among several variables, such as vehicle hours or vehicle miles of service, which are considered causally linked to the encumbrance of expenses in each subcategory. A multivariable equation can then be derived by calculating a unit coefficient for each factor (i.e., dividing the total cost of all subcategories by vehicle hours, etc.). Whereas the unit cost method allocates variable expenses cross-sectionally (usually for an annual period), the regression method typically estimates operating cost using time-series data. Econometric models can be employed to statistically relate operating costs to explanatory variables which account not only for the influence of such service characteristics as vehicle miles but also for contextual variables such as average vehicle age and service area population.

Under the unit cost method, subcategories of operating expenses have traditionally been linked with one of four factors: 1) vehicle miles; 2) vehicle hours; 3) revenue passengers; and 4) peak buses. Typically, the following associations are made. The cost of fuel, tires, maintenance and repairs are related to vehicle miles. Driver wages and fringe benefits are allocated to the vehicle hour factor. The peak vehicle factor usually encompasses expense items related to the size of the peak period fleet: administrative overhead, clerical staff, storage facilities, etc. And the revenue passengers factor accounts for expenses associated with accident payments and liability premiums. However, not all expenses can be clearly tied to a single explanatory factor. For example, a case can be made for relating maintenance and repair expenses not only to the distance traveled but also to the vehicle hour factor so as to reflect the effect of route congestion on equipment depreciation. Therefore, some cost subcategories are often apportioned among several explanatory factors to account for a multiplicity of influences.

Both the unit cost and regression methods have gained extensive applications over the past fifteen years. One of the earlier applications of the unit cost approach was by Ferreri (1968) in a study of Miami's metropolitan transit system. Ferreri's model allocated operating costs as follows: vehicle miles - 27.9 percent; vehicle hours - 54.3 percent; peak vehicles - 10.5 percent; and passenger-revenue - 7.3 percent. In a more recent study of the Trenton-Mercer Metro System, Cherwony (1977) derived a unit cost model which apportioned operating costs among explanatory factors in a manner surprisingly similar to Ferreri's model: vehicle miles - 27.8 percent; vehicle hours - 55.3 percent; peak vehicles - 10.1 percent; and passenger-revenue - 6.9 percent. Longitudinal regression cost models with good statistical fits have been developed by Nelson (1972) and Wells, et al. (1972), principally using log-linear equations developed from cost data of a large sample of transit properties.

The unit cost method is used in this study to allocate operating expenses among the three properties' bus routes. It was chosen over regression analysis since each property lacked a longitudinal data base which could be disaggregated at a route level. Moreover, a cross-sectional unit cost allocation approach seemed analytically most appropriate for drawing comparisons with revenue data compiled from on-board ridership surveys (which were administered at a single point in time). In addition, systemwide unit cost estimates had already been derived for each of the three properties using data from time periods which approximated those during which on-board ridership surveys were conducted. Given these factors plus the fact that managers from each agency have been employing the unit cost approach in their analyses of line-by-line performance, the unit cost method was deemed most appropriate for this study.

The SCRTD, AC Transit, and SDTC employ the following models for the purpose of allocating a share of total operating costs to any given bus line:

SCRTD: $$OC = 0.41(VM) + 16.44(VH) + 17.57(PO) + 107.77(PV) \quad (4.1)$$

AC TRANSIT: $$OC = [0.47(VM) + 13.56(VH)] \cdot 1.298 \quad (4.2)$$

SDTC: $$OC = 0.43(VM) + 20.76(VH) \quad (4.3)$$

where:
OC = Operating Cost (in dollars)
VM = Vehicle Miles
VH = Vehicle Hours
PO = Pull Outs
PV = Peak Vehicles.

By inserting into the appropriate formula the daily number of bus miles, hours, etc. generated by the operation of a particular bus line, a daily operating cost can be estimated for the route in question.

Each property's assignment of cost subcategories used in the computation of factor coefficients is displayed in Tables 4-1 through 4-3.[2] All data used in calibrating factor coefficients were from a one year time period, except in the case of SDTC's model where a fiscal quarter time period was employed.

Several major differences in the agencies' accounting procedures and assignment approaches are revealed by comparing the three tables. Though all included similar cost items, the classifications of expense subcategories varied noticeably. SCRTD disaggregated expenses on a "cost item" basis, while SDTC broke them down according to internal departments (e.g., transportation, planning, etc.). Another difference pertains to expenses related to the depreciation of fixed capital. The SCRTD lumped all depreciation for rolling stock, buildings, and equipment together under the categories of "local match, capital" and "debt service" using a declining-balanced method. AC Transit segregated depreciation of revenue equipment from that of overhead assets, while the SDTC excluded annual depreciation expenses altogether from its model. Also, AC Transit used a straight-line approach to capital depreciation rather than accelerating the rate of decline in the value of assets during the early years of service life. Since these data predated UMTA's Section 15 requirements on uniform accounting standards, inconsistencies in the itemization of expenses could have been expected. Thus, an exact comparison of the agencies' assignment of cost subcategories to factors is compounded by idiosyncratic accounting approaches.

Among the three agencies, four overall explanatory factors were utilized to estimate unit costs. All agencies attributed a large proportion, if not all, of their costs to the "vehicle mileage" and "vehicle hour" variables. In the case of SDTC, total (in-service plus out-of-service) vehicle miles and hours were applied, whereas SCRTD employed only in-service data (i.e., exclusive of deadhead or non-revenue miles and hours). AC Transit, by contrast, expressed the "vehicle mileage" factor in terms of scheduled (in-service) operations whereas the vehicle hour data was on a total platform (i.e., including non-revenue) basis. Also, SCRTD used a "peak vehicle" variable and a "pull out" variable. The "peak vehicle" factor served to relate expenses incurred in scaling service levels to accommodate peak loads while the "pull out" variable reflected those costs associated with buses entering and leaving a divisional garage.[3]

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[2]The sources of the tables were: SCRTD - Woodhull, J. (1978), "The Nature and Use of the Standard Cost Formula," SCRTD internal memorandum; AC Transit (1978), Five Year Plan: Fiscal Years 1979-83; and SDTC (1978), Five Year Plan Update: FY 1979-83.

[3]The "peak vehicle" variable represents the largest number of buses in operation at any one point in time, whether the morning or evening period. The term "pull out," on the other hand, refers to the number of buses required for the morning peak, plus the number of buses operating in the evening peak that were not needed for midday service. Arithmetically, this is equivalent to the sum of the morning and evening buses, less the number of midday vehicles. The "pull out" variable reflects expenses incurred during out-of-service operation. Together, the "pull out" and "peak vehicle" factors express incremental costs imposed by peak demands which are integral to the temporal analysis of transit fare policies.

TABLE 4-1. SCRTD COST COMPUTATIONS (FISCAL YEAR 1978)

Cost Subcategory	Total Costs (000)	In-Service Miles (VM)	In-Service Hours (VH)	Pullouts (PO)	Peak Vehicles (PV)
Mechanics' Labor	$ 14,000	0.70[a]	0.20	0.10	
Mechanics' Fringes	3,275	0.70	0.20	0.10	
Utilitymen's Labor	6,700				1.00
Utilitymen's Fringes	1,500				1.00
Maintenance Supervision, Clerical	5,820	0.20			0.80
Fringes	1,330	0.20			0.80
Fuel, Tires, etc.	19,000	0.70	0.20	0.10	
Indirect Purchases	2,100				1.00
Operators' Wages	85,000		0.88	0.075	0.045
Operators' Fringes	19,300		0.88	0.075	0.045
Superv., Clerical	7,270				1.00
Fringes	1,620				1.00
Indirect Purchases	1,000				1.00
Board, Gen. Mgr., Sec.	390				1.00
Legal, Safety	725				1.00
Operations, General	850			0.25	0.75
Building Services	1,750				1.00
Print Shop	880		0.70		0.30
Schedules	2,800	0.25	0.25	0.25	0.25
Planning	1,460				1.00
Customer Relations	3,300			0.20	0.80
Employee Relations	1,500	0.20	0.40	0.20	0.20
Accounting, Fiscal	3,000				1.00
Purchasing, Stores	920				1.00
Administration	890				1.00
Bus Facilities Eng.	600	0.75	0.20	0.05	
PL & PD Insurance	12,000	0.78	0.25		
Other Insurance	100				1.00
Local Match, Capital	9,900				1.00
Debt Service	2,900				1.00
Marketing	+ 2,400	+	+	+ 0.25	+ 0.75
Column Costs:	$216,120	$36,892	$104,225	$14,542	$60,460
Percent of Total Costs:		7.1%	48.2%	6.9%	28.0%
PARAMETER TOTALS:		89,000,000	6,340,000	2,682	1,781
FORMULA FACTORS:[b]		$0.41	$16.44	$17.57	$107.77
SCRTD Cost Allocation Model:	= 0.41(VM) + 16.44(VH) + 17.57(PO) + 107.77(PV)				

NOTES:

[a] Percentages represent the share of the cost item attributed to the factor.

[b] Formula Factors = (Column Costs ÷ Parameter Totals).

TABLE 4-2. AC TRANSIT COST COMPUTATIONS (FISCAL YEAR 1978)

Cost Subcategory	Total Costs (000)	(VM) Vehicle Miles	(VH) Vehicle Hours	(EF) Expansion Factor[a]
Maintenance Department:	$11,907	1.00[b]		
Parts and Supplies Fuel, Oil, Tires Revenue Equipment Depreciation				
Transportation Department:	28,902		1.00	
Driver Wages Driver Fringes				
All Other Departments:	12,161			1.00
Administration Supervision Insurance Marketing Services				
Column Totals:	$52,970	$11,907	$28,902	$12,161
Percent of Total Costs:		22.4%	54.6%	23.0%
Parameter Totals:		25,014,817	2,128,299	–
Formula Factors:[c]		$0.476	$13.58	29.8%
AC Transit Cost Allocation Model:	= [(0.476(VM) + 13.58(VH)] x 1.298			

NOTES:

(a) Expansion Factor accounts for overhead-related expenses. It equals Total Costs divided by Transportation and Maintenance costs.

(b) Percentages represent the share of the cost item attributed to the factor.

(c) Formula Factors = (Column Costs ÷ Parameter Totals).

TABLE 4-3. SDTC COST COMPUTATIONS (JULY 1978 - SEPTEMBER 1978)

Department	Total Costs	Vehicle Miles	Vehicle Hours
General Manager	$ 42,613	0.50[a]	0.50
Transportation	4,864,829	—	1.00
Maintenance	1,202,043	1.00	—
Planning/Scheduling	99,393	0.50	0.50
Customer Services and Marketing	96,372	0.50	0.50
Administration Services	296,597	0.50	0.50
Personnel	44,323	—	1.00
General Expense	69,023	0.50	0.50
Column Costs:	$6,715,193	$1,504,042	$5,211,151
Percent of Total Costs:		22.4%	77.6%
Parameter Totals:		3,505,644	250,993
Formula Factors:[b]		$0.43	$20.76
SDTC Cost Allocation Model:	= 0.43(VM) + 20.76(VH)		

NOTES:

[a]Percentages represent the share of cost item attributed to factor.

[b]Formula Factors = (Column Costs ÷ Parameter Totals).

Rather than associating cost subcategories with a single factor, the SCRTD and SDTC divided them among several variables. Both agencies pro-rated costs among competing factors using a Delphi-type approach which elicited expert opinions from a committee of transit professionals. AC Transit, on the other hand, used an "all-or-nothing" approach which assigned 100 percent of each cost subcategory to one of the two formula factors.

The formulae calibrated for these properties all differ from the traditional four factor model structure employed by Ferreri, Cherwony, and others. The most obvious difference is AC Transit's and SDTC's adoption of a simplified two factor formula. In both cases, a position was taken that system operating costs could be adequately associated with the "mileage" and "hours" factors, thereby allowing a streamlining of the model structure. AC Transit also used an expansion factor (1.298) to adjust the operating cost estimate of each route to account for general administrative and overhead expenses. Another notable difference was the omission of a "passenger revenue" factor from each property's model. Rather than link liability insurance expenses to "passenger revenues," the three properties incorporated such costs into either the "peak vehicle" or "vehicle mileage" factors. Also, SCRTD's and AC Transit's segregation of expenses into factors which account for either in-service (revenue-generating) or out-of-service (non-revenue) operations represents a further variation from the traditional cost allocation model.

4.3 Cost Centers Approach

The unit cost approach represents an attempt to apportion transit operating expenses among all lines using cost parameters generated from systemwide data. An implicit assumption of this "aggregate" approach is that driver wage levels, equipment qualities, maintenance practices, exogenous influences and efficiency levels are the same throughout a transit system. To the extent that these factors are invariant among routes or operating divisions, the computation of unit cost estimates from systemwide data seems reasonable. Realistically, however, the cost characteristics of routes would be expected to differ as surrounding surface street congestion, frequency of passenger boarding and alighting, vehicle age and similar factors varied among lines. An inner-city route requiring frequent stopping to load and discharge passengers, for example, would be expected to experience higher maintenance and repair expenses than a non-stop express service.

In contrast to the unit cost method, the direct assignment of driver wages, fuel, repairs, and promotional expenses to the particular routes in which they were incurred would improve the accuracy of operating cost estimates. The direct linkage of costs to individual routes would necessitate an elaborate accounting system. The marginal gains in accuracy, however, would unlikely be sufficient to justify the additional accounting expenses. Ideally, a cost allocation method which struck a balance between the unit cost method and the direct assignment approach is called for.

The concept of "cost centers" offers a compromise between these two extremes. Alford and Bangs (1948, p. 1449) define cost centers as "units, functions, or areas within an establishment that are homogenous from the cost point of view. They are natural divisions of an organization for cost finding purposes." Dierks (1975) adds that:

> As an ideal, every item of cost incurred would be assigned to the cost objective which caused the incurrence of the cost. In particular, though, this ideal is rarely attained as many costs are incurred at a point significantly removed from the cost objective which caused its incurrence. Intermediate cost objectives, or cost centers, are then utilized to pass the cost through an organization to the final cost objective - the product produced. Costs not directly identified with final cost objectives are grouped into logical and homogenous cost pools and assigned through the hierarchy of intermediate cost objectives by employing an allocation procedure at each hierarchical level. Thus, a cost allocation process is basically the accumulation of costs into cost pools and assignment of those costs ... through the use of an allocation procedure.

In the transit industry, these "intermediate cost pools" referred to by Dierks are best represented by "operating divisions." For most large transit properties, divisions are identifiable facilities at which groups of bus lines operate, drivers receive specific route assignments, maintenance activities are conducted, and separate accounting records are maintained. Divisions are most easily visualized as the individual complexes of administrative buildings, storage facilities and garages which serve as a home base for a specific network of bus routes. Accordingly, they represent logical units for performing a "cost centers" analysis.

A "cost centers" approach was employed in refining SCRTD's and AC Transit's unit cost formulae. Since SDTC maintains only one division for all operations, its systemwide cost formula was retained. In the case of SCRTD, individual four factor equations were calibrated for each of the eleven divisions from which its thirty sample lines operated. Also, four unique unit allocation models were developed to characterize the cost features of AC Transit's divisions. The formula factors calibrated for each of the two properties' operating divisions are displayed in Table 4-4. The particular sample bus lines from each division are also identified in Table 4-4.[4]

For both SCRTD and AC Transit, fiscal year 1977-78 audited cost data on operations, maintenance, and general administration were gathered from each division to estimate "cost centers" allocation formulae. At SCRTD's division level, cost subcategories were pro-rated among the four competing factors using the systemwide apportionment rates previously shown in Table 4-1. Since data on vehicle miles, vehicle hours, pull outs, and peak vehicles were available at

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[4]Some lines operate out of several divisions, thus accounting for some repeated listing of routes.

TABLE 4-4. COST CENTERS REFINEMENTS OF UNIT COST ALLOCATION FORMULAE
(In dollars)

SCRTD (FY 1978-79)					
Division	Lines	In-Service Vehicle Miles	Scheduled Vehicle Hours[a]	Pull-Outs	Peak Vehicles
I	3,28,801,826	.42	13.56	16.88	88.53
II	2,22,25,29,91,95	.51	14.48	16.18	97.76
III	6,42,47,87,435	.42	14.56	20.08	99.05
V	73,607,828,	.40	14.13	16.50	87.32
VI	873	.41	13.36	13.84	87.16
VII	3,42,89,91	.42	12.78	14.77	89.05
VIII	35,144	.41	13.16	14.65	86.70
IX	480	.37	15.41	16.47	87.91
XII	33,814	.42	15.37	15.94	82.76
XV	154	.38	13.66	20.75	99.57
XVIII	3,29,34,114,869,873	.45	14.76	18.17	106.22
SYSTEM AVERAGE[b]		.41	14.14	16.58	91.41

AC TRANSIT (FY 1978-79)				
Division	Lines	Total Vehicle Miles	Total Vehicle Hours	Overhead Expansion
II	A,11,51/58,65,72,306	.25	18.40	1.298
III	G,31,70	.30	18.02	1.298
IV	K/R,46/87,54,79 80/81,82/83,84,90/92	.29	18.62	1.298
VI	U,22/24,32	.21	18.93	1.298
SYSTEM AVERAGE[c]		.26	18.46	1.298

NOTES:

(a) Scheduled vehicle hours (including pull out, pull in, deadhead, layover, and off-route time) were used in lieu of in-service vehicle hours for the "cost center" model due to the unavailability of in-service data at the division level.

(b) SCRTD's systemwide factor coefficients differ somewhat from those displayed in Table 4.1 due to the use of cost data from different time periods as well as the replacement of the in-service vehicle hour factor with a scheduled service variable.

(c) AC Transit's systemwide factor coefficients differ from those displayed in Table 4.2 due to the use of cost data from different time periods.

the division level only on a daily basis, expansion factors were developed to annualize these variables in order to calibrate cost coefficients.[5]

A comparison of each property's systemwide and divisional factor coefficients (from Table 4-4) reveals a significant variation in unit cost characteristics. In the case of SCRTD, the divisional factor coefficients varied around the system's mean coefficients by ten to twelve percent, with the largest differential in the "pull out" factor and the smallest in the "vehicle hour" variable.[6] The variability among divisions of AC Transit's factor coefficients was similar; the average differential of the vehicle mileage coefficients (around the mean) was 2.4 percent while the vehicle hour coefficients varied by slightly less.

The attraction of the "cost centers" approach is its ability to reflect the unique cost characteristics of bus lines according to division of operation. To the extent that factor coefficients vary when disaggregated at the divisional level, it can be argued that the accuracy of individual bus line cost estimates is improved. Accordingly, the relative differences in the factor coefficients calibrated for the SCRTD and AC Transit would seem to support the use of "cost centers" estimation procedures. However, it can also be argued that the "cost centers" approach offers no real improvement over the systemwide unit cost formula if bus lines within divisions exhibit heterogenous cost characteristics. For instance, if there were a mix of intra-city, high-volume bus lines and inter-city express services operating within each division, the variance in cost characteristics could be larger among routes within the division than among routes between divisions. Thus, a "cost centers" approach could create a false impression that the systemwide formula was being refined.

It is impossible to perform an Analysis of Variance test on the divisional cost data to evaluate within versus between group differences since the true costs of operating individual bus lines cannot be derived (short of directly assigning wages, fuel, parts, overhead, etc. to each line). However, routes within divisions can be subjectively evaluated in terms of their comparative operating and cost characteristics. Generally, bus routes assigned to each of SCRTD's and AC Transit's divisions appear quite homogenous in terms of service types, rider composition, and geographic area of service. For example,

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[5]For annualization, a "non-holiday, school-day, non-race" weekday was chosen to represent the vehicle mileage, vehicle hour, etc. characteristics of both properties' Monday-through-Friday divisional operations. Then, the vehicle miles, hours, etc. of each division's "typical" weekday (as well as weekend) were expanded to 365 days and divided into annual cost figures to compute a series of "cost centers" equations.

[6]The relative standard deviations of factor coefficients (measured as percents of means) ranged from 7 percent for the vehicle hour variable to 13 percent for the pull-out variable. The relative difference between low and high coefficient values (again expressed as percents of means) ranged even more, from a low of 16 percent for the vehicle hour variable to a high of 41 percent for the pull out factor.

SCRTD's Division VIII serves as the home base for primarily express and inter-city services between downtown Los Angeles and suburban communities in the San Gabriel valley. Table 4-4 indicates that Division VIII's four factor coefficients lie at or below the average system coefficients, perhaps suggesting economies in serving longer distance trips. On the other hand, the bus routes of Division XVIII can all be characterized as high volume, inner-city operations serving predominantly transit-dependent populations. Again referring to Table 4-4, Division XVIII's factor coefficients exceed the system's averages, perhaps indicating some relative diseconomies in the operation of these services. In view of the relative homogeneity of routes within the two properties' divisions, the "cost centers" approach would seem to capture the individual cost attributes of groups of bus lines, consequently improving line-by-line cost estimates.

4.4 Route Cost Estimates and Analysis

Preliminary estimates of each sample route's daily operating costs were derived by inserting operating data (on vehicle miles, hours, etc.) into the appropriate divisional cost formulae. These estimates were further divided by daily counts of route passengers, in-service vehicle hours, in-service vehicle miles, and total passenger miles to derive unit costs. Results are presented in Tables D-1 to D-6 in the Appendix.

The unit costs were analyzed to determine whether the cost centers approach demonstrated any distance economies. Recall from Chapter Two, unit costs have been empirically shown to decrease with travel distance. Using data from Appendix D, the relationship of daily unit costs with such variables as average trip distance, one way route miles, and average travel speed were analyzed using both correlation and multiple regression techniques.

The seven distance-related independent variables used in the analysis of unit operating costs are defined as follows:

1. Oneway Route Miles measure the uni-directional distance between a bus route's terminals. Oneway mileage best distinguishes short from long routes.

2. Average Daily In-Service Miles represent the total bus mileage traversed by a single bus run during a typical weekday while serving revenue passengers (i.e., in-service operations).[7]

3. Average Trip Distance represents the mean trip length of a bus route's daily ridership.

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[7]This variable does not necessarily reflect travel distance. A circuitous bus run may amass a large amount of mileage during a driver's tour of duty but may cover a geographically limited area and serve predominantly short trips. However, long distance routes would generally be expected to score higher on this variable than short distance ones.

4. Average Travel Speed measures the average in-service mileage covered during one hour of operation. Routes operating segments within congested areas would be expected to experience slower speeds while routes with express or low-density links would generally record higher ones.

5. Daily Passengers consist of 24-hour ridership counts. This variable serves as a proxy for the relative service density of a route as well as the level of boarding/alighting activity it experiences. High ridership routes with considerable on/off activity generally operate in dense, inner urban areas while long distance lines typically accommodate fewer passengers in less congested surroundings.

6. Average Load Factor is an index of seating availability averaged over a daily period. It is computed by dividing a bus route's average ridership at maximum load point by the seating capacity of vehicles assigned to the route. The load factor represents an alternative proxy measure of route densities and volume intensities.

7. Express Dummy Code represents a nominal-scale variable whereby express routes are assigned the value 1 and all other routes are assigned 0. Express routes are defined as those operations in which at least 25 percent of in-service bus miles are on non-stop (or freeway) links.

Table 4-5 presents matrices of Pearson product moment correlations, derived from associating these seven variables with each property's unit cost estimates. The Cost/Passenger and Cost/Bus Hour variables appear to be positively correlated with indices of travel distance and route length, however negatively associated with variables reflecting high-density operations (i.e., "passengers" and "load factors"). For all three study sites, costs per passenger and per hour generally increased with longer average trip distances and faster travel speeds. Moreover, SCRTD's and AC Transit's express (dummy) variable was positively correlated with these measures of unit cost. The highest correlation was found between SDTC's cost per bus hour and one-way bus miles variables: .97.

The positive relationships between travel distance and both Cost/Passenger and Cost/Hour reflect the fact that many long distance and express routes carry relatively small numbers of passengers during limited hours of the day, thereby inflating the unit cost ratios. Conversely, routes serving shorter distance trips generally operate in relatively high density areas where passenger loads are often high; thus, the large denominators of these routes' cost ratios produce relatively low unit costs. Although Cost/Passenger and Cost/Hour capture the effect of ridership loads on unit costs, they appear inappropriate for evaluating "cost centers" models' propensities for reflecting "distance economies."

Cost/Bus Mile and Cost/Passenger Mile serve as better indicators of how "distance" influences unit costs. By factoring operating expenses on the basis of vehicle mileage as well as passenger volumes, components of route distance, ridership loads, and service densities are merged into the unit cost measure. Coefficients from Table 4-5 generally indicate that Cost/Mile and Cost/Passenger-Mile are inversely related to distance: the higher the speed, the longer the average trip length, and the more one-way bus miles - the lower the unit costs.

TABLE 4-5. CORRELATIONS OF DISTANCE-RELATED VARIABLES WITH UNIT COST ESTIMATES[a]

		One-Way Route Miles	Average Daily In-Service Bus Miles	Average Trip Distance	Average Travel Speed	Daily Passengers	Average Load Factor	Express Dummy Code
SCRTD	Cost/Passenger	.49	-.62	.88	.83	-.69	#	.63
	Cost/Bus Hour	#	#	.60	.76	#	#	#
	Cost/Bus Mile	-.83	#	-.72	-.87	.78	#	-.43
	Cost/Passenger-Mile	-.46	-.53	#	#	-.45	#	#
AC TRANSIT	Cost/Passenger	#	#	#	.74	-.52	#	.46
	Cost/Bus Hour	#	#	.86	.92	#	-.48	.74
	Cost/Bus Mile	#	#	-.82	-.96	#	#	-.78
	Cost/Passenger-Mile	#	-.44	-.52	#	#	-.65	-.45
SDTC	Cost/Passenger	#	#	#	.72	-.84	-.49	#
	Cost/Bus Hour	.97	.75	.48	.67	#	#	#
	Cost/Bus Mile	-.72	#	-.80	-.93	.72	#	-.68
	Cost/Passenger-Mile	-.70	-.64	-.58	#	-.50	#	-.59

NOTE: a - All Pearson coefficients shown are significant at the .05 level.
- Denotes either an insignificant or meaningless relationship.

For all three operators, "average speed" emerged as the independent variable most negatively correlated with Cost/Mile.[8] In addition to the "one-way bus miles" and "average trip distance" variables, a strong negative correlation was found between the "express dummy" variable and Cost/Mile. The significantly positive correlations between SCRTD's and SDTC's "passenger" and "cost per mile" variables, by contrast, suggest that each mileage increment of a high-volume route is relatively more expensive to operate. Cost/Passenger Mile, and the "passenger" variable were negatively correlated, showing that unit cost savings can be reaped from high usage levels, frequent service headways, long routes, or a combination of these factors. As with the "cost per mile" variable, Cost/Passenger-Mile generally declined with longer routes, bus mileage, longer average trips, and express service.

To supplement the correlation analysis, scattergrams were prepared to determine whether any non-linear patterns existed between measures of unit cost and the seven independent variables. For all three properties, costs per mile and per passenger mile appeared to decline with several of the independent variables at a decreasing rate. In order to capture these non-linear relationships, a number of least-squares multiple regression equations were fitted to the data.

The regression equations providing the best least squares fit between the distance-related independent variables and the criterion variables (Cost/Mile and Cost/Passenger Mile) are summarized below for each study site.

4.4.1 SCRTD Unit Cost Analysis

The two models explaining the highest proportion of variance in SCRTD's Cost/Mile and Cost/Passenger-Mile variables are:

$$C/M = 2.86 - \underset{(44.7)^{**}}{.034(OWRM)} + \underset{(11.6)^{**}}{.15(PASS)} \tag{4.4}$$

$$C/PM = .16 + \underset{(84.1)^{**}}{1.17(ATD)^{-2}} - \underset{(39.0)^{**}}{.0065(PASS)} + \underset{(5.2)^{*}}{10160(ABM)^{-2}} \tag{4.5}$$

where:

C/M = Cost per Bus Mile, in dollars
C/PM = Cost per Passenger-Mile
OWRM = Oneway Route Miles
PASS = Daily Passengers, in thousands
ATD = Average Trip Distance
ABM = Average Daily In-service Bus Miles
* = t-Statistic Significant at the .05 level
** = t-Statistic Significant at the .01 level.

These equations led to a good fit, yielding multiple correlations (R^2) of .80 and .92, respectively. Both were significant at the .01 level. Also, the t-statistics of all regression coefficients were highly significant.

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[8]This correlation is consistent with Holthoff and Knighton's (1976) finding that the relative cost per bus mile of three New York State municipal operators declined between 13 and 18 percent for every one mile per hour increase in average vehicle speed.

Equation (4.4) indicates that SCRTD's Cost/Mile declines linearly with longer route structures and lower passenger volumes. Equation (4.5) suggests that Cost/Passenger-Mile declines at a decreasing rate as average trip lengths become longer and total in-service miles increase and at a linear rate as passenger volumes rise. The inference to be drawn from these relationships is that SCRTD's unit costs tend to decrease with longer trip lengths, and that "passengers" are positively related to costs on a "per mile" basis (although negatively related in terms of "passenger-miles"). Thus, SCRTD inter-city and express routes appear to experience "distance economies" as measured in Cost/Mile. However, both longer-distance routes and high-volume operations enjoy some economies when expenses are indexed in terms of Cost/Passenger-Mile.

4.4.2 AC Transit Unit Cost Analysis

The two "best" models calibrated from AC Transit's data on Cost/Mile and Cost/Passenger-Mile are:

$$C/M = 2.16 - \underset{(13.7)^{**}}{.53(EC)} + \underset{(5.9)^{**}}{.66(ATD)^{-2}} \qquad (4.6)$$

$$C/PM = .62 - \underset{(10.1)^{**}}{.66(LF)} + \underset{(10.0)^{**}}{.79(ATD)^{-2}} \qquad (4.7)$$

where (in addition to the previous definitions):

EC = Express Dummy Code
LF = Load Factor.

The R^2 estimates of equations (4.6) and (4.7) are .68 and .64, respectively. Again, the multiple correlations and the accompanying regression coefficients differ significantly from zero at the .01 level.

In both equations, unit costs decline in a rectangular hyperbolic manner with average trip length: routes serving short distance trips experience high cost ratios while those with medium-to-long distance trips incur relatively low unit costs. The negative sign of the express (dummy) variable of equation (4.6) lends further support to the existence of "distance-related economies" in AC Transit's operations.[9] The "load factor" variable's negative sign, on the other hand, indicates that high-volume operations appear cost-efficient whenever expenses are factored on a "passenger-mile" basis.

The influence of route structure on AC Transit's Cost/Mile can be illustrated by applying equation (4.6) to data from dissimilar bus operations. Comparing AC Transit's six sample express lines with the remaining non-express sample routes, equation (4.6) yields respective Cost/Mile estimates of 1.63 and 2.23, a differential of 30 percent. However, the differential fell to 22 percent when the comparison was between express routes and regular services

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[9]Holding the ATD variable constant, the Cost/Mile of express routes is found to be one-quarter less than that of regular services.

which accommodate mid-distance trips (over 4 miles). It can be inferred that "distance economies" are the greatest between AC Transit's routes which serve very short trips and those which serve long-haul commutes, with the relationship diminishing between express services and moderate trip length operations.

4.4.3 SDTC Unit Cost Analysis

Equations (4.8) and (4.9) identify SDTC's best Cost/Mile and Cost/Passenger-Mile operations:

$$C/M = 2.31 - \underset{(20.8)^{**}}{.028(OWRM)} + \underset{(38.9)^{**}}{.0013(PASS)} - \underset{(6.7)^{*}}{.24(EC)} \qquad (4.8)$$

$$C/PM = .23 + \underset{(110.8)^{**}}{1.90(PASS)^{-2}} - \underset{(33.8)^{**}}{.0086(ATD)}. \qquad (4.9)$$

The fits were very good, producing R^2 values of .98 and .97, respectively. All regression coefficients were highly significant at the .01 level, with the exception of the express (dummy) variable which had a t-value significant at the .05 level.

Equations (4.8) and (4.9) reveal that averages of Cost/Mile and Cost/Passenger-Mile among SDTC's lines decline linearly with higher one-way route miles, longer distance journeys, and express service levels. As with the SCRTD system, SDTC's "passenger" variable (as a proxy of usage intensity) is positively related with Cost/Mile, yet inversely associated with Cost/Passenger-Mile.

4.4.4 Comparative Unit Cost Analysis

From these analyses, it appears that the "cost centers" estimates of each property's range of bus services did result in an element of "distance-related" economies, at least when unit costs were expressed on the basis of "mileage" and "passenger-miles." Such was the case even for the SDTC, where no division-level refinement of cost data was performed. Whenever costs per mile or per passenger-mile were found to be non-linear functions of such variables as "oneway bus miles" and "average trip distance," disparities in unit costs were seen to be greatest between routes characterized by short distance travel and those serving more moderate to long-haul journeys. That is, the hyperbolic relationship meant that "very high" unit costs were associated with routes oriented toward short distance travel and that cost differences were relatively small between routes accommodating mid-range trip distance and those providing express services.

4.5 Peak/Off-Peak Cost Apportionments

There are two primary differences between peak and off-peak operations which should be accounted for in the analysis of transit costs: (1) capital and overhead outlays are scaled to accommodate peak loads, thus warranting the allocation of higher rates of fixed costs to peak time periods; and (2) labor costs, although paid at a standard hourly rate, effectively vary by time-of-day since peak work activities lead to more spread time and overtime duties, resulting in more "payhours" per "vehicle hour" of operation.

Three steps were taken to attribute each property's full range of operating and capital costs to either the peak or base period. First, the "vehicle hour" variable of each "cost center" allocation formula was adjusted to account for the relatively high proportion of "payhours" during peak periods in comparison with those in the base. Second, systemwide capital costs were apportioned among time periods on a route-by-route basis. Finally, unit cost factors (i.e., "vehicle miles," "vehicle hours " etc.) were assigned to either the peak or base period so as to attain separate time-of-day cost estimates. Each of these cost allocation stages is discussed in the remainder of this section.

4.5.1 Time-of-Day Specification of the Vehicle Hour Coefficient

The cost allocation models calibrated for the three study sites assume that unit costs are the same throughout the day. Accordingly, estimates produced by these models represent a weighted average of peak and base conditions. For three of the factors - "vehicle miles," "pull outs," and "peak vehicles" - the use of weighted average coefficients to estimate costs seems appropriate. Generally, unit costs associated with these three factors are independent of peak or base usage. For instance, maintenance costs associated with the "vehicle mileage" factor are essentially the same for peak and off-peak services since the wear and tear of a bus is fairly constant for each mile of travel. Due to the larger number of vehicle miles, pull outs, and buses in operation during the peak compared to the base, however, proportionally more expenses would generally be allotted to the peak.

By far, the largest cost difference between peak and base time periods relates to the labor component of the "vehicle hour" factor. It is widely accepted that stipulations in most labor contracts which prohibit the hiring of part-time drivers and limit split-shifts and spread time duties have increased the cost of providing transit services significantly. The effects of these penalizing labor provisions are particularly important because transit is a highly labor-intensive industry. Since the size of transit's labor force is scaled to the level of peak demand, many attribute the cost of these labor restrictions to the peak period. Wagon and Baggaley (1975) have estimated that the crew costs per minute of London Transport's peak operations are approximately twice those of the base due to labor union influences. Goldstein (1974), on the other hand, estimated that the effects of AC Transit's union agreement increased peak operating expenses only 20 percent above those in the base.

Given the extremes in estimates of labor unions' effects on transit cost differentials, it is important to clearly understand the components of labor contracts before apportioning expenses between time periods. Generally, the SCRTD, AC Transit, and SDTC operate under labor agreements which contain the following provisions:

1. Straight time duties are guaranteed among a fixed percentage of peak period drivers, thus ensuring that many work a continuous, uninterrupted day.

2. Guaranteed time ensures full-time drivers a minimum of 40 hours of pay irrespective of number of hours worked, even if only a fraction of the 40 hour week.

3. Combination time prescribes a full day's pay to drivers working around a peak period for less than eight hours.

4. Spread time penalties impose premium pay for any work performed beyond a fixed daily time span (e.g., time and a half pay for tripper duties over eight hours in an eleven hour spread).

5. Split-shift time limits the time span between work assignments (e.g., no more than two hours).

6. Over-time duties on straight or split tours are compensated at a bonus rate.

7. Part-time work is generally prohibited.

A similar consequence of these prohibitions and penalities is that transit's labor force, the size of which relates to peak ridership, is maintained intact throughout much of the day, whether or not there is sufficient off-peak demand to warrant such employment levels. The problem is compounded by the diurnal nature of commuting patterns - peak loads occur during a two to three hour time span in the morning and evening, necessitating full scale operations over a twelve hour stretch of time. Although many of these excess wage expenditures occur during off-peak periods, a legitimate argument can be made for attributing them to the peak. In addition to these union-related influences, other factors should be considered when assessing the "true" labor costs incurred during the peak period. For one, labor efficiency tends to be relatively low under peak operations since considerable time is spent deadheading to additional runs. In general, the proportion of out-of-service to in-service payhours is higher in the peak than the base due to these deadheading activities.

In attributing a larger proportion of total labor costs to peak operations, a procedure is needed to adjust the "vehicle hour" factor - upward in the peak model and downward in the base model - since the weighted-average "vehicle hour" factor underestimates the costs of peak service and exaggerates those of the base. Ideally, a cost allocation model which employs "payhours" in lieu of "vehicle hours" is called for. However, the scarcity of good payhour data has historically led to use of the "vehicle hour" factor as a surrogate measure. Cherwony and Mundle (1978) have developed an approach which ties together the "vehicle hour" and "payhour" indices in the temporal apportionment of operating costs. The most salient feature of their approach is that the "vehicle hour" coefficient is modified for the peak and off-peak periods based on two factors: relative labor productivity and a service index. The "labor productivity" factor adjusts the unit cost coefficient by comparing the ratio of payhours to vehicle hours in the peak versus the base. The "service index" simply compares the number of vehicle hours in the peak with those in the base. While the "labor productivity" factor functions as a measure of the penalizing features of labor agreements, the "service index" measures the relative amount of service offered in each time period.

The equations developed by Cherwony and Mundle to adjust the respective peak and base "vehicle hour" coefficients are:

$$VH_p = \frac{n(1+s)}{1+ns} VH \tag{4.10}$$

$$VH_B = \frac{1+s}{1+ns} VH \tag{4.11}$$

where:

VH_p = Peak vehicle hour coefficient

VH_B = Base vehicle hour coefficient

VH = Weighted-average daily vehicle-hour coefficient

n = Relative labor productivity: ratio of peak to base payhour/vehicle hour

s = Service index: ratio of peak to base vehicle hours of service.

The authors derived these adjustment equations through a series of algebraic substitutions between alternative unit cost expressions of "vehicle hour" and "payhour" factors (Cherwony and Mundle, 1978, pp. 53-54).

Before applying these adjustment factors to the "vehicle hour" coefficients of the three case studies' "cost centers" equations, a process had to be developed for attributing each route's payhours to either the peak or the base period. The attribution of payhours to time periods is inherently a subjective process, relying on an observer's interpretation as to whether a route's overtime pay hours, premium pay hours, etc. were "caused" by demands in the peak, the base, or jointly. Without any prescribed rules for attributing payhours to time periods, however, one runs the risk of inconsistently applying different standards among routes and bus runs. Thus, a priori assumptions were made which could be universally and consistently applied among all bus runs of each property in order to minimize the "subjectivity" of assigning payhours and to lend structure to the attribution process.

The following "attribution rules" were applied in assigning SCRTD, AC Transit, and SDTC's vehicle hours and payhours to either the peak or base periods:

1. Vehicle hours were attributed to the peak and base according to their occurrence (i.e., SCRTD's vehicle hours occurring between 6:15-8:45 a.m. and 3:15-5:45 p.m. were assigned to the peak and all others to the base).

2. All deadhead time, sign on, time-on, sign off, time-off, elapse time, and miscellaneous time was allotted to the base for straight runs and to the peak for split runs.[10]

3. Overtime earned during the base was attributed to the base for straight runs and peak for split runs.

4. Premium and combination payhours provided for driver tours of less than eight hours were allocated solely to the peak under the premise that such pay represents compensated time revolving around peak loads for which insufficient off-peak demand exists.

5. All biddable and non-biddable tripper[11] time (including that for deadhead, sign-on, premium, etc.) was assigned to the peak except those portions extending into the base time period.

6. Overtime payhours for biddable and non-biddable trips which exceeded eight hours within an eleven hour spread of time were allocated to the peak at a rate of time and a half.

7. Any extra operator payhours spent driving trippers or sitting idle were assigned to the peak. Extra operators' time substituting for regular drivers was pro-rated between the peak and base according to time period of occurrence.

These "attribution rules" are similar to the ones used by Reilly (1977) in his study of Albany's CDTC peak costs. As with Reilly's attribution assumptions, they are relatively conservative in that uncertainties are resolved by assigning those payhour allocations which are debatable to the base period.

The attribution of each property's vehicle hours and payhours to either the peak or base period was performed by applying the aforementioned "rules" to data from work assignment sheets maintained by the Scheduling and Planning departments of each agency.[12] Sometimes referred to as "basics," these work

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[10] Though the nomenclature varies among properties, these time categories generally represent non-revenue producing work periods in which drivers sign on-board, check the bus, deadhead to and between runs, wait for additional runs, return to the division, and sign off.

[11] Trippers are supplemental bus runs during peak time periods which operators drive in conjunction with their regular tours. Trippers are distinguished by those runs which are up for bid based upon driver seniority and those which are directly assigned (non-biddables).

[12] The work assignment data were compiled from the following internal records of each agency's Scheduling Department: SCRTD Work Runs; AC Transit Synopsis of Runs; and SDTC Work Assignments. Also, work run summaries detailing each of SCRTD's tripper operations were obtained by accessing stored schedule data using the Scheduling Department's interactive Univac 1100 "Sched" program.

assignment sheets provide a detailed, line-by-line breakdown of each individual bus run's payhours according to such designated categories of time as revenue, vehicle hours, deadhead, overtime, and so forth. Since these assignment sheets change whenever there is a "shake-up"[13] in work activities, "basics" from the time periods most closely corresponding to the fiscal period of each case study's cost data were utilized.

The accumulated totals of payhours and vehicle hours attributed to the peak and base periods of each transit property's routes are presented in Tables E-1 through E-3 of the Appendix. Averaging from all sample routes, SDTC's peak period required 52.8 percent more payhours than vehicle hours, while the base period had only 14 percent more payhours than vehicle hours - yielding a labor productivity differential of 33.7 percent. For the SCRTD system, there were 39.3 percent more payhours than vehicle hours in the peak, yet only 7 percent more in the base - producing a differential of 30.2 percent. On the other hand, AC Transit's average differential between the peak and base payhour/vehicle hour ratio was smaller - 14.2 percent.[14] The comparatively large proportion of payhours accumulated during SDTC's and SCRTD's peak operations can be partly attributed to their use of split runs and tripper services to handle a sizable share of commuter trips.

The "vehicle hour" coefficient displayed in Columns (12) and (13) of Appendix E are unique, reflecting the individual scheduling, labor productivity, and service characteristics of each route. Averaged among all the sample lines of each property, these temporal adjustments led to the following differentials between the peak and base period "vehicle" coefficients: SCRTD - 28.3 percent; SDTC - 27.9 percent; and AC Transit - 10.4 percent. These coefficient refinements are significant in view of the fact that well over fifty percent of each property's total operating expenses are attributable to the "vehicle hour" factor.

A review of a number of other studies suggest that the estimates in Appendix E are reasonable. Reilly (1977) found a 12.5 percent differential between the peak and base vehicle hour cost factor of Albany's CDTA system while Cherwony and Mundle estimated the temporal differences for the same factor for the Minneapolis-St. Paul MTC to be 15 percent. These relatively modest variations in peak/off-peak vehicle hour costs, however, have also been countered by estimates of substantial differentials. In Mohring's (1972) study of the Twin Cities MTC system, for example, a 100 percent difference in the vehicle hour factor was estimated. Similarly, Boyd et al. (1973) estimated peak vehicle hour costs to be incurred at twice the rate of those in the base (using national bus and rail transit data). Wagon and Baggaley (1975),

[13] "Shake-ups" are routine reassignments of bus runs and rebiddings of tripper and overtime duties undertaken to reflect changes in seniority status and work rules.

[14] AC Transit's payhour/vehicle hour ratio compares closely with several other studies, notably Cherwony and Mundle's finding of a 14.1 percent differential in the relative labor productivity of the Twin Cities' MTC operation.

in an analysis of London Transport's cost structure, also estimated an effective 100 percent differential in the "vehicle hour" factor between time periods.

4.5.2 Time-of-Day Allocations of Capital Costs

Several steps were taken to incorporate the cost of owning and using capital into the temporal analysis of transit expenses. First, each property's capital expenses were annualized. Next, annual depreciation estimates were apportioned into peak and base period components. Lastly, "cost centers" models were adjusted to capture these time-of-day differences. Each step is discussed below.

In order to compare transit's capital expenses with variable (operating) costs, it is necessary to express the value of fixed capital assets on an annual basis. This is normally done by computing an annual depreciation (or debt service) estimate which accounts for the monetary value of utilizing capital over a one year time period. It is recalled from section 4.2 that SCRTD and AC Transit included a depreciation cost item in their respective unit cost models. SCRTD linked all depreciation expenses to the "peak hour" factor while AC Transit spread depreciation among the "vehicle mileage" and "overhead expansion" factors. For these two agencies, it was necessary to apportion between the peak and base periods a share of total expenses incorporated in those formula factors containing depreciation costs. In the case of the SDTC, however, a large share of capital depreciation costs were omitted altogether from the system's allocation model;[15] thus, a capital cost component was needed to augment the agency's two factor equation.

The annual depreciation of each agency's total fixed assets (during fiscal year 1978-79 for SCRTD and AC Transit and fiscal year 1977-78 for SDTC) was: SCRTD - $7.83 million; AC Transit - $1.88 million; and SDTC - $0.95 million.[16] Generally, these depreciation estimates reflect the annual decline in value of such physical assets as rolling stock, buildings, shop equipment, office equipment, storage and maintenance facilities, and accessories (like fareboxes, radios, and shelters). In computing annual estimates of capital depreciation, each agency generally assumed the following functional service lives: buildings - 30 to 40 years; rolling stock and revenue equipment - 12 to 15 years;

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[15] Depreciation on buildings and rolling stock were excluded from SDTC's unit cost allocation model. However, some minor capital expenses on garage equipment and office furniture were allocated to the "vehicle hour" and "vehicle mileage" factors under the Maintenance and Administration Services departments. These accounted for less than six percent of total depreciation costs, however, and were thus not considered in the time-of-day analysis of SDTC's capital costs.

[16] Sources for these data were: SCRTD (1979), SCRTD Annual Report 1978-1979; AC Transit (1979), Financial Report for the Fiscal Period July 1, 1978 to June 30, 1979; and Arthur Anderson & Co. (1978), SDTC Financial Statements as of June 30, 1978 and 1977.

and all other capital - 5 to 10 years.[17] Also, salvage values (of between five and ten percent of the original purchase value of all assets) were used in deriving annual depreciation estimates. In addition, each agency employed a "straight-line" approach to depreciation (without any interest factor), with the one exception that the SCRTD applied a "declining balance" method in depreciating revenue equipment such as buses. SCRTD chose the "declining balance" approach since rolling stock historically declines in value at a non-linear rate, with the largest proportion of depreciation occuring during early service life.

For purposes of this study a "capital recovery factor" approach to the depreciation of assets was employed. Under this approach, the net value of capital (i.e., original cost minus accumulated depreciation and scrap value) is amortized over an asset's entire service life using an interest rate which reflects the true opportunity cost of resources and which also attributes a larger proportion of depreciation expenses to future years. When the net worth of capital is multiplied by this factor, an annual depreciation estimate is derived which, when summed with interest over a specified period of time, would equal the amount to which the original expenditure would be expected to grow (with interest). Using net capital asset values from the balance sheets of each agency's annual reports, assuming an eight percent interest rate, and retaining the previous assumptions on service lives and salvage values, the "capital recovery factor" method resulted in the following estimates of annual depreciation: SCRTD - $7.91 million; AC Transit - $2.06 million; and SDTC - $0.98 million.[18] In comparing these revised figures with those presented previously, there appears to be only a marginal increase in the estimate of each agency's annual depreciation.

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[17] Estimates of useful service life range only slightly among the agencies. For example, AC Transit assigned a functional life of twelve years for buses while SCRTD assumed a fifteen year longevity. All assumptions were consistent with service life guidelines suggested by the Internal Revenue Service and the American Institute of Certified Public Accountants.

[18] Data between 1972 and 1979 were used to derive estimates of each agency's average net worth of capital assets (with all inputs adjusted to 1979 dollars at an eight percent interest rate). An averaging approach was employed since the net value of capital as of any particular fiscal year can vary drastically from previous periods. For example, were a transit system to purchase a new fleet of buses or convert their computer facilities during the particular fiscal year of analysis, the annual depreciation figure would be inflated relative to preceeding years. An average net worth estimate reduces any possible aberrations in the data. In the case of SDTC, the following calculations were used in estimating the $0.98 million annual depreciation figure. With a weighted-average service life of 17 years for SDTC's building and revenue equipment and an interest rate of 8 percent, the capital recovery factor is 0.109629. Multiplying this factor by the average net worth of capital ($8.94 million) yielded an annual provision of $0.98 million. Similar computations were made for the other two agencies.

Before factoring each agency's (model) data inputs to account for temporal capital cost differences, it was necessary to apportion the revised annual depreciation estimates into peak and off-peak components. Boiteux, Steiner, and others have presented arguments for charging the total costs of capital outlays to rush hour commuters since peak demand determines fleet size and overhead requirements. Precedents for assigning 100 percent of capital depreciation to the peak period have been established in studies by Keeler, et al. (1975), Parker and Blackledge (1975), Mohring (1972), Goldstein (1974), and Cherwony and Mundle (1978). Others, however, challenge this convention, arguing that the depreciation of transit assets should be dependent on utilization. Instead, they call for a sharing of capital expenses among all users including those riding during the off-peak. Recall from Chapter Two, Boyd, et al. (1973) determined through simulation analysis that between 72 and 100 percent of transit's capital costs should be allocated to the peak. The authors suggested 85 percent as a reasonable benchmark. Studies by Lee (1975), McClenahan and Kaye (1974), Levinson (1978), and Taylor (1975) have opted for a pro-rating of capital costs between time periods, with the peak's share falling within the range established by Boyd, et al. (1973).

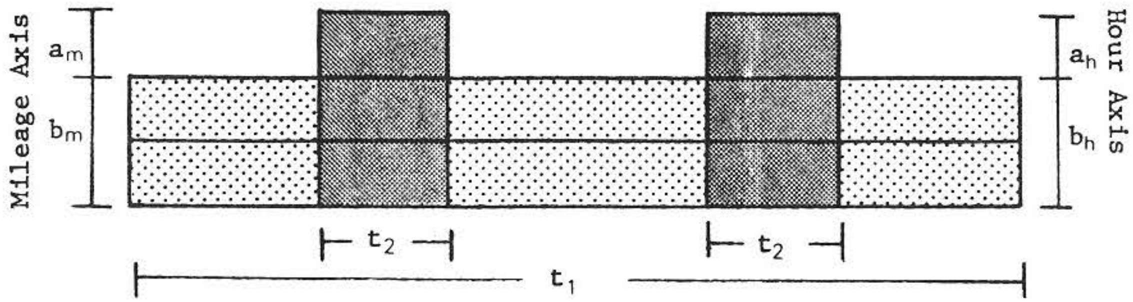
The 85/15 percent split of capital costs between the peak and base periods was employed in this study. The position was taken that this apportionment ratio reasonably attributes some of the wear and tear of buses to off-peak usage and is also consistent with other a fortiori assumptions which were favorable toward reducing costs attributed to the peak. Applying this apportionment split to the revised annual depreciation estimates led to the following capital cost allocations: SCRTD - $6.72 million to the peak and $1.19 million to the base; AC Transit - $1.75 million to the peak and $0.31 million to the base; and SDTC - $0.83 million to the peak and $0.15 to the base.

Following the estimation of each agency's annual depreciation and the subsequent 85/15 percent apportionment between the peak and base, the final step entailed translating depreciated dollar allocations into the data inputs used in the unit cost allocation models. For each sample bus route, a share of "peak vehicle," vehicle miles, etc. were assigned either to the peak or base period to reflect depreciation costs.

4.5.3 Time-of-Day Cost Computations

Computation of the total cost of operating each sample route during the peak and off-peak entailed inserting appropriate input data (on vehicle miles, vehicle hours, etc. for each time period) into the respective peak-adjusted and off-peak-adjusted cost allocation models. The apportionment of each sample route's "vehicle miles" and "vehicle hours" between time periods was fairly straightforward. Figure 4-1 shows that bus miles and hours which accumulated during the span of time t_2 (minus those already assigned to account for capital depreciation) were allocated solely to the peak. All others were allotted to the base.

The allocation of SCRTD's two additional factor inputs - "pull outs" and "peak vehicles" - was not quite as simple. The "pull out" factor, it is recalled, measures the sum of morning and evening peak buses, less the base



Factor	Daily Measure	Total Base	Total Peak	Peak Increment	Base Allocation	Peak Allocation
VEHICLE MILEAGE:	$b_m(t_1)+a_m(2t_2)$	$b_m(t_1)$	$(b_m+a_m)(2t_2)$	$a_m(2t_2)$	$b_m(t_1)-b_m(2t_2)$	$(a_m+b_m)\cdot(2t_2)$
VEHICLE HOUR:	$b_h(t_1)+a_h(2t_2)$	$b_h(t_1)$	$(b_h+a_h)(2t_2)$	$a_h(2t_2)$	$b_h(t_1)-b_h(2t_2)$	$(a_h+b_h)\cdot(2t_2)$

WHERE:

t_1 = 24 hour time period

t_2 = Total duration of each peak

a_m = Increment of Vehicle Miles above the base for each peak

b_m = Vehicle Miles during the base period

a_h = Increment of Vehicle Hours above the base for each peak

b_h = Vehicle Hours during the base period

FIGURE 4.1. APPORTIONMENT OF THE VEHICLE MILEAGE AND VEHICLE HOUR FACTORS

volume of buses operating during the midday. As such, it captures some of incidental expenses related to buses going into and out of service (i.e., deadheading). The "peak vehicle" factor reflects expenses related to expanded operations by measuring the maximum number of buses in service during either the morning or evening period (whichever is greater). Both factors generally accounted for non-capital overhead expenses on such functions as clerical support, building services, accounting, planning, and administration. The difficulty presented by these two factors, in contrast to vehicle miles and hours, is that there is no time continuum for causally assigning measures of "pull out" and "peak vehicles" between the peak and the base. Rather, both factors measure service intensity solely during the peak; accordingly, there is no theoretical basis for factoring a portion of these peak-related parameters into the base period.

Appendix F describes several alternative approaches tested for apportioning "pull outs" and "peak vehicles" between time periods. Based on a sensitivity analysis, the apportionment technique chosen as the most "reasonable" was as follows: increments of "pull outs" and "peak vehicles" above the base level were allocated solely to the peak and the residuals were pro-rated according to each time period's "vehicle hours."

Employing these allocation principles and adjusting each property's model coefficients to account for capital depreciation, separate peak and base period cost estimates were derived. Daily cost estimates for each property's time periods are displayed in Tables G-1 through G-3 in the Appendix.[19]

Based on the multi-stage allocation process described in this chapter, SCRTD's five hours of peak service accounted for 55.8 percent of the system's total daily costs. In comparison, AC Transit's four hour peak and SDTC's six hour peak constituted 58.5 percent and 52.5 percent respectively of each system's total daily costs. In sum, the estimation procedures used in this

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[19]Factor coefficients in the Appendix generally vary among the sample routes of each property, reflecting the individual "cost centers" models calibrated for each operating division. Each route's "vehicle hour" coefficient also differs between the peak and base periods; the adjustments to this factor reflect the payhour analysis presented in Appendix E. In assigning factor units to these coefficients, capital depreciation was initially apportioned as discussed in subsection 4.5.2. The net units of the model factors (i.e., minus depreciation allocations) were then assigned according to procedures described in this subsection. Both "vehicle miles" and "vehicle hours" apportionments were based on Figure 4-1. For AC Transit and SDTC, an expansion factor was adjoined to both the peak and base period equations to derive daily time-of-day cost estimates. In the case of SCRTD, Alternatives II and III (in Appendix F) were employed in allocating "pull-outs" and "peak vehicles" respectively.

research led to the allocation of over one half of each property's total operating and capital costs to the peak period. Since the peak period accounted for less than fifty percent of each property's daily ridership, it appeared to be less "cost-efficient" than other time periods.

4.6 Peak and Off-Peak Costs Per Passenger-Mile

The final stage of the cost analysis entailed factoring the peak and off-peak estimates (in Appendix G) on the basis of passenger-miles. By dividing each 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.[20] Results are shown in Tables 4-6 through 4-8.

Substantial differences in the costs per passenger-mile between routes, time periods, and study sites are revealed in these tables. Among the three properties, AC Transit exhibited the highest average cost/per passenger mile for both the peak and base periods while the SCRTD averaged the lowest rate in both time periods. All three properties averaged higher cost/passenger-mile rates in the peak than the base, although the two smaller properties' differentials were negligible. SCRTD's average cost/passenger-mile was 17.6 cents in the peak and 14.6 cents in the base - a 10 percent differential. By contrast, AC Transit and SDTC had average unit costs of around 20 and 18 cents per passenger-mile respectively in both the peak and base periods; for both agencies, temporal unit cost differentials were less than 0.5 percent. The similarities in unit cost rates between time periods reflected the fact that although peak costs tended to exceed those in the base, so did the peak period's passenger-miles. Conversely, the base period's relatively low operating costs tended to be inflated when expressed in units of passenger miles, due to the occurrence of relatively shorter trips and fewer passengers during off-peak periods.

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[20] The factoring of cost estimates on the basis of passenger-miles yielded unit measures of the expense incurred in accommodating each patron for one mile of travel during each time period. While the estimates of revenue per passenger-mile were derived directly from the fare and trip length data of on-board surveys, the factoring of peak and base costs relied upon route-by-route breakdowns of passenger-miles by time periods. For the SCRTD, fairly precise apportionments of passenger-miles between time periods were attained for each sample route from the results of boarding and alighting surveys. These surveys provided running counts of the number of passengers boarding and departing at each bus stop for each bus run. Passenger-mile estimates were produced for fifteen minute intervals by integrating the cumulative count of net passenger load by the distance traversed. Each route's fifteen minute intervals of passenger-miles were then aggregated to correspond with the time span of each agency's peak and base period.

A different approach was taken in the estimate of AC Transit's peak and off-peak costs per passenger-mile. Using data from the agency's on-board survey, each route's average trip length during the peak and base periods were multiplied by passenger counts for respective time periods. The resultant time-of-day passenger-mile estimates were considered to be reasonably accurate since survey data constituted a full day sample of system users.

TABLE 4-6. ESTIMATES OF SCRTD UNIT COSTS BY ROUTE AND TIME-OF-DAY

	PEAK			BASE		
LINE	COST($)	PASSENGER-MILES	COST/ PASSENGER-MILE	COST($)	PASSENGER-MILES	COST/ PASSENGER-MILE
2	3,935	23,242	.169	3,132	18,643	.168
3	6,452	38,128	.169	5,478	44,383	.142
6	6,282	43,985	.143	4,330	42,566	.102
22	321	700	.459	408	940	.414
25	3,828	16,312	.235	1,823	12,723	.143
27	2,933	19,259	.152	2,783	19,067	.146
28	6,489	39,790	.163	4,089	35,073	.167
29	5,022	24,944	.201	4,068	31,554	.129
33	1,633	10,655	.153	1,084	12,685	.086
34	1,090	4,437	.246	651	4,217	.146
35	5,580	56,401	.099	3,536	44,099	.080
42	5,697	24,524	.239	3,526	30,462	.116
47	3,514	19,562	.180	2,273	9,935	.236
73	1,442	5,973	.241	1,275	5,156	.267
87	788	1,787	.441	970	2,009	.493
89	2,684	15,883	.169	3,409	20,530	.166
91	9,847	53,396	.184	4,054	59,994	.068
95	6,205	32,757	.189	6,108	37,794	.162
114	489	1,241	.394	708	1,321	.536
144	1,891	13,385	.155	177	1,142	.115
154	1,334	4,457	.299	1,662	4,028	.416
435	897	3,020	.297	1,636	4,309	.380
480	4,829	42,367	.114	3,350	35,930	.093
607	1,269	3,906	.325	1,979	5,626	.352
801	1,584	8,425	.188	522	6,034	.087
814	1,301	4,802	.271	448	4,433	.101
826	1,461	7,206	.203	2,351	7,441	.316
828	1,960	16,145	.121	3,537	12,977	.273
869	1,319	4,125	.327	1,753	3,402	.515
873	1,414	7,357	.192	2,978	10,556	.282
TOTAL	93,490	548,171	.176	74,182	527,587	.146
	STANDARD DEVIATION		.166	STANDARD DEVIATION		.235

TABLE 4-7. ESTIMATES OF AC TRANSIT UNIT COSTS BY ROUTE AND TIME-OF-DAY

	PEAK			BASE		
LINE	COSTS ($)	PASSENGER-MILES	COST/ PASSENGER-MILE	COSTS ($)	PASSENGER-MILES	COST/ PASSENGER-MILE
A	831	2,481	.335	1,105	5,185	.213
G	1,317	6,521	.202	0	0	0[a]
K/R	8,118	72,899	.120	0	0	0
U	3,647	9,364	.390	0	0	0
11	614	1,005	.611	391	827	.473
22/24	729	530	1.376	1,098	2,548	.431
31	259	1,482	.175	0	0	0
32	473	3,895	.121	0	0	0
46/87	1,052	787	1.337	1,052	787	1.337
51/58	4,116	26,674	.154	4,527	33,010	.124
54	1,767	2,566	.689	1,767	2,566	.687
65	887	2,339	.379	778	2,353	.331
70	833	4,020	.207	558	2,690	.207
72	3,323	12,511	.266	4,466	25,601	.174
79	755	1,179	.640	601	1,389	.433
80/81	1,610	2,576	.625	2,574	6,608	.390
82/83	5,756	32,506	.177	6,178	46,190	.134
84	442	509	.868	458	555	.825
90/92	1,318	2,104	.626	1,380	4,015	.344
306	694	456	1.522	381	219	1.740
TOTAL	38,541	186,404	.207	27,314	134,543	.203
	STANDARD DEVIATION		.661	STANDARD DEVIATION		.639

NOTE:

(a) Routes with a zero unit cost estimate are express services operating solely during the peak.

TABLE 4-8. ESTIMATES OF SDTC UNIT COSTS BY ROUTE AND TIME-OF-DAY

	PEAK			BASE		
LINE	COST($)	PASSENGER-MILES	COST/PASSENGER-MILE	COST($)	PASSENGER-MILES	COST/PASSENGER-MILE
2	1,542	5,619	.274	1,264	5,778	.218
3	1,464	6,511	.225	1,610	7,339	.219
5	2,495	14,125	.177	1,777	14,228	.125
20	2,758	23,199	.119	1,884	16,625	.113
21	651	1,446	.450	1,019	2,264	.451
27	928	4,529	.205	1,223	5,160	.238
43	761	1,490	.521	1,030	2,113	.488
51	196	436	.450	307	679	.452
80	876	4,171	.210	998	5,455	.183
90	1,222	10,269	.119	698	6,156	.113
TOTAL	12,893	71,795	.180	11,810	65,797	.179
STANDARD DEVIATION			.248	STANDARD DEVIATION		.235

Variations in cost per passenger mile seemed to be larger among routes within each transit property than between the properties themselves. The standard deviations in unit costs were lowest for both time periods among SCRTD's thirty sample routes and highest among AC Transit's twenty sample routes; in fact, there was over three times as much variance in cost/passenger-mile (for both time periods) among AC Transit's routes as among SCRTD's routes. For all three agencies, the distribution of cost/passenger-mile was positively skewed (to the right of the mean). In particular, AC Transit operated five low ridership routes which faced costs/passenger-mile of over 80 cents (i.e., more than four times the mean rate of 20 cents). Neither of the other two agencies operated any services for which average cost/passenger-mile exceeded 55 cents.

AC Transit's and SDTC's variances in unit costs were slightly higher during the peak, whereas SCRTD's base period rates of cost/passenger-mile varied more. Only two of SDTC's ten sample routes and one of AC Transit's twenty sample routes experienced higher unit costs in the base period than the peak. However, eleven of SCRTD's sample routes cost relatively more on a passenger mile basis to operate during the base. These eleven routes were primarily intercity operations which served both short trips and relatively few passengers during the off-peak.

4.7 Summary

The estimates of each sample route's cost per passenger-mile evolved from a multi-stage process of refining cost allocation models and apportioning both operating and capital expenses between time periods. Initially, systemwide models were derived which linked operating expenses to causal factors. These systemwide models were then respecified in terms of "cost centers" models which captured individual cost characteristics of the divisions from which sample routes operated. It was found that these "cost centers" models encapsulated "distance economies" - unit rates of costs tended to be lower for routes serving longer trips and operating over more one-way bus miles. Next, the vehicle hour coefficients of each agency's cost models were recalibrated to account for the relatively higher wage levels emanating from peak operations and restrictive labor agreements. For all routes studied, vehicle hour coefficients were raised in the peak and lowered in the base. Both capital depreciation and operating expenses were then apportioned into time periods based on analyses of cost responsibility. Upon allocating factor units among time periods, daily peak and base period cost estimates were computed for all sample routes using the adjusted "cost centers" models. Finally, peak and base period cost estimates were factored on a passenger-mile basis.

The rates of cost/passenger mile computed for each agency's sample routes tended to be higher for peak than base period services. Generally, the higher costs of peak services were countered by higher ridership levels and longer trips, producing rates of cost per passenger mile only slightly above those during the base. However, to the extent that revenues per passenger-mile are relatively lower during the peak period (due to longer trips), current fare policies would be engendering some degree of price inefficiency and possibly inequities. The intent of the next chapter is to statistically test whether fare cross-subsidization exists within the three transit properties and if so, to assess its severity and incidence.

CHAPTER FIVE

ANALYSIS OF THE EFFICIENCY AND EQUITY IMPACTS OF CURRENT FARE POLICIES

5.1 Introduction

This chapter combines the revenue, ridership, and cost data presented in the previous two chapters for the purpose of evaluating current fare policies. The six hypotheses posed in the first chapter are tested by associating revenue data with estimates of unit costs for various categories of trip distance, time-of-day, and ridership. Following the testing of hypotheses, general assessments of each property's fare policies are made. Inter-agency comparisons of price efficiency and equity are also presented.

The ratio of revenue per passenger-mile to cost per passenger-mile formed the basis for measuring relative efficiency and equity levels across categories of trip distance and time-of-day. ("RPM/CPM" is employed throughout this chapter 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 times-of-day, a marginal revenue/cost analysis is approximated.[1]

The two primary statistical techniques employed in testing fare policy hypotheses were analysis of variance (ANOVA) and difference of means (DOM). The statistical significance of variations in RPM/CPM among categories of trip distance, time-of-day, etc. were largely determined by "F" or "t" tests. Since the directions of mean differences were hypothesized, *a priori*, in Chapter One, one-tailed tests were used. Other statistical approaches used in evaluating price efficiency and equity were tests of association, multiple regression, and analysis of covariance.

To facilitate the comparison of price efficiency and equity among properties, RPM/CPM estimates were sometimes standardized. In these instances, the RPM/CPM estimate for each category of trip distance, time period, income, age, etc. was expressed as a percentage of each system's average RPM/CPM. Standardization held each agency's operating ratio (i.e., total revenue-to-total cost) constant, thereby providing a scale for comparing levels of cross-subsidization between properties.

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[1]As noted in Chapter Two, comparisons of unit rates of revenue and cost by categories of trip distance and time-of-day more accurately resemble "incremental" rather than "marginal" pricing. Under this approach, individual estimates of average revenue and cost derived for each category of trip distance and time-of-day are used in the comparative analysis of pricing. Only by relating these averaged ratios of revenue to cost across ordinal categories of travel distance and time-of-day can this approach approximate the concept of marginal pricing.

Finally, it should be noted that the tests of statistical significance presented in this chapter were hypersensitive to sample sizes. Since each property's sample size exceeded 10,000 cases, differences in RPM/CPM were magnified by both t and F tests. Blalock (1979, p. 162) cautions:

> if we have 10,000 cases, we should not be very surprised if we are able to reject at the 0.001 level, and we should be on guard against reporting our finding as though it were a highly important one. Statistical significance should not be confused with practical significance. (It) can tell us only that certain sample differences would not occur very frequently by chance if there were no differences whatsoever in the population.

It follows that the importance of the statistical tests presented in the chapter lies not so much with reported significance levels but rather with the directions and magnitudes of differences in RPM/CPM. Measures of association such as the correlation ratio (E^2), the product-moment correlation (r), and the coefficient of determination (R^2) are therefore integral to understanding how strong the relationship is between RPM/CPM and other causal variables.

5.2 Description of Trip Distance, Time-of-Day, and Revenue/Cost Estimates

This section presents descriptive statistics on the sample distribution of trip lengths, time periods of travel, and ridership demographics as well as computed averages of RPM/CPM. Data are drawn only from those passengers sampled on the routes chosen for this research. To fully appreciate the potential magnitude of fare cross-subsidization, the proportion of riders commuting a certain distance or representing a particular minority group should be recognized.

5.2.1 Trip Distance Distributions

Figure 5-1 depicts each property's distribution of trip length across twelve distance categories. Approximately 57 percent of both SCRTD's and SDTC's total trips and 71 percent of AC Transit's journeys were under four miles. Since the distributions were positively skewed, mean distances were higher: SCRTD - 4.37 miles; AC Transit - 3.63 miles; and SDTC - 4.97 miles. The largest proportion of sampled trips were 1-2 miles long except in the case of SDTC where the mode was 2-3 miles. By far, SDTC accommodated the largest share of long journeys, having over three times the proportion of trips exceeding fifteen miles as that served by AC Transit.

Longer trips were generally associated with higher income patrons commuting to or from work during the peak period. Also, a higher proportion of long distance travel was found among male patrons, English-speaking respondents, and daily users. Table 5-1 contrasts differences in trip length among several bipolar user groups.

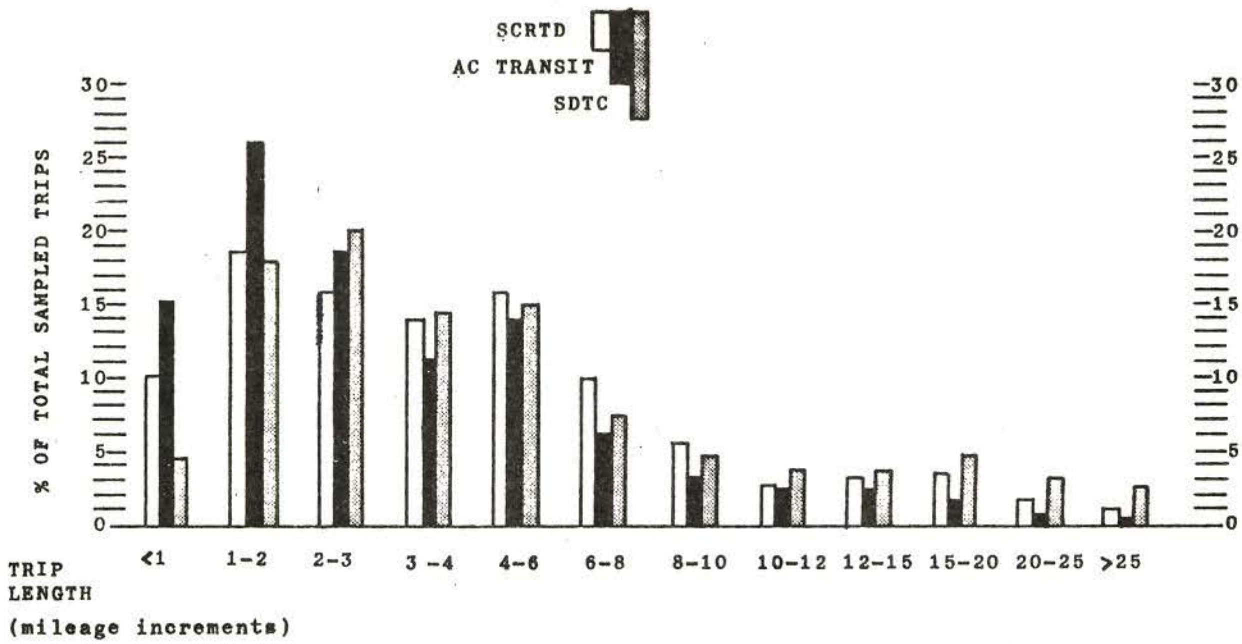

FIGURE 5-1. TRIP LENGTH DISTRIBUTIONS

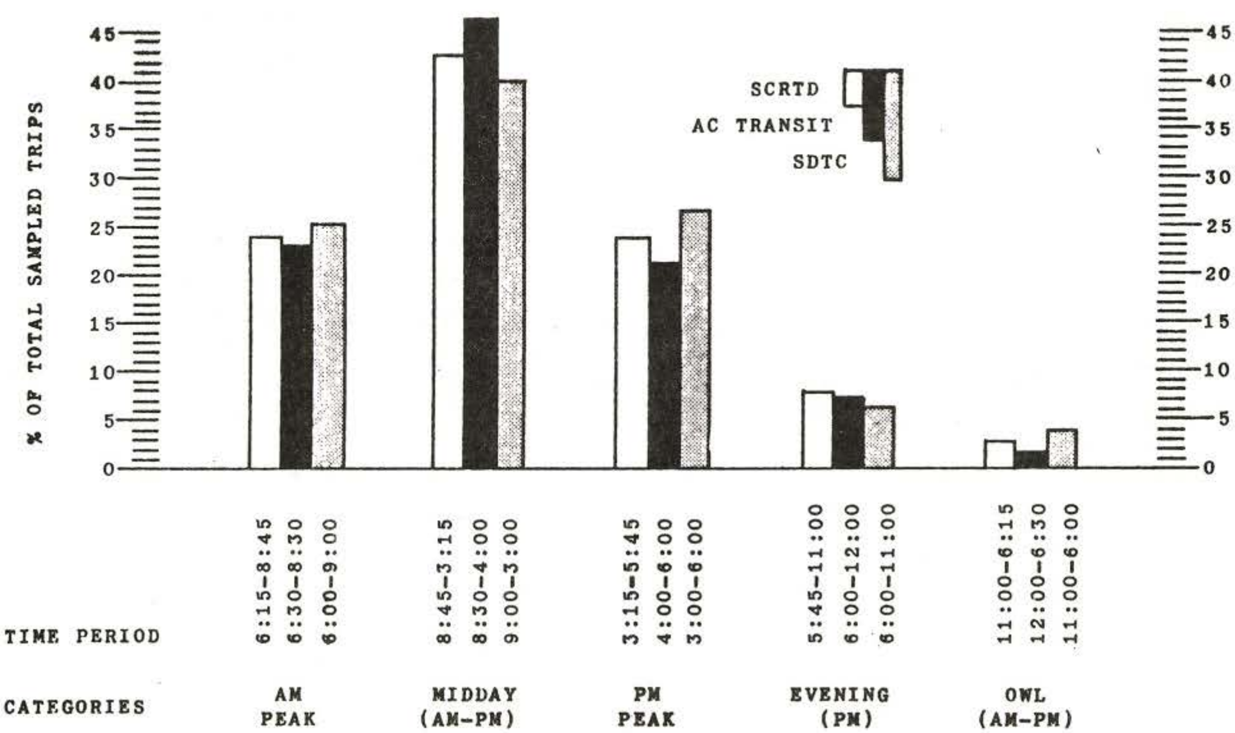

FIGURE 5-2. TIME PERIOD DISTRIBUTIONS

TABLE 5-1. AVERAGE TRIP LENGTHS (IN MILES)

TRIP OR RIDER CHARACTERISTIC:	SCRTD	AC TRANSIT	SDTC
Midday	3.83	3.18	3.88
Peak	4.76	4.92	5.66
Family Income <$ 7,000	4.16	3.50	3.53
Family Income >$25,000	5.78	5.04	6.87
Non-Work	3.92	3.47	4.05
Work Trip	4.90	4.68	5.37
Female	4.31	3.63	4.82
Male	4.44	3.95	5.45
Hispanic	4.31	3.44	3.94
Non-Hispanic	4.68	3.82	5.01
TOTAL SAMPLE	4.37	3.64	4.97

5.2.2 Time Period Distributions

Approximately half of each property's daily trips occurred during the morning and evening peak periods (Figure 5-2). SDTC accommodated the largest share of peak trips while AC Transit's ridership was more concentrated in the midday period. The predominance of midday AC Transit travel was partly due to the orientation of many services to university activities in the Berkeley area and to the relatively longer span of time encompassed by AC Transit's midday period. Peak riders could generally be characterized as long-distance commuters who were male, middle-aged, English-speaking, and of a relatively higher-income status.

5.2.3 Fare Characteristics

Use of available fare types varied considerably (Figure 5-3). A sizable majority of AC Transit and SDTC patrons paid cash while SCRTD's ridership used a wider assortment of fare payment methods. AC Transit served a large proportion of transfer patrons. Both SCRTD's and SDTC's pass usage was concentrated among lower-income patrons who traveled during peak hours. AC Transit's ticket fares were largely used by patrons who were of a higher-income status and senior citizens.

Table 5-2 presents revenue data averaged from the survey responses, including equivalent cash fare estimates assigned to passes. Among all sampled trips, SCRTD averaged the highest fare, followed by SDTC and AC Transit. The average revenue paid was much higher among AC Transit's ticket users (59.1 cents) than cash travelers (32.9 cents) due to the preponderance of ticket usage for express journeys. Also, SCRTD's and SDTC's express pass users averaged over twice the fare level paid by other patrons. Overall, variations in fares were sizable, ranging as follows: SCRTD - 0 to $4.25; AC Transit - 0 to $3.00; and SDTC - 0 to $0.50. There was less range in SDTC's fares because a flat 15 cent surcharge separated express from local services.

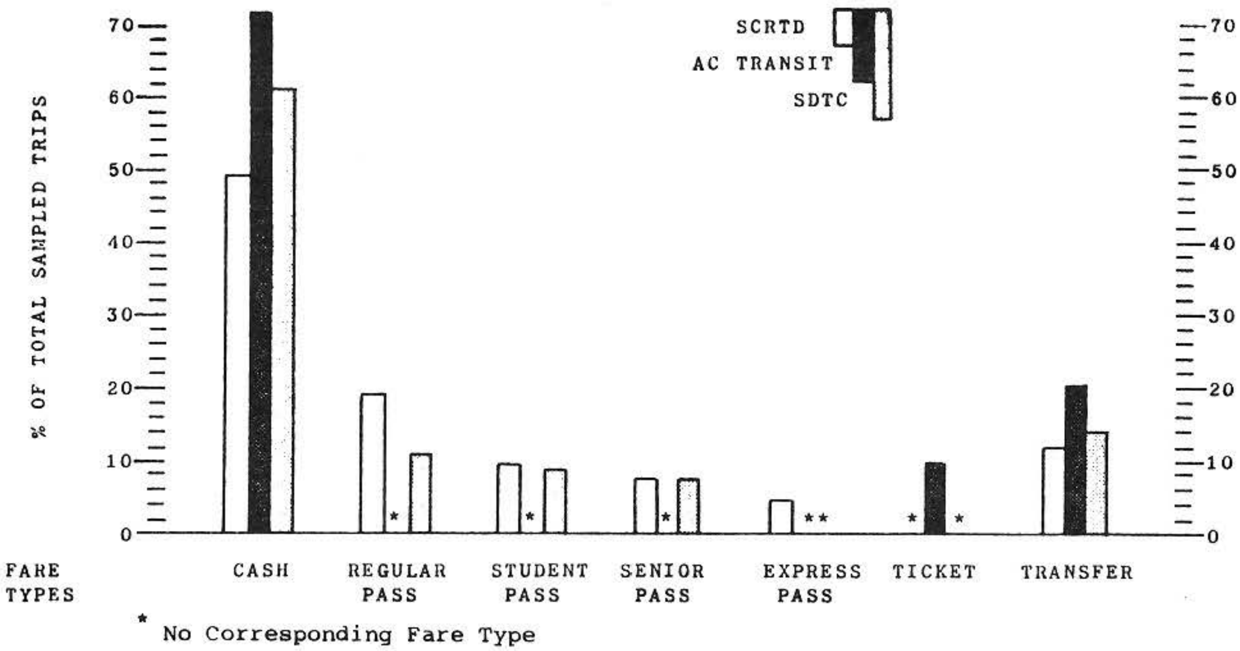

FIGURE 5-3. DISTRIBUTION OF FARE TYPES

It is evident from Table 5.2 that all three agencies' fare policies incorporated some distance-based as well as time-differentiated pricing. An AC Transit peak hour commuter traveling beyond 25 miles, for example, paid approximately 85 cents more for his or her services than someone traveling less than a mile at the noon hour. Others paying higher average fares included those who were male, middle-aged, English-speaking, wealthier, and bound to or from work.

The SCRTD enjoyed the highest average revenue per passenger-mile partly because of its large share of short-distance rider, relatively high base fare, and graduated pricing of express services (see Table 5-3). In contrast, SDTC's many longer distance services in combination with its uniform pricing structure yielded comparatively low revenue returns.

TABLE 5-2. COMPARISON OF AVERAGE FARES PAID FOR SAMPLED TRIPS (IN CENTS)

Trip or Rider Characteristics:	SCRTD	AC TRANSIT	SDTC	
<1 Mile Traveled	31.9	23.2	30.1	AVERAGE REVENUE
>20 Miles Traveled	56.8	102.7	44.8	
Midday	35.2	24.9	31.7	
Peak	38.5	33.9	35.6	
Family Income <$7000	34.7	27.2	36.6	
Family Income >$25000	45.2	35.2	31.1	
TOTAL SAMPLE	37.3	28.9	32.2	
Standard Deviation	29.2	21.3	12.5	MOD[b]
Coefficient of Variation (a)	.78	.75	.39	

Note: [a]Coefficient of Variation equals the standard deviation divided by the sample mean. It serves as a measure of homogeneity relative to the mean.
[b]MOD denotes Measures of Dispersion.

TABLE 5-3. COMPARISON OF AVERAGE REVENUE PER PASSENGER-MILE (IN CENTS)

Trip or Rider Characteristics:	SCRTD	AC Transit	SDTC	
Midday	9.81	8.54	7.70	AVERAGE RPM
Peak	8.79	8.51	6.27	
Family Income <$7000	10.04	8.44	7.11	
Family Income >$25000	8.61	8.18	6.51	
No Family Cars	8.96	8.37	7.94	
One or More Family Cars	9.36	8.52	6.34	
Hispanic	9.32	8.91	6.88	
Non-Hispanic	9.22	8.40	6.95	
Female	9.48	8.68	7.06	
Male	7.95	8.25	6.45	
TOTAL SAMPLE	9.24	8.45	6.94	
Standard Deviation	33.76	11.99	6.79	MOD
Coefficient of Variation	3.65	1.42	.98	

Table 5-3 also reveals considerable variation in estimates of revenue per passenger-mile (RPM) among the three properties. Estimates ranged as follows: SCRTD - 0 to $8.48; AC Transit - 0 to $2.00; and SDTC - 0 to $1.28. Again, SDTC's more uniform price structure produced less revenue for every mile traveled by passengers. The large coefficients of variation computed for SCRTD and AC Transit, in contrast, reflected both greater heterogeneity in pricing and higher levels of short distance travel. It should be noted that trips under one mile produce extremely high RPM estimates which, in turn, yield inflated variances. For example, the average RPM of two trips, each covering four miles at a total fare of 40 cents, is 10 cents. However, were these eight total miles divided between a very short journey of 0.2 miles and a longer one of 7-8 miles, the average RPM would be $1.03. The RPM index is obviously hypersensitive to extremely short journeys. Consequently, SCRTD's and AC Transit's large proportion of very short trips tended to produce far greater variation in RPM than that of SDTC.

Unit revenues were decisively lower for peak period travel, with the one exception that there was virtually no time-of-day difference in AC Transit's RPM. AC Transit's higher average peak fares appeared to offset the greater average length of commuter trips so as to neutralize the rate of RPM between time periods. Table 5-3 also indicates that lower-income and female patrons paid higher averages of RPM. Further, the two larger properties' RPM estimates were slightly higher among users from households with cars; conversely, SDTC's carless patrons paid higher rates.[2] High fares per mile traveled were also found among SCRTD's patrons who were under sixteen years of age, SCRTD's users making medical trips, AC Transit's Hispanic and Native American riders, and SDTC's unemployed travelers.

5.2.4 Comparison of Unit Costs With Unit Revenues

Cost per passenger mile estimates presented at the end of Chapter Four were assigned to each sample passenger to reflect the particular cost characteristics of his or her bus route and time period of travel. Employing all sampled users, weighted-average estimates of cost per passenger mile (CPM) were derived: SCRTD - 21.68 cents; AC Transit - 22.94 cents; and SDTC - 20.85 cents.[3] For all three agencies, CPM estimates generally declined with trip distance, suggesting again that express operations embody some economies.

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[2]Nearly all of SDTC's long distance commuters owned automobiles while the other two properties' long haul commuters represented a broader mix of socio-economic status. Thus, only SDTC's RPM estimates appeared to be inversely correlated with car ownership.

[3]These estimates varied somewhat from the unweighted route averages shown in Tables 4-9 through 4-11 of Chapter Four because survey response rates differed among sample lines.

Estimates of CPM assigned to each surveyed passenger were multiplied by the user's trip length to derive an approximate measure of cost per trip (CPT).[4] The average cost of serving each sampled user ranged from around 80 cents (for the AC Transit system) to slightly under one dollar (for SDTC operations). In general, higher trip costs tended to be associated with peak period commuters who were male, non-Hispanic, of a higher income status, and paid cash fares (Table 5.4).

One would expect a transit system with an efficient price structure to produce high correlations between estimates of trip costs, revenues, and trip length. From Table 5.5 only revenues seemed to be moderately associated with trip costs. When fares were expressed on a "per passenger-mile" basis, the

TABLE 5-4. COMPARISON OF AVERAGE COST PER TRIP ESTIMATES (IN CENTS)

Trip or Rider Characteristic:	SCRTD	AC TRANSIT	SDTC	
Midday	79.7	76.2	80.8	AVERAGE COST PER TRIP
Peak	109.3	102.8	110.1	
Family Income < $7000	89.1	80.8	80.2	
Family Income > $25000	139.3	110.3	124.9	
Hispanic	95.9	85.4	95.9	
Non-Hispanic	85.5	88.0	98.7	
Female	102.0	84.7	97.3	
Male	103.3	87.4	104.9	
Cash Fare	103.9	81.8	105.7	
Non-Cash Fare	91.8	84.3	85.0	
TOTAL SAMPLE	94.7	82.8	98.6	
Standard Deviation	107.4	92.0	85.6	MOD.
Coefficient of Variation	1.13	1.11	.87	

TABLE 5-5. PRODUCT MOMENT CORRELATIONS BETWEEN COST, REVENUE, AND TRIP LENGTH ESTIMATES

	COST PER TRIP (CPT)		
	SCRTD	AC TRANSIT	SDTC
Fare Revenue	.23 N=12409 P=0.000	.34 N=44307 P=0.000	.37 N=18117 P=0.000
Trip Length	.80 N=12398 P=0.000	.76 N=46544 P=0.000	.88 N=19154 P=0.000
Revenue Per Passenger-Mile (RPM)	-.24 N=12398 P=0.000	-.39 N=44307 P=0.000	-.54 N=18117 P=0.000
Note: N = Sample Size	P = Significance Level		

[4]The ratio comparison of each user's fare revenue with the estimated cost of his or her trip is actually another way of expressing the RPM/CPM index. That is, [Revenue - CPM (Trip Length)] = [(Revenue/Trip Length) - CPM] = RPM/CPM.

correlation became negative. That is, riders paying the lowest fare for each mile of travel were generally the costliest to serve. This suggests that existing fare structures underprice some trips while overpricing others.

Dividing revenue per passenger-mile by the estimated cost per passenger-mile of each trip, systemwide averages were obtained (Table 5-6). These estimates are slightly larger than the systemwide operating ratios presented in Table 3-1 of Chapter Three. The differences are partly attributable to estimation errors, unavoidable sampling biases, and the hypersensitivity of the RPM numerator to extremely short trips. The coefficients of variation indicate that RPM/CPM estimates vary widely among sampled passengers, suggesting, prima facie, that current pricing policies embody a considerable degree of fare cross-subsidization. The identity of the cross-subsidy "gainers" and "losers" is explored next in the testing of hypotheses.

5.3 Trip Distance Analysis

5.3.1 Distance Hypothesis

This section tests the following null and alternative hypotheses:

H_0: Transit services are efficiently priced with respect to trip distance.

H_1: Estimates of RPM/CPM are significantly lower for long distance trips than for short distance ones.

A one-way ANOVA structure is used to contrast differences in the mean estimates of RPM/CPM among twelve categories of trip distance.

Results of testing the null hypothesis (i.e., $\mu_1 = \mu_2 = \ldots = \mu_{12}$) for the three study sites are presented in Table 5-7. The same information is displayed in Figure 5-4 in a standardized fashion. The horizontal line in Figure 5-4 serves as a "subsidy threshold" - those traveling distances with RPM/CPM estimates above it are, in effect, cross-subsidizing those riders from distance categories below the line. For SCRTD and AC Transit, the two mile mark separated trips into "gainer"and "loser" categories. SDTC's "subsidy threshold" was slightly longer - three miles. Viewed in terms of sample proportions, Figures 5-5 through 5-7 suggest a slightly larger threshold: for all three agencies, the share of total revenues collected was greater than the share of total costs incurred for trips shorter than four miles in length.

It is evident that the fare structure of each property redistributed resources with respect to travel distances. Short journeys produced revenues in excess of costs whereas losses were sustained in serving long-haul trips. Disparities in RPM/CPM were highly significant in all cases. The correlation ratios (Eta^2), representing the proportion of total sum of squares explained, suggested that reasonably strong associations between RPM/CPM and trip length, particularly in the case of SDTC operations.[5]

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[5]The relatively large differences between Eta^2 and R^2 indicate that each agency's relationship between trip length and RPM/CPM is highly non-linear.

TABLE 5-6. COMPARISON OF AVERAGE RPM/CPM ESTIMATES

	SCRTD	AC TRANSIT	SDTC
System Operating Ratio	.402	.320	.324
Mean RPM/CPM Estimates	.463	.397	.354
Standard Deviation	1.805	.656	.360
Coefficient of Variation	3.899	1.652	1.016

TABLE 5-7. ANOVA COMPARISON OF MEAN RPM/CPM ESTIMATES AMONG TRIP DISTANCE CATEGORIES

	SCRTD	AC TRANSIT	SDTC
Mean RPM/CPM for Trips < 1 Mile(s)	2.219	1.137	1.369
" 1-2 "	.663	.475	.629
" 2-3 "	.376	.292	.382
" 3-4 "	.260	.208	.288
" 4-6 "	.203	.145	.220
" 6-8 "	.176	.097	.187
" 8-10 "	.126	.089	.195
" 10-12 "	.128	.109	.178
" 12-15 "	.117	.131	.158
" 15-20 "	.098	.143	.132
" 20-25 "	.088	.172	.117
" > 25 "	.064	.151	.073
Mean RPM/CPM for Total Sample	.463	.397	.354
Between Groups Mean Square	1147.0	804.3	657.8
Within Groups Mean Square	11.4	1.42	1.11
F Ratio	99.7	566.4	592.6
F Probability	0.000	0.000	0.000
R^2	.158	.253	.347
Eta^2	.337	.450	.728

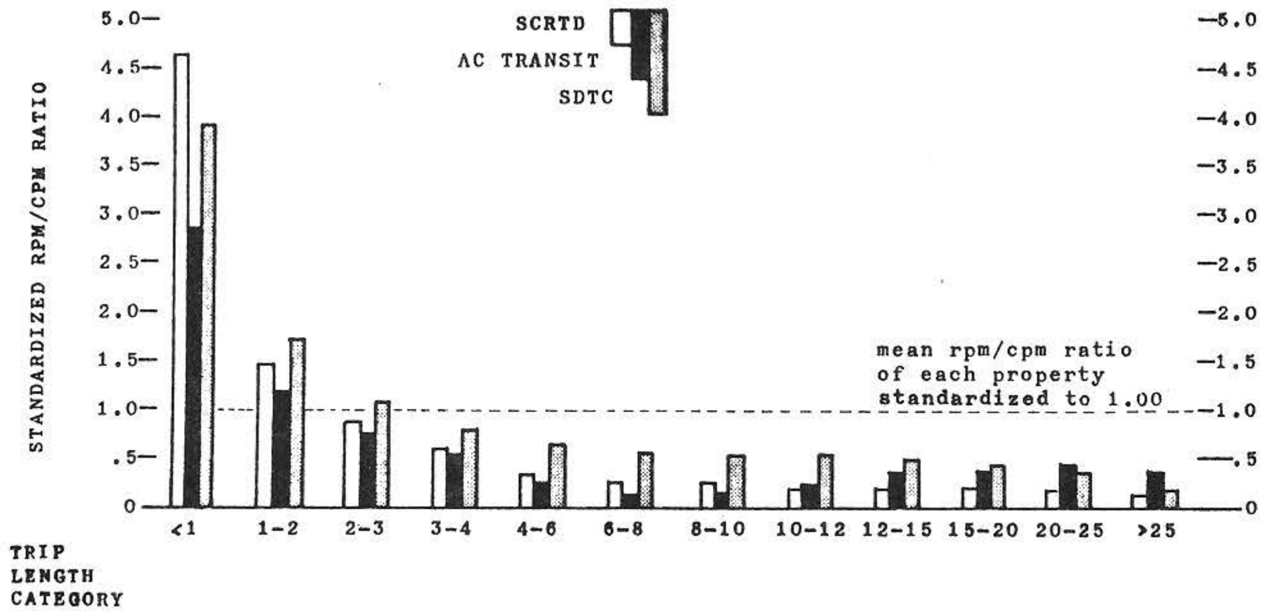

FIGURE 5-4. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TRIP DISTANCE CATEGORIES

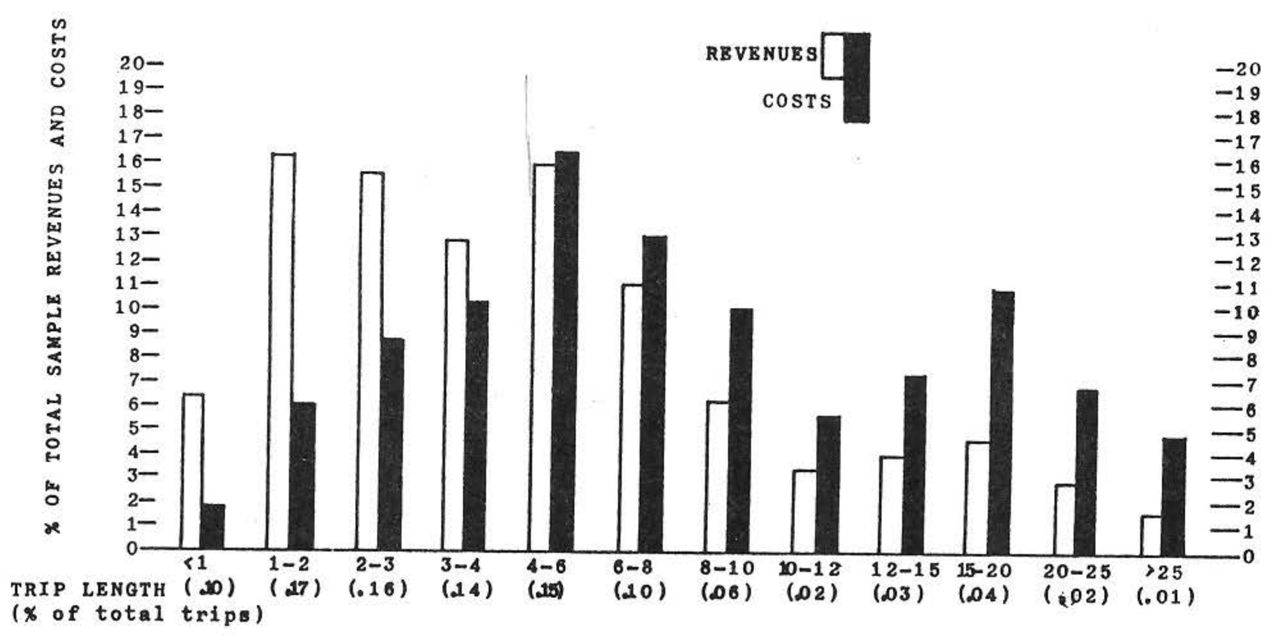

FIGURE 5-5. COMPARISON OF SCRTD's REVENUE AND COST PROPORTIONS BY DISTANCE CATEGORIES

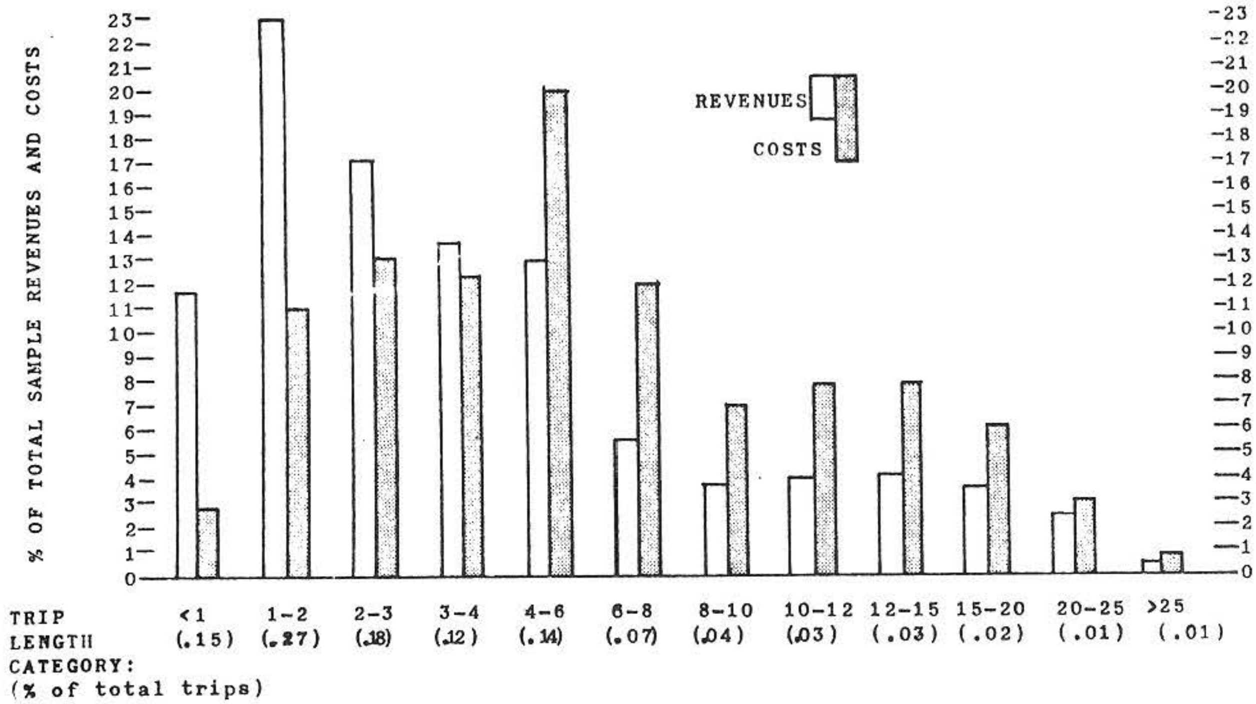

FIGURE 5-6. COMPARISON OF AC TRANSIT'S REVENUE AND COST PROPORTIONS BY DISTANCE CATEGORIES

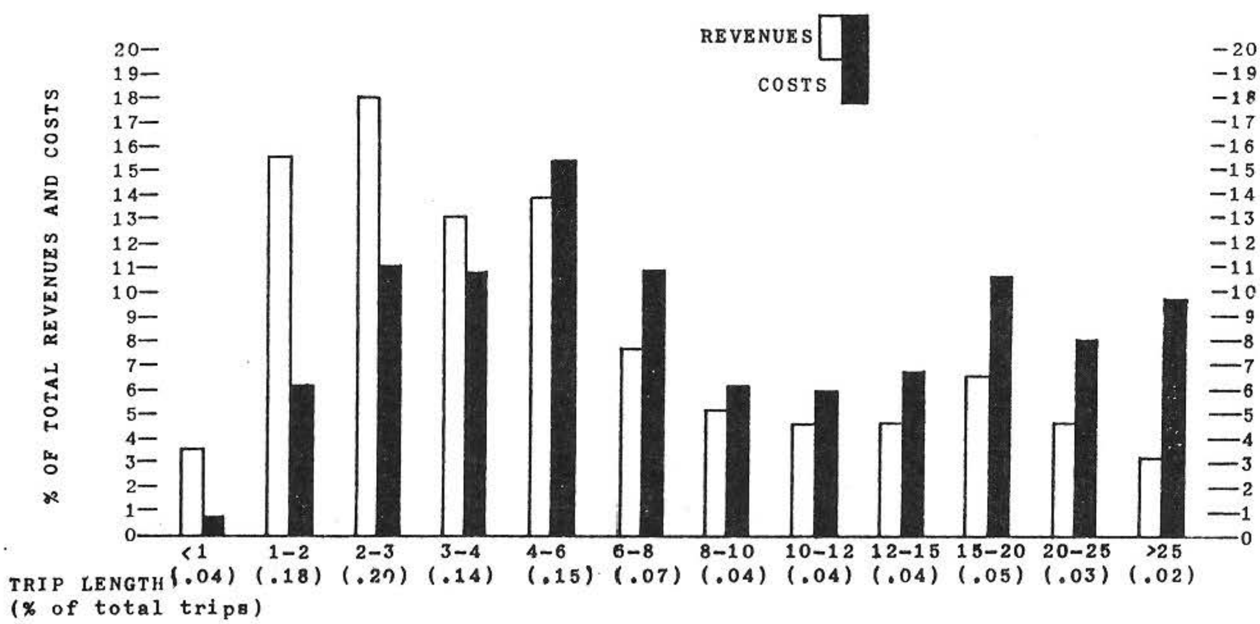

FIGURE 5-7. COMPARISON OF SDTC'S REVENUE AND COST PROPORTIONS BY DISTANCE CATEGORIES

Price inefficiencies were most prominent between trips below one mile and all others. For all three operators, those riding less than a mile paid over twice as much per mile of service as those traveling two miles. The most striking differential was among SCRTD trips, where the mean RPM/CPM of the shortest trips was thirty-five times that of the longest ones! In absolute terms, SCRTD's trips under one mile in length were found to generate a profit of 16.7 cents while those exceeding twenty-five miles were estimated to incur a loss of \$3.17. For each agency, the estimated dollar difference between the profit of serving a trip under one mile and the loss in accommodating a trip exceeding twenty-five miles was SCRTD - \$3.34; AC Transit - \$2.19; and SDTC - \$3.01.

Using six miles as a benchmark for dividing trips into "short" and "long" categories, a comparison of mean RPM/CPM supported the alternative hypothesis (i.e., H_1: $\mu_{long} < \mu_{short}$). The negative "t" values in Table 5-8 indicate that the RPM/CPM estimates of long trips were significantly less than those of short ones.

5.3.2 Structural Analysis of Distance and Pricing

In order to better ascertain the structure of RPM/CPM differences as a function of trip distance, "a posteriori" range tests were conducted. The Tukey(a) method was used to segregate distance categories into homogenous subsets for which the difference between any two groups was not significant at the 0.05 level.[6] The test results in Table 5-9 show the structure of mispricing with respect to travel distance, and provide a basis for conceptualizing alternate fare systems. The table is a statistical representation of the standardized histograms displayed in Figure 5-4.

Distance categories are ranked in each cell of Table 5-9 from the lowest to the highest RPM/CPM ratio.[7] It should be noted that distance subsets are classified according to RPM/CPM differences within, rather than between,

[6]That is, mean differences between RPM/CPM of any two distance categories within a subset were consistent with the null hypothesis. Stated another way, mean differences were only significant between subsets. Although the power of the Tukey (a) test is less than other a posteriori procedures, it reduces Type I errors since the critical value for distinguishing all subsets is based on the maximum number of steps separating the group means (i.e., highest RPM/CPM difference of all distance categories). Winer (1971, p. 201) remarks that "because the Tukey (a) test is applicable in a relatively broad class of situations ... there is much to recommend (it) for general use in making a posteriori tests."

[7]In several instances, trip categories fell into multiple subsets. For demonstrative purposes, however, trip distance categories in Table 5-9 were assigned to only one subset.

TABLE 5-8. ONE-TAILED TEST OF DIFFERENCES IN RPM/CPM MEANS BETWEEN SHORT AND LONG TRIPS

	SCRTD	AC TRANSIT	SDTC
RPM/CPM for Trips <6 Miles	.637	.574	.491
RPM/CPM for Trips >6 Miles	.122	.139	.183
t-Value	-17.67	-62.81	-65.10
Degrees of Freedom	12400	44305	19152
One-Tailed Probability	0.000	0.000	0.000

agencies because the properties' subsidy levels (i.e., operating ratio) differed. Table 5-9 should therefore be interpreted according to differences in the columns rather than the rows.[8] Results of each study site's range test are summarized below.

5.3.2.1 SCRTD Distance Ranges. The largest differences in RPM/CPM estimates of short versus long trips were produced by SCRTD's pricing policies. Very short trips appeared to be playing a larger role in cross-subsidizing longer journeys than for any other operator. Trips between one and two miles in length seemed efficiently priced while those between two and four miles received only moderate cross-subsidies. Beyond five or so miles, however, the range test found little difference in RPM/CPM among distance categories. Essentially, a five mile journey was as highly subsidized as a twenty-five mile one. Compared to the other agencies, SCRTD's "highly subsidized" classification encompassed a far wider range of distance categories.

The functional relationship between SCRTD's RPM/CPM estimates and distance categories can be described as hyperbolic. The standardized histogram of Figure 5-4 shows quite vividly that the high productivity associated with short trips declines markedly with distance, although at a decreasing rate. It follows that an efficient distance-based price structure for SCRTD operations would have a low base fare and perhaps three or more stages with the largest step levied against trips beyond six miles.[9] Equation (5.1) reveals the best fit between SCRTD's RPM/CPM estimates and trip length. This

[8]For example, a 3-4 mile trip is labeled moderately-to-highly subsidized under SCRTD operations yet a 20-25 mile journey receives the same classification if made on the SDTC system. The relative difference between a 3-4 mile trip on the SCRTD system and a 20-25 mile one on the SDTC system is best captured in Figure 5-4. Compared to the one mile category, there is not much difference in RPM/CPM among SCRTD trip over three or four miles. For SDTC, however, the relative difference between the RPM/CPM of a short and a mid-distance trip versus a short and a long-haul trip is far more significant.

[9]Express surcharges would also be retained since this analysis is based on current fare structures which already incorporated graduated fares on express services.

TABLE 5-9. HOMOGENEOUS SUBSETS OF DISTANCE CATEGORIES BASED ON A POSTERIORI RANGE TESTS[a]

Subsets:	SCRTD[b]	AC TRANSIT[b]	SDTC[b]
1: Highly Subsidized	> 25 miles (.064) 20-25 " (.088) 15-20 " (.098) 12-15 " (.117) 10-12 " (.128) 8-10 " (.126) 6-8 " (.176)	8-10 miles (.089) 6-8 " (.097) 10-12 " (.109)	>25 miles (.073)
2: Moderately to Highly Subsidized	4-6 miles (.203) 3-4 " (.260)	12-15 miles (.131) 15-20 " (.143) 4-6 " (.146) > 25 " (.151)	20-25 miles (.117) 15-20 " (.132)
3: Moderately Subsidized	-	20-25 miles (.172) 3-4 " (.208)	12-15 miles (.158) 10-12 " (.178) 6-8 " (.187) 8-10 " (.195)
4: Lightly to Moderately Subsidized	2-3 miles (.376)	-	4-6 miles (.220)
5: Lightly Subsidized	-	2-3 miles (.292)	3-4 miles (.288)
6: Lightly Subsidizing	1-2 miles (.663)	1-2 miles (.475)	2-3 miles (.382)
7: Moderately Subsidizing	-	-	1-2 miles (.629)
8: Highly Subsidizing	<1 mile (2.219)	<1 mile (1.137)	<1 mile (1.369)

NOTES: [a]Bracketed numbers are mean RPM/CPM estimates within each distance category.
[b]Table ranges of 4.62 were used as the basis for the multiple range test.

exponential decay relationship suggests that stages in a distance-based SCRTD price structure could be tapered to a logarithmic function (i.e., increase at a decreasing rate).

$$\text{RPM/CPM} = (0.539)e^{-0.095(\text{Trip Length})} \qquad r^2 = 0.66. \qquad (5.1)$$

5.3.2.2 AC Transit Distance Ranges. AC Transit's relationship between RPM/CPM and trip distance was similar to that of SCRTD, with several notable exceptions. More distinct subsets of distance categories were found for AC Transit operations, suggesting the need for greater differentiation of fare stages. Also, the lowest rates of RPM/CPM were not among AC Transit's longest trips but rather among mid-distance ones (i.e., 6-10 miles). AC Transit's graduated pricing of transbay and express services appeared to return higher rates of revenue than its flat pricing of mid-distance local services.

Table 5-9 suggests that to achieve more consistent levels of RPM/CPM, higher fares should be levied against all trips exceeding six miles, with the largest proportional increase among mid-distance ones. Also, AC Transit's base fare might be lowered in conjunction with zonal pricing since the RPM/CPM estimate for trips of less than one mile exceeds one. Equation (5.2) establishes a non-linear inverse relationship between AC Transit's RPM/CPM and trip length.

$$\text{RPM/CPM} = 0.07 + 1.3(\text{Trip Length})^{-1} \qquad r^2 = 0.47. \qquad (5.2)$$

5.3.2.3 SDTC Distance Ranges. The range test produced a relatively large number of distinct trip distance subsets for SDTC operations. Trips exceeding 25 miles were the most "highly subsidized." Mid-range trips were classified as "moderately subsidized." For trips less than six miles, each distance category took on a separate subsidy classification. The finer separation of SDTC distance groups into distinct subsets reflected greater uniformity in the system's current price structure relative to the other two study sites (i.e., SDTC's relatively flat price system produced less variation in RPM/CPM). It follows that a finely graduated fare structure might improve SDTC's financial performance. Equation (5.3) indicates that a low base fare with declining step increments would best equalize current RPM/CPM disparities.

$$\text{RPM/CPM} = (0.512)e^{-0.079(\text{Trip Length})} \qquad r^2 = 0.73. \qquad (5.3)$$

5.3.3 Distance Analysis Summary

Disparities in RPM/CPM were strongly related with distance for all three properties. The two to four mile distance range was generally found to represent the "subsidy threshold": those traveling distances above the range were generally cross-subsidized by those traveling distances below it. Only trips under one mile were found to be money-makers, with the exception of SCRTD where two miles was the profit threshold. Differences in RPM/CPM among distance categories were found to be sufficiently large so as to lend support to the pricing of transit services on the basis of multiple stages or possibly even finely graduated distance increments. Distance-based price structures with declining steps seemed to hold promise for correcting inefficiencies associated with each property's current fare practices.

5.4 Time-of-Day Analysis

The following hypotheses seek to test whether the three operators' pricing policies give rise to cross-subsidization between time periods:

> H_0: Transit services are efficiently priced with respect to time-of-day.
>
> H_2: Estimates of RPM/CPM are significantly lower for peak period trips than for non-peak ones.

Whether peak services return a higher proportion of their costs through the farebox than base services has been debated within the public transit industry. Research findings of Oram (1979), Parker and Blackledge (1975), Cherwony and Mundle (1978) and others have suggested that higher peak-period revenues are overshadowed by comparatively higher peak costs. Others, however, have asserted that "the transit industry's prevailing opinion has been that the (peak's) revenue effect exceeds the cost effect. That is, peak service has better financial performance in terms of the ratio of revenue to costs than the base service (Reilly, 1977, p. 3)." It can be argued that transit managers view the peak's financial performance favorably because of the longstanding industry practice of apportioning expenses on an average cost basis. Whenever the true cost of peak demand is overlooked, "the peak usually does show more favorable revenue-to-cost ratios than off-peak periods and ... is fully exploited as the high-yield market." (Oram, 1979, p. 138.) To the extent that the procedures discussed in Chapter Four capture the true marginal costs of peak services, the following hypothesis test should provide a reasonable basis for analyzing the incidence of fare cross-subsidization between time periods.

Results of the ANOVA test of the null hypothesis are presented in Table 5-10. RPM/CPM estimates from this table are also shown in Figure 5-8 as standardized values.

Midday services generally returned the highest share of unit costs through the farebox. In contrast, peak periods were found to recover only about one third of their costs - significantly less than each property's average return. The discrepancy in RPM/CPM between midday and peak periods was largest for SCRTD operations and smallest for AC Transit services. The reader will recall that these two agencies also registered the highest and lowest differences in RPM/CPM over trip distance categories. Evening and owl periods generally produced RPM/CPM estimates which fell between those of peak and midday periods.[10]

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[10] Evening services generally produced RPM/CPM levels which matched each agency's average RPM/CPM. The largest variation in RPM/CPM among properties was during the owl period. SDTC's owl operations returned the largest proportion of revenues in relation to costs while AC Transit's early morning services yielded the lowest RPM/CPM. These differences are attributable to the relatively longer travel distance of owl services on the AC Transit system.

TABLE 5-10. ANOVA COMPARISONS OF MEAN RPM/CPM ESTIMATES AMONG TIME PERIODS

	SCRTD	AC TRANSIT	SDTC
Mean RPM/CPM for A.M. Peak	.377	.358	.300
" Midday	.683	.456	.418
" P.M. Peak	.419	.350	.327
" Evening	.482	.417	.363
" Owl	.471	.291	.419
Mean RPM/CPM for Total Sample	.474	.402	.359
Between Group Mean Squares	101.5	107.4	22.7
Within Group Mean Squares	12.6	1.8	.26
F Ratio	8.01	58.1	85.3
F Probability	.000	.000	.000
R^2	.019	.041	.072
Eta^2	.094	.138	.215

Although the ANOVA comparison revealed significant differences in financial performance between time periods, the R^2 and Eta^2 values indicated that RPM/CPM estimates were not strongly associated with time-of-day. Also, the large difference between Eta^2 and R^2 meant that most of the explained variation in RPM/CPM was non-linear. This suggests that a truly efficient time-dependent fare structure would require multiple price changes over the course of a day.

A posteriori range tests were performed to investigate the degree of fare differentiation which might be warranted by time-of-day differences in RPM/CPM (Table 5-11). As was the case for trip distance, SCRTD's time periods were stratified into subsets. A bifurcation of SCRTD's fares into peak and base components appeared sufficient to correct temporal price distortions. In contrast, a more complex structure of time-dependent pricing could be warranted in the case of the other two properties. Compared with differences in RPM/CPM over trip distances, inefficiencies due to the uniform pricing of services throughout the day were small. Owl and evening periods constituted around six percent of each system's daily ridership. Thus, any temporal price adjustments beyond a peak/base differentiation would probably be difficult to justify because of their high cost of administration.

The merger of RPM/CPM estimates from the owl, evening, and midday periods into the "base" category sharpened the contrast of time-of-day differences in transit's financial performance. Results from one-tailed contrast tests (Table 5-12) confirmed the alternative hypothesis - rates of RPM/CPM were significantly lower in the peak than the base. Base period estimates of RPM/CPM exceeded those of the peak by 51 percent, 24 percent, and 29 percent for SCRTD, AC Transit, and SDTC respectively.

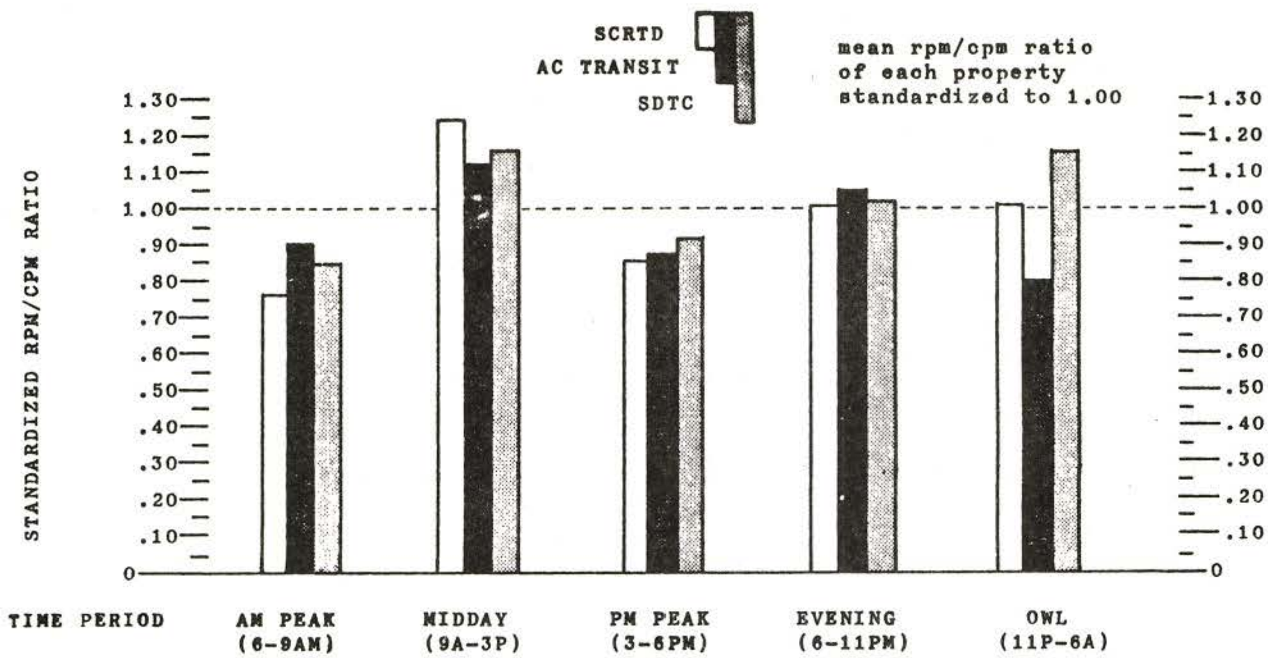

FIGURE 5-8. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TIME PERIOD

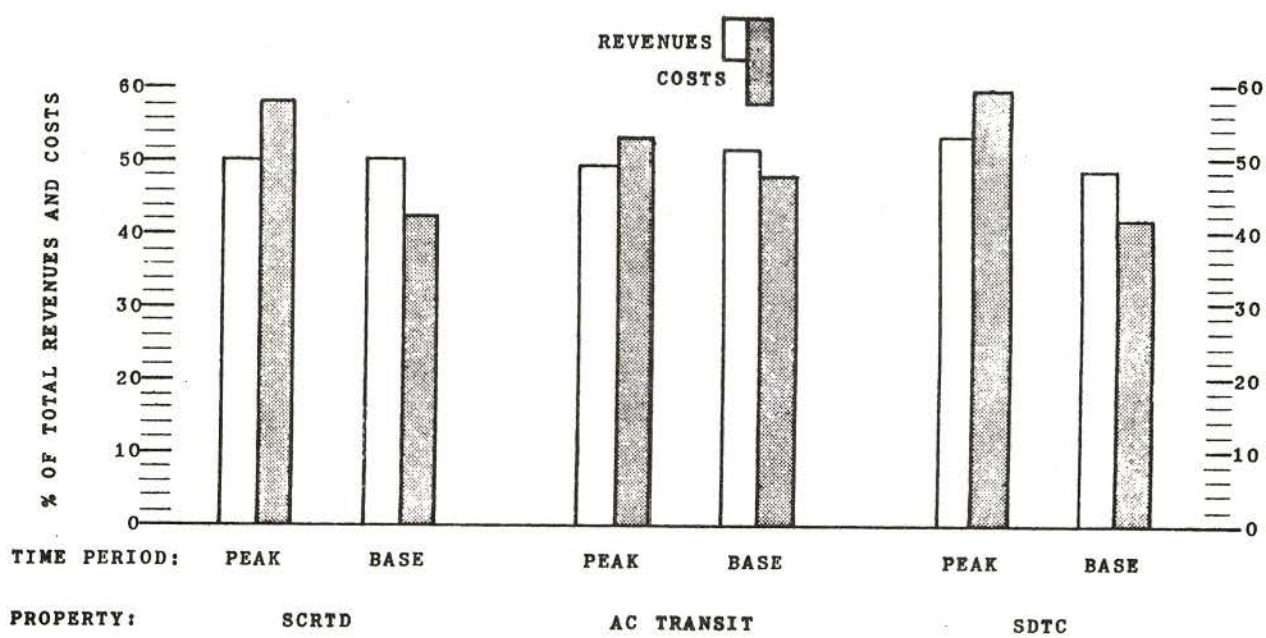

FIGURE 5-9. PROPORTION OF TOTAL REVENUES AND COSTS IN EACH TIME PERIOD

Net differences in the average fare paid and average cost of serving each passenger trip were also contrasted between the peak and base (Table 5-13). Generally, estimated loss per trip among the three systems was around 61 cents per ride during the peak and between 38 cents and 43 cents per ride during the base - an average differential of around 20 cents per trip. Viewed in terms of proportions, each agency's peak services generally accounted for over 55 percent of total costs yet only 50 percent of total revenue (Figure 5-9).

TABLE 5-11. HOMOGENEOUS SUBSETS OF TIME PERIOD CATEGORIES BASED ON A POSTERIORI RANGE TESTS(a)

Subsets:	SCRTD	AC TRANSIT	SDTC
1: Moderately Subsidized	Morning Peak (.377) Afternoon Peak (.419)	Owl (.291)	Morning Peak (.300)
2: Slightly Subsidized	-	Afternoon Peak (.350) Morning Peak (.358)	Afternoon Peak (.327)
3: Slightly Subsidizing	-	Evening (.417)	Evening (.363)
4: Moderately Subsidizing	Owl (.471) Evening (.482) Midday (.683)	Midday (.456)	Midday (.418) Owl (.419)

(a) Bracketed numbers are mean RPM/CPM. Also, table ranges between 2.47 and 3.86 were used

TABLE 5-12. ONE-TAILED TEST OF DIFFERENCES IN RPM/CPM MEANS BETWEEN THE PEAK AND BASE

	SCRTD	AC TRANSIT	SDTC
Mean RPM/CPM for Base	.555	.437	.418
Mean RPM/CPM for Peak	.367	.352	.323
t-Value	-5.39	-14.26	-18.01
Degrees of Freedom	10400	47145	18115
One-Tailed Probability	.000	.000	.000

TABLE 5-13. DIFFERENCES IN FARE REVENUES AND ESTIMATED TRIP COSTS FOR EACH TIME PERIOD (IN CENTS)

Time Period	SCRTD	AC TRANSIT	SDTC
Base	-37.6	-43.1	-41.9
Peak	-62.7	-61.5	-60.8
Weighted Average	-48.4	-53.6	-52.0

The higher net cost of peak services reflected several factors. Although average revenue receipts were between 7.6 percent and 27.5 percent higher during the peak than the base (for SDTC and AC Transit respectively), this "revenue effect" was overcome by an even higher "cost effect." Peak trips were found to be considerably longer than journeys during the off-peak. In the case of SCRTD, peak commuters averaged 37 percent more miles than their off-peak counterparts while AC Transit's and SDTC's peak travelers logged 29 and 20 percent more miles per trip respectively. Moreover, each agency's costs per passenger-mile were slightly higher during the peak. These factors gave rise to trip cost estimates which were between 35 and 45 percent higher during the peak than the base. Consequently, the substantially higher costs of trips during the peak hours were paired with only slightly higher revenues, rendering peak services as comparatively low yield operations.

In summary, the findings of this section indicate that off-peak users cross-subsidize peak hour passengers. The higher average fares paid by peak customers were found to be insufficient to offset the decisively higher costs of their trips. The pricing of transit services at average cost throughout the day appeared to result in a net transfer of between 21 cents and 25 cents per ride from off-peak users to peak travelers. Although RPM/CPM estimates generally differed among the five time periods, a peak/base dichotomy of fares generally seemed sufficient to correct temporal price inefficiencies.

5.5 Equity Analysis

The following hypotheses probe the equity implications of current fare policies:

> H_0: Transit services are priced equitably among user groups.
>
> H_3: Estimates of RPM/CPM are significantly higher for users who have lower incomes, own fewer cars, represent an ethnic minority, are female, and are at a non-working age.

The analysis in this section focuses primarily on users' "ability-to-pay" and transit dependency as reflected in such measures as family income, car ownership (or availability), and ethnic status.

5.5.1 Family Income

The breakdown of RPM/CPM estimates on the basis of each sample respondent's family income shows different equity impacts among the three study sites. As shown in Table 5-14 and Figure 5-10, the distributive effects of current fare structures appeared to be mildly progressive in the case of the SCRTD and slightly to moderately regressive with respect to the other two properties. Lower income patrons of the SDTC and AC Transit system generally bore a disproportionately large share of operating expenses, whereas SCRTD's more affluent patrons tended to cross-subsidize some of the costs incurred in serving

TABLE 5-14. COMPARISONS OF MEAN RPM/CPM ESTIMATES ACCORDING TO USERS' ANNUAL HOUSEHOLD INCOME

	Mean RPM/CPM for Annual Family Income of:	SCRTD	AC TRANSIT	SDTC
ANALYSIS OF VARIANCE TEST	< 5000	.524	----	.348
	< 7000	----	.402	----
	5-7000	----	----	.374
	5-10000	.407	----	----
	7-10000	----	----	.412
	7-15000	----	.409	----
	10-15000	.437	----	.334
	15-20000	.371	----	----
	15-25000	----	.368	.3185
	20-25000	.560	----	----
	> 25000	.492	----	.337
	25-35000	----	.395	----
	> 35000	----	.341	----
	Mean RPM/CPM for Total Sample	.469	.396	.354
	Between Group Mean Squares	33.18	9.85	7.09
	Within Group Mean Squares	14.78	1.60	.251
	F Ratio	2.245	6.147	28.23
	F Probability	.047	.000	.000
	R^2	.02	.03	.03
	Eta^2	.05	.07	.08
DIFFERENCE OF MEANS TEST	< 15000	.458	.404	.365
	>15000	.480	.370	.327
	t-Value	0.39	-4.38	-5.70
	Degrees of Freedom	7379	34148	15092
	One-Tailed Probability	.348	.000	.000

NOTE:
(a) Because income categories specified on each property's on-board survey differed, there are duplications of income ranges in this table. Blank responses denote the absence of a corresponding income category in the respective property's questionnaire.

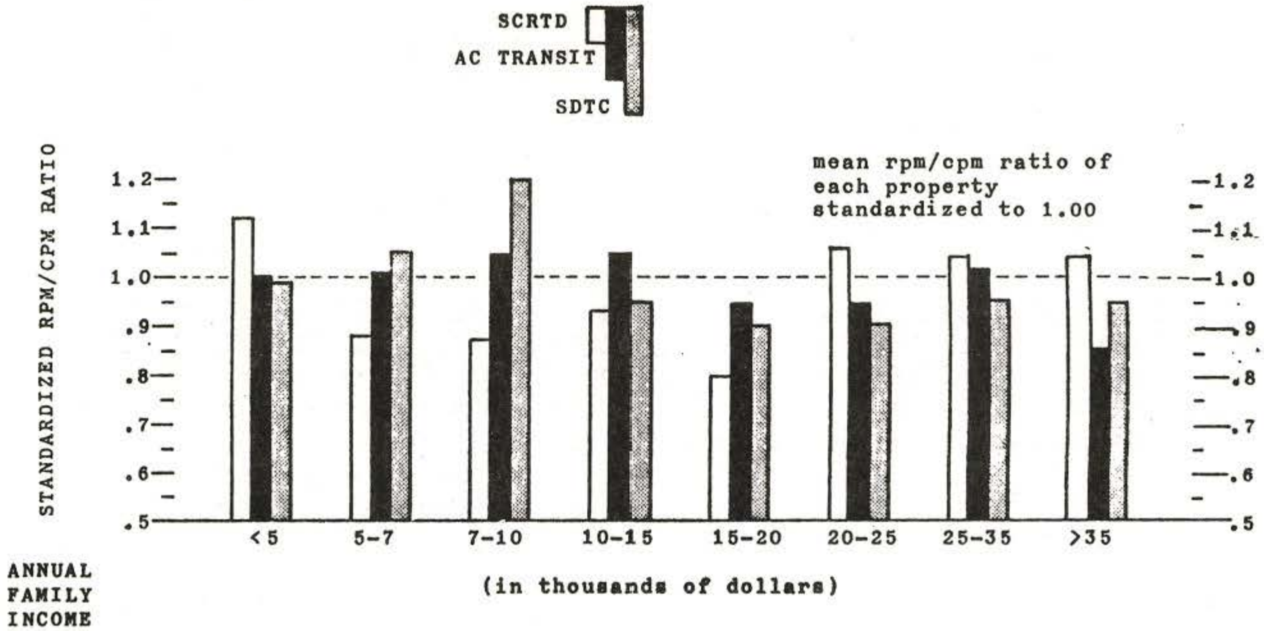

FIGURE 5-10. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY FAMILY INCOME CATEGORIES

lower income groups.[11] Although F ratios of all three ANOVA tests were significant at the 0.05 level, associations between income and RPM/CPM appeared rather weak (as attested by the low R^2 and Eta^2 values). Still, the one-tailed t-test produced statistically significant variations in RPM/CPM between riders with family incomes above and below $15,000 for two of the three study sites. Accordingly, the null hypothesis was rejected, but only with respect to AC Transit's and SDTC's pricing policies; the net transfer effect of SCRTD's fare system actually favored lower income patrons.

A combination of factors gave rise to these contrasting distributional impacts. Patrons with annual family incomes above $15,000 were generally found to make longer trips than lower income users. The range was sizable, from a 16 percent differential in trip lengths of SCRTD's low and high income riders to over 60 percent between SDTC's two income extremes. Due to the economies inherent in operating longer distance services, however, the estimated costs of wealthier patrons' trips were on the average only twenty percent higher than the costs of lower-income users' journeys. The average fare collected from wealthier patrons exceeded other users' fares by 19 percent, 12 percent, and 3.5 percent for the SCRTD, AC Transit, and SDTC respectively. However, only for SCRTD operations did the more affluent passengers pay a higher fare sufficient to offset the comparatively higher costs of their services. In particular, SCRTD's wealthier customers generally traveled on express routes where fare premiums were charged. Differentiated pricing tended to improve not only the financial performance of SCRTD's express services but also the system's general equity position. In constrast, the underpricing of services patronized by SDTC's and AC Transit's wealthier passengers resulted in lower income users paying approximately 1.3 and 0.8 cents more per passenger-mile, respectively.

Two-way ANOVA tests were also conducted to discern whether redistributive pricing impacts varied across trip length categories or between time periods. Generally, relative differences in RPM/CPM among income categories did not co-vary with trip distance or time-of-day. Trip distance explained far more of each property's variance in RPM/CPM than did either income or time period.[12]

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[11] Actually, SCRTD's upper-lower income group was most heavily cross-subsidized since the lowest income stratum returned a higher rate of fare revenues than the system's average. It should also be noted that the average RPM/CPM of SCRTD users with family incomes in the $20-25,000 range were comparatively high due to a number of extremely short trips (of less than a mile) made during the morning in which high priced passes were used. These trips represented outlier data which inflated the unit estimates of revenue and cost for these users. The removal of these aberrations did not substantially effect the overall incidence of fare cross-subsidization among SCRTD's income groups, and they were retained in the analysis presented in this section.

[12] Eta square values generated by the trip distance variable ranged from SCRTD's 0.31 to SDTC's 0.79; however, neither the family income or time period variables explained more than eight percent of any system's total variance.

5.5.2 Vehicle Ownership and Availability

The degree of access transit users had to an automobile served as a measure of transit dependency. Table 5-15 indicates that only SDTC's pricing structure led to a significant difference in RPM/CPM among car ownership categories. SDTC's passengers from carless households averaged a rate of RPM/CPM exceeding the system's mean ratio of 0.358. These transit-dependents were found to travel primarily during off-peak periods when marginal service costs were low.

As was the case for family income, it was the extremes of SCRTD's vehicle ownership variable which bore a disproportionate share of system costs - those owning either no vehicles or else three or more. Generally, SCRTD's users who owned the most cars also patronized high-yield express routes while its carless passengers usually traveled short distances. For both groups, unit revenues were high in relation to unit costs. In the case of AC Transit, virtually no difference in RPM/CPM estimates surfaced between those with and without access to a vehicle.

5.5.3 Ethnic and Language Background

Ethnicity information was gathered only from AC Transit's passenger survey. The other two agencies, however, did identify whether users responded in English or Spanish.[13] The distribution of RPM/CPM estimates according to these ethnic and language groups is displayed in Table 5-16. As with income and vehicle ownership, redistributive impacts among ethnic and language groups varied considerably with each property. While SDTC's regressive fare structure was found to be advantageous to Hispanic users, SCRTD's progressive pricing redistributed income away from Spanish-speaking patrons.

The most striking variation in RPM/CPM was found among AC Transit's ethnic groups. The null hypothesis (i.e., equitable pricing) was easily rejected since rates of RPM/CPM varied significantly between minorities and non-minorities. An a posteriori range test paired AC Transit's Asians and Hispanics together as the system's major cross-subsidizers. Redistributive impacts were found to benefit white users the most. Trips made by AC Transit's Asian and Hispanic users were financially more productive than other groups, not so much because they were shorter but rather because they were concentrated primarily during the midday. In contrast, AC Transit's white customers traveled predominantly during the peak when service costs were comparatively high.

SCRTD's Spanish-speaking passengers took on a cross-subsidizing role because their trips were generally far shorter than those of English-speaking patrons. However, there was greater variation in RPM/CPM estimates within than between SCRTD's language groups. Consequently, the null hypothesis could not be rejected in the case of SCRTD.

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[13] It should be noted that survey response rates among minorities and Hispanics were probably below other user groups, thereby posing a possible bias in the data. Sample biases due to the non-involvement of ethnic minorities are a problem common to many surveys and polls. The problem is exacerbated in such areas as Southern California due to the large numbers of undocumented aliens who patronize public transit.

TABLE 5-15. COMPARISON OF MEAN RPM/CPM ESTIMATES AMONG VEHICLE OWNERSHIP OR AVAILABILITY CATEGORIES

Mean RPM/CPM for those:	SCRTD	AC TRANSIT	SDTC
Owning No Vehicle	.468	-	.393
Owning 1 "	.429	-	.348
Owning 2 "	.445	-	.314
Owning ≥3 "	.602	-	.309
With No Vehicle Available	-	.393 (b)	-
With ≥1 "	-	.401	-
Mean RPM/CPM for Sample	.460	.395	.358
Between Group Mean Squares	18.57	1.37	14.13
Within Group Mean Squares	11.46	1.49	.263
F Ratio	1.62	.92	53.7
F Probability	.182	.337	.000
R^2	.01	.00	.05
Eta^2	.02	.01	.05

NOTE:
(a) Ownerships refers to the number of automobiles owned by the user's family. SDTC also limited ownership to vehicles in running condition.
(b) AC-Transit only solicited whether sample users had a car available or not.

TABLE 5-16. COMPARISON OF MEAN RPM/CPM ESTIMATES AMONG ETHNIC AND LANGUAGE RESPONSE GROUPS

Mean RPM/CPM for:	SCRTD	AC TRANSIT	SDTC
Asians	-	.466	-
Blacks	-	.400	-
Hispanics	-	.463	-
Whites	-	.382	-
English-Speaking	.460	-	.356
Spanish-Speaking	.477	-	.287
Mean RPM/CPM for Total Sample	.463	.399	.354
Between Group Mean Square	1.21	26.59	7.48
Within Group Mean Square	12.19	1.71	.27
F Ratio	.099	13.55	27.92
F Probability	.752	.000	.000
R^2	- (a)	.03	- (a)
Eta^2	.00	.07	.01

NOTE: (a) With fewer than three groups, the relationship is linear.

The most surprising finding was that SDTC's English-speaking patrons paid higher unit revenues than Hispanic passengers, in spite of the earlier evidence that the system's price structure embodied some regressivity. Hispanics were found to travel, on average, approximately two fewer miles per trip than English-speaking users. However, they also paid lower average fares and frequently patronized those sample routes which were the least profitable. Though the t-test of differences was significant, there was virtually no association between SDTC's RPM/CPM and language variables.

5.5.4 Other Demographic Indicators

Comparisons of RPM/CPM among each agency's male and female patrons, handicapped and non-handicapped riders, and age mixes are presented in Table 5-17. Female users were generally found to pay slightly higher fares per mile, although differences in RPM/CPM between genders were significant only for SDTC operations. For all three systems, females traveled comparatively shorter distances and more frequently during the midday. For these reasons, they incurred lower costs. AC Transit's male passengers generally paid fares which sufficiently offset the higher costs of their services. The absence of a similar "revenue effect" resulted in SCRTD's and SDTC's female users partially cross-subsidizing male commuters.

The incidence of fare cross-subsidization was generally quite sensitive to the age of passengers. In the case of SCRTD, RPM/CPM was found to decline with age. SCRTD's school-aged passengers often traveled much shorter distances than other users, yet generally paid the base level fare. Consequently, they generated higher revenue per mile of service. In contrast, AC Transit's and SDTC's youth fares were a dime below the base level, thereby producing far lower RPM/CPM. Middle-aged users of AC Transit and SDTC generally seemed to be compensating losses from youth fare programs.

A particularly high rate of RPM/CPM was found among AC Transit patrons between the ages of 18 and 30. A large number of these passengers were university students who patronized low-cost local services during the midday. Similarly, SCRTD's college age travelers (between 18 and 22 years of age) paid comparatively high fares for their trips.

The large cross-subsidies enjoyed by each agency's senior and handicapped patrons clearly indicate that current fare programs more than satisfy the mandate of Section 16 of the Urban Mass Transportation Act, as amended. With each agency's senior and handicapped fare of approximately one-quarter the base level, the "target efficiencies"[14] of special discount programs were quite high. Dividing the RPM/CPM generated by senior and handicapped patrons by each agency's operating ratio produced the following indicators of these groups' "relative subsidies": SCRTD - 0.41; AC-Transit - 0.52; and SDTC - 0.67. The index computed for SDTC was relatively high because the agency limited special discounts to non-peak periods.

---

[14]"Target efficiency" is used in the sense of distinguishing how much a targetted or needy group benefits in relation to all others. In this example, it assesses to what degree elderly and handicapped patrons who are paying a discounted fare benefit in comparison to all other users who also receive a benefit in the form of a systemwide subsidy (as measured by the operating ratio).

TABLE 5-17. COMPARISON OF MEAN RPM/CPM ESTIMATES AMONG DEMOGRAPHIC GROUPS

	SCRTD	AC TRANSIT	SDTC
Gender:			
Mean RPM/CPM for Females	.482	.396	.360
" Males	.440	.398	.347
F Ratio	.916	.121	6.24
F Probability	.169	.364	.006
Handicap Status:			
Mean RPM/CPM for Handicapped	.361	.206	- [a]
" Non-Handicapped	.467	.402	-
F Ratio	1.266	106.6	-
F Probability	.130	.000	-
Age: [b]			
Mean RPM/CPM for Age <13	.608	.196	-
" <16	-	-	.349
" 13-17	.434	.303	-
" 16-24	-	-	.360
" 18-22	.559	-	-
" 18-30	-	.463	-
" 23-30	.460	-	-
" 25-44	-	-	.383
" 31-44	.418	-	-
" 31-59	-	.402	-
" 45-59	-	-	.373
" 45-62	.369	-	-
" 60-64	-	.412	-
" >60	-	-	.238
" >62	.191	-	-
>64	-	.208	-
F Ratio	5.460	115.860	70.200
F Probability	.000	.000	.000
Mean RPM/CPM for Total Sample	.463	.397	.354

NOTE:

[a] No information on handicap status was compiled from SDTC's survey.

[b] Each agency specified age categories differently on their respective on-board survey.

5.5.5 Equity Summary

To summarize the findings of this section, the null hypothesis (of equitable pricing) was rejected with respect to the following: AC Transit's and SDTC's "family income" variable; SDTC's "vehicle ownership" variable; AC Transit's "ethnicity" variable; and SDTC's "gender" variable. Only in these cases did current pricing seem to transfer wealth in a manner which was either regressive or disadvantageous to minorities and transit-dependents. Virtually no maldistributive impacts emerged from SCRTD's price structure, except for those patrons of college age or less who paid a disproportionally high fare for their services. Senior and handicapped patrons were, by far, the largest benefactors of fare cross-subsidization among all socio-economic groups studied.

5.6 Analysis of Distance and Time Period Interrelationships

The relative advantages of pricing transit services according to either distance or time-of-day are explored by testing the following hypotheses:

> H_0: Price inefficiencies are greater between time periods than between travel distances.
>
> H_4: Disparities in RPM/CPM are relatively greater between short and long trips than between peak and base periods.

It has already been shown in Table 5-1 that average trip lengths during peak hours exceeded those during mid-day by between one and two miles. These differences yielded t-values for each property which were significant at the 0.01 level. Although differences were statistically meaningful, the levels of association between trip length and time period were not particularly strong. The correlation ratios (Eta^2) of 0.18, 0.11, and 0.11 computed for SCRTD, AC Transit, and SDTC suggest that variations in trip length are at least as great within time periods as between them. The inference to be drawn is that time-dependent price structures might encapsulate the distance component, but only marginally since trip lengths would continue to vary significantly within the peak and base periods.

Given the rather weak association between trip length and time period, a reasonable query would be: "which pricing approach could reduce overall inefficiencies to a greater extent - distance-based or time-dependent pricing?" The null hypothesis postulates the latter. Several statistics shed some light on this question. Two-way ANOVA tests generally attributed a much larger share of explained variance in RPM/CPM to "trip length" than to "time period." The explained variance assigned to "trip length" was: SCRTD - 0.33; AC Transit - 0.45; and SDTC - 0.73; in comparison, the highest Eta^2 value computed for "time period" was (SDTC's) 0.21. Accordingly, the relationship between RPM/CPM and trip length was decisively stronger in terms of the latter variable's ability to explain larger shares of variance in the dependent variable.

To test the hypothesis, average differences in RPM/CPM were computed for peak versus base trips and for journeys more than six miles versus those less than six miles. The comparison of mean differences in Table 5-18 indicates that price inefficiencies were far greater with respect to the distance factor. Distance-based pricing seems to hold a particular advantage over peak pricing in the case of the AC Transit system since the differential in RPM/CPM was over five times as large.

It is apparent that the null hypothesis can be safely dismissed for all three properties. In sum, the total cost differences between very short and very long journeys was substantially larger than the marginal cost differences in peak versus base services.

5.7 Service Type Analysis

The major question posed in this section is whether current levels of graduated pricing on express operations sufficiently offset the higher costs incurred in serving longer distance trips during peak hours. The null hypothesis posits that express services' "revenue effect" generally compensates the "cost effect":

> H_0: Efficiency and equity levels do not vary between service types.
>
> H_5: Estimates of RPM/CPM are significantly higher for local services than express or inter-city services.

From passenger surveys, average fares paid for express services were found to be substantially higher than those paid on local routes: SCRTD - 55.9 cents (express) to 35.0 cents (local); AC Transit - 69.2 cents (express) to 25.0 cents (local); and SDTC - 46.0 cents (express) to 30.2 cents (local). Also, cost per passenger-mile estimates for express services were between 15 and 32 percent lower than those for local services, due in part to the fact that longer distance operations make fewer stops. However, given that express trips were generally four times as long as local ones, the total cost of each express passenger trip was estimated to be between 225 percent (for SDTC) and 296 percent (for AC Transit) higher. The interplay of these differences in average revenues, costs, and trip lengths resulted in the RPM/CPM estimates shown in Table 5-19. The null hypothesis was easily rejected, inferring that local services generally cross-subsidized express routes.

Differences in the financial performance of express and local services were most prominent among the two larger properties.[15] In the case of the AC Transit system, however, estimates of RPM/CPM ranged considerably among

[15] SDTC's express routes generated comparatively high rates of RPM/CPM because express services showed considerable economies. SDTC's revenues generated from the three sample express routes were low (on a per passenger-mile basis) because only a single surcharge of 15 cents was levied against express riders. The other agencies charged as many as five different stages (at 15 to 20 cents per step) for express services. However, the cost savings of SDTC's express services were sufficiently large to yield the highest RPM/CPM estimates of the three study sites.

TABLE 5-18. COMPARISON OF RPM/CPM DIFFERENCES BETWEEN CATEGORIES OF TRIP DISTANCE AND TIME PERIOD

Index	Category:	SCRTD	AC TRANSIT	SDTC
(1)	Mean RPM/CPM for trips < 6 Miles	.637	.547	.491
(2)	Mean RPM/CPM for trips ≥6 Miles	.122	.139	.183
(3)	(1) - (2)	.515	.435	.308
(4)	Mean RPM/CPM for Base trips	.555	.437	.418
(5)	" Peak trips	.367	.352	.323
(6)	(4) - (5)	.188	.085	.095
(7)	(3) - (6)	.327	.350	.213
(8)	(3) ÷ (6)	2.740	5.111	3.210

TABLE 5-19. COMPARISON OF RPM/CPM ESTIMATES BETWEEN EXPRESS AND LOCAL SERVICES

Mean RPM/CPM for:	SCRTD	AC TRANSIT	SDTC
Express Trips	.275	.217	.282
Local Trips	.482	.410	.390
Weighted Average	.463	.387	.354
t-Value	-3.64	-16.71	-15.44
Degrees of Freedom	11275	44339	18117
One-Tailed Probability	.000	.000	.000

different "types" of local operations. In particular, District 2 fixed route services, BART contract lines, and other local contract operations were estimated to return less than ten percent of costs.[16] Transbay and eastbay express services produced RPM/CPM estimates between two and three times higher than District 2 and the contract services. Of all AC Transit service types, only eastbay local operations generated revenue returns sufficient to exceed the system's average RPM/CPM ratio of forty percent. Consequently, the direction of AC Transit's cross-subsidies were not so much from local to express services but rather from eastbay local operations to all others.

[16]These services are primarily intra-city operations which either supplement other AC Transit routes or are contracted outside the District's jurisdiction. These services produced very high rates of cost per passenger-mile due to their low ridership and short distance orientation. The reason overall local services were found to have high rates of RPM/CPM was due solely to eastbay local operations since the supplemental and contracted services represented only three percent of the total sample trips.

TABLE 5-20. TWO-WAY COMPARISON OF RPM/CPM ESTIMATES BETWEEN SERVICE TYPES AND TRIP DISTANCE CATEGORIES

Property:	SCRTD		AC TRANSIT		SDTC	
Mileage Category: \ Service Type:	Express	Local	Express	Local	Express	Local
< 1	.98 (6)	2.23* (866)	.61 (131)	1.22* (6170)	3.11* (21)	1.37 (707)
1-2	1.07* (38)	.66 (1759)	.29 (227)	.51* (11277)	2.50* (141)	.61 (2981)
2-3	.52* (144)	.37 (1650)	.26 (89)	.31* (8184)	.91* (108)	.39 (3435)
3-4	.34* (23)	.26 (1447)	.41* (58)	.22 (4832)	.53* (137)	.28 (2463)
4-6	.32* (71)	.20 (1563)	.20* (40)	.15 (6128)	.38* (182)	.22 (2496)
6-8	.34* (101)	.15 (926)	.12* (26)	.10 (2721)	.28* (437)	.16 (897)
8-10	.16* (51)	.12 (550)	.13* (304)	.08 (1070)	.29* (361)	.14 (441)
10-12	.21* (45)	.11 (231)	.19* (462)	.06 (628)	.25* (383)	.12 (334)
12-15	.16* (109)	.08 (208)	.17* (720)	.05 (258)	.19* (500)	.11 (177)
15-20	.11* (138)	.07 (226)	.18* (497)	.04 (124)	.16* (675)	.09 (220)
20-25	.09* (131)	.05 (51)	.20* (263)	.02 (24)	.13* (553)	.07 (34)
> 25	.07* (63)	.01 (21)	.17* (80)	.04 (28)	.08* (442)	.06 (12)
Weighted Average	.275 (1821)	.482 (9454)	.217 (2815)	.410 (41444)	.282 (3921)	.390 (14136)

NOTE:

( ) - Bracketed numbers represent the sample size of each cell

* - Designates the higher ratio of RPM/CPM between express and local services for the particular mileage category of each property.

The relatively poor financial performance of express lines does not imply that a particular trip of a given distance will cost less if made on a local instead of an express route. In fact, given the economies of express operations, we would expect a ten mile trip to cost more on a local route traveling surface streets than on a free-flow express line. The point here is that costly trips are associated primarily with longer distance travel and not necessarily with express services.

This is best demonstrated by contrasting efficiency levels among the twelve trip distance categories of both local and express services. As shown in Table 5-20, the RPM/CPM estimates for most distance categories were generally higher for express trips; in contrast, local services produced higher revenue returns only for very short trips. In the case of SDTC, yields were consistently higher for trips made on express than local routes. For AC Transit, only trips less than three miles in distance produced higher rates of RPM/CPM when made on local lines; for moderate length and long haul journeys, both transbay and eastbay express routes were more revenue-productive. Generally, local services produced a superior ratio of RPM/CPM due to their monopoly on short distance travel. When trips under three miles were removed from the analysis, express operations returned significantly higher rates of revenue. Since nearly one-half of all transit trips were under three miles long, however, the <u>overall</u> direction of cross-subsidies was still from local to express users.[17]

5.8 Analysis of Fare Types

The following hypotheses compare revenue and cost differences among fare payment types:

> H_0: Efficiency levels do not differ among fare payment types.
>
> H_6: Rates of RPM/CPM are higher among pass users since they generally travel shorter distances.

[17] In addition to the trip distance variable, differences in the RPM/CPM estimates of express and local services were also analyzed across categories of time period, family income, car ownership, and user ethnicity. The following emerged from these two-way ANOVAs. Midday local services consistently produced the highest revenue returns of all time period/service type combinations. In the case of AC Transit, midday local operations generated an estimated net profit of 1.5 cents per passenger-mile. AC Transit's and SDTC's price structures produced an equal level of regressivity for both express and local services. The slight progressivity in SCRTD's fare system, in contrast, was solely attributable to local operations. Transfer effects from SCRTD's express services were essentially neutral. Finally, AC Transit's Asian passengers were the major donors for local trips yet the major beneficiaries of cross-subsidies among express trips. This diametric pattern of cross-subsidization was partly due to wide variations in their travel behavior - from extremely short, midday journeys to long-haul, peak period commutes.

The alternative hypothesis postulates that pass users generally pay higher rates of revenue due to their short trip lengths. Were this the case, the price of a pass could be lowered in conjunction with a general increase in cash fare so as to improve overall efficiency. The intent of analyzing RPM/CPM differences among fare types is to explore the potential gains in efficiency and equity which could be achieved by either raising or lowering relative rates for passes, cash fare, tickets, or transfers.

Standardized ratios of mean RPM/CPM are displayed in Figure 5-11 for the range of fare types employed by the three properties. Trips paid for in cash generally produce high rates of revenue in comparison with costs. Other high yield fare modes were SCRTD's express pass[18] and SDTC's regular pass. Not surprisingly, special passes and discount arrangements generated low ratios of RPM/CPM. Given these wide variations, the null hypothesis was rejected for all three study sites.[19]

For SCRTD and SDTC, the typical user paying cash traveled farther, rode more during the off-peak, and had a higher income than the "average" regular pass-holders. On average, the cost of a pass user's trip was found to be nearly ten percent below both agencies' mean trip cost. Since SDTC's pass-holders paid for forty trips per month regardless of actual use, their ratios of RPM/CPM exceeded all other fare groups. In contrast, SCRTD's discounts on general passes generated such low average revenues that the majority of trips made with a pass were generally cross-subsidized. Consequently, the alternative hypothesis was confirmed only by the price policies of SDTC.

Based on these findings, several alternate price strategies seem promising for SCRTD and SDTC. An increase in the cost of SCRTD's passes, perhaps combined with a lowering of base fares, could possibly improve the system's fiscal performance while also neutralizing current redistributive impacts. Alternately, the initiation of a discount pass program in tandem with higher cash fares could offer efficiency gains for the SDTC system.

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[18] The relatively high revenues paid by SCRTD's express passholders seemingly contradicts the finding of Hypothesis 5 (that express users receive cross-subsidies). Express passholders emerged as cross-subsidizers because they tended to travel moderate trip distances (sometimes on non-express routes). Though express pass users traveled nearly twice as far as the "average" SCRTD patrons, their trips were only two-thirds the distance of the "average" express user. The combination of relatively high express pass fares and moderate distance travel produced high estimates of RPM/CPM.

[19] Analysis of variance tests of all three properties' fare types produced highly significant F values. A fairly large share of the total variation in RPM/CPM was explained by fare payment categories: SCRTD - 23 percent; AC Transit - 17 percent; and SDTC - 31 percent. These Eta^2 values were the highest among all analysis variables except trip length.

5.9 Trip Purpose and Attitudinal Analysis

Differences in revenues and costs were also analyzed in terms of trip purpose, frequency of travel, and attitudinal responses to questions concerning appropriate price levels. Work and school trips were generally found to be cross-subsidized by all other trip purposes (Figure 5-12). This mainly reflected short distance, off-peak travel subsidizing peak period commutes. The most dramatic difference in RPM/CPM was between SCRTD's medical trips and all others. The former group of trips was, on average, only slightly over two miles in length and almost entirely during the midday. Lastly, SCRTD's social, shop and personal business trips were fairly unproductive in comparison to similar trips of the other two agencies.[20]

Lastly, RPM/CPM estimates were compared with attitudinal responses elicited from SCRTD's passenger survey. Those who felt fares were too high were found to pay significantly higher rates of RPM/CPM than all other users. On average, those expressing dissatisfaction with current fare policies paid three cents more per mile of travel than the average SCRTD patron. Most were short distance, midday, and middle income users. Based on the findings of this chapter, their preceptions of inequities in SCRTD's pricing policies appear justified.

5.10 Summary

All three transit properties' pricing structures were found to be inefficient in terms of distance and time period of travel. Disparities were more strongly associated with distances, however. Equity impacts varied considerably among properties. SCRTD's price structure appeared mildly progressive; only those patrons below 22 years of age and those making medical trips paid significantly more than the "average" user. In contrast, both AC Transit's and SDTC's price structures exhibited some regressivity. Others losing from fare cross-subsidization included AC Transit's ethnic minorities and college-age passengers as well as SDTC users who were carless, unemployed, female, and English-speaking. In addition, local services tended to cross-subsidize express services - not because they operated more efficiently but rather because they were priced closer to their true costs.

Figures 5-13 through 5-15 summarize these findings by ordering efficiency and equity variables in terms of relative differentials in RPM/CPM. Clearly, the two efficiency indicators - trip distance and time-of-day - dominated all other factors. Disparities in RPM/CPM were generally over three times as great when expressed in terms of trip distance than with any of the equity factors. Likewise, cross-subsidization was more closely linked with the time-of-day of travel than with any equity indicators, particularly in the case of SCRTD. It seems apparent that discrepancies in RPM/CPM were much more closely related to the characteristics of trips than the characteristics of travelers.

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[20] Pass usage was found to be relatively high on these non-work trips, consequently generating low average fares among shoppers and social trippers.

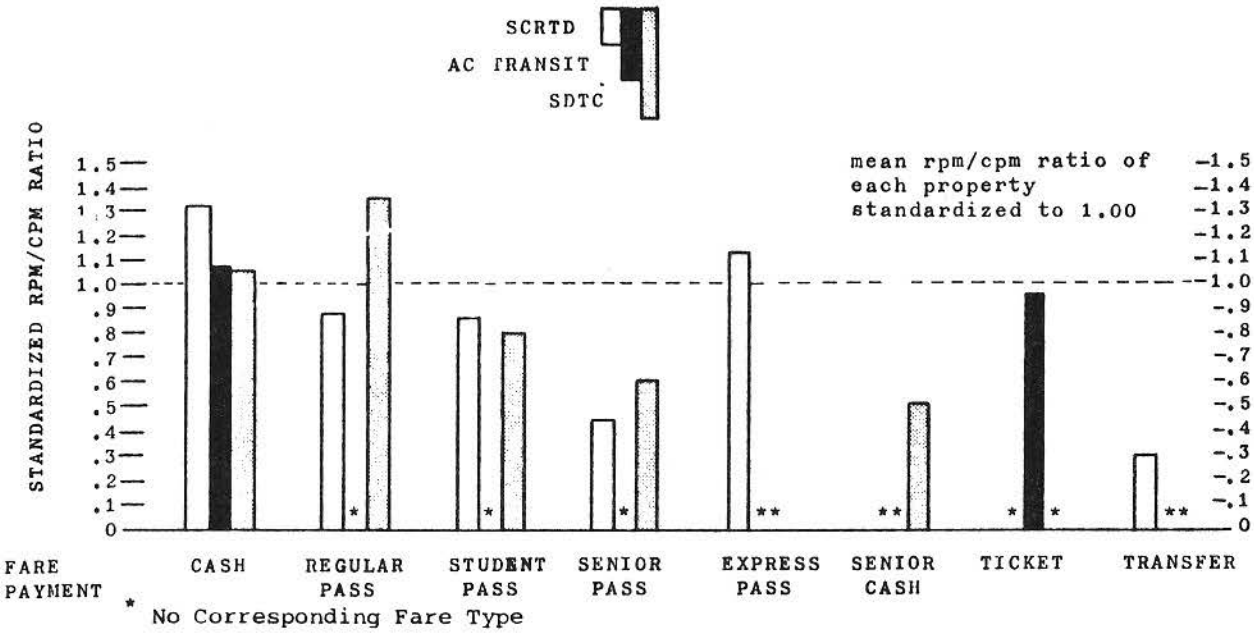

FIGURE 5-11. COMPARISON OF STANDARDIZED REVENUE/COST RATIOS BY FARE PAYMENT CATEGORIES

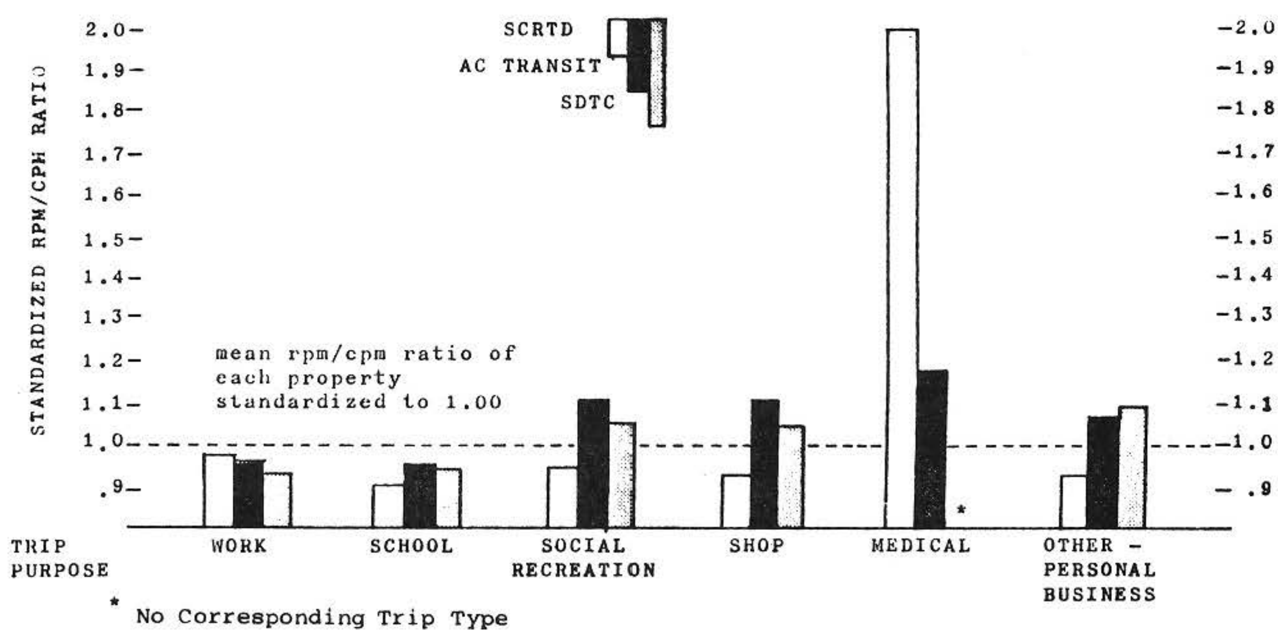

FIGURE 5-12. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TRIP PURPOSE CATEGORIES

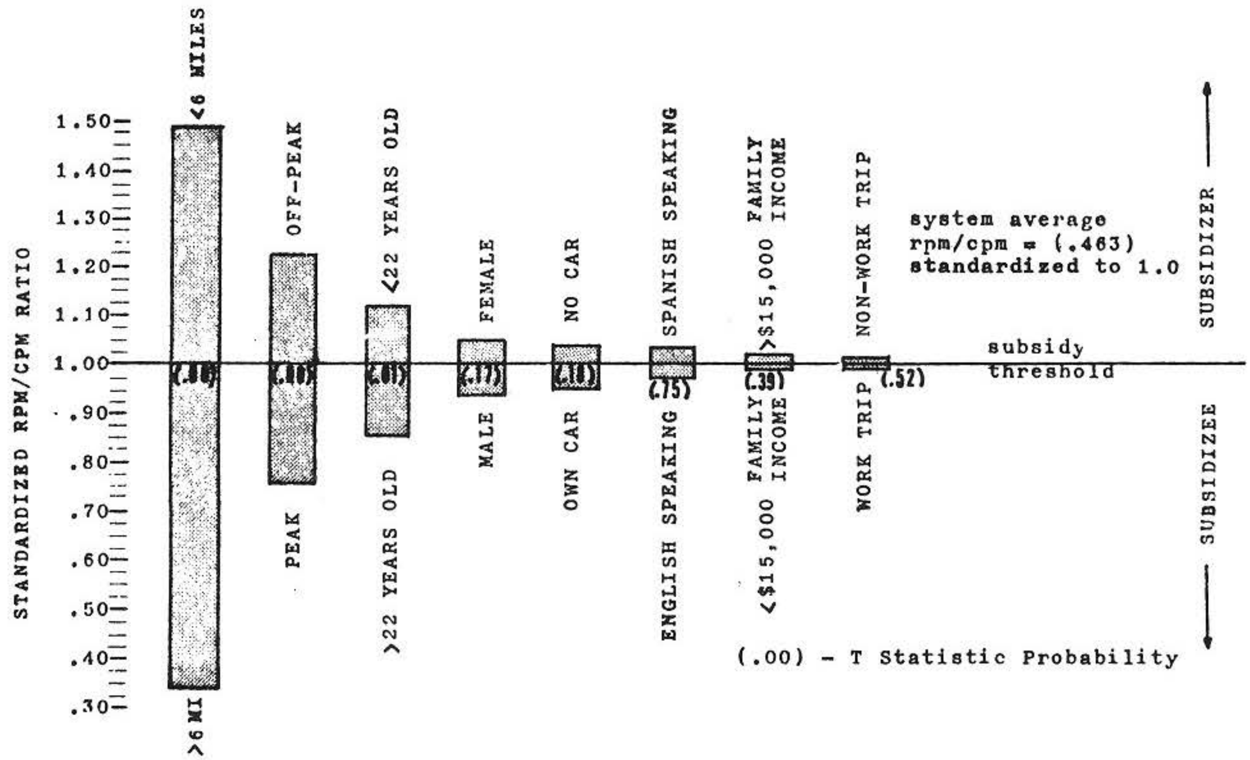

FIGURE 5-13. ORDERING OF SCRTD RPM/CPM LEVELS
BY EFFICIENCY AND EQUITY FACTORS

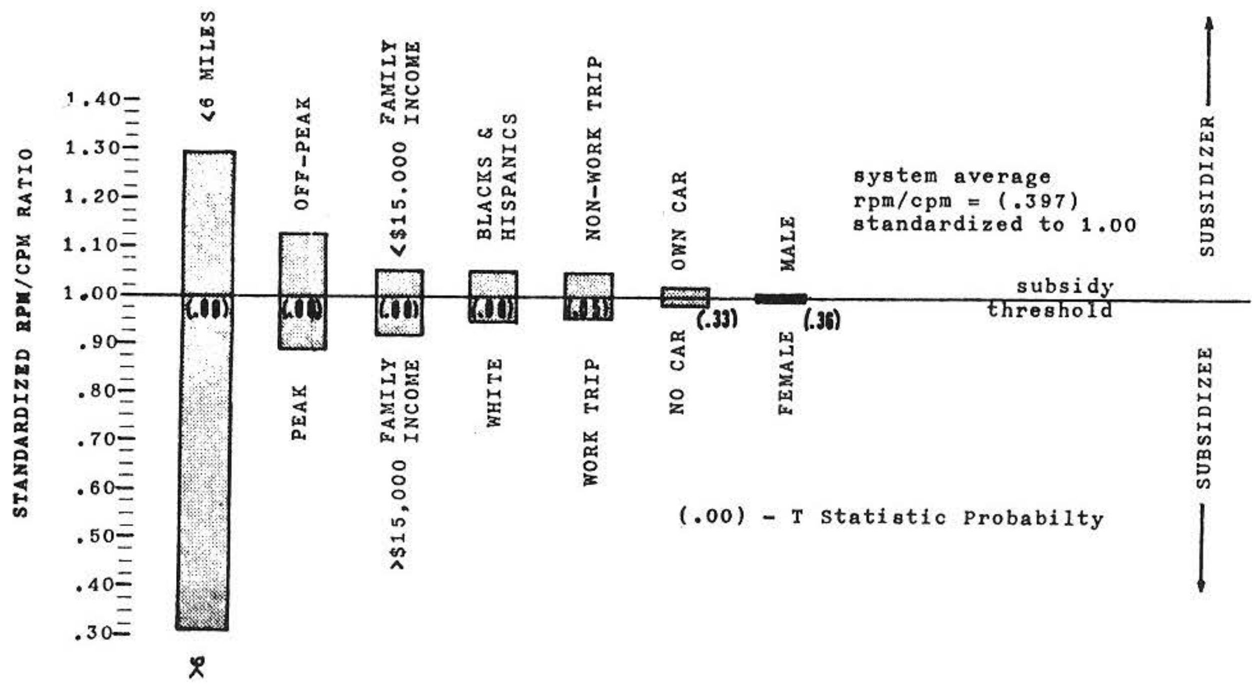

FIGURE 5-14. ORDERING OF AC TRANSIT RPM/CPM LEVELS
BY EFFICIENCY AND EQUITY FACTORS

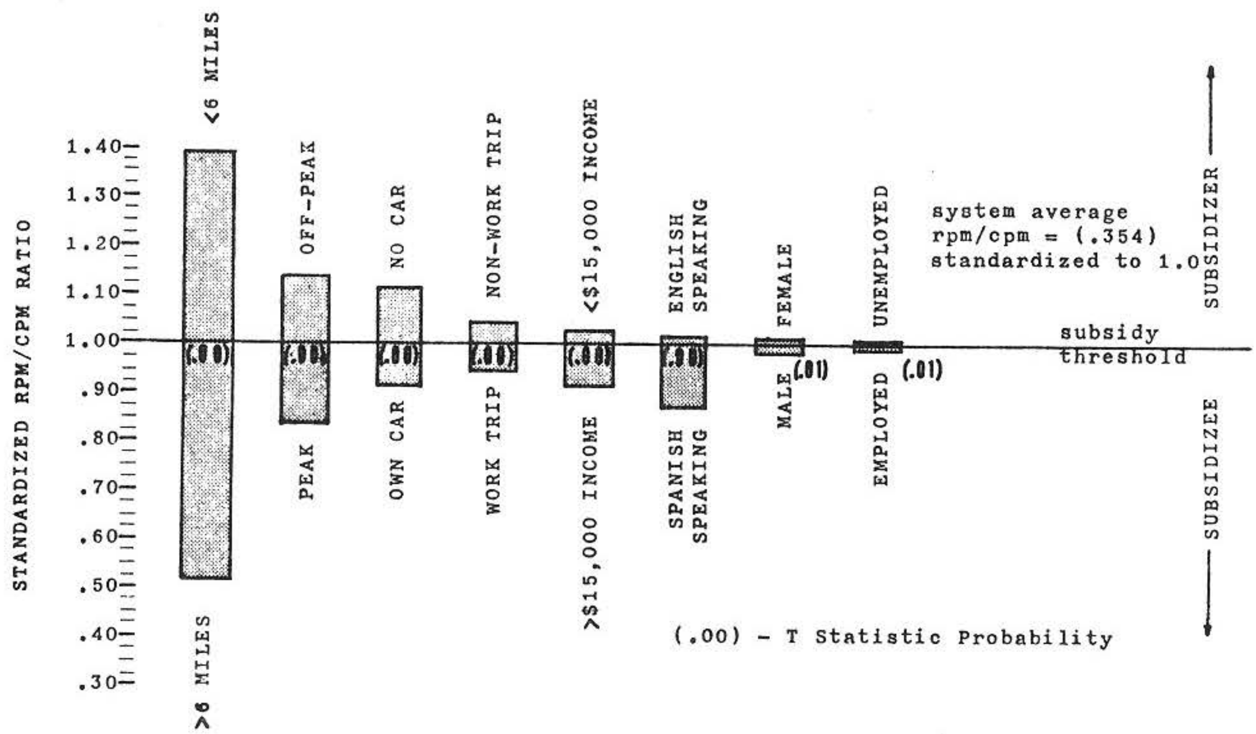

FIGURE 5-15. ORDERING OF SDTC RPM/CPM LEVELS BY EFFICIENCY AND EQUITY FACTORS

Equity impacts generally seemed incidental to the larger problem of inefficient pricing. Maldistributive effects of the three study sites' price policies were generally less pervasive than what might have been expected based on the literature. Indeed, there actually appeared to be a progressive side to some of the subsidy transfers. Overall, however, those who were transit-dependent and captive users were found to lose more from fare cross-subsidization than others.

In sum, changes in current pricing practices should be directed primarily toward correcting price inefficiencies. There also appear to be opportunities for improving the distributional consequences of current fare policies through more differentiated pricing of services, however, probably only to a modest extent. The degree to which alternative distance-based and peak load pricing strategies can reduce price inefficiencies and also enhance distributional equity is explored in the next two chapters.

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CHAPTER SIX

PRICING EVALUATION: MODEL AND DATA INPUTS

6.1 Introduction

This chapter presents a model for evaluating the policy implications of various pricing approaches. In addition to the cost and ridership data presented in previous chapters, the model relies on several important inputs: 1) specification of alternative pricing structures; 2) fare elasticity estimates; and 3) collection cost estimates. Each of these is discussed in this chapter as a prelude to the testing of alternative pricing scenarios in the next one.

This chapter concludes with a mathematical description of the pricing evaluation model.

6.2 Pricing Approaches

Current pricing discrepancies provide the baseline from which various fare scenarios were developed for the three study sites. The pricing alternatives tested in the next chapter are differentiated according to distance, time-of-day, service type, and fare payment method. Distance-based systems involve pricing on the basis of graduated stages or zonal boundaries. Finely graduated structures which levy charges on a per mile basis come the closest of all fare options to approximating marginal cost pricing. Such structures, however, require fairly elaborate collection systems which monitor trip distance. Advocates argue that gains in revenue and efficiency sufficiently offset higher collection costs.

In contrast, graduated structures can be more coarse, charging users for mileage steps (stages) or geographic boundaries (zones) crossed during a trip. Operationally, the stage pricing approach divides routes into sections of roughly the same length, charging riders extra for each stage crossed. The zonal approach is even simpler. It divides the transit service area, rather than the route, into geographic zones and collects extra fees for each boundary traversed. Some complain that zonal pricing penalizes short-distance travelers who cross a boundary yet rewards those commuting crosstown within an elongated zone by charging a single fare. Zonal systems which are laid out in recognition of predominant travel patterns, which overlap boundaries, and which restrict surcharges to minimum trip distances can mitigate such inequities.

Time-dependent price systems typically raise base fares during peak hours and either maintain or lower them during other periods. The intent of peak pricing is to efficiently utilize resources by levying congestion charges, thereby encouraging higher patronage during periods of excess capacity. Leicester and Wynn (1974), for example, estimated that a fifty percent peak/off-peak fare differential on Washington, D.C.'s WMATA system increased overall ridership by 5 percent and farebox receipts by 8.7 percent. However, off-peak shopper and elderly discount programs - which account for the vast majority of time-differentiated fare systems in this country - usually result in revenue losses and only marginal ridership gains (Dygert, et al., 1976).

Prices can also be differentiated with respect to service type, special user groups, and method of payment. Fare systems which are unique for local, inter-city, and express routes can capture distance and time-related cost differences of services. Equity can be enhanced by offering reduced fares to certain distinguishable groups - the elderly, handicapped, school children, and college students. However, findings from the previous chapter identified most of these groups as beneficiaries of current fare policies. Thus, no group fare arrangements are analyzed in the next chapter, except for price changes targetted at SCRTD's and AC Transit's college-age patrons. Finally, pass-to-cash fare ratios can be altered to reduce cross-subsidies, such as those linked to SCRTD's discounting of pass usage.

The next several sections of this chapter describe procedures used to estimate fare elasticities and transaction costs, and to model pricing scenarios.

6.3 Fare Elasticities

6.3.1 Fare Elasticity Concepts

An important step in evaluating alternative fare policies involves measuring the effect of price changes on ridership. The concept of "fare elasticity" offers such a yardstick. Formally, "fare elasticity" can be defined as the proportional change in transit demand resulting from and expressed as a proportion of change in price. Elasticities serve as indices of riders' sensitivity to fare changes.

Ridership responses to fare changes are often described as being elastic, inelastic, or of unitary elasticity. Responses are elastic when a fare change causes a proportionately greater change in ridership. Thus, if a ten percent increase in fares leads to a twenty percent decrease in ridership, ridership is considered to be elastic. Responses are inelastic if the ridership change is proportionately smaller than the fare change. Thus, if a ten percent increase in fares gives rise to a five percent decrease in ridership, patronage would be inelastic. Finally, responses have elasticities of unity when the proportional change in ridership is approximately equal to the proportional change in fares. In this case a ten percent increase in fares results in roughly a ten percent decrease in ridership.

A wealth of "fare elasticities" have been estimated over the past thirty years. With few exceptions, each study has concluded the same thing: transit service is price inelastic. In a survey of 281 operators between 1950 and 1967, APTA (1961; 1968) found that fare elasticities varied widely - ranging from -0.004 to -0.97, with the average at -0.33. Curtin (1968), in studying 77 cases of fare increases over a twenty year period, produced the most widely cited elasticity findings: transit demand declines by one-third of 1 percent for every 1 percent rise in fare. Labeled "shrinkage ratio," this rule-of-thumb has been used extensively by the industry in assessing the impacts of fare increases.

Several alternative approaches are found in the transportation literature for computing fare elasticities. The most theoretically satisfying measure is point elasticity, defined as:

$$\eta_p = (\partial Q/\partial P) \cdot (P/Q) \tag{6.1}$$

where Q represents ridership and P is price. Point elasticity expresses the slope of the demand curve at any single tangent. The measure can only be calculated, however, when a functional relationship can be established between Q and P. In practice, a scarcity of data has hampered the computation of point elasticities. Also, attempts to capture price-demand relationships longitudinally have proven difficult because of the contaminating effects of other variables over time, including changes in service levels, seasonal influences, and secular growth. Kemp (1974) and Smith and McIntosh (1974) developed time-series models which successfully isolated the effects of exogenous variables on ridership; their resulting elasticity estimates were intuitively reasonable, in the range of -0.25 to -0.58. Still, most operators require simpler, less data-intensive approaches to measuring fare elasticities.

As an alternative to causal demand models, elasticity can be measured on the basis of only two observations - ridership before and after a fare change. The simplest approach is to draw a line between data points and compute a constant elasticity slope. Grey (1975) calls this measure a <u>line elasticity</u>, defined as:

$$\eta_l = (Q_a - Q_b/Q_b) \div (P_a - P_b/Q_b) \tag{6.2}$$

where subscripts b and a refer to the respective ridership and price before and after a fare change. This approach assumes a linear demand curve and measures elasticity in terms of <u>initial</u> ridership and price. It also assumes symmetry - demand changes at a similar rate regardless of whether prices increase or decrease. In the case of a price hike, "line elasticity" is equivalent to the industry's "shrinkage ratio" index. As McGillivray (1979) notes, "growth ratio" is the more accurate term when referring to the linear demand slope of a fare reduction.

Two other elasticity indices respond to this criticism of the line measure. Grey (1975) offers a <u>midpoint elasticity</u> index which establishes a hyperbolic relationship between any two points of fare and ridership change. He defines it as:

$$\eta_m = \frac{Q_b - Q_a}{1/2\ (Q_b + Q_a)} \div \frac{P_b - P_a}{1/2\ (P_b + P_a)} . \tag{6.3}$$

The midpoint index expresses change in relation to the arithmetic average of the "before" and "after" price and ridership level. A final non-linear measure is <u>arc elasticity</u>. Kemp (1974) defines it as:

$$\eta_a = \frac{\log Q_b - \log Q_a}{\log P_b - \log P_a} . \tag{6.4}$$

Using exponents (from the base 10) of Q and P, it establishes a convex demand relationship between any two observations of price change.

6.3.2 Comparison of Alternative Elasticity Concepts

The unavailability of longitudinal data suitable for modeling demand relationships for the three case studies precluded the use of the point elasticity concept in this study. Which concept, then, is most appropriate for measuring elasticity from "before and after" data - line, midpoint, or arc? With very small changes in fares, all of the approaches provide a close approximation to point elasticities.[1] As fare changes become larger, however, the ridership effects attributable to the three alternate concepts differ considerably. Since the previous chapter's findings suggested that major fare revisions be investigated, the "sensitivities" of the three approaches to various price changes are compared below.

Given a fixed elasticity estimate, a current price and ridership level, and a proposed new fare, future demand can be easily projected. Equations (6.5) through (6.7) present the appropriate formulae for computing future ridership (Q_a) using the line, midpoint, and arc concepts respectively.

$$Q_{a(\text{line})} = Q_b + Q_b \left[(\eta_1 \cdot P_a)/P_b - \eta_1 \right] \tag{6.5}$$

$$Q_{a(\text{midpoint})} = \frac{1/2 \left[\eta_m (P_a - P_b) + P_a + P_b \right] Q_b}{(P_a - \eta_m P_a - P_b + \eta_m P_b)} \tag{6.6}$$

$$Q_{a(\text{arc})} = \text{antilog} \left[\eta_a \log P_a - \eta_a \log P_b + \log Q_b \right]. \tag{6.7}$$

Setting $\eta = 0.3$, $P_b = 30$ cents, and $Q_b = 100$ passengers, the effects of each elasticity concept on future demand projections (Q_a) were computed for a range of hypothetical future fares (P_a). Results are summarized in Figure 6-1.

The figure clearly indicates that the rate at which ridership changes from the origin (P_b, Q_b) varies with the choice of elasticity measure. Differences also depend on whether the hypothesized new fare (P_a) is an increase or decrease from 30 cents (P_b). The line approach yields a constant elasticity throughout the range of possible fare changes. Compared with the other measures, it generates sharp ridership losses with large increases in fare. The midpoint and arc approaches, in contrast, produce convex demand curves. As prices deviate more from the origin (P_b), the demand curve approaches the axis (P_a and Q_a) asymptotically under both measures. The midpoint elasticity, however, seems more hyperbolic (i.e. knee-shaped) than the arc measure.

[1] In the mathematics of calculus, as the limit of change in price approaches zero, a change in demand will be the same regardless of the shape of the curve at a particular point. Thus, as the difference between P_b and P_a diminishes, elasticity estimates converge, regardless of the demand curve's form.

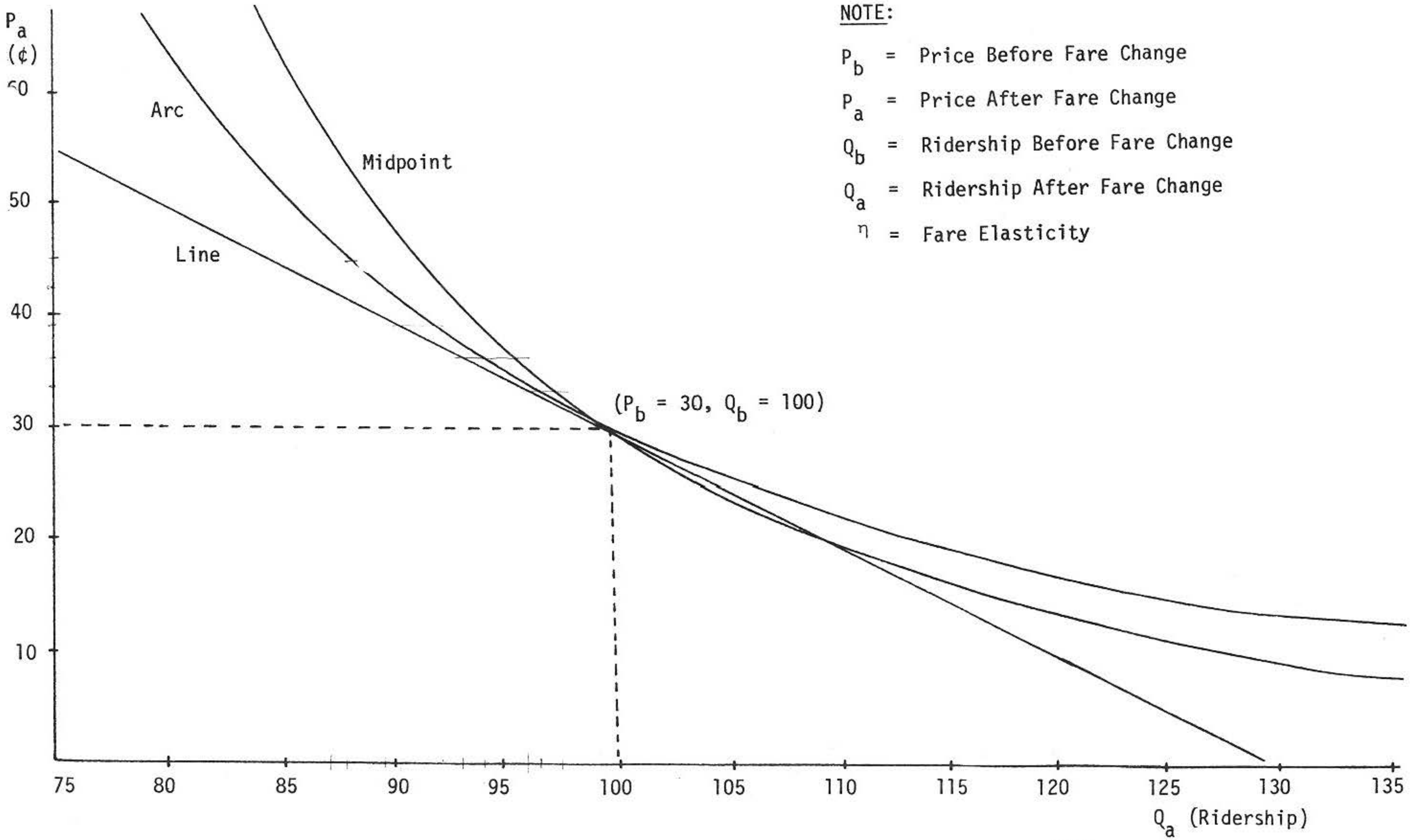

FIGURE 6-1. DEMAND RELATIONSHIPS FOR ALTERNATIVE ELASTICITY ESTIMATES
(For $\eta = -0.30$, $P_b = 30$, and $Q_b = 100$)

The ridership effect of any pricing scenario is obviously quite sensitive to the particular elasticity concept employed. Grey (1975, p. 79) remarks that the choice between approaches "should be governed primarily by which is likely to give the best approximation to the true demand curve over the range of price changes being considered" (emphasis added). Given the large price changes which are to be tested in this research, demand curves in Figure 6-1 should be contrasted on the basis of price extremes.

Past demand models have consistently produced log-linear relationships between fares and ridership, similar in shape to the arc and midpoint curves. (Nelson, 1972; Smith and McIntosh, 1973; Kemp, 1974a; McFadden, 1974; Schmenner, 1976; and Frankena, 1978.) Thus, the line approach seems the least appropriate elasticity option. However, which of the other two approaches is theoretically the most sound - midpoint or arc? Several empirical findings shed light on this question. Kemp (1974b) and Donnelly (1975) found ridership responses to fare increase (forward elasticities) to be higher than to fare decreases (backward elasticities). For Atlanta's and San Diego's fare changes, for example, Kemp computed forward elasticities in the neighborhood of -0.52 to -0.55 and backward elasticities around -0.27. Figure 6.1 indicates that the arc measure produces the highest forward elasticities whereas the midpoint approach produces the lowest backward elasticities. That is, the arc approach produces more reasonable results for increases in fare while the midpoint performs better for falling prices. However, the figure indicates that the curves are closer together for fare reductions than increases. This suggests the midpoint approach will probably underestimate ridership losses from fare hikes to a greater extent than the arc index will exaggerate patronage gains from fare decreases.

Grey (1975, p. 79) recommends use of the arc over the midpoint approach since "the latter can be ruled out as it is further away from the true demand curve for price increases, and is also more complicated." The arc approach generally seems better suited to research which emphasizes fare increases. Since the distance-based and peak/off-peak price scenarios tested in the next chapter involve more increases than reductions in fare, the "arc" elasticity was chosen as the more theoretically appropriate concept.

6.3.3 Fare Elasticity Estimates

Attempts to compute arc elasticities from data compiled "before" and "after" the three study sites' previous fare changes produced unsatisfactory results. Three general problems were encountered. First, each property's fare revision was accompanied by changes in route coverage and headways. In the absence of time-series data and suitable indices of service level, it was impossible to isolate the impact of fares from these service changes. Also, other exogenous factors were found to have biased ridership levels following fare changes. In the case of SCRTD, for example, the survey following the system's 1978 summer fare increase was conducted when temperatures exceeded 100^{o} Fahrenheit. With temperatures some thirty degrees above those during the "before" survey, ridership levels during the post-hoc period were unusually low (Johnson, 1979). Finally, "before" and "after" ridership data were gathered largely at the system level. This precluded disaggregation of elasticity estimates according to trip distance, time-of-day, or user demographics. Since differential price systems explored in this study are targetted at specific trip patterns and user groups, refined estimates of elasticities are essential.

The scarcity of disaggregate elasticity data, however, is not restricted to these three agencies. The problem is prevalent throughout the industry. As expressed during the 1979 Forum on Transit Pricing Techniques sponsored by UMTA:

> "Most work to date has emphasized the overall response of ridership to fare changes ... Far more disaggregate information is needed if transit policies are to be increasingly tailored to the preferences of specific submarkets. Elasticity oriented research needs to focus on specific subjects such as ... peak/off-peak fare differentials, geographic sub-areas such as the CBD or low density suburbs, (and) ... specific market segments and special user groups..." (Public Technology, Inc., 1979, p. 62)

Fortunately, a number of past empirical studies provide a basis for estimating a range of arc elasticities for the three properties. SCRTD planners have estimated the system's line elasticity to be around -0.25 immediately following a fare change, dropping to around -0.1 over the long run (Woodhull, 1977).[2] Using a binary logic analysis, McFadden (1974) has estimated AC Transit's fare elasticity to be -0.45. Kemp (1974) computed point fare elasticities between -0.40 and -0.45 for SDTC's fare increases and -0.28 for its price reductions. From a 1972 SDTC decrease in fare, Carulo and Roess (1974) calculated a higher backward arc elasticity of -0.42.

The empirical estimates computed for AC Transit and SDTC are considerably higher than those used by the respective agencies for planning purposes. Both agencies employ elasticities between -0.2 and -0.3. This deflation of elasticity estimates is generally supported by empirical evidence that riders in larger cities are less sensitive to price changes than those in smaller cities. Curtin (1968) argued, for example, that -0.2 should be set as a fare elasticity standard for larger urban areas, based on his finding that only 2 of 13 large cities had shrinkage ratios above -0.3. Hartgen and Howe (1976) report average fare elasticities of -0.25 for New York State's larger cities and -0.55 for its smaller ones. Moreover, surveys by Kemp (1973) and Pratt, et al. (1977) found large city fare elasticities to be around two thirds those of smaller cities. Weighing this evidence, the following systemwide arc elasticity ranges appear reasonable for evaluating price changes of the three properties: SCRTD = -0.07 to -0.15; AC Transit = -0.15 to -0.25; and SDTC = -0.18 to -0.30.

Based upon other empirical evidence, these systemwide elasticity ranges can be further disaggregated to reflect dominant trip and demographic characteristics of user groups. Findings of Lassow (1968), Thomson (1967), and Schemenner (1976) reveal that those traveling short distances tend to be more price sensitive than long-haul users. Baum (1973) cites findings of a German

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[2]SCRTD's experience is inconsistent with findings by Thomson (1967) and Pucher and Rothenberg (1976) that fare elasticities generally increase with time. With large fare increases, users usually require several weeks or more to arrange alternative travel modes. However, SCRTD's elasticity estimates have been based on small adjustments in fare, usually only a nickel increase in the base price. During periods of high inflation, time moderates the effect of small fare increases on ridership. In real dollar terms, small fare hikes usually reflect a stabilization of fares. Accordingly, the attenuation of elasticities over time for small price increases seems reasonable.

study which estimated fare elasticities of -0.32 for short trips and -0.12 for long ones. Moreover, most studies show that off-peak patrons are typically twice as sensitive to fare changes as peak users (Pratt, et al. 1977, Mullen, 1975). Smith and McIntosh (1973) documented off-peak elasticity values of -0.87 and peak values of -0.27 for several British cities. Further, Kemp (1974) and Wabe and Cole (1975a) computed fare elasticities for non-work trips which were approximately 2.5 times those for work trips. Finally, other studies suggest that fare elasticities tend to be positively related to user age and inversely related to user income (Grey, 1975; Pratt, et al. 1977; Kemp, 1973; Holland, 1974; Weary, et al. 1975; and Morlok, et al. 1971).

The fare elasticity estimates employed in this research are presented in Appendix H for each property, disaggregated on the basis of trip distance, time-of-day, and rider demographics. These arc elasticities are assumed to represent long run responses to fare changes (i.e., six months to one year following fare revisions).[3] Given some of the uncertainties associated with these estimates, a range of values are proposed for the sensitivity testing of alternative pricing scenarios. SCRTD's elasticity estimates range from -0.05 for lower-income, school-age patrons traveling longer distances during the peak to -0.60 for elderly patrons making short trips during the midday. Similar ranges were estimated for the same user groups of the other two properties, though AC Transit's and SDTC's absolute elasticity values were considerably higher than SCRTD's estimates.

In closing, it is important to note that these elasticity estimates should not be interpreted as precise predictive measures. Pratt (1977, p. 281) remarks that most elasticity estimates "simply serve to indicate the likely order of magnitude of responses to system changes, as inferred from aggregate data on the experience in other, hopefully comparable, instances. However, they can be very useful in providing first-order estimates of the changes in demand which may be expected for certain price changes."

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[3] In employing these estimates to assess pricing policies, several other assumptions are being implicitly made. For distance-based fare revisions, users are assumed to adjust only the frequency and not the length of trips. This assumption is supported by Grey's (1975) findings - the London Transport's implementation of zonal fares had no impact on average trip lengths since most origin-destination patterns remained the same. Another important point is that peak and off-peak elasticities fail to directly account for ridership shifts between time periods. One intent of temporal fare differentials is to divert discretionary trips from the shoulders of the peak to the off-peak period. Several studies have found the level of shifting (to the off-peak period) induced by temporal price differentials to be small, however (Connor, 1979; Swan, 1979). Thus, the inability of elasticities to enumerate the level of shifting is probably only a minor drawback. Finally, it is assumed that the elasticity figures in the Appendices reflect changes in the real value of money from the time of initial fare change to six months later when ridership responses are measured. With high inflation, elasticity estimates can vary considerably, depending whether constant or unadjusted dollar figures are used in computations (Grey, 1975).

6.4 Transaction Costs

Another important step in evaluating alternative fare structures involves comparisons of implementation costs. The conversion of a property's fare structure to a more complicated pricing system can introduce additional costs related to marketing, administration, and fare collection. By far, the collection process is responsible for the largest share of costs borne in inaugurating new fare policies.

6.4.1 Fare Collection Methods

Collection systems can make certain types of fare policies workable while precluding others. Ideally, collection systems should strive to minimize delays and inconveniences. This suggests that collection technology is called for which could accept payment, control entry, and issue tickets, thus speeding the egress and exit of passengers while keeping passenger-driver interaction to a minimum.

Obviously, collection costs increase as price structures become more complex and differentiated. Finely graduated fare systems can require fairly sophisticated distance-monitoring collection equipment. In addition to capital overhead, other factors which should be considered when evaluating collection systems include: 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.

Distance and time differentiated price policies rely heavily on automatic collection systems. Historically, the technology of mechanized collection has been almost exclusively confined to rail systems. Fare transactions on rail systems such as San Francisco's BART and Washington's Metro take place at stations where vending machines issue and cancel magnetically-encoded tickets which monitor distance and time. The removal of the collection process from the transit vehicle is essential to maintain high service levels on rail systems. Over the past decade, however, a number of European cities have made major advances in adapting similar technology to conventional bus transportation. The following collection approaches offer opportunities for implementing differentiated fare structures on conventional bus systems: 1) On-Board Automatic Collection; 2) Prepayment Automatic Collection; 3) Post-Payment Collection; and 4) Honor Systems.

With the <u>on-board automatic collection</u> approach, all fare transactions - from ticket issuance to fare cancellation - occur on the bus itself. Typically, users insert exact payments into fareboxes commensurate with their travel distances. Patrons move forward to a ticket issuing machine, thus vacating space around the collection box for other boarding passengers. Tickets with magnetic strips record distance and time information. Also, canceller machines are usually stationed near the front and rear doors for passengers to validate their payment of proper fares upon alighting. If the on-board collection system is engineered for maximal circulation, Leicester and Wynn (1974) estimated that average boarding times of between 3 and 3.75 seconds per passenger could be expected. If drivers are relied upon in the collection process (i.e., to issue tickets according to origin and destination), Werz (1973) suggests that the average operating speeds would be reduced by approximately 10 percent. Also, the reliability of automatic dispensers and cancellers has been shown to be quite high, processing as many as one-half million fares with only a single incidence of machine failure.[4]

Current experiences with on-board automated collection systems has been limited almost exclusively to European transit systems. West Midlands Passenger Transport Executive in Birmingham, England operates bus services with fares based upon trip length and time-of-day. Fares are collected both manually and automatically. Passenger admission control and fare collection are both on-board. The passenger deposits the exact fare in a coin box located at the bus's entrance, then receives a ticket from an automated issuing machine located along the passenger's entrance path, a short distance from the coin box. The driver is responsible for making sure correct payment is made by inspecting the coin display plate of the fare collection machine. The fare collection hardware includes ticket issuing machine, coin receiver cash vault, self-locking coin box, statistical counters, remote control unit and cables (Lea 1977, p. 7).

An off-site prepayment approach can also be used in monitoring distance and time-of-travel. Such systems remove the ticket issuance function from the vehicle, thus increasing average speeds and relieving drivers of additional duties. Prepayment fares can include magnetically-recorded tickets, tokens, punch cards, permits, and passes. Many European cities have used curbside automats in instituting pre-paid collection systems. The automatic vending machines have maps which allow patrons to purchase tickets and passes which correspond in value to the length or time of their trip. Typically, automats also dispense multi-ride coupons for repeated traveling. Electronic readers aboard buses decrement the appropriate value from each rider's prepaid multi-ride coupon. Thus, "electronic money" purchased off-board and used in combination with on-board recording equipment, provides an analog to the fare collection technology of modern rail systems.

Although automat prepayment systems increase the capital costs of fare collection significantly, they also confer such indirect benefits as improved driver efficiency, shorter passenger dwell times, better headway stability, and reduced liklihood of fare fraud. Frankena (1979) reports that in Ottawa the introduction of prepaid passes reduced the average board time per passenger by 25 percent. Mateyka (1979) found that the installation of curbside automats reduced fare collection operating costs by nearly five percent in Syracuse.

In addition to the automat arrangement, differentiated prepaid fare systems could be administered by employers. Passes priced to reflect the length of each employee's daily commute trip could be issued by employers on a payroll deduction basis. Employer sponsored pass programs are currently integral components of fare systems in Boston and Pittsburgh (Hershey, et al., 1976).

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[4]These test results were conducted by Vapor Corporation during a 14-month demonstration of Model M canceller machines on the New York Port Authority TransHudson system.

One of the most extensive off site collection systems is found in Basel, Switzerland. Baseler-Verkehrs-Betriebe (BVB) currently operates light rail and bus transit, using an automated passenger admission processing system that includes machines for fare collection and ticket issuance installed at all stops. Automatic machines display maps from which the passenger determines the fare rate according to the destination zone. The passenger presses a button corresponding to the destination zone which then activates a luminous display on the machine showing the amount payable. When the exact fare is deposited, a ticket is issued. A multi-journey ticket may also be purchased, and must be reinserted into the machine for cancellation prior to boarding. Each stop also has a machine which cancels multi-journey tickets. In addition, machines issuing 24-hour passes are located at major stops. Yearly, monthly or weekly passes with passenger's photo may also be prepurchased (Lea, 1977, p. 5).

A third fare collection technique which enables distance and time monitoring involves post-payment. Under this approach, passengers insert major bank credit cards into electronic recorders when boarding and alighting. Transit agencies then bill users for the precise costs of their trips. Since not all users have access to credit cards, a more equitable post-payment arrangement would involve the issuance of special credit/identification cards to all users.

A novel post-payment system was tested in Derby, Connecticut during the mid-1970's. As a pilot demonstration, the city's transit agency implemented a finely-zoned fare structure using a deferred-billing credit card system. Passengers inserted special cards into cassette recorders when boarding and departing. Processing the cassettes by computer, Derby's transit agency accumulated account balances and sent out monthly billings to its customers (Hershey, et al., 1975). The system could also bill a third party, such as a social service agency. Passengers generally praised the credit system for its convenience. The high cost of automated collection and credit billing eventually led to the discontinuation of the Derby demonstration. However, project officials generally agreed that the inherent economies of large scale transit operations could render post-payment systems cost-effective.[5]

Lastly, differential fares could be collected on an honor system basis. Several German transit systems have adopted this approach, employing inspectors to check passengers at random for proper fare credentials. Strict sanctions are imposed on those who ride without paying a fare. Lesser penalties are levied against users who fail to pay proper surcharges. The honor system offers

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[5]The primary reason for discontinuing the service recorder-computer system was the high cost of the automated system. The cost of bill preparation was 11 cents per ride from March 1973 through June, 1975. Five cents of the 11 cents was attributed to computer cost. However, computer cost during this period were exceptionally low because of the low rates charged by the firm responsible for processing. A total cost of 21 to 25 cents would have been more typical. From July, 1975 to July 1977 the cost was approximately 25 cents per ride. Since then the cost has been about 20 cents per ride, half of which is the cost of the system's minicomputer (Urban Mass Transportation Administration, 1979b, pp. 1-15).

the obvious advantage of reduced overhead costs, although labor expenses invariably increase. Cities employing the honor approach maintain that the savings in fraud reduction and operating efficiency easily justify hiring inspectors.[6] Werz (1973) estimated that honor systems were responsible for an 11 percent average increase in the operating speed of several European transit systems. Mateyka (1979) reported a ten percent increase in the vehicle productivity (as measured by revenue hours per vehicle) of systems converting to honor collection.

These four approaches to collecting differentiated fares are by no means mutually exclusive. For instance, a joint prepayment and credit card scheme could offer considerable diversity in fare collection. Likewise, inspectors could be used in combination with on-board automatic collection systems as an added safeguard. An example of such composite collection systems is found in Munich, Germany where six concentric zones demarcate transit fares. Tickets are purchased with exact cash from off-board fare collection/ticket issuing machines located at heavy rail stations and at the major stops of the light rail and bus transit systems. Before purchasing a ticket, passengers must determine the number of zones crossed during the trip by consulting maps displayed at all stations and stops. Tickets are also available at ticket kiosks and at more than 250 private ticket sales concessions, a transit agency and a tourist office. Single and multiple ride tickets, with eight or twelve sections for an equal number of zones, may be purchased. Passengers are required to cancel their tickets prior to each trip by inserting them into a cancellation machine installed on each bus. Enforcement of payment is made by roving inspectors (Lea, 1977, p.22). Thus, a combination of off-board prepayment, on-board collection, and honor inspection provides Munich's transit operators with a sufficiently diverse collection technology to institute differentiated pricing.

Cost estimates of several fare collection options are presented next for use in the testing of alternative pricing scenarios in Chapter Seven. A combination of prepayment, automatic collection, and honor system monitoring is used in the cost analysis.

6.4.2 Cost Estimates of Fare Collection Systems

The full cost of implementing the automated collection technology on systems comparable to the three study sites is difficult to estimate with certainty because of limited precedents in this country. Hershey, et al. (1976, p. 35) remark that "mass production costs of bus automatic fare collection equipment are unknown but likely to be quite high in comparison to conventional fareboxes." Using manufacturer prices for hardware as well as cost figures from other studies, however, reasonable estimates can be derived for various differential price systems.

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[6] Although European systems have nonpayment problems, they have not considered the rate of cheating significant enough to warrant abandoning differentiated fare structures. Some have speculated that the incidence of fraud would be higher in the United States than in Europe due primarily to cultural differences. In Europe, people tend to take considerable pride in their bus systems, while in the U.S. the relationship of passenger to the transit property is probably more adversarial.

It is assumed that a finely graduated fare system would require a ticket issuing machine and two cancellers on each vehicle.[7] Ticket dispensers cost approximately $1,200 each while cancellers range in price between $2,000 and $3,800 per unit.[8] In addition, it is assumed that curbside automats would be installed at key loading points on all routes of each system.[9] Automats generally cost about $10,000-$12,000 each (Frankena, 1979). Finally, a corps of inspectors is assumed necessary to police graduated price structures. Inspector salaries and fringe benefit costs are assumed to be commensurate with those of each agency's administrative staff.[10] Other incidental costs which could be expected include those related to maintenance, operations, fare handling, and retrofitting vehicles.

The installation of automats and fare monitoring equipment in Syracuse was found to increase the Centro Transit system's capital costs of collection by 478 percent, from $0.83 million to $3.97 million (Mateyka, 1979). Operating costs, including inspector wages, increased by a factor of 2.25. Overall, the system's total collection cost rose from 1.7 cents to 5.6 cents per vehicle mile. Toronto officials recently reported that a similar automated collection system "would involve a one-time capital cost of $9 to $12 million and an increase in annual operating costs by $5 to $8 million because of the need for inspectors" (Frankena, 1979, p. 42).

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[7]Cancellers would be installed at both the front and rear exits. For simplification purposes, standard 55 passenger, two-door vehicles are assumed in the analysis.

[8]These 1979 prices were quoted by the Vapor Corporation for their Model M cancellers and Model E ticket issuing machines. The Model M canceller is used in conjunction with prepaid multi-ride tickets. The ticket code is determined by stripes on one side of the ticket. When the ticket is inserted in the canceller, the canceller checks for the proper code. If the proper code is confirmed, the canceller cancels a ride from the ticket. In this process, a numbered square representing a ride is physically removed from the ticket, the cancellation is recorded on a counter, and information is printed on the ticket. This information can include time, date, route number, direction, zone number, machine number, etc. and can be used for transfer purposes for proof of payment. There is an option for a bell to indicate a valid ticket and a buzzer to indicate an invalid or used-up ticket. The canceller can also release a turnstyle when a valid ticket is cancelled. Special versions of the Model M unit that can accept more than one kind of coded ticket at the same time are also being marketed.

[9]It is assumed that automats would be spaced approximately one mile apart. This results in approximately 15 automats per route on the SCRTD system and 10 to 12 per route on the other two systems.

[10]It is assumed that a single shift of inspectors would be necessary during the busiest operating hours, with each inspector responsible for two routes.

In analyzing collection costs of more coarsely graduated systems such as stage structures, it is assumed that only on-board automatic equipment would be necessary. Also, the assumption is made that drivers rather than inspectors would be responsible for enforcing proper payment of fare steps. These collateral duties would likely spawn union demands for higher wages commensurate with increased responsibilities.[11]

In implementing time-differentiated price structures, it is assumed that fareboxes equipped with clocks (such as those used on many Swiss and German systems) would control peak and base period fares. Compared with distance graduated systems, the capital and operating costs of peak/off-peak fare structures would be small. Officials in Toronto estimated the one-time capital cost of introducing time-of-day fares would be $0.7 million, or approximately seven percent the cost of installing a distance-monitoring collection system.

Employing these assumptions and cost data, the total annual collection costs of graduated, zonal, and peak-load fare systems were estimated for each property. Table 6-1 presents the combined annual depreciation and operating cost estimates of each collection approach. Equipment was depreciated over a fifteen to twenty year service life at an eight percent discount rate, assuming zero scrap value. Other cost elements accounted for in the analysis include maintenance, operations, inspectors, and increased driver wages.

A fairly wide range of collection cost estimates is revealed in Table 6-1. These figures generally seem consistent with findings from Syracuse, Toronto, and several European cities. Annual collection costs of graduated fare systems were estimated to vary from $1.1 million for SDTC to $6.2 million for SCRTD. Finely graduated fare systems could generally be expected to raise each property's current fare collection costs by over 700 percent. Annual operating costs would likely increase between 2.5 and 3.5 percent. Zonal and stage price systems were projected to incur less than one-half the annual collection costs of graduated structures. These estimated savings resulted from the elimination of automats and inspectors from the more coarsely graduated fare systems. Finally, time-differentiated pricing approaches were projected to incur the lowest collection costs. A peak/off-peak bifurcation of fares could be expected to increase collection costs approximately 50 percent above current levels, considerably less than the distance-based structures.

Estimates from Table 6-1 were integrated into the analysis by adjusting "cost per passenger-mile" (CPM) rates. The CPM estimates of each bus route were increased under each fare scenario based on the fraction of <u>additional</u> collection costs to systemwide costs. For example, the CPM estimate of each

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[11] The average driver's annual wage is assumed to increase 0.25 percent due to the additional work responsibilities of enforcing a zonal price system.

TABLE 6-1. FARE COLLECTION COST ESTIMATES OF DIFFERENTIAL PRICE SYSTEMS

FARE SCENARIO	COLLECTION COST COMPONENTS	COST ESTIMATES		
		SCRTD	AC-TRANSIT	SDTC
Finely Graduated Fare System	On-Board Ticket Dispensers and Cancellers @ $8500 per vehicle (including farebox costs)	$17,000,000	$ 6,375,000	$2,932,500
	Curbside Automats @ $10,000 each	16,000,000	6,100,000	2,800,000
	Total Capital Costs	33,000,000	12,475,000	5,732,500
	Annual Depreciation @ 8% interest and 15 - 20 year service life	3,615,250	1,366,090	627,790
	Annual Inspector Cost @ $17,000 per Inspector	1,700,000	665,000	323,000
	Other Annual Operating and Maintenance Costs @ 25% of Capital Depreciation	903,930	341,520	156,950
	Projected Annual Total Collection Cost	6,219,180	2,372,610	1,107,740
	Current Annual Collection Cost	980,000	375,000	180,000
	Difference Between Projected and Current Costs	5,239,180	1,997,610	927,740
	Difference as Percent of Total System Costs	2.40%	3.63%	3.44%
Stage or Zonal Fare System	On-Board Dispensers and Cancellers @ $8500 per vehicle (including farebox costs)	$17,000,000	$ 6,375,000	$2,932,500
	Annual Depreciation @ 8% interest and 15 year life	1,986,100	744,790	342,600
	Annual Operating and Maintenance Costs @ 35% of Capital Depreciation	695,140	260,680	119,910
	Additional Driver Wages due to enforcement responsibilities @ .25% of Current Wage Bill	212,500	72,250	48,650
	Projected Annual Total Collection Cost	2,893,750	1,077,720	511,160
	Current Annual Collection Cost	980,000	375,000	180,000
	Difference Between Projected and Current Costs	1,913,750	702,720	331,160
	Difference as Percent of Total System Costs	.89%	1.28%	1.23%
Peak/Off-Peak Fare System	On-Board Time-Monitoring Equipment and Fareboxes @ $3700 each	$ 7,400,000	$ 2,775,000	$1,202,500
	Annual Depreciation @ 8% interest and 15 year service life	864,540	324,200	140,490
	Annual Operating and Maintenance Costs @ 50% of Capital Depreciation	432,270	162,100	70,240
	Additional Driver Wages due to enforcement responsibilities @ .25% of current Wage Bill	212,500	72,250	48,650
	Projected Annual Total Collection Cost	1,509,310	558,550	259,380
	Current Annual Collection Cost	980,000	375,000	180,000
	Difference Between Projected and Current Costs	529,310	183,550	79,380
	Difference as Percent of Total System Costs	.24%	.33%	.29%

SCRTD route was increased by a factor of 1.024 under the graduated fare scenario.[12] The model employed in simulating the revenue and cost effects of these pricing scenarios is described next.

6.5 Pricing Evaluation Model

An exploratory model was developed for forecasting the ridership, efficiency, and equity impacts which could be anticipated under various pricing options. A fairly disaggregate model structure was adopted because of the need to capture detail at the individual passenger level. Using current passenger survey data on fares, travel behavior, and demographic characteristics, the model evaluated pricing options by weighting data cases (records) on the basis of fare elasticities. The weighting scheme captured the sensitivity of specific user groups to price changes, adjusting each survey record to reflect relative "frequency of use" under the fare policy of interest. Revenue and ridership impacts were then estimated by aggregating the adjusted sample. By merging costs and revenue data (reflecting both changes in fares and implementation costs), price scenarios were further analyzed with respect to their possible efficiency and equity repercussions.

Figure 6-2 summarizes key elements of this pricing evaluation model in a step-wise fashion. The model initially calls for the analyst to specify an alternative fare policy. Fares associated with trip distance, time period, etc. are delineated at this step. Data from on-board surveys are then used to drive the model. These survey data provide an initial index for estimating ridership responses. The relative change in each passenger's "frequency of use" (Q_{a_i}) is computed on the basis of the new fare (P_a) associated with his or her trip:

$$Q_{a_i} = \text{antilog}\left[(\eta_i \log P_{a_i} - \eta_i \log P_{b_i} - \log Q_{b_i})\right] \qquad (6.8)$$

where:

Q_a = Relative "frequency of use" after fare change

Q_b = Relative "frequency of use" before fare change

P_a = Price after fare change

P_b = Price before

i = Individual passenger

η_i = Arc elasticity of passenger.

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[12] By pro-rating these extra collection costs uniformly among all routes, it is assumed that users from all time periods are equally responsible for these expenses. No attempt was made to factor the additional capital costs of collection between time periods on a 85/15 percent basis (as done for other capital assets). Since off-peak users benefit from peak-load price systems, the attribution of extra collection costs solely to peak users seemed excessive. Thus, the same adjustment factor was applied to the CPM estimates of both time periods.

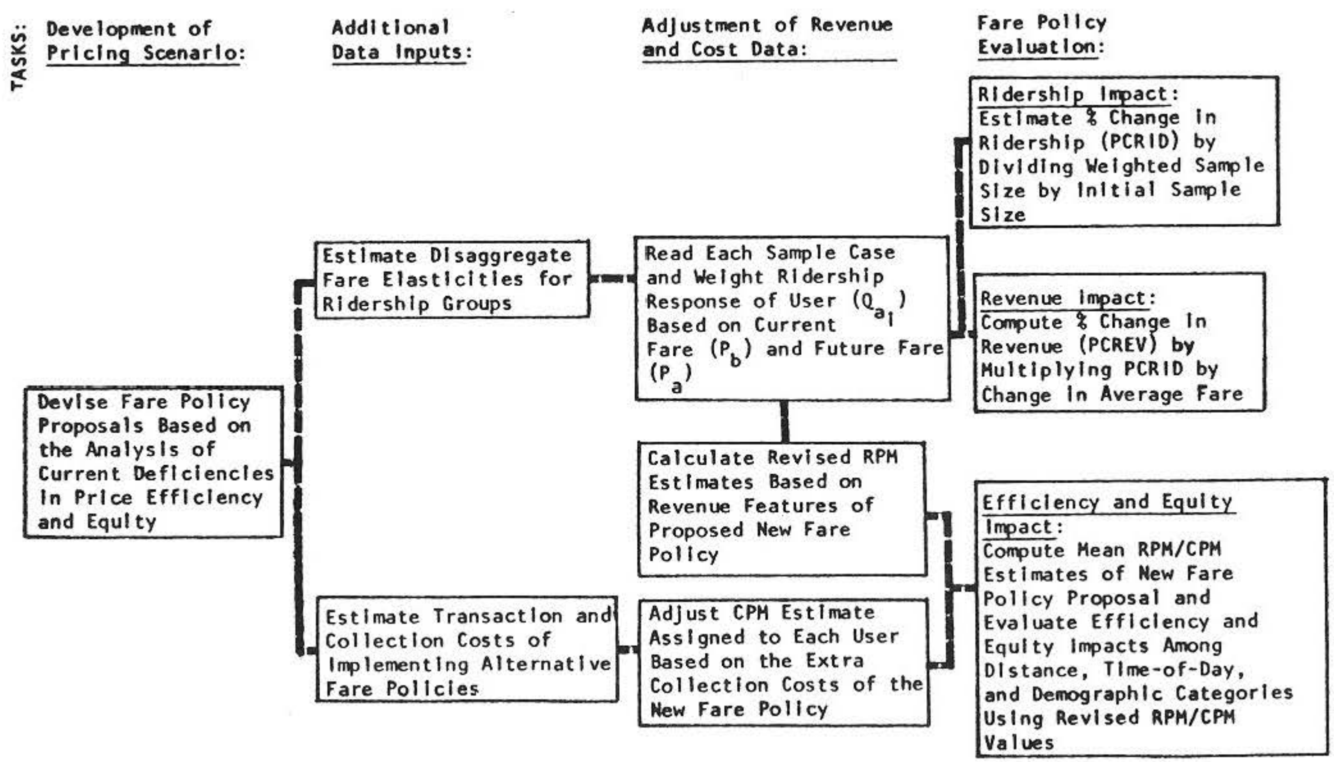

FIGURE 6-2. STEPWISE SUMMARY OF THE PRICING EVALUATION MODEL

This equation projects future usage on the basis of disaggregate arc elasticities presented in Section 6.2. Since each record from on-board surveys represents a single passenger, equation (6.8) can be expressed as a weight (WT_i) by setting Q_{b_i} equal to 1:[13]

$$WT_i = \text{antilog}\left[(\eta_i \log P_{a_i} - \eta_i \log P_{b_i})\right] \qquad (6.9)$$

where:

WT_i = ridership response weight for new fare policy.

In examining price systems, the model aggregates individual weighted responses. Through aggregation, the scope of analysis is expanded to reflect the entire riding population. The three criteria used in evaluating pricing options at the system level are: 1) ridership impact; 2) revenue impact; and 3) efficiency and equity impacts. Ridership impacts are measured in terms of the percent change in initial patronage (PCRID):

$$PCRID = 100 \cdot \left\{ \frac{\sum_{i=1}^{n} \left[\text{antilog}\ (\eta_i \log P_{a_i} - \eta_i \log P_{b_i})\right]}{n} - n \right\} \qquad (6.10)$$

where:

PCRID = percent change in system ridership under new fare policy

n = initial sample size from on-board survey.

The revenue impacts can then be computed as the product of the proportional change in ridership and the proportional change in average fare:

$$PCREV = 100 \cdot \left\{ \left[\left(1 + \frac{PCRID}{100}\right) \cdot \frac{\frac{\sum_{i=1}^{n} P_{a_i}}{n}}{\frac{\sum_{i=1}^{n} P_{b_i}}{n}} \right] - 1 \right\} \qquad (6.11)$$

where:

PCREV = percent change in system revenue under new fare policy.

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[13] Since weights were previously assigned to each record based on the procedures described in Appendix B, each passenger's ridership response is estimated as the product of the individual weights. That is, the weight assigned to each record to adjust for sampling bias was multiplied by the weight reflecting relative changes in "frequency of use."

In general, new fare systems generate higher revenue returns whenever price increases are relatively greater than patronage losses.

Efficiency and equity impacts of alternative price systems are evaluated in a manner similar to that employed in evaluating current price systems. A RPM/CPM index again serves as the criterion variable. New fares (R) are assigned to sampled users commensurate with their distance or time of travel. Trip costs (C) are adjusted to reflect the collection features of the fare alternative. Also, the analysis assumes that passenger-miles (PM) change at the rate of the weighted increase in ridership (WT). Combining these data, the mean RPM/CPM of each proposal can be computed from equation (6.5):

$$RPM/CPM = \frac{\sum_{j=1}^{n} \sum_{k=1}^{n} \sum_{i=1}^{n} (R_{ijk}/PM_{ijk} \div C_{ijk}/PM_{ijk})}{n_a \cdot n_t \cdot n_r} \qquad (6.12)$$

where:

R = price paid by rider i under new fare policy

C = cost of rider i's trip on route j during time period k (including additional collection costs) under new fare policy

PM = passenger-miles traveled by rider i

j = route surveyed

k = time period

i = individual passenger

n_r = number of routes surveyed

n_t = number of time periods

n_a = weighted sample size for route r and time t.

The efficiency and equity analysis of each pricing scenario can then be performed by contrasting RPM/CPM differences among categories of trip distance, time-of-day, and user demographics. Together, these criteria provide a full picture of each pricing policy's possible range of economic and distributional impacts.

6.6 Summary

An exploratory model was designed for evaluating pricing scenarios. The model analyzes fare strategies by weighting sample cases from passenger surveys based on disaggregate price elasticity estimates. Fare elasticities were estimated to reflect the sensitivity of specific user groups to price changes based largely on a review of the literature.

Another important factor in evaluating fare policy options is transaction costs. General collection systems were evaluated in terms of their compatibility with differentiated fare structures, including on-board automatic collection, pre-payment, post-payment, and self-administered honor payments. Cost estimates were derived for various collection systems and integrated into the analysis of pricing scenarios. The merger of each scenario's cost and revenue features provides the basis for analyzing changes in RPM/CPM among distance, time-of-day, and demographic groups. The next chapter presents the results of applying this evaluation model to various distance-based peak/off-peak, and service-differentiated pricing scenarios.

CHAPTER SEVEN

EFFICIENCY, EQUITY, AND RIDERSHIP IMPACTS OF ALTERNATIVE FARE POLICIES

7.1 Introduction

In establishing fare policy, public officials often face 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 "simplification" goals can be most easily achieved by eliminating fares altogether. Realistically, operators must choose fare systems somewhere between the extremes of pure marginal cost pricing and free services. Differentiating fares according to distance, time-of-day, or service type represent possible compromises.

This chapter analyzes a range of pricing policies in terms of their likely impacts on efficiency, equity, ridership, and fiscal performance. The ridership and revenue effects of alternative fare systems are estimated from fare elasticities presented in Chapter Six. Using the evaluation model, efficiency and equity are then analyzed by combining the revenue and cost features of each pricing scenario into a RPM/CPM index. Scenarios are compared in terms of RPM/CPM differences among trip distances, time periods, and demographic groups.

This chapter tests six fare scenarios for each operator. Among the distance-based scenarios are stage pricing, more finely graduated pricing based on declining steps, and fares graduated linearly with distance. In addition, time-of-day pricing is examined along with scenarios which differentiate fares by both distance and time. Other scenarios presented involve changing fare rates on passes and among service types. Following these analyses, the model is applied to fare systems currently being proposed by the three properties' Board of Directors. Finally, all scenarios are contrasted with current fare systems to provide a "before and after" basis of analysis. The relative strengths and weaknesses of the various fare alternatives in remedying current pricing deficiencies are also discussed. A comparative analysis of pricing concepts concludes the chapter. Each pricing alternative is contrasted with current fare systems to provide a "before and after" basis of analysis. The relative strengths and weaknesses of each scenario in remedying current pricing deficiencies are also discussed. A comparative analysis of pricing concepts concludes the chapter.

7.2 Stage Pricing Scenario

Stage fare structures aim to capture some of the costs incurred in serving long-haul journeys, yet without the expense burden of elaborate distance-monitoring collection equipment. Typically, stages are set on the basis of network structure and traffic flow. Major interchanges, activity centers, and natural boundaries often serve to demarcate each step in a stage price system.

Ideally, a stage system would exact equal fares from those traveling the same approximate distance and systematically varying fares from patrons journeying different distances.

Several pricing policies with step functions were tested for each case study as approximations of stage and zonal fare systems.[1] Those which appeared to reduce distance price inefficiencies the most are presented in this section.

Table 7-1 displays the pricing features of the "best" stage scenario for each property. Each step shown in the table encompasses a particular mileage range.[2] Basic, senior, and (in the case of AC Transit and SDTC) student fares corresponding to each mileage band are also shown. For example, SCRTD's patrons traveling between 6 and 10 miles would generally cross five stages under this scenario and pay a fare of 85 cents; seniors traveling these distances, in contrast, would pay only 30 cents.

Employing the pricing evaluation model, ridership and revenue impacts of the stage scenarios were measured for each property. Table 7-2 summarizes these results, using mid-range arc elasticities and stage fare data from the previous table. Each property is projected to lose a margin of riders under stage pricing. However, significant revenue gains could generally be expected. Stage pricing holds particular promise for increasing SCRTD's revenue yield. Merging the collection costs of stage pricing into the analysis, RPM/CPM estimates increased appreciably for all three systems. As a proxy of each property's "operating ratio," RPM/CPM estimates generally rose between 15 and 30 percent under stage pricing.

The potential efficiency impacts of stage pricing with respect to distance and time-of-day appear even more dramatic. As shown in Table 7-3, stage pricing appears to generate markedly lower RPM/CPM estimates for short trips and much higher ones for long journeys. The largest percentage decreases in RPM/CPM were estimated for very short trips of less than one mile while the greatest increases were generally projected among the longest trips. The exception was AC Transit, where the highest percentage increase was for mid-range distances. The reader will recall from Chapter Five that AC Transit trips between 4 and 10 miles were the least efficiently priced journeys. In general, the stage price scenarios appear to offer considerable efficiency gains for all three properties.

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[1]These scenarios approximate stage and zonal policies by assuming that route sections and area boundaries would be judiciously designed so that, on average, all user groups traveling a certain mileage range would pay identical fares.

[2]The mileage ranges assigned to stages in Table 7-1 reflect the structural analysis of distance inefficiencies (Table 5-9). Accordingly, SCRTD's hypothetical stage system claims eight steps in comparison with the ten steps of the other two properties. Also, the fares for shorter distances are graduated more finely, and for longer distances more coarsely. Generally, a dime separates each step, except for stages on the fringes of the properties' service areas where hypothetical surcharges are set at 25 cents or more.

TABLE 7-1. STAGE PRICING SCENARIOS

SCRTD[a]			AC TRANSIT[b]				SDTC[c]			
Distance step (in miles)	Basic Fare	Senior Fare	Distance step (in miles)	Basic Fare	Senior Fare	Student Fare	Distance step (in miles)	Basic Fare	Senior Fare	Student Fare
(1) < 1	$ .15	$.05	(1) < 1	$ .15	$.05	$ .10	(1) < 1	$ .15	$.10	$.15
(2) 1-2	.25	.10	(2) 1-2	.25	.10	.15	(2) 1-2	.25	.15	.20
(3) 2-3	.45	.15	(3) 2-3	.40	.10	.25	(3) 2-3	.35	.20	.25
(4) 3-6	.65	.20	(4) 3-4	.55	.15	.40	(4) 3-4	.45	.25	.30
(5) 6-10	.85	.30	(5) 4-6	.75	.20	.50	(5) 4-6	.55	.30	.40
(6) 10-15	1.10	.35	(6) 6-10	.90	.25	.60	(6) 6-10	.75	.35	.50
(7) 15-25	1.35	.45	(7) 10-15	1.10	.30	.75	(7) 10-15	.90	.40	.60
(8) > 25	1.70	.55	(8) 15-20	1.30	.35	.85	(8) 15-20	1.10	.50	.70
			(9) 20-25	1.55	.45	1.00	(9) 20-25	1.25	.50	.80
			(10) > 25	1.90	.50	1.15	(10) > 25	1.50	.50	.90

[a] All other SCRTD fare components, including special pass arrangements, were retained in this analysis. They were assumed to be priced at the same rate of corresponding cash fares; however, pass discount rates from the base year were retained. Also, dime transfers were retained in the analysis.

[b] These distance rates were applied to all service types. Free transfers were also assumed. Special passes were again excluded from the AC Transit analysis.

[c] Passes were assumed to be priced at the same rate as cash fares. No price distinction was made between express and local fares other than distance of travel. Transfers were again excluded from the SDTC analysis.

TABLE 7-2. RIDERSHIP AND REVENUE IMPACTS OF STAGE PRICING SCENARIOS

	SCRTD	AC TRANSIT	SDTC
% Change in Ridership	-2.4	-2.6	-6.2
% Change in Revenue	+30.8	+14.6	+24.4
RPM/CPM	.60	.46	.46
% Change in Operating Ratio	+29.7	+16.2	+30.9

The improvements in price efficiency over distance can be best illustrated in standardized form. In comparison with current pricing, Figure 7-1 reveals that RPM/CPM estimates converge toward the subsidy threshold (i.e., 1.00) under stage fare structures. The current hyperbolic relationship between RPM/CPM and distance flattens markedly with the stage scenario. Though stage pricing seems to reduce disparities, the incidence of fare cross-subsidization still appears to favor longer distance trips. For each property, patrons traveling under one mile continue to function as the major cross-subsidizers while those commuting beyond 25 miles remain the major beneficiaries. However, the threshold distinguishing gainers from losers has increased from two miles to four miles for SCRTD and AC Transit. Although SDTC's subsidy threshold remains unchanged, stage pricing seems to offer a comparatively high revenue return for the system's long distance trips.[3]

Although stage systems price according to distance, Table 7-3 reveals that temporal improvements in price efficiency could emerge as well. RPM/CPM ratios increased 30 percent more during the peak than the base for SCRTD and AC Transit. For SDTC, the relative increase in the peak period's RPM/CPM was even greater - 94 percent.

Stage pricing scenarios were also evaluated in terms of equity criteria. Table 7-4 indicates that stage pricing could potentially reduce the regressivity of AC Transit's and SDTC's current fare systems. RPM/CPM disparities between those with annual family incomes above and below $15,000 were virtually eliminated. Stage pricing, however, appeared to retain SCRTD's mildly progressive transfer incidence. Further, stage fares seem particularly advantageous to SCRTD's and SDTC's carless patrons. In addition, cross-subsidies from AC Transit's minority patrons to white users could be expected to decline by approximately fifty percent with step pricing.

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[3]While Table 7-3 and Figure 7-1 indicate that step pricing structures generally attenuate distance disparities, RPM/CPM can nonetheless vary appreciably within stages. In the case of each property's 10-15 mile stage, for example, ten mile trips return decisively higher revenue rates than fifteen mile ones. Such price inequities, however, are inherent in coarsely designed fare structures. In general, the gains in reducing RPM/CPM disparities between distance categories overshadow inequities within price stages or zones.

TABLE 7-3. EFFICIENCY ANALYSIS OF STAGE PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Stage Pricing	% Change	Current Pricing	Stage Pricing	% Change	Current Pricing	Stage Pricing	% Change
Trip Distance (in miles):									
< 1	2.22	.95	-233	1.14	.53	-113	1.31	.75	-74
1-2	.66	.65	-3	.48	.50	+5	.63	.56	-13
2-3	.38	.65	+70	.29	.50	+71	.38	.47	+24
3-4	.27	.64	+145	.21	.46	+112	.29	.41	+41
4-6	.20	.50	+145	.15	.39	+160	.22	.40	+82
6-8	.18	.52	+195	.10	.30	+180	.19	.42	+121
8-10	.13	.39	+206	.09	.22	+129	.20	.43	+115
10-12	.13	.50	+289	.11	.26	+141	.19	.45	+139
12-15	.12	.42	+255	.13	.24	+183	.16	.37	+131
15-20	.10	.41	+317	.14	.25	+74	.13	.40	+203
20-25	.09	.49	+452	.17	.26	+53	.12	.37	+191
> 25	.06	.37	+478	.15	.23	+53	.07	.28	+283
Time Period:									
Base	.55	.70	+27	.44	.50	+13	.42	.49	+17
Peak	.37	.49	+35	.35	.41	+17	.32	.43	+33
Total Sample:	.46	.60	+30	.40	.46	+15	.35	.46	+31

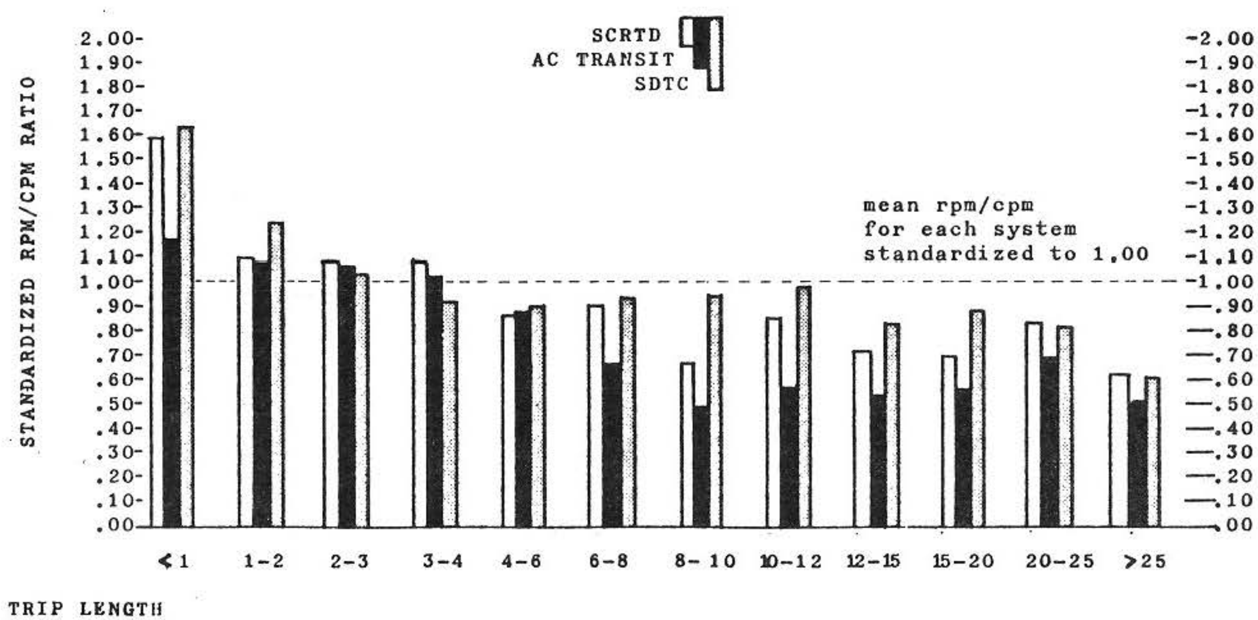

FIGURE 7-1. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TRIP DISTANCE UNDER STAGE PRICING SCENARIO

TABLE 7-4. EQUITY ANALYSIS OF STAGE PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Stage Pricing	% Change	Current Pricing	Stage Pricing	% Change	Current Pricing	Stage Pricing	% Change
Annual Family Income:									
< $15,000	.45	.60	+33	.41	.48	+17	.37	.47	+27
> $15,000	.48	.63	+31	.37	.46	+24	.32	.46	+43
Vehicles Own or Available:									
None	.47	.58	+23	.39	.46	+18	.40	.48	+20
≥ 1	.45	.60	+33	.40	.47	+18	.33	.45	+36
Ethnic or Language Background:									
Whites	-	-	-	.38	.45	+18	-	-	-
Others[a]	-	-	-	.44	.47	+9	-	-	-
English-speaking	.46	.59	+28	-	-	-	.36	.46	+28
Spanish-speaking	.48	.67	+39	-	-	-	.29	.38	+31
Gender:									
Females	.48	.59	+23	.40	.45	+13	.36	.45	+25
Males	.44	.61	+39	.40	.47	+18	.34	.47	+38
Age Groups:[b]									
Youth	.50	.58	+16	.25	.34	+36	.35	.38	+9
College	.56	.68	+21	.46	.52	+13	.36	.45	+25
Middle	.42	.61	+45	.41	.48	+17	.38	.51	+34
Seniors	.19	.25	+32	.21	.22	+5	.24	.35	+46
Trip Type:									
Work	.45	.61	+36	.40	.46	+15	.32	.48	+50
Non-Work[c]	.46	.58	+26	.40	.46	+15	.39	.45	+15
Medical	1.04	.85	-22	-	-	-	-	-	-
Total Sample:	.46	.60	+30	.40	.46	+15	.35	.46	+31

[a] Included in AC Transit's "others" group are Asians, Blacks, and Hispanics.

[b] Age spans of groups are as follows. "Youth": SCRTD and AC Transit = <17; SDTC = <16, "College": SCRTD = 18-22; AC Transit = 18-30; SDTC = 16-24. "Middle": SCRTD = 23-62; AC Transit = 31-64; SDTC = 25-60. "Senior": SCRTD = >62; AC Transit = >64; SDTC = >60.

[c] SCRTD's non-work trips exclude medical journeys

The stage pricing simulation revealed that a reversal in the direction of current cross-subsidies could be expected between men and women users. For each system, stage fares appear to elicit higher revenue returns from males than females. Also, RPM/CPM rates generally increase at a slower rate for SCRTD's and AC Transit's college age patrons under stage pricing; however, these users would likely continue to cross-subsidize other age groups. Finally, stage fares appear to increase the revenue productivity of work trips in comparison with others. This, of course, reflects the higher fares captured from long distance trips made during peak periods. Moreover, SCRTD's patrons making medical trips could anticipate appreciable savings under a distance-based stage price arrangement.

In sum, stage pricing seems to offer substantial gains in the revenue productivity and price efficiency of transit operations. Ridership levels, however, could possibly decline as a result. In addition, current discrepancies in RPM/CPM could probably be significantly reduced with step fares. Finally, the distributional consequences of stage pricing generally seem advantageous to those users least able to pay and in the greatest need of transit services.

7.3 Graduated Pricing Scenario

In contrast with step pricing, distance-based fares can be finely graduated either as a linear or logarithmic function of distance. In theory, the distance covered by any one fare value can be made smaller and smaller until a unique fare is charged for virtually every trip. A more practical approach, however, would involve pricing on the basis of small distance increments, such as one-half mile units. Narrower distance bands could largely eliminate price inequities among trips within steps of a stage or zonal fare system. A key question is whether gains in revenue, efficiency, and equity justify investments in elaborate collection systems. Would these gains be relatively greater than those projected under stage or zonal systems? This section probes these questions by testing both logarithmic and linear distance-based price structures.

7.3.1 Logarithmic-Based Distance Pricing

The price features of logarithmic-based fare scenarios are summarized in Table 7-5. For trips under 1.5 miles, the scenarios call for flat fares of $0.05 and $0.10.[4] Beyond this mark, charges are set as logarithmic functions of distance.[5] Thus, price steps increase at a declining rate. For instance,

[4]Flat fares are set for very short trips because the logarithm of a fraction is a negative value. In general, a logarithmic function is suited to the pricing of service according to distance only for trips beyond one and a half miles in length.

[5]These price functions were designed in order to reduce the distance-related disparities in RPM/CPM presented in Chapter Five. Since trip length data were measured at one-tenth of a mile intervals, fairly precise distance charges are produced by these formulae. However, these functions could also be used to conceptualize the pricing implications of larger steps (i.e., 0.5 miles) by analyzing the mean RPM/CPM between any two distance marks (i.e., 3.5 to 4.0 miles).

most patrons traveling four miles would be charged approximately $0.45 while those traveling fourteen miles would generally pay $0.90. In addition, senior and student fare discounts are assumed to be logarithmically related to distance. Finally, the analysis assumes prices shown in Table 7-5 apply to all fare and service types (i.e., no basic pass discounts or price differentials among local and express services).

The estimated revenue and ridership impacts of these logarithmically-graduated scenarios are presented in Table 7-6. In contrast to the stage scenarios, logarithmic pricing is projected to increase SCRTD's and AC Transit's ridership. Also, the projected SDTC patronage loss is less than one-half that estimated under stage pricing. Although logarithmic pricing generally appears to offer comparative advantages with respect to ridership, its potential for increasing revenue returns is estimated to be less than that of stage pricing. Moreover, Table 7-6 reveals that each system's average RPM/CPM could be expected to increase, however at only about one-third the rate projected for the stage scenarios. The relatively lower financial productivity and operating efficiency of the logarithmic scenarios can be attributed to both their lower average fares and higher collection costs.

TABLE 7-5. LOGARITHMIC-BASED GRADUATED PRICING SCENARIOS

	SCRTD	AC TRANSIT	SDTC
Basic fare for trips:			
< .75 miles	$.05	$.05	$.05
.75 to 1.5 miles	$.10	$.10	$.10
>1.5 miles	$.80 · log(Trip Length)	$.80 · log(Trip Length)	$.75 · log(Trip Length)
Senior fare for trips:			
> 1.5 miles	$.40 · log(Trip Length)	$.35 · log(Trip Length)	$.40 · log(Trip Length)
Student fare for trips:			
> 1.5 miles	$.55 · log(Trip Length)	$.55 · log(Trip Length)	$.55 · log(Trip Length)
Transfers	$.10	$.00	-

TABLE 7-6. RIDERSHIP AND REVENUE IMPACTS OF LOGARITHMIC-BASED GRADUATED PRICING SCENARIOS

	SCRTD	AC TRANSIT	SDTC
% Change in Ridership	+0.6	+3.0	-2.4
% Change in Revenue	+7.4	+5.5	+16.6
RPM/CPM	.49	.42	.40
% Change in Operating Ratio	+5.5	+4.9	+12.8

The efficiency implications of logarithmic-based pricing are further analyzed in Table 7-7 and Figure 7-2 in terms of distance and time-of-day. The logarithmic scenarios appear quite effective in equalizing RPM/CPM ratios among distance categories. For SCRTD and AC Transit, there is generally less than a fifteen percent differential in the RPM/CPM of all trips under eight miles. In the case of SDTC, there emerges an even greater equalization of price disparities: RPM/CPM estimates are within fifteen percent of one another for all journeys below fifteen miles. Further, each agency's "subsidy threshold" is projected to increase to the 6-8 mile range under the logarithmic pricing approach.[6]

From Figure 7-2 it is apparent that the logarithmic price scenarios perform better than the stage scenarios in reducing RPM/CPM disparities among short and mid-range journeys. However, over longer distances, the logarithmic price function produces relatively lower revenue returns. In the case of SCRTD, standardized RPM/CPM estimates are generally thirty percent higher under the stage price scenario than the logarithmic one for trips exceeding fifteen miles. The exception is AC Transit, for which logarithmic-based pricing seems to yield more equitable standardized RPM/CPM ratios among short and long distance trips alike. Viewing standardized RPM/CPM estimates over the entire range of distance categories, logarithmic pricing appears particularly well suited to the SDTC system.

Table 7-7 also reveals the sensitivity of logarithmic scenarios to temporal discrepancies in pricing. In general, logarithmic pricing seems to increase RPM/CPM ratios at a faster rate during the peak than the base periods. In the case of SDTC, it virtually eliminates disparities between time periods.

Logarithmic-based fares also seem to offer potential equity benefits. Table 7-8 suggests that RPM/CPM disparities could be attenuated with respect to patrons' ability-to-pay. Only in the case of AC Transit is fare cross-subsidization among income groups exacerbated by the logarithmic price scenario. In terms of the vehicle availability criterion, logarithmic pricing seems particularly advantageous to captive users. In the case of SCRTD and SDTC, carless patrons could be expected to switch from a cross-subsidy donor to a recipient role under logarithmic fares. Other potential beneficiaries of logarithmic-based pricing include female passengers, non-work travelers, AC Transit's non-white users, SCRTD's and AC Transit's college-age riders, and SCRTD's medical trip patrons.

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[6]Although RPM/CPM estimates of short and mid-range trips converge markedly toward 1.00 in Figure 6.4, the standardized values of the 1-2 mile distance range appear conspicuously low. They fall below the threshold line because a flat dime fare was assigned to trips in the 0.75 to 1.50 mile range under each scenario. The RPM/CPM rates rise precipitously at the two mile mark, since the logarithmic pricing function increases fares at the fastest rate for short trips. On the whole, however, differentials in RPM/CPM are quite modest for all trip categories under eight miles.

TABLE 7-7. EFFICIENCY ANALYSIS OF LOGARITHMIC-BASED GRADUATED PRICING SCENARIOS

	SCRTD			AC-TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Log-Graduated Pricing	% Change	Current Pricing	Log-Graduated Pricing	% Change	Current Pricing	Log-Graduated Pricing	% Change
Trip Distance (in miles):									
< 1	2.22	.60	-270	1.14	.42	-171	1.31	.44	-198
1-2	.66	.44	-50	.48	.41	-17	.63	.37	-70
2-3	.38	.59	+55	.29	.52	+79	.38	.43	+13
3-4	.27	.58	+115	.21	.49	+133	.29	.42	+45
4-6	.20	.52	+160	.15	.45	+200	.22	.42	+91
6-8	.18	.49	+172	.10	.39	+290	.19	.40	+110
8-10	.13	.39	+200	.09	.33	+266	.20	.42	+110
10-12	.13	.41	+215	.11	.32	+191	.19	.41	+115
12-15	.12	.37	+208	.13	.32	+146	.16	.38	+138
15-20	.10	.29	+190	.14	.31	+121	.13	.35	+169
20-25	.09	.24	+166	.17	.29	+71	.12	.32	+167
> 25	.06	.20	+233	.15	.27	+80	.07	.23	+229
Time Period:									
Base	.55	.57	+4	.44	.46	+5	.42	.41	-2
Peak	.37	41	+11	.35	.37	+6	.32	.39	+22
Total Sample:	.46	.49	+7	.40	.42	+5	.35	.40	+14

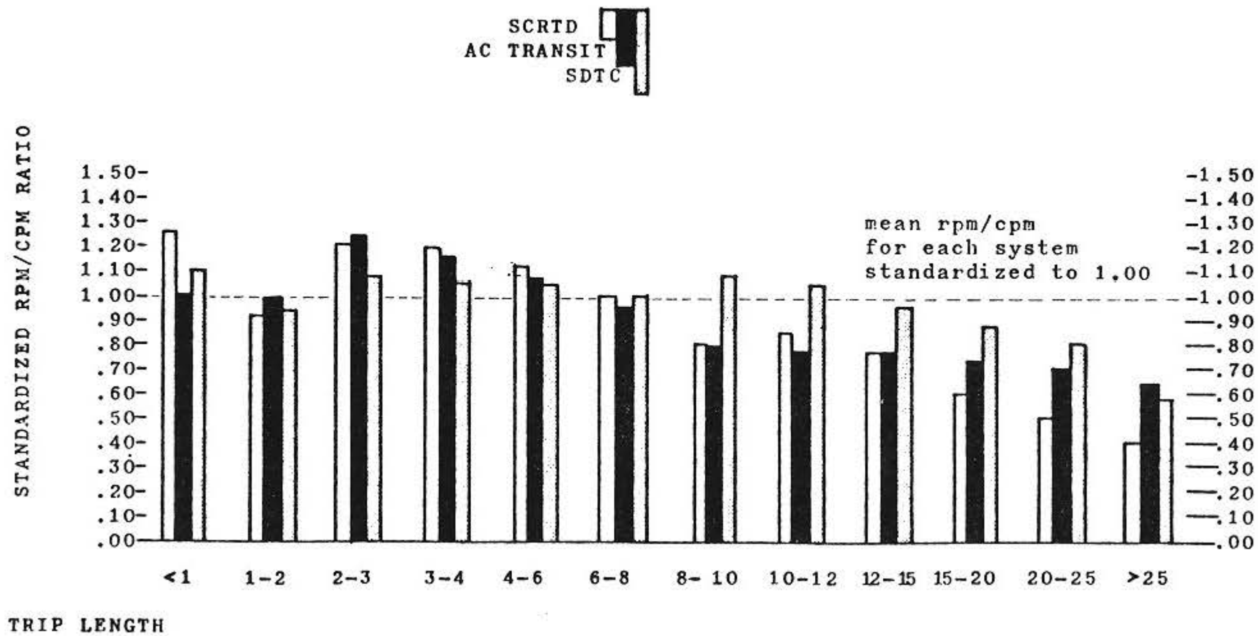

FIGURE 7-2. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TRIP DISTANCE UNDER LOGARITHMIC-BASED PRICING SCENARIOS

TABLE 7-8. EQUITY ANALYSIS OF LOGARITHMIC-BASED GRADUATED PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Log-Graduated Pricing	% Change	Current Pricing	Log-Graduated Pricing	% Change	Current Pricing	Log-Graduated Pricing	% Change
Annual Family Income:									
≤$15,000	.45	.49	+9	.41	.43	+5	.37	.40	+8
>$15,000	.48	.48	0	.37	.37	0	.32	.40	+25
Vehicles Own or Available:									
None	.47	.44	-7	.39	.41	+5	.40	.40	0
≥ 1	.45	.56	+24	.40	.43	+8	.33	.40	+20
Ethnic or Language Background:									
Whites	-	-	-	.38	.41	+8	-	-	-
Others	-	-	-	.44	.42	-5	-	-	-
English-speaking	.46	.48	+4	-	-	-	.36	.41	+19
Spanish-speaking	.48	.55	+25	-	-	-	.29	.34	+17
Gender:									
Females	.48	.49	+2	.40	.41	+4	.36	.40	+11
Males	.44	.50	+14	.40	.42	+6	.34	.41	+21
Age Groups:									
Youth	.50	.46	-9	.25	.27	+8	.35	.38	+9
College	.56	.57	+2	.46	.47	+2	.36	.41	+14
Middle	.42	.55	+31	.41	.45	+10	.38	.42	+11
Seniors	.19	.29	+52	.21	.20	-5	.24	.28	+17
Trip Type:									
Work	.45	.50	+11	.40	.42	0	.32	.42	+31
Non-Work	.46	.48	+4	.40	.42	0	.39	.39	0
Medical	1.04	.56	-86	-	-	-	-	-	-
Total Sample:	.46	.49	+7	.40	.42	+5	.35	.40	+14

7.3.2 Linear Distance-Based Fares

A number of fare scenarios were tested which priced service as a linear function of distance. Those which offered the greatest efficiency and equity gains are described in this subsection. The "best" linear price scenarios set hypothetical base fares for journeys under one mile at five cents, with a nickel surcharge for trips between one and 1.5 miles. These base fares applied to all users, except in the case of SCRTD where the nickel fare was retained for senior and student pass patrons traveling 1.5 miles or less. Beyond 1.5 miles, graduated surcharges of 8 cents, 6 cents, and 4 cents per mile supplemented base fares for regular, student, and elderly passengers respectively. For example, regular users of each property traveling five miles were generally assigned a $0.50 fare. Finally, there were no special fare provisions for pass or express users under these scenarios. Also, current transfer policies were retained in these simulations.

From Table 7-9, the potential ridership impacts of these pure distance-based price scenarios seem modest, except for SDTC. These projected patronage responses generally fall between the extremes estimated for the previous scenarios - less appreciable than either the ridership losses of stage pricing or the ridership gains of logarithmic-based fares. Moreover, the revenue productivity of these linear distance-based scenarios appears greater than that of logarithmic structures yet less than that of coarsely priced systems. In general, significant increases in each property's operating ratio could be expected under the linear pricing approach, with the estimated rate of increase twice that projected with logarithmically-graduated fares.

The efficiency gains projected for the linear graduated pricing model are revealed in Table 7-10 and Figure 7-3. Clearly, current price disparities among distance categories are virtually eliminated by the linear pricing scenarios. In fact, no subsidy threshold is distinguishable among distance groups. Long-haul journeys appear as financially productive as short distance ones. In the case of SCRTD, pure distance pricing is projected to reduce the RPM/CPM ratio of trips below one mile by 275 percent while increasing it over 700 percent for trips exceeding 25 miles - a differential of nearly 1000 percent. Only in the case of AC Transit's and SDTC's mid-range trips are RPM/CPM ratios noticeably low because of their high concentration of elderly and student discount trips. Finally, Table 7-10 shows that linearly-graduated fare systems could neutralize RPM/CPM ratios between time periods, particularly in the case of SDTC.

TABLE 7-9. RIDERSHIP AND REVENUE IMPACTS OF LINEAR DISTANCE-BASED PRICING SCENARIOS

	SCRTD	AC TRANSIT	SDTC
% Change in Ridership	+0.1	+0.3	-5.2
% Change in Revenue	+11.3	+16.8	+24.8
RPM/CPM	.50	.45	.43
% Change in Operating Ratio	+8.7	+13.7	+24.8

TABLE 7-10. EFFICIENCY ANALYSIS OF LINEAR DISTANCE-BASED PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM for:			RPM/CPM for:			RPM/CPM for:		
	Current Pricing	Linear Pricing	% Change	Current Pricing	Linear Pricing	% Change	Current Pricing	Linear Pricing	% Change
Trip Distance (in miles):									
<1	2.22	0.59	-276	1.14	0.49	-132	1.31	0.40	-228
1-2	0.66	0.47	- 40	0.48	0.47	- 2	0.63	0.47	- 34
2-3	0.38	0.54	+ 42	0.29	0.50	+ 72	0.38	0.44	+ 16
3-4	0.27	0.51	+ 89	0.21	0.43	+105	0.29	0.40	+ 38
4-6	0.20	0.49	+145	0.15	0.39	+160	0.22	0.39	+ 77
6-8	0.18	0.50	+177	0.10	0.38	+280	0.19	0.40	+111
8-10	0.13	0.47	+262	0.09	0.36	+298	0.20	0.45	+125
10-12	0.13	0.51	+292	0.11	0.37	+236	0.19	0.47	+147
12-15	0.12	0.53	+342	0.13	0.42	+223	0.16	0.46	+181
15-20	0.10	0.48	+380	0.14	0.45	+221	0.13	0.47	+261
20-25	0.09	0.50	+455	0.17	0.47	+176	0.12	0.48	+303
>25	0.06	0.48	+706	0.15	0.48	+220	0.07	0.49	+616
Time Period:									
Base	0.55	0.58	+ 5	0.44	0.49	+ 11	0.42	0.44	+ 5
Peak	0.37	0.42	+ 14	0.35	0.40	+ 14	0.32	0.42	+ 31
Total Sample	0.46	0.50	+ 9	0.40	0.45	+ 13	0.35	0.43	+ 23

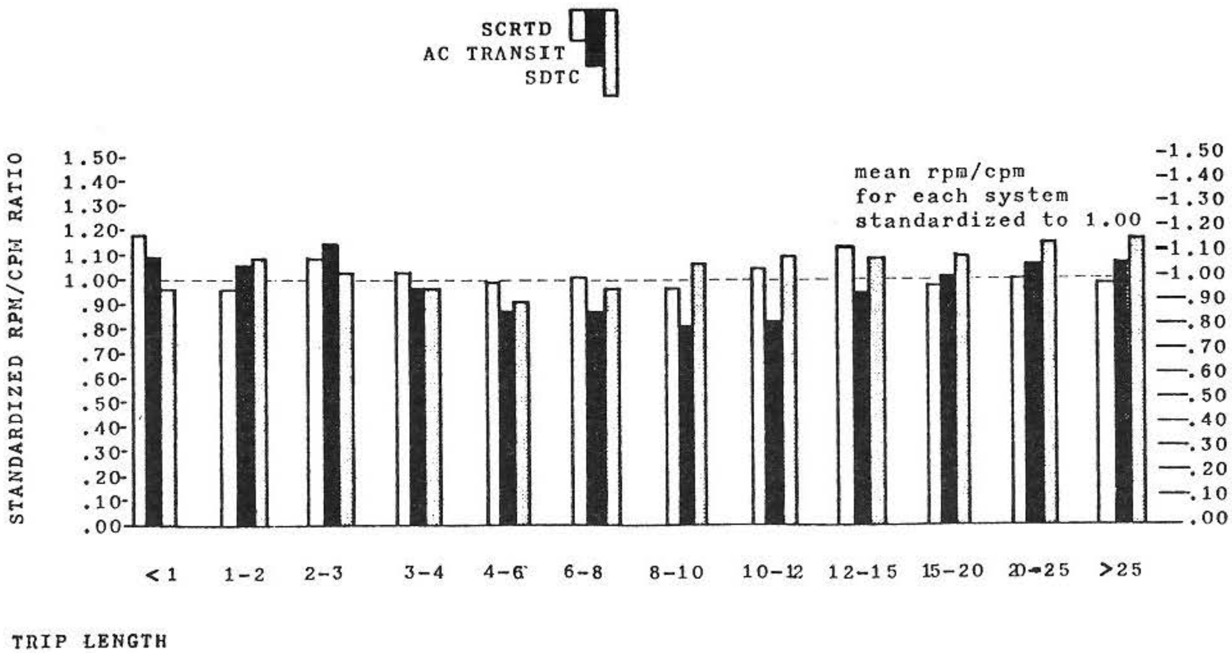

FIGURE 7-3. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TRIP DISTANCE UNDER LINEAR GRADUATED PRICING SCENARIOS

The equity impacts of the linear-based fare scenarios generally parallel those of the logarithmic-priced approaches (Table 7-11). In the case of SCRTD and AC Transit, linearly-graduated fares appear to equalize RPM/CPM among income groups. With SDTC, pure distance-based fares could potentially transform the agency's price system from a mildly regressive to a mildly progressive one. Also, linearly-graduated pricing could redistribute fares so as to reverse the incidence of cross-subsidization in favor of SDTC car-less patrons. In general, linear price increments could be expected to benefit patrons who are female, minorities, college-age, and making non-work trips.

7.3.3 Graduated Pricing Summary

Distance-based fare policies appear to offer opportunities for improving the efficiency and distributional impacts of pricing. Compared with coarsely-priced structures, graduated fares seem to exert fewer pressures on ridership. However, higher collection costs appear to dilute the revenue productivity of graduated pricing relative to stage fare structures. Nonetheless, investments in distance-monitoring collection systems seem justifiable given the potential for increasing each property's financial performance under graduated pricing.

Graduated fare policies which fashion surcharges on the basis of either constant or declining steps could generally be expected to improve efficiency levels with respect to distance traveled. Pure distance-based structures with constant eight cent mileage increments could potentially equate users' fares with the marginal costs of their trips. Moreover, the maldistributive effects of current flat fares could probably be significantly reduced in terms of users' time period of travel and demographic characteristics. Both the logarithmic and linear scenarios exhibited high target efficiencies, generally conferring benefits to users least able to pay and most dependent on transit services. Linearly-graduated fares, in particular, appear sensitive to current price disparities. They clearly offer the greatest efficiency and equity gains among the distance-based fare structures tested, while also improving fiscal performance.

7.4 Time-Dependent Pricing Scenarios

Disparities between the three properties' peak and off-peak RPM/CPM estimates warrant the investigation of time-of-day fare differentials. The time-dependent scenarios which best equalize current price inefficiencies are presented in this section. In the case of SCRTD, a 56 percent differential distinguishes peak and off-peak basic fares under the scenario shown in Table 7-12. In comparison, proposed fares vary by only 30 percent between AC Transit's time periods - 40 cents during the peak as opposed to 30 cents during the base. SDTC's time-based scenario calls for off-peak fares to cost approximately one-half as much as peak ones. Current discount programs are retained in these scenarios, although peak surcharges supplement senior and student fares, pass prices, and transfers.

From Table 7-13 time-of-day fares are estimated to increase each property's overall ridership slightly. Lower base period fares could also be expected to increase off-peak patronage so as to more than compensate for peak period ridership losses. Only in the case of SDTC, however, would the

TABLE 7-11. EQUITY ANALYSIS OF LINEAR DISTANCE-BASED PRICING SCENARIOS

	SCRTD			AC-TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Linear Pricing	% Change	Current Pricing	Linear Pricing	% Change	Current Pricing	Linear Pricing	% Change
Annual Family Income:									
≤ $15,000	.45	.50	+11	.41	.45	+10	.37	.43	+16
> $15,000	.48	.50	+4	.37	.45	+22	.32	.46	+44
Vehicles Own or Available:									
None	.47	.51	+9	.39	.45	+15	.40	.42	+5
≥ 1	.45	.50	+11	.40	.45	+13	.33	.44	+33
Ethnic or Language Background:									
Whites	-	-	-	.38	.44	+16	-	-	-
Others	-	-	-	.44	.44	0	-	-	-
English-speaking	.46	.49	+7	-	-	-	.36	.43	+19
Spanish-speaking	.48	.52	+8	-	-	-	.29	.36	+24
Gender:									
Females	.48	.50	+4	.40	.44	+10	.36	.42	+17
Males	.44	.50	+14	.40	.45	+13	.34	.45	+32
Age Groups:									
Youth	.50	.46	+9	.25	.43	+72	.35	.40	+14
College	.56	.55	+2	.46	.45	-2	.36	.43	+19
Middle	.42	.50	+19	.41	.45	+10	.38	.46	+21
Seniors	.19	.31	+63	.21	.35	+67	.24	.35	+46
Trip Type:									
Work	.45	.49	+9	.40	.43	+8	.32	.46	+44
Non-Work	.46	.50	+9	.40	.45	+13	.39	.43	+5
Medical	1.04	.66	-58	-	-	-	-	-	-
Total Sample:	.46	.50	+9	.40	.45	+13	.35	.43	+23

TABLE 7-12. TIME-DEPENDENT PRICING SCENARIO

	SCRTD	AC TRANSIT	SDTC
Peak Period:			
Basic Fares	$ 0.55	$ 0.40	$0.45
Senior Fares	0.20	0.15	0.20
Student Fares	0.25	0.30	0.30
Express Fares	0.40 - 0.90	0.40 - 1.45	0.65
Base Pass Fares	0.50	—	0.45
Transfers	0.15	0	0
Off-Peak Period:			
Basic Fares	0.35	0.30	0.30
Senior Fares	0.15	0.10	0.10
Student Fares	0.15	0.20	0.20
Express Fares	0.75 - 1.65	0.30 - 1.10	0.40
Base Pass Fares	0.30	—	0.30
Transfers	0.10	0	—

TABLE 7-13. RIDERSHIP AND REVENUE IMPACTS OF TIME-DEPENDENT PRICING SCENARIOS

	SCRTD	AC TRANSIT	SDTC
% Change in Ridership	+0.4	+1.0	+1.3
% Change in Revenue	+13.5	+11.6	+3.0
RPM/CPM	.53	.44	.36
% Change in Operating Ratio	+14.3	+11.5	+2.7

ridership gains of time-variant fares be expected to exceed those projected under logarithmically-graduated fares.

Higher revenue yields could also be anticipated with peak/off-peak fares. In general, however, time-based fares do not appear to match the revenue-productivity of distance-based fares. Yet, when collection costs are merged into the analysis, the financial performance of time-dependent pricing seems on a par with the graduated scenarios. In the case of SCRTD and AC Transit, peak/off-peak differentials could be expected to raise each property's operating ratio above that forecasted under both graduated pricing proposals. However, stage pricing appears more solvent than peak-load pricing in all three study cases.

The three scenarios appear effective at equalizing current price discrepancies between time periods. Table 7-14 indicates that current RPM/CPM estimates would increase markedly during the peak while declining during base periods. Peak-load pricing seems particularly responsive to SCRTD's temporal disparities. From Figure 7-4, it is apparent that time-of-day differentials would lead to a homeostasis - standardized RPM/CPM ratios generally converge toward 1.00 during both peaks and the midday period. In all cases, peak period RPM/CPM ratios lie slightly above the subsidy threshold. Although evening and owl period patrons generally reap excess benefits from these scenarios, they constitute such a small proportion of total ridership that the overall redistributive effects between peak and base users would be essentially neutral. Finally, Table 7-14 indicates that a marginal equalization of RPM/CPM ratios between short and long trips would emerge under time-based pricing. However, the relative reduction in distance disparities projected under peak/off-peak differentials appear less than the relative reduction of temporal disparities projected under graduated pricing. Thus, time-of-day differentials seem to hold less potential for improving overall price efficiency in comparison with distance-based fares.

TABLE 7-14. EFFICIENCY ANALYSIS OF TIME-DEPENDENT PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Time-Based Pricing	% Change	Current Pricing	Time-Based Pricing	% Change	Current Pricing	Time-Based Pricing	% Change
Time Period:									
AM Peak	.38	.54	+42	.36	.46	+28	.30	.38	+27
Midday	.68	.55	-24	.46	.43	-7	.42	.34	+24
PM Peak	.42	.56	+33	.35	.46	+31	.33	.40	+21
Evening	.48	.46	-4	.42	.46	+9	.36	.32	-13
Owl	.47	.42	-12	.29	.29	0	.42	.34	-24
Base	.55	.53	-4	.44	.45	+2	.42	.39	-8
Peak	.37	.53	+43	.35	.43	+23	.32	.34	+6
Trip Distance (In miles):									
≤ 6	.64	.68	+6	.57	.52	-10	.49	.45	-9
> 6	.12	.15	+25	.14	.19	+36	.18	.20	+11
Total Sample:	.46	.53	+15	.40	.44	+10	.35	.36	+3

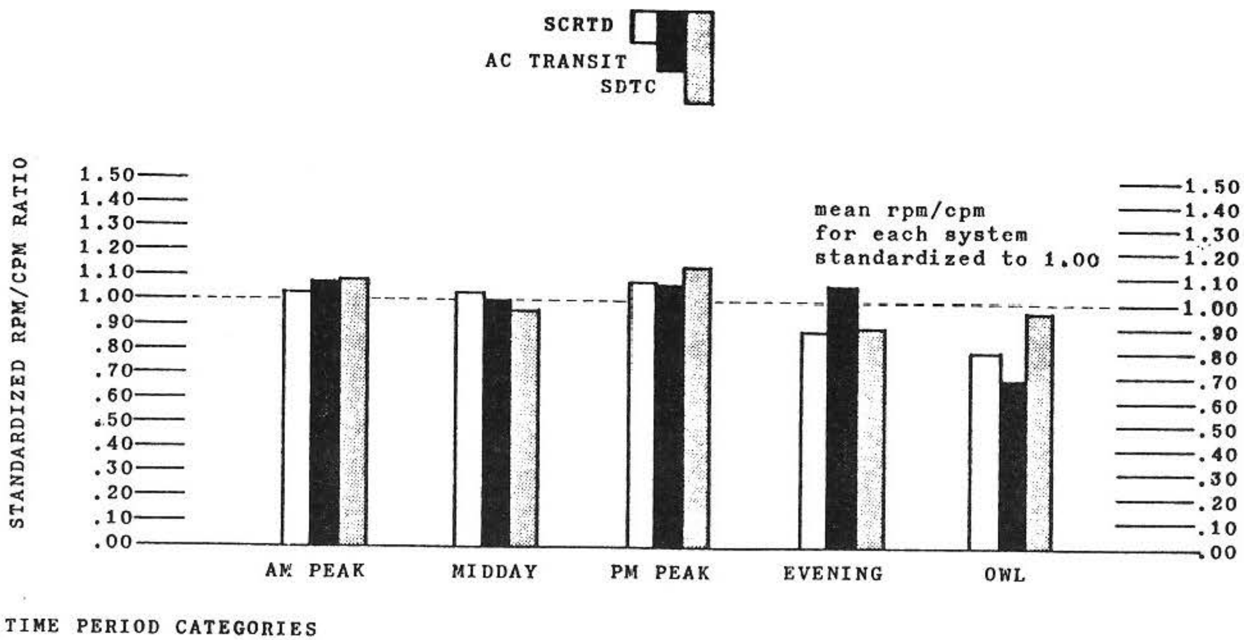

FIGURE 7-4. COMPARISON OF STANDARDIZED RPM/CPM RATIOS BY TIME PERIOD UNDER TIME-DEPENDENT PRICING SCENARIOS

Equity implications of time-dependent pricing are revealed in Table 7-15. The three scenarios produce few discernable changes in the distributive effects of current pricing. In the case of SDTC, those with lower incomes and the fewest travel options could generally be expected to pay disproportionately high fares under the time-dependent arrangement. Likewise, AC Transit's peak/off-peak fare scenario appears to retain the regressive features of flat fares. In general, minorities and females could also be expected to continue subsidizing patrons who are white and male. Further, SCRTD's and AC Transit's college-age riders would probably remain cross-subsidizers under time-of-day pricing. The only perceptible change in the current distributive effects of pricing is among each property's work and non-work patrons. The relatively high RPM/CPM ratios associated with work trips generally reflect the concentration of commuter travel during peak periods.

In sum, time-dependent fares could be expected to eliminate price disparities between the peak and base periods while also increasing ridership, revenue intake, and operating efficiency. The revenue productivity of time-differentiated pricing appears comparable to that of graduated fare structures, but less than that of stage pricing. Few equity benefits, however, would likely be gained under these scenarios. Moreover, peak/off-peak fares generally seems insensitive to current price discrepancies related to travel distance.

7.5 Joint Distance/Time Based Pricing Scenarios

Stage and peak/off-peak fare scenarios were combined to create joint distance/time-based pricing proposals. In theory, a joint approach can approximate marginal cost pricing more closely than when fares are differentiated solely on the basis of distance or time-of-day. By embracing both distance and temporal pricing principles, however, fairly complex fare structures emerge. Table 7-16 displays hypothetical distance/time based price systems tested for the three study sites. Under each scenario, fares increase as a step function of distance. However, steps increase at a markedly faster rate during the peak. Special senior, student, and transfer discounts are also accounted for in the scenario.

Significant ridership losses accompanied by sizable revenue gains were projected under these scenarios (Table 7-17). Based on mid-range elasticity estimates, patronage could be expected to decline by four to nine percent. However, far greater revenue gains could be anticipated than with any of the previous scenarios. Moreover, each agency's operating efficiency would in all liklihood increase dramatically. In the case of SCRTD, the farebox could be expected to return over three-quarters of total expenses under distance/time based fares. Clearly, the high collection costs associated with the distance/time based pricing scenarios are more than offset by their high revenue productivity.[7]

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[7]Elaborate distance and time monitoring collection equipment were assumed to be necessary for implementing these joint pricing scenarios. Collection costs estimates associated with graduated fare systems were employed in the analysis of distance/time based pricing.

TABLE 7-15. EQUITY ANALYSIS OF TIME-DEPENDENT PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Time-Based Pricing	% Change	Current Pricing	Time-Based Pricing	% Change	Current Pricing	Time-Based Pricing	% Change
Annual Family Income:									
≤ $15,000	.45	.52	+16	.41	.45	+10	.37	.38	+3
> $15,000	.48	.55	+15	.37	.42	+14	.32	.33	+3
Vehicles Own or Available:									
None	.47	.53	+13	.39	.44	+13	.40	.40	+1
≥ 1	.45	.52	+16	.40	.45	+13	.33	.34	+3
Ethnic or Language Background:									
Whites	-	-	-	.38	.43	+13	-	-	-
Others	-	-	-	.44	.49	+11	-	-	-
English-speaking	.46	.52	+13	-	-	-	.36	.37	+3
Spanish-speaking	.48	.59	+23	-	-	-	.29	.29	+1
Gender:									
Females	.48	.55	+15	.40	.44	+10	.36	.37	+2
Males	.44	.51	+16	.40	.44	+10	.34	.36	+5
Age Groups:									
Youth	.50	.56	+12	.25	.33	+32	.35	.35	0
College	.56	.64	+14	.46	.52	+13	.36	.37	+3
Middle	.42	.55	+31	.41	.44	+7	.38	.40	+5
Seniors	.19	.26	+37	.21	.20	-5	.24	.22	-9
Trip Type:									
Work	.45	.55	+22	.40	.44	+10	.32	.36	+13
Non-Work	.46	.51	+11	.40	.43	+8	.39	.38	-3
Medical	1.04	1.12	+8	-	-	-	-	-	-
Total Sample:	.46	.53	+15	.40	.44	+10	.35	.36	+3

TABLE 7-16. DISTANCE/TIME BASED PRICING SCENARIOS

	SCRTD			AC TRANSIT			SDTC		
	Basic Fare	Senior Fare	Student Pass Fare	Basic Fare	Senior Fare	Student Fare	Basic Fare	Senior Fare	Student Fare
Peak:									
< 1 mile(s)	$ .15	$.10	$ .10	$ .15	$.10	$.10	$ .15	$.10	$.10
1-2 "	.30	.15	.15	.30	.15	.20	.25	.15	.15
2-3 "	.55	.20	.20	.45	.15	.30	.35	.20	.20
3-4 "	.75	.25	.25	.65	.20	.45	.45	.25	.25
4-6 "	.75	.30	.35	.80	.25	.65	.60	.30	.35
6-10 "	1.00	.35	.45	1.05	.35	.80	.80	.35	.45
10-15 "	1.25	.45	.55	1.25	.40	.85	1.10	.40	.60
15-20 "	1.55	.55	.70	1.50	.45	.95	1.25	.45	.70
20-25 "	1.55	.55	.85	1.70	.50	1.05	1.40	.50	.80
> 25 "	1.95	.65	1.00	1.95	.55	1.15	1.75	.50	.90
Base:									
< 1 mile(s)	$ .10	$.05	$.10	$ .10	$.05	$.10	$ .10	$.05	$.05
1-2 "	.25	.10	.10	.20	.10	.15	.20	.10	.10
2-3 "	.45	.15	.15	.35	.10	.25	.30	.15	.15
3-4 "	.45	.20	.20	.50	.15	.35	.40	.20	.20
4-6 "	.65	.20	.25	.70	.20	.45	.50	.25	.25
6-10 "	.85	.25	.30	.80	.25	.55	.70	.30	.35
10-15 "	1.10	.35	.40	.90	.30	.60	.90	.35	.45
15-20 "	1.35	.45	.50	1.05	.35	.65	1.10	.40	.50
20-25 "	1.35	.45	.60	1.15	.40	.75	1.20	.40	.60
> 25 "	1.70	.50	.70	1.25	.40	.75	1.50	.40	.65

TABLE 7-17. RIDERSHIP AND REVENUE IMPACTS OF DISTANCE/TIME BASED PRICING SCENARIOS

	SCRTD	AC TRANSIT	SDTC
% Change in Ridership	-5.8	-4.3	-8.9
% Change in Revenue	+67.5	+56.1	+33.0
RPM/CPM	.76	.60	.46
% Change in Operating Ratio	+63.6	+50.6	+28.5

Table 7-18 indicates that joint time and distance based fares could generally establish an equilibrium of RPM/CPM estimates in terms of both efficiency and equity criteria. It was estimated that stage and peak/off-peak pricing could only neutralize discrepancies with respect to either distance or time-of-day. The joint scenarios, in contrast, appear to balance RPM/CPM estimates for short and long trips as well as for peak and off-peak ones. Table 7-18 also reveals that maldistributive effects of current pricing could largely be mitigated by distance/time based fares. The joint pricing approach appears particularly progressive in terms of family income and vehicle ownership variables. The distance/time based scenarios were found to be most beneficial to female, college-age patrons making work trips.

7.6 Other Pricing Concepts

A number of other fare policy scenarios were tested which either revised current pass prices or differentiated fares by service type. These fare refinements were tested in combination with distance and time based fares. Findings from several of these scenarios are briefly discussed below.

In Chapter Five, SDTC's pass users were found to travel shorter distances than those paying cash fares. In consequence, SDTC's passholders appeared to be producing disporportionately high RPM/CPM levels. A scenario was tested which raised SDTC's cash fares by a nickel while retaining current pass prices. Moreover, stage fares previously shown in Table 7-1 were employed in the analysis, with the exception that cash patrons' were assumed to pay 5 cents and 20 cents more at each stage than their passholder counterparts. This scenario yielded an estimated 9 percent loss in SDTC ridership while increasing revenue by approximately one-third. The system's operating ratio was projected to nearly reach the 50 percent mark under this scenario.

The efficiency and equity implications of this cash-adjusted stage pricing scenario seemed particularly appealing. Table 7-19 indicates that RPM/CPM estimates would be approximately the same among short and long trips as well as between time periods. By far, this scenario reduced distance and temporal related price discrepancies to a greater extent than any others. Equally impressive was the apparent equity potential of this scenario. Almost a complete reversal in the incidence of cross-subsidization could be expected. The cash-adjusted stage scenario appears capable of changing the role of low-income, carless, female, and non-work SDTC patrons from subsidy donors to subsidy recipients.

Another scenario involved raising the base fares of SCRTD's pass users by approximately ten cents per ride. This scenario was estimated to increase system revenue by around eight percent while essentially maintaining current ridership levels. However, this pricing approach did not appear to change the current efficiency and distributional features of SCRTD's current price policies.

Finally, a set of pricing scenarios was tested which raised fares on AC Transit's transbay, express and contract services by between 10 and 15 percent while retaining current local service prices. These arrangements were generally projected to increase AC Transit's revenue income by nearly one-quarter, thereby producing operating ratios of slightly less than fifty percent. Although distance-related discrepancies were reduced by the service

TABLE 7-18. EFFICIENCY AND EQUITY ANALYSIS OF DISTANCE/TIME BASED PRICING SCENARIOS

	SCRTD			AC-TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	Distance/ Time Based Pricing	% Change	Current Pricing	Distance/ Time Based Pricing	% Change	Current Pricing	Distance/ Time Based Pricing	% Change
Distance (in miles):									
≤ 6	.64	.80	+25	.57	.60	+5	.49	.47	-4
> 6	.12	.59	+391	.14	.57	+307	.18	.41	+127
Time-of-Day:									
Base	.55	.79	+44	.44	.62	+41	.42	.45	+7
Peak	.37	.71	+92	.35	.57	+63	.32	.46	+44
Annual Family Income:									
≤ $15,000	.45	.76	+69	.41	.61	+49	.37	.46	+24
> $15,000	.48	.78	+63	.37	.60	+62	.32	.46	+44
Vehicles Owned or Available:									
None	.47	.76	+62	.39	.58	+49	.40	.46	+15
≥ 1	.45	.74	+64	.40	.63	+58	.33	.45	+36
Ethnic Background:									
White	-	-	-	.38	.59	+55	-	-	-
Others	-	-	-	.44	.61	+39	-	-	-
English-speaking	.46	.74	+61	-	-	-	.36	.46	+28
Spanish-speaking	.48	.84	+75	-	-	-	.29	.39	+35
Gender:									
Females	.48	.73	+52	.40	.58	+45	.36	.46	+28
Males	.44	.77	+75	.40	.60	+50	.34	.45	+32
Age Groups:									
Youth	.50	.72	+44	.25	.45	+81	.35	.47	+34
College	.56	.83	+48	.46	.68	+48	.36	.45	+25
Middle	.42	.79	+88	.41	.65	+59	.38	.46	+21
Seniors	.19	.33	+74	.21	.25	+19	.24	.30	+25
Trip Type:									
Work	.45	.81	+80	.40	.63	+58	.32	.46	+44
Non-Work	.46	.67	+46	.40	.57	+43	.39	.46	+18
Medical	1.04	.92	-13	-	-	-	-	-	-
Total Sample:	.46	.76	+65	.40	.60	+51	.35	.46	+31

TABLE 7-19. EFFICIENCY, EQUITY, AND RIDERSHIP ANALYSIS OF SDTC CASH-ADJUSTED STAGE PRICING SCENARIO

	RPM/CPM FOR:		
	CURRENT PRICING	CASH-ADJUSTED STAGE PRICING	% CHANGE
TRIP DISTANCE (IN MILES):			
≤6	0.49	0.46	-7
>6	0.18	0.47	+161
TIME PERIOD:			
Base	0.42	0.46	+10
Peak	0.32	0.47	+47
ANNUAL FAMILY INCOME:			
≤ $15,000	0.37	0.46	+24
>$15,000	0.32	0.49	+53
VEHICLES OWN OR AVAILABLE:			
None	0.40	0.45	+13
≥1	0.33	0.46	+39
LANGUAGE:			
English-speaking	0.36	0.46	+28
Spanish-speaking	0.29	0.39	+34
GENDER:			
Females	0.36	0.45	+25
Males	0.34	0.48	+41
AGE GROUPS:			
Youth	0.35	0.40	+14
College	0.36	0.46	+28
Middle	0.38	0.53	+39
Seniors	0.24	0.26	+8
TRIP TYPE:			
Work	0.32	0.50	+56
Non-Work	0.39	0.42	+8
TOTAL SAMPLE:	0.35	0.46	+31

type pricing scenarios, the redistributive impacts were largely insignificant. In general, the differentiation of fares by distance and time-of-day emerged as more effective pricing alternatives than the service type scenarios.

7.7 New Fare Proposals: Steps in the Right Direction?

At the time of this writing, each of the three study agencies were contemplating new fare systems. Several new pricing policies have been proposed in response to spiralling costs and faltering revenues. Given the findings of Chapter Five, a reasonable question to ask is: "Do these new fare proposals represent steps in the right direction? - Compared with other pricing strategies, are they sensitive to efficiency and equity issues?" The pricing evaluation model was employed to shed some light on these questions.

SCRTD's new fare policy (Spring 1980) calls for a base fare of 50 cents, a significant increase in the cost of passes, and a 10 cent additional charge for each express stage. In addition, the new proposal eliminates peak period senior discounts and transfers. AC Transit's new fare proposal also sets base fares at 50 cents along with a moderate price increase for transbay and express services. Finally, the latest SDTC proposal sets basic fares at 60 cents, off-peak senior fares at 30 cents, and express fares at 75 cents.

Since ridership and cost data used in this research were from 1977 through 1979, the analysis in this section is based on the above fare proposals being implemented during these years. Thus, test results should not be interpreted in terms of the efficiency and equity impacts which could have been expected during the analysis years.

Table 7-20 indicates that these new fare proposals would probably have led to significant ridership reductions and revenue increases. Each agency's operating ratio would also have most likely increased above fifty percent.

While the new fare proposals appear promising in terms of revenue yield, Table 7-21 indicates that few efficiency and equity benefits would likely accrue. Since these proposals reinforce current flat fare structures by essentially increasing fares "across-the-board," RPM/CPM estimates generally remain the same among short and long trips as well as between the peak and base. In the case of AC Transit and SDTC, current distance and time related price inefficiencies would probably be even exacerbated by these proposals. Moreover, these two agencies' new proposals appear more regressive than current structures, redistributing disproportionately more income away from low-income, transit-dependent users. SCRTD's new proposal, in contrast, demonstrates some progressiveness. The proposed lowering of base fares in conjunction with higher express charges seems capable of neutralizing SCRTD's RPM/CPM ratios in terms of vehicle availability, gender, and age variables.

In sum, these proposed price changes seem largely unresponsive to misallocative and maldistributive effects of current price policies. This finding is not particularly surprising since these new proposals fail to introduce structural changes in pricing. Only in the case of SCRTD does the fare proposal actually appear to be a step in the right direction.

TABLE 7-20. RIDERSHIP AND REVENUE IMPACTS OF NEW FARE PROPOSALS

	SCRTD	AC TRANSIT	SDTC
% Change in Ridership	- 6.7	- 9.8	-20.0
% Change in Revenue	+22.1	+43.0	+41.6
RPM/CPM	0.56	0.57	0.50
% Change in Operating Ratio	+21.3	+43.5	+42.6

7.8 Summary

A variety of hypothetical fare policies were examined in this chapter with respect to their potential efficiency, equity, and ridership impacts. The scenarios tested involved pricing on the basis of coarse stages, finely-graduated distance steps, time-of-day, and combined distance/time differentials. Employing the evaluation model, a fairly wide range of ridership, revenue, efficiency and equity impacts emerged. Tables 7-22 through 7-24 summarize the chapter's findings for each study site. Although these findings were based on mid-range elasticities, sensitivity testing found them to be fairly robust - ridership and revenue impacts changed very little with either low or high elasticity extremes.

From Tables 7-22 through 7-24, it is apparent that pricing options performed differently among the three properties depending upon the evaluation criterion one chooses. Given the objective of "minimizing patronage losses," logarithmically-graduated fares and time-of-day differentials appeared to be attractive options. The stage, linearly-graduated, and joint distance/time based structures, in contrast, seemed to offer the most promise for increasing revenues. All approaches could be expected to increase each property's operating ratio, suggesting that elaborate fare collection systems would prove to be cost-effective investments.

Each scenario was found to offer significant efficiency and equity gains. In general, the more differentiated pricing options, such as graduated and joint distance/time-based structures, appeared to hold the greatest potential for reducing fare discrepancies. These approaches appeared highly target efficient, equalizing RPM/CPM ratios between poor, transit-dependent users and affluent, non-captive users. In general, those who were found to lose the most under current pricing practices could be expected to gain the most under the finely-differentiated fare alternatives.

A central theme emerges from this analysis: pricing systems should be structured so as to match the specific objectives of transit decision-makers. Given a policy mandate to implement distance-based fares, for example, stage pricing seems most promising in terms of revenue productivity whereas graduated structures appear particularly suited to eliminating inequities. Another trade-off could involve the apparent ridership advantages of peak-load pricing and the

TABLE 7-21. EFFICIENCY AND EQUITY ANALYSIS OF NEW FARE PROPOSALS

	SCRTD			AC TRANSIT			SDTC		
	RPM/CPM For:			RPM/CPM For:			RPM/CPM For:		
	Current Pricing	New Proposal	% Change	Current Pricing	New Proposal	% Change	Current Pricing	New Proposal	% Change
Distance (in miles):									
≤ 6	.64	.73	+14	.57	.66	+16	.49	.66	+35
> 6	.12	.16	+33	.14	.15	+7	.18	.21	+17
Time-of-Day:									
Base	.55	.61	+11	.44	.63	+43	.42	.57	+36
Peak	.37	.50	+35	.35	.49	+40	.32	.43	+34
Annual Family Income:									
≤ $15,000	.45	.55	+22	.41	.57	+39	.37	.53	+43
> $15,000	.48	.59	+23	.37	.53	+43	.32	.44	+37
Vehicles Owned or Available:									
None	.47	.56	+19	.39	.56	+44	.40	.57	+43
≥ 1	.45	.56	+24	.40	.57	+43	.33	.46	+39
Ethnic Background:									
White	-	-	-	.38	.54	+42	-	-	-
Others	-	-	-	.44	.58	+32	-	-	-
English-speaking	.46	.56	+22	-	-	-	.36	.50	+39
Spanish-speaking	.48	.58	+21	-	-	-	.29	.43	+48
Gender:									
Females	.48	.55	+15	.40	.57	+43	.36	.51	+42
Males	.44	.57	+30	.40	.56	+40	.34	.48	+41
Age Groups:									
Youth	.50	.63	+26	.25	.42	+68	.35	.59	+69
College	.56	.68	+21	.46	.67	+40	.36	.51	+42
Middle	.42	.55	+31	.41	.57	+39	.38	.49	+38
Seniors	.19	.28	+47	.21	.27	+29	.24	.35	+46
Trip Type:									
Work	.45	.58	+29	.40	.55	+38	.32	.44	+38
Non-Work	.46	.54	+17	.40	.57	+43	.39	.55	+41
Medical	1.04	.94	-11	-	-	-	-		
Total Sample:	.46	.56	+22	.40	.57	+44	.35	.50	+43

TABLE 7-22. SUMMARY COMPARISON OF ALTERNATIVE PRICING SCENARIOS

CRITERION \ FARE POLICY	1	2	3	4	5	6	7
% Change in Ridership	—	- 6.7	- 2.4	+0.6	+ 0.1	+ 0.4	- 5.8
% Change in Revenue	—	+22.1	+30.8	+7.4	+11.3	+13.5	+67.5
RPM/CPM Where Trip or User:							
(*) <6 miles	0.64	0.73	0.65	0.53	0.50	0.68	0.80
(*) >6 miles	0.12	0.16	0.45	0.40	0.49	0.15	0.59
(*) Base	0.55	0.61	0.70	0.57	0.58	0.53	0.79
(*) Peak	0.37	0.50	0.49	0.41	0.42	0.53	0.71
(*) <$15000 Income	0.45	0.55	0.60	0.49	0.50	0.52	0.76
(*) >$15000 Income	0.48	0.59	0.63	0.48	0.50	0.55	0.78
(*) No Vehicle	0.47	0.56	0.58	0.44	0.51	0.53	0.76
(*) >1	0.45	0.56	0.60	0.56	0.50	0.52	0.74
(*) English-Speaking	0.46	0.56	0.59	0.48	0.49	0.52	0.74
(*) Spanish-Speaking	0.48	0.58	0.67	0.55	0.52	0.59	0.84
(*) Work Purpose	0.45	0.58	0.61	0.50	0.50	0.55	0.81
(*) Non-Work Purpose	0.46	0.54	0.58	0.48	0.50	0.51	0.67
Average RPM/CPM	0.46	0.56	0.60	0.49	0.50	0.53	0.76

KEY:
1 = Current Pricing
2 = New Fare Proposal
3 = Stage Pricing Scenario
4 = Logarithmic-Based Graduated Pricing Scenario
5 = Linear-Based Graduated Pricing Scenario
6 = Time-Dependent Pricing Scenario
7 = Distance/Time Based Pricing Scenario

TABLE 7-23. SUMMARY COMPARISON OF ALTERNATIVE PRICING SCENARIOS FOR AC TRANSIT

CRITERION \ FARE POLICY	1	2	3	4	5	6	7
% Change in Ridership	—	- 9.8	- 2.6	+3.0	+ 0.3	+ 1.0	- 4.3
% Change in Revenue	—	+43.0	+14.6	+5.5	+16.8	+11.6	+56.1
RPM/CPM Where Trip or User:							
(*) <6 miles	0.57	0.66	0.49	0.47	0.46	0.52	0.60
(*) >6 miles	0.14	0.15	0.31	0.37	0.39	0.19	0.57
(*) Base	0.44	0.63	0.50	0.46	0.49	0.45	0.62
(*) Peak	0.35	0.49	0.41	0.37	0.40	0.43	0.57
(*) <$15000 Income	0.41	0.57	0.48	0.43	0.45	0.45	0.61
(*) >$15000 Income	0.37	0.53	0.46	0.37	0.45	0.42	0.60
(*) No Vehicle	0.39	0.56	0.46	0.41	0.45	0.44	0.40
(*) >1	0.40	0.57	0.47	0.43	0.45	0.45	0.63
White	0.38	0.54	0.45	0.41	0.44	0.43	0.59
Others	0.44	0.58	0.47	0.42	0.44	0.49	0.61
(*) Work Purpose	0.40	0.55	0.46	0.42	0.43	0.40	0.40
(*) Non-Work Purpose	0.40	0.57	0.46	0.42	0.46	0.40	0.40
Average RPM/CPM	0.40	0.57	0.46	0.42	0.45	0.40	0.60

KEY:
1 = Current Pricing
2 = New Fare Proposal
3 = Stage Pricing Scenario
4 = Logarithmic-Based Graduated Pricing Scenario
5 = Linear-Based Graduated Pricing Scenario
6 = Time-Dependent Pricing Scenario
7 = Distance/Time Based Pricing Scenario

TABLE 7-24. SUMMARY COMPARISON OF ALTERNATIVE PRICING SCENARIOS FOR SDTC

CRITERION \ FARE POLICY	1	2	3	4	5	6	7
% Change in Ridership	—	-20.0	- 6.2	- 2.4	- 5.2	+1.3	- 8.9
% Change in Revenue	—	+11.6	+24.4	+16.6	+24.8	+3.0	+33.0
RPM/CPM Where Trip or User:							
(*) <6 miles	0.49	0.66	0.43	0.41	0.41	0.48	0.47
(*) >6 miles	0.18	0.21	0.49	0.38	0.48	0.20	0.41
(*) Base	0.42	0.57	0.49	0.41	0.44	0.39	0.45
(*) Peak	0.32	0.43	0.43	0.39	0.42	0.34	0.46
(*) <$15000 Income	0.37	0.53	0.47	0.40	0.43	0.38	0.46
(*) >$15000 Income	0.32	0.44	0.46	0.40	0.46	0.33	0.46
(*) No Vehicle	0.40	0.57	0.48	0.40	0.42	0.40	0.46
(*) >1	0.33	0.46	0.45	0.40	0.44	0.34	0.45
(*) English-Speaking	0.36	0.50	0.46	0.41	0.43	0.37	0.46
(*) Spanish-Speaking	0.29	0.43	0.38	0.34	0.36	0.29	0.39
(*) Work Purpose	0.32	0.44	0.48	0.42	0.46	0.36	0.46
(*) Non-Work Purpose	0.39	0.55	0.45	0.39	0.41	0.38	0.46
Average RPM/CPM	0.35	0.50	0.46	0.40	0.43	0.36	0.46

KEY:
1 = Current Pricing
2 = New Fare Proposal
3 = Stage Pricing Scenario
4 = Logarithmic-Based Graduated Pricing Scenario
5 = Linear-Based Graduated Pricing Scenario
6 = Time-Dependent Pricing Scenario
7 = Distance/Time Based Pricing Scenario

relative structural efficiency of distance/time based fares. Viewing these criteria collectively, however, the more highly-differentiated scenarios appear to offer the greatest balance - modest patronage losses combined with significant revenue, efficiency, and equity gains.

In closing, differentiated price structures seem responsive to many of the problems associated with flat fare systems. 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 trips, those most in need of transit also stand to gain. Highly differentiated structures hold the potential for virtually eliminating regressive fare transfers. They also could be expected to generate higher revenue returns - an important factor during times of rampant cost escalation. Together, these findings compel one to conclude that distance-based and time-dependent fare policies deserve strong consideration in future transportation policy debates.

CHAPTER EIGHT

SUMMARY, POLICY IMPLICATIONS, AND DIRECTIONS FOR FURTHER RESEARCH

8.1 Summary of Research Findings

The three case studies' flat pricing policies seem to foster significant inefficiencies and modest inequities. They generally ignore the effects of changing travel patterns on costs, thereby contributing directly to fare cross-subsidization and rising deficits. By assessing uniform charges against all users, current fare practices operate on a compensatory basis: short distance, off-peak users pay disproportionately high fares to offset losses incurred in serving long-haul, peak hour trips. On the whole, those highly dependent on transit and least able to pay lose the most from cross-subsidization. Others hurt include those supporting public treasuries through sales and income taxes and those forced to forego short distance, off-peak usage because of inordinately high fares.

With respect to efficiency and equity, fare policy should bear a strong relationship to cost characteristics of transit services. Sound arguments can be made for designing fare systems which adhere closely to principles of marginal cost pricing. Fares differentiated by distance and time-of-day could eliminate cross-subsidies, improve revenue productivity, and possibly increase patronage. These statements suggest that transit policymakers should begin facing the challenge of moving from simple fare concepts to a new generation of price innovations.

Five principal findings have emerged from this research which can be summarized as follows:

a. Effects of Pricing on the Industry's Financial Posture: Transit agencies are facing unprecedented financial hardships caused by spiralling costs matched with constant farebox revenues. Higher costs can be partly attributed to longer trips and an intensification of peak hour usage. While costs have escalated over the past fifteen years, prevailing practice has been to keep fares low and underwrite deficits. Not only have average fare levels declined in real terms, but price structures have generally become less and less differentiated. Consequently, today's fare structures are largely insensitive to travel and cost trends, charging constant fares regardless of when and where patrons travel.

b. Estimates of Transit Costs: Traditional cost allocation models fail to acknowledge that transit expenses vary by time-of-day and service type. Aggregate models reinforce mispricing by allocating average rather than marginal costs to particular services. A multi-stage process was used in this research to refine cost estimates. Cost centers equations were developed which captured unique cost features of operating divisions. Costs were further divided into peak and base period components to reflect the penalizing effects of labor union restrictions on each property's wage bill. Among the three study sites, drivers' wages were effectively between 20 and 30 percent higher during the peak than the base for every hour of duty. In all three cases, over one-half of total expenses were attributable to the peak, even though the peaks' share of total ridership and revenue was less than 45 percent. On a per passenger-mile basis, peak costs were around ten percent greater than those in the base.

c. Inefficiencies in Current Pricing: Disparities between users' fares and trip costs were largest in terms of travel distance. Those traveling less than two miles were generally found to cross-subsidize other users. Short distance patrons were paying between ten and twelve times as much per mile for their trips as the average user. Beyond six miles, the gap between unit revenues and unit costs was fairly constant for all journeys. Thus, redistribution was positively skewed in terms of trip distance. Price disparities were also prevalent between peak and base periods. Off-peak patrons generally paid forty to fifty percent more revenue per unit cost as their peak period counterparts. A slightly positive association was found between peak period usage and length of travel, suggesting that distance pricing could also reduce temporal discrepancies.

d. Inequities in Current Pricing: Overall, the redistributive effects of current fare practices appeared to be mildly regressive. Those with lower incomes were generally found to pay disproportionately higher fares, although the relationship was not as strong as one might have expected. Cross-subsidization appeared more closely related to users' transit-dependency than ability-to-pay: carless patrons generally paid higher fare rates than users owning vehicles. On average, those who were minorities, female, college-age, and making medical trips served as cross-subsidizers. However, pricing disparities were much more strongly associated with trip distance and time-of-day than with user demographics.

e. Policy Implications of Alternative Pricing Structures: Differential fare structures offer promise for improving the industry's financial performance. As price structures become more finely differentiated, major improvements in price efficiency and equity could be expected. Fares graduated as a linear function of distance seem particularly responsive to current pricing deficiencies. Differentiated structures also appear capable of generating appreciably higher revenue returns. Moreover, each agency's operating ratio would likely increase significantly under variable pricing, suggesting that the higher collection costs associated with fare differentials could probably be justified on a financial basis. In general, the relatively low collection costs of coarse fare structures could be expected to raise the overall fiscal performance of stage or peak-load pricing above that of graduated pricing. Under conditions of deficit constraints, stage or peak-load structures emerge as attractive pricing options. Where economic efficiency and distributional equity are primary objectives, finely graduated pricing holds considerable potential.

These findings support many of the theoretical arguments found in the public utilities literature. In the second chapter, marginal cost pricing emerged as a guiding principle for allocating resources of natural monopolies. Unlike other industries in which fluctuating demand prevail, transit companies have generally resisted peak-load and differential pricing practices. This research argues that transit properties would reap substantial economic benefits by following the pricing practices of airline, rail, and power utility industries. Not only would the transit industry's financial posture improve, but greater overall benefits would accrue to society. Many who avoid transit for short trips under flat structures would patronize services priced closer to true costs. To the extent these latent users represent society's poor, distributional consequencies of differential pricing could be even greater than suggested in this research. In general, social welfare would improve since the consumer surplus gains reaped by these users would far exceed the consumer surplus losses incurred by long-haul, peak-hour commuters.

It is essential that transit officials address pricing issues within the context of overall service planning. Major emphasis should be placed on identifying the specific demand characteristics of different market segments. Where transit services are improved to meet market demands, prices should be set based on efficiency principles. In sum, fare policy should be an integral component of a comprehensive marketing program to upgrade service qualities consistent with user demands.

8.2 Implications of Research Findings on Transportation Policies and Programs

A principal conclusion of this research is that transit operators should design pricing structures according to efficiency principles. This suggests that state and federal transportation policies and programs should embrace efficiency objectives, particularly with respect to subsidy policy.

At the federal level, primary sources of financial support for public transit are Sections 3 and 5 of the 1964 Urban Mass Transportation Act, as amended. This legislation allocates operating assistance to public transit operators principally on the basis of their service areas' population and population densities. It can be argued that these support funds give rise to mispricing since transit agencies are partly relieved of the responsibility for rising operating costs. It is plausible that the movement toward flat fare structures during the early seventies was spawned in part by the availability of massive financial assistance. Although transit services clearly merit federal support, serious consideration should be given to the encouragement of pricing innovations through subsidy policy.

Several policy reforms could promote efficient pricing practices. Currently, federal financial assistance is tied to a "maintenance of effort" condition. Local agencies must maintain at least the same level of non-fare expenditure as they had before their receipt of federal operating subsidies. This requirement discourages operators from increasing fares or revising price structures in order to match available federal dollars. A provision which would allow revenues generated from new pricing innovations to be counted in the maintenance of effort computations could promote efficiency in pricing. Another concept worthy of some attention involves linking performance criteria to funding allocation formulae. At present, Senate Bill 27-20 sponsored by Senator Williams of New Jersey proposes new allocation formulae which would include an "incentive tier" provision - financial bonuses for efficient operations. Such incentive concepts could serve to stimulate pricing innovations.

The Transportation System Management (TSM) planning requirements sponsored jointly by UMTA and FHWA also bear a direct relation to transit fare policy. Fare innovations should be intimately tied to TSM programs aimed at improving service quality and reducing vehicle miles of travel. Price differentials, for example, could be linked with TSM programs which reserve preferential bus lanes, encourage express services, or upgrade scheduling. Moreover, staggered work hour and flex-time arrangements could be coordinated with peak/off-peak fare programs in order to stimulate greater off-peak usage.

In the State of California, public transit agencies also receive financial assistance from sales tax revenues earmarked under the 1971 Transportation Development Act (TDA). Hollis (1979, p. 141) remarks that "one of the intents stated in the Act was to stabilize fare levels ... (to) aid in establishing flat fares and fare reductions." TDA dollars are relied upon heavily by transit operators within the State, on average matching revenues generated by the farebox. As with federal programs, the maintenance of effort provision and allocation formulae of the TDA could be revised to encourage efficient pricing practices. In distributing funds to local municipalities, several counties in the state are promoting efficiency through performance criteria which call for minimum farebox recovery (Conant and McDonnell, 1979). Recent legislation, such as Senate Bill 620, has also sought to mandate minimum farebox returns as preconditions for TDA assistance. As public pressures mount to reduce government spending, transit subsidy programs in California can be expected to embrace efficiency principles to an even greater extent.

A successful transit fare policy will require a clear statement of transportation goals and objectives at the local, state, and national levels. As energy conservation becomes an increasingly important national priority, a stronger emphasis on ridership goals can be expected. Moreover, state and national efforts to balance public treasuries mean that productivity goals will probably gain added importance in the future. These trends suggest that differential price structures which offer higher revenue yields and potentially greater patronage deserve strong policy consideration. Local decision-makers, however, must balance these goals against those related to passenger convenience and fare simplification. Conflicting objectives should be confronted through public debates and citizen input. Finally, the success of transit fare innovation rests to a large extent on pricing improvements made in other competing transport sectors. As long as highway usage is underpriced and parking is subsidized by employers, for example, efficiency-based fare reforms could prove counterproductive. Therefore, transit fare innovations should be part of a larger effort to correct pricing distortions found throughout the transportation system.

8.3 Political and Institutional Environment of Fare Decisions

Although this research has demonstrated a clear need for alternative pricing approaches, the decision to inaugurate differentiated fare systems is ultimately a political one. In the case of SCRTD and AC Transit, distance-based pricing in previous years was eliminated due to union pressures. Labor has historically voiced a dislike for variable pricing systems because of disputes which often occur between obstreperous passengers and drivers. Politicians are also keenly sensitive to the riding public's demand for simple, comprehendible transit services. Thus, the greatest barrier to the feasibility of differentiated pricing is the unwillingness of labor, elected officials, and the public to give up the convenience and simplicity of flat fares in favor of more complex pricing mechanisms.

In an attempt to gauge the political pulse of transit pricing issues, interviews were conducted with policy and staff members of SCRTD and AC Transit. Also, events which transpired during SCRTD public hearings on proposed fare changes were observed. The following discussion provides a general picture of the attitudes and perceptions which prevail among those who influence public transit decisions.

The Boards of Directors of SCRTD and AC Transit make final decisions on fare structure and fare level. Whether the Board is elected or appointed, the extent to which directors represent parochial or special interests has an impact on decisions concerning fares. SCRTD's board of directors consists of eleven members: the Los Angeles County supervisors appoint one director each, the Los Angeles Mayor appoints two directors, and the remaining four are elected officials of other municipalities within SCRTD's district who are appointed by a City Selection Committee. County Supervisors have, on occasion, appointed themselves to positions on the Board.

The composition of the Board of Directors gives the County Board of Supervisors considerable influence over transit decisions. The Supervisors, in addition to appointing members to the SCRTD Board, are members of the Los Angeles County Transportation Commission (LACTC), a state-created agency that makes formula-determined allocations of government funds to all transit operators in the region. A Supervisor can designate an alternate to sit on the Commission in his or her place. As a consequence of the option to serve or appoint representatives to both the SCRTD Board of Directors and the LACTC, supervisors may: 1) involve themselves directly in operating and funding decisions; 2) influence by delegation, or 3) abstain from influence or interest in transit decisions, allowing their appointees or alternates free rein. The role played by the supervisors has varied. In 1974, two supervisors served on the SCRTD Board of Directors. Presently, both these supervisors have appointees serving on the Board. However, both appointees strongly identify with the views of the appointing supervisor. The appointees level of interest in policy direction vary. For example, one supervisor is a staunch advocate of rail for the Los Angeles area. When interviewed as part of this study, his appointee expressed an intense concern with future rail systems for Los Angeles, and less interest in fare structure. Another supervisor's appointee evidenced a primary concern with efficiency of operations and meeting costs, reflecting the fiscal conservatism of much of the Board.

All seven members of AC Transit's Board of Directors are elected by popular vote from municipalities within the transit district. Conceivably, board members who are appointed by mayors or popularly elected could have primarily provincial interests. Observations made at board meetings of each property revealed little parochialism and an apparent overriding concern with the special interests of the elderly, handicapped and students. It is impossible to say to what degree the apparent concern with these special interests is symbolic, or to what degree it is encouraged by government funding policies.

There was no doubt, however, that the most pressing concern of both properties' directors, evident in board meetings and during interviews, was the problem of meeting costs.

During the period of this study, the SCRTD Board of Directors twice voted to raise fares, the second fare increase being made only five months after the first. The second fare increase, however, was postponed because the LACTC voted to authorize money from its reserve fund to subsidize SCRTD for the remainder of the fiscal year. Although SCRTD traditionally considers fare changes annually, rapidly escalating costs forced the Board to propose a fare increase only four months later.

The pressures which shape fare policy for SCRTD are shared by most bus operators in the United States. A combination of government funding policies, special interest demands, labor union influence and spiraling operating costs, coupled with demands for higher service levels, all find their nexus at the questions of fare rate and structure. The October public hearing for SCRTD's considered fare increase was a theater of these pressures. The interested citizens and press, overflowing the hearing room's seating capacity, witnessed the executive staff advise the director on the expected budget deficits and anticipated ridership losses of each alternative, while the Board heard pleas from church ministers, workers, students, the old and the handicapped to maintain current fares.

The Board's final decision on fares was influenced greatly by the concerns voiced by the public. The fare structure finally arrived at by the directors was not the structure recommended by the staff, nor was it among any of the suggested alternatives. The Board voted to raise the basic cash fares ten cents, from 45 cents to 55 cents, and to raise the elderly and handicapped fares five cents, from 15 cents to 20 cents. However, transfer charges were reduced by five cents, from ten cents to five cents, while current pass, stamp and express cash charge were retained.

The most recent SCRTD fare system approved by the Board also differed from all of the staff's recommended alternatives. One staff member told of being forced to make "wild guesses" about the revenue impact of the unanticipated changes as they were being considered by the directors. In debating the first change in fare structure, the directors had seemed to be concerned primarily with the public's desire to keep the fares low, but in the second change their concern seemed to have shifted to meeting the pressures of rising operating costs and the rising inflation rate. An issue raised at the April, 1980 public hearing that had not been discussed at the October, 1979 public hearing concerned the revenue lost from the fraudulent use of passes and transfers. This issue was partly inspired by the testimony of SCRTD bus drivers who outlined the means by which transfers and passes are misused. Some riders simply covered the transfer's date when showing the transfer to a driver. Others produced bogus transfers meticulously pasted together to show the correct date and time. In addition, transfers were often stolen from the buses in batches and sold for half price on the streets. In interviews, staff members reported being offered transfers for sale on the street near the SCRTD administration building. Passes, the drivers reported, are used by people who they were certain could not have been college students. The upshot of the drivers' testimony at the public hearing was a decision by the Board that transfers were to be completely eliminated, and student passes were no longer to be available to college students.

The most recent SCRTD fare change (Spring 1980) proposed a reduction of base fare by five cents, accompanied by a fare increase for virtually all other categories. This included payment of full fares by elderly and handicapped users during peak hours.

While the SCRTD Board of Directors must be concerned with meeting costs, LACTC is more preoccupied with providing service. An internal SCRTD memo, circulated 22 days following the April public hearing and only six days before the fare increase was to go into effect, outlined a "crash program which would require five weeks to implement and reduce our cost of operation through the end of the fiscal year by approximately $4.5 million." The program includes suspension of 36 local bus lines and 50 express bus lines, and the furlough of 1500 employees. Five days after this memo was written, the LACTC voted to provide a $4.5 million subsidy to SCRTD. Although LACTC voted unanimously to provide the subsidy, SCRTD's Board was not unanimous in its willingness to accept it. A Los Angeles Times article quotes opinions of three of the dissenting directors all agreeing that acceptance of the subsidy is only a stop gap measure that will not obviate the need for future fare increases.

In sum, the political environment surrounding public transit pricing issues is a stormy one. Discussions seem to focus on increasing revenue regardless of which types of trips and services are most directly responsible for cost escalation. Directors address pricing issues in a short term context, with the goal of alienating as few constituents as possible. Labor also exerts strong pressures on policymakers to reduce the complexity and increase the safety of drivers' duties. These concerns have been translated into an overwhelming preference for flat fares. Moreover, policymakers tend to view pricing issues only within the context of across-the-board increases in fares. Although the theoretical arguments in favor of differentiated pricing systems appear quite convincing, political barriers are formidable.

8.4 Directions for Further Research

A number of important fare policy issues have emerged from this research which merit further study. Of foremost importance are current impediments to fare policy reform. The attitudes of various participating groups who influence fare policy decisions need to be thoroughly researched. Transit managers, labor representatives, and policy-makers likely perceive pricing needs differently. Regulatory bodies historically have shown a reluctance to drastically alter pricing structures. Moreover, any fare revisions which increase drivers' responsibilities would probably be challenged by labor unions. Thus, institutional and political barriers as well as opportunities should be clearly understood before embarking on major fare reform.

User attitudes and perceptions of pricing issues are equally important data needs. Research should focus on what service and pricing combinations will draw people out of private automobiles and into buses. Market research should also be oriented toward better understanding the sensitivity of specific user groups to pricing changes. A sizable amount of "before" and "after" ridership data needs to be gathered at a fairly detailed level to allow the computation of disaggregate elasticities by user demographics, time-of-day, etc. Methods of isolating non-price influences from fare elasticity computations also warrant further exploration. Moreover, studies of the responsiveness of users and non-users to service changes should also be pursued. Uniform survey methods are especially needed for assessing user preferences and responses to both service and price changes.

The current state-of-the-art in fare collection technology represents another potential impediment to pricing innovation. Pilot demonstration projects which assess the feasibility of various fare structure and collection system combinations should be considered. Research should also focus on the impacts of complex collection systems on service qualities, driver work performance, and user's attitudes.

Industry procedures for analyzing costs and pricing issues also need to be advanced. Models which allocate both operating and capital costs by time-of-day and trip direction should be further refined. In addition, research priority should be given to the development of uniform allocation procedures which would enable inter-agency comparisons of transit costs to be made. Model structures should be relatively simple, yet robust enough to ensure reasonable prediction accuracy. Interactive computer models and management aids should also be developed for evaluating pricing policies on an on-going basis. Information systems which store and maintain disaggregate data on costs, revenues, and fare elasticities could be an invaluable asset to fare research and fiscal planning.

The scope of many of the fare policy issues raised in this study could also be broadened. In order to understand the full equity repercussions of transit financing, for example, redistributive effects of other funding sources need to be investigated. A reasonable research question would be whether "the regressivity of fare cross-subsidization is neutralized by the subsidies generated by progressive funding sources such as income taxes?" In California, the collective equity effects of various funding sources is even more difficult to ascertain because of the State's heavy reliance on sales tax revenues to support transit services. Moreover, fare policy research could be expanded to analyze optimal fare levels as well as fare structures by assessing the full range of transit costs and benefits. Through longitudinal analysis, the historical effects of fare policy on urban development patterns could also be probed.

In sum, a range of important questions related to transit pricing practices merit further study. Priority should be given to analyzing the political and institutional environment which surrounds fare policy issues. Efforts should be directed at reducing the barriers and exploiting the opportunities associated with fare policy innovation. Through an active program of public involvement, research, and policy promotion, a path can be opened for innovative fare systems which embrace both efficiency and equity objectives.

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APPENDIX A

SELECTION PROCESS AND SAMPLE ROUTES OF THE THREE TRANSIT PROPERTIES

SCRTD

On-board passenger survey data from May and September of 1978 and March of 1979 served as the primary bases for selecting SCRTD's sample routes. Unlike the other two case study sites, less than all of SCRTD's total number of routes were sampled over the three survey periods. (Slightly under 25 percent of SCRTD's 219 total bus routes were actually sampled.) In the case of the two 1978 surveys, forty routes were randomly selected by the SCRTD staff from a stratified sampling of all routes, with strata defined according to geographic area served and by type of service (i.e., express or local). The March, 1979 survey encompassed twenty pre-selected routes. Allowing for route duplication among the three separate surveys, a total of fifty-five routes were available for evaluating revenue, ridership, and demographic characteristics of SCRTD's users.

Matrices were prepared for each of the three survey dates which compared various cost, revenue, socio-economic, and trip-making indices for all routes surveyed. From these summary matrices, routes were then stratified into each of the following categories: 1) Local/Transit-Dependent; 2) Local/Mixed; 3) Inter-city/Transit-Dependent; 4) Inter-city/Mixed; 5) Express/Mixed; and 6) Express/Non-Captive. Category descriptions were defined as follows. A local service classification referred to short-to-moderate distance trips within urban jurisdictions; inter-city service involved medium-distance trips between municipalities; and express service consisted of trips with over 25 percent of the route miles operated on limited-access freeways. Transit-dependent ridership indicated a predominance of either low income, ethnically-disadvantaged, female, or elderly patrons while mixed compositions included passenger types spanning all age, income, and ethnic backgrounds. The non-captive classification identified those services characterized by middle and higher income riders commuting to and from suburban communities.

In selecting a number of the fifty-five available routes from the six strata, the first step involved eliminating those routes with built-in survey biases, small response rates, and non-random sampling. Eight routes were deleted from the selection field of fifty-five either due to excessively congested buses (indicated by high load factors), a disproportionate sampling of certain user groups, or documented evidence of discriminatory survey practices and sampling errors. Also, several routes with a sizable number of extreme data points were purged from the sample. The final screening task involved eliminating those routes with inconsistent sample results between the May and September surveys. In several cases, for example, income and auto ownership levels were high in one survey and low in the other.

The elimination of routes with potentially biased and spurious sample data resulted in the following thirty routes (broken down by strata) being chosen as representative of SCRTD ridership:

Local Transit-Dependent		Local Mixed		Intercity/Transit-Dependent	
2	47	22	91	29	114
3	87/14	27	869	33	826
28		42		34	

Intercity/Mixed		Express/Mixed	Express/Non-Captive
6	154	35	144
25	435	480	607
73	828	801	814
89	873		
95			

AC TRANSIT

In selecting AC Transit's sample routes, bus services in both of the property's two districts were designated as either local, transbay, express, contract, or BART-coordinated operations. Also, the above classifications were further divided into either mixed or transit-dependent operations to reflect the economic and ethnic composition of patronage. Because of the relatively small number of riders accommodated by mini-route and dial-a-ride services in District II (in all, less than 1,400 total weekday patrons), routes represented by these two service types were removed from the list of candidate routes.

AC Transit's Five Year Plan and Title VI Compliance Report were relied upon to review the performance characteristics and ridership profiles of the system's 100 or so routes. The five year planning report provided a line-by-line summary on system productivity, including such indicators as load factors, farebox ratios, passengers per mile and per hour, subsidies per passenger, operating costs, and composite evaluation scores. The affirmative action plan, on the other hand, pinpointed routes serving minority populations and assessed each route's accompanying service level. After deleting potentially biased and unrepresentative routes from the analysis, the following twenty routes were selected from the two districts:

DISTRICT I

Eastbay Local/Mixed		Eastbay Local/Minority		Transbay	Eastbay Express
54	84	11	70	A	31
80/81	90/92	46/87	72	G	32
		51/58	79	K/R	
		65	82/83		

DISTRICT II

Local	Contract	BART-Coordinated
22/24	306	U

SDTC

As with the other two operators, data from on-board ridership surveys and planning documents were relied upon in selecting SDTC's analysis routes. SDTC's on-board survey, conducted on all of the system's 43 routes, provided a considerable amount of data on travel patterns, demographic profiles, and fare payment characteristics. Equally important to the selection process was the system's extensive data base related to the efficiency, effectiveness, and productivity of all routes. Both the 1979-83 and 1980-84 Five Year Plans contained detailed route rankings according to such performance indicators as total cost per revenue passenger, passengers per mile, subsidy per revenue passenger, subsidy per mile, seating capacity percentages, peak load factors, and composite route evaluation scores.

The number of candidate routes was reduced from the 43 bus routes surveyed in late 1977 on the basis of several factors. For one, since SDTC relied on a local property tax to finance areawide transit services, California's Proposition 13 resulted in the cancellation of nine low-productivity routes and the transfer of seven others to the jurisdiction of the North County Transit District (NCTD). After consultation with SDTC's management, a decision was made to eliminate these sixteen routes from this research. Although some of the sixteen routes could have provided an interesting contrast to some of the more productive routes selected for this analysis, SDTC management felt few practical pricing insights could be gained by retaining such routes in the analysis since a prior policy decision had been made to eliminate the services. However, since not all of the least productive routes were cancelled (apparently due to political reasons), several lines characterized by low ridership and high unit costs were chosen to ensure representativeness in the sample. Other factors which resulted in the streamlining of candidate routes included incidences of bias and non-random sampling, cases of excessively crowded lines, and the existence of routes with sizable outlier data sets.

The following ten routes were chosen as representative of SDTC's system. Service types were defined as: 1) shuttle, providing intra-community service; 2) local, providing inter-community service with bus stops placed approximately one-fourth mile apart; and 3) express, providing inter-city service with bus stops placed approximately one-half of a mile apart and with some route portions utilizing the freeway system. Again, minority and mixed classifications distinguished the socio-economic characteristics of user groups.

Shuttle	Local/Minority	Local/Mixed	Express
51	2	21	20
	3	27	80
	5	43	90

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APPENDIX B

WEIGHTING TECHNIQUES

Since each property's trip types, ridership groups, and fare modes were sampled unequally, a set of weights (or expansion factors) were derived to reduce the incidence of sample bias. The factors served to adjust the relative weight of each sample case (i.e., questionnaire response), based on the particular trip-making attributes of the person surveyed so as to reflect the true ridership characteristics of the entire transit property.

In the case of SCRTD, the following weighting formula was applied to all 8,600 cases:

$$WT_{ijk} = \frac{R_i}{S_i} \times \frac{R_j}{S_j}, \text{ for all k's}$$

where:

WT_{ijk} = Weight Factor for sample case k using Route i and Service Type j

R = Daily Ridership

S = Sample Size

i = Route subscript

j = Service Type subscript for express, inter-city, and local operations

k = Sample Case subscript.

The first part of the factor standardized the response rate among users of each route while the second part adjusted the weight to reflect the relative proportion of total system ridership which a particular service type accommodates. By multiplying both independent parts of the equation, a composite weight reflecting the "representativeness" of a particular sample case was derived. This weighting scheme was chosen primarily for SCRTD since sampling rates varied among routes and only a fraction of all routes were surveyed.

The weighting factor assigned to each AC Transit case equalled the number of scheduled trips of a particular service type divided by the number of trips of that type surveyed:

$$WT_{jk} = \frac{R_j}{S_j}, \text{ for all k's}$$

where:

WT_{jk} = Weight Factor for sample case k using Service Type j

R = Daily Ridership

S = Sample Size

j = Service Type subscript for express, transbay, local and contract operations

k = Sample Case subscript.

Since surveys were collected among all riders on the routes which were sampled, no adjustments to the response rates of each route were necessary.

The weighting process applied to the SDTC sample set was the most complex. A "general factor" was used to achieve a representative sample by adjusting each case according to the time-of-day and expanding the sample size to account for daily ridership. Moreover, an "annualization factor" was applied in order to attain a sample representative of the average weekday. Finally, a fare adjustment factor served to downweight cases where prepaid passes were used and to inflate other fare payment cases due to an oversampling of saverpass users. Accordingly, the 8,100 SDTC cases were weighted as follows:

$$WT_{ijmnk} = \frac{R_i}{S_i} \times \frac{R_j}{S_j} \times \frac{R_m}{S_m} \times \frac{M_i}{R_i} \times \frac{F_{ni}}{S_{ni}}, \text{ for all k's}$$

where:

WT_{ijmnk} = Weight Factor for sample case k using Route i and Service Type j, travelling during Time Period m, and paying by Fare Type n

R = Daily Ridership

S = Sample Size

M = Mean Weekday Ridership

F = Mean Daily Usage of Fare Type n

i = Route subscript

j = Service Type subscript for express, local, and shuttle services

m = Time Period subscript

n = Fare Type subscript

k = Sample Case subscript.

While the first three factors accounted for the general case expansion, the fourth factor converted the weight to reflect a typical weekday, and the final factor adjusted the weight according to true rates of fare payment usage.

These weighting factors expanded the total sample size of each case study site as follows: SCRTD - 8,610 to 22,100 (256%); AC Transit - 14,870 to 36,300 (244%); and SDTC - 8,100 to 15,150 (186%). Dividing these expanded sample sizes by each transit property's daily system ridership, the percentages in Column 9 of Table 3.4 were increased as follows: SCRTD - 0.8% to 2.2%; AC Transit - 6.0% to 14.7%; and SDTC - 7.2% to 13.4%.

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APPENDIX C

ON-BOARD RIDERSHIP SURVEY PROCEDURES AND QUESTIONNAIRES

SCRTD

Over the past several years, the Market Research Unit of the SCRTD conducted three extensive on-board surveys of passengers riding a statistically-selected sample of the system's routes. The first two surveys were conducted in May and September of 1979 as part of a before-and-after study to assess the ridership impacts of the July, 1978 fare increase. The latest survey was undertaken in March, 1979 for the purpose of evaluating ridership characteristics of thirty routes which were to undergo major restructuring.

A stratified random sample was taken to select forty of the system's 220 total lines for the before-and-after surveys. Initially, SCRTD planners stratified all bus lines into eighteen categories which represented various mixes of geographic areas and service types. Random numbers were then used to select the forty analysis routes and a sampling of bus runs from each route.

For all three survey periods, a corps of thirty-five surveyors was employed to administer questionnaires. Each surveyor was assigned to a particular bus run and compiled responses for approximately eight hours. Numerically-ordered questionnaires written in both English and Spanish were distributed to all patrons and sequences of survey responses were attributed to particular bus runs. All questionnaire forms, whether completed or not, were gathered in order to determine response rates.

The three survey projects were all conducted on Tuesday or Thursday, considered by SCRTD planners to be survey days typifying "average" ridership levels. Also, the March survey form differed slightly from the previous ones, soliciting several additional questions concerning family household size and user's age category. The questionnaire form employed during the May and September surveys is shown in Figure C-1.

AC Transit

The AC Transit Board hired the firm of Crain and Associates to conduct a statistically valid sample of riders on all routes during the last two weeks of September, 1978. The on-board survey was designed to obtain an accurate data base on travel patterns, passenger characteristics, and fare revenues.

Thirty survey workers distributed bilingual questionnaires to all customers on approximately ten percent of each route's one-way trips spanning all time periods and days of the week. Survey workers checked demographic characteristics of refusals and non-respondents in order to make necessary weighting adjustments to reduce the incidence of sample bias. Also, two or more workers were used on those bus runs experiencing high proportions of short trips in order to assist riders to complete their questionnaires so as to reduce refusal and non-response rates.

The self-administered questionnaire shown in Figure C-2 solicited a range of responses similar to those of the SCRTD, with the notable exception that AC Transit compiled information on the ethnic background of users. Nine separate pre-tests were performed before the final format/question content and question sequencing was decided upon.

SDTC

San Diego's Comprehensive Planning Organization (CPO) conducted an extensive on-board survey from mid-October to mid-November of 1977, gathering data on SDTC's patronage for all forty-three bus routes. Initially, routes were examined to determine the most representative bus runs for sampling. Workers were then hired to administer the survey among all users during an entire operating day. Quality control measures, similar to those used by SCRTD and AC Transit, were introduced in order to attain an unbiased, statistically valid sample. General socio-economic characteristics of non-respondents were catalogued for the purposes of adjusting user sample rates.

Figure C-3 displays the English version of SDTC's questionnaire form. SDTC's initial questionnaire contents and design were revised several times following pretests during the summer of 1977. Unlike the other two case study sites, the SDTC survey did not solicit responses from persons transferring onto the bus or users under six years of age, although ridership counts were taken of transferers and children for weighting purposes.

PASSENGER SURVEY

The RTD is surveying passengers on this bus line in order to find out what your transit needs are and how we can best respond to your needs. All replies are completely confidential, so please answer all the questions as accurately as possible. Thank you for your help.

PLEASE ANSWER ALL THE QUESTIONS AND RETURN THIS FORM TO THE RTD REPRESENTATIVE

1. Where did you start this trip? (Indicate nearest street intersection) (6-10)

   ______________ (Major Street) and ______________ (Nearest Cross-Street)

2. Where are you going? (Indicate nearest street intersection) (11-15)

   ______________ (Major Street) and ______________ (Nearest Cross-Street)

3. How did you get to *this bus?*

   Drove ☐ 16-1 · Walked ☐ -2 · Was Driven ☐ 16-4 · Other ______ (PLEASE SPECIFY) -5

   Transferred from bus line number ______ (SPECIFY) (17-19) -3

4. Where did you get on *this bus?* (Indicate nearest street intersection) (20-26)

   ______________ (Major Street) and ______________ (Nearest Cross-Street)

5. Where will you get off *this bus?* (Indicate nearest street intersection) (27-33)

   ______________ (Major Street) and ______________ (Nearest Cross-Street)

6. After you get off this bus, you will:

   Drive ☐ 34-1 · Walk ☐ -2 · Be Driven ☐ 34-4 · Other ______ (PLEASE SPECIFY) -5

   Transfer to bus line number ______ (SPECIFY) (35-37) -3

7. How many days a week do you usually ride the bus?

   Five or more ☐ 38-1 · Four ☐ -2 · Three ☐ -3 · Two ☐ 38-4 · One ☐ -5 · Less Than One ☐ -6

8. What is the purpose of this trip? (Check one)

   Work ☐ 39-1 · School ☐ -2 · Social/Recreational ☐ -3 · Shopping ☐ 39-4 · Medical ☐ -5 · Other ______ (PLEASE SPECIFY) -6

9. What type of fare did you pay to get on this bus?

   Cash Fare of ____c 41-1 (Specify Amount) (40-42) · Used a Transfer ☐ -2 · $20 Monthly Pass ☐ -3 · Monthly Pass with Express Stamp ☐ -4 · $14 Student Pass ☐ 43-5 · $4 Senior Citizen Pass ☐ -6 · $4 Handicapped Pass ☐ -7 · Other ______ (PLEASE SPECIFY) -8

10. What is your home address?

    Number (44-48) · Street (49-58) · Apartment Number (59-61) · City (62-75) · Zip Code (76-80)

11. You are: Male ☐ 6-1 · Female ☐ 6-2

12. What is your age? ______ (PLEASE SPECIFY) (7-8)

13. How many automobiles in running condition are there in your household?

    No Cars ☐ 9-1 · One Car ☐ -2 · Two Cars ☐ 9-3 · Three or more Cars ☐ -4

14. Please indicate the number of persons in each age group who live in your household. (Include yourself)

    Under 18 ____ (10-11) · 18-29 ____ (12-13) · 30-39 ____ (14-15) · 40-49 ____ (16-17) · 50-61 ____ (18-19) · 62 and over ____ (20-21)

15. What is the total annual income of your household?

    Under $5000 ☐ 22-1 · $5,000 to $9,999 ☐ -2 · $10,000 to $14,999 ☐ -3 · $15,000 to $19,999 ☐ 22-4 · $20,000 to $24,999 ☐ -5 · $25,000 and over ☐ -6

16. Do you have any physical handicaps which make it difficult for you to get to or use the bus?

    Yes ☐ 23-1 · No ☐ 23-2

17. What is the main reason you ride the bus?

    No car available ☐ 24-1 · Prefer bus to driving ☐ -2 · Bus is economical ☐ -3 · Bus is convenient ☐ 24-4 · Other ______ (PLEASE SPECIFY) -5

18. How would you rate RTD as an agency providing public transportation?

    Excellent ☐ 25-1 · Good ☐ -2 · Fair ☐ 25-3 · Poor ☐ -4

FIGURE C-1. SCRTD ON-BOARD RIDERSHIP QUESTIONNAIRE

SI UD. PREFIERE PUEDE PEDIR UN CUESTIONAIRIO EN ESPANOL

AC TRANSIT ON-BOARD RIDERSHIP QUESTIONNAIRE

PLEASE HELP AC TRANSIT PLAN SERVICE FOR YOU.

THESE QUESTIONS CONCERN THE RIDE YOU ARE NOW TAKING.

1. WHERE DID YOU JUST GET ON? ______________________
   STREET & NEAREST CROSS STREET (OR TERMINAL)

2. HOW DID YOU GET FROM YOUR STARTING POINT TO WHERE YOU JUST GOT ON? (CHECK ONE)
   - 1 ◯ WALKED. HOW MANY BLOCKS? ____
   - 2 ◯ CAR. HOW MANY MILES? ______
   - 3 ◯ TRANSFERRED FROM AC TRANSIT BUS. WHAT LINE NO.? ______
   - 4 ◯ TRANSFERRED FROM ___BART ___MUNI
   - 5 ◯ BIKE. HOW MANY MILES? ____
   - 6 ◯ OTHER ______

3. WHAT FARE DID YOU JUST PAY WHEN YOU GOT ON?
   - 1 ◯ CASH. HOW MUCH? ______
   - 2 ◯ TICKET. HOW MUCH? ______
   - 3 ◯ TRANSFER FROM ___AC ___BART
   - 4 ◯ SHOPPER PASS
   - 5 ◯ FUN PASS
   - 6 ◯ NONE (MAIL CARRIER, POLICE OFFICER)

4. WHERE WILL YOU GET OFF THIS BUS? ______________________
   STREET & NEAREST CROSS STREET (OR TERMINAL)

5. WILL YOU TRANSFER WHEN YOU GET OFF THIS BUS?
   - 1 ◯ NO
   - 2 ◯ YES, TO AN AC TRANSIT BUS. WHICH LINE NO.? ______
   - 3 ◯ YES, TO BART
   - 4 ◯ YES, TO ANOTHER TRANSIT SYSTEM. WHICH ONE? ______

6. HOW MANY AC TRANSIT BUSES WILL YOU USE FOR THIS ONE-WAY TRIP?
   1 ◯ ONE 2 ◯ TWO 3 ◯ THREE OR MORE

7. ARE YOU NOW GOING: 1 ◯ TO HOME 2 ◯ FROM HOME 3 ◯ NEITHER

PLEASE TURN OVER

FIGURE C-2. AC TRANSIT ON-BOARD RIDERSHIP QUESTIONNAIRE

8. HOW OFTEN DO YOU RIDE AC TRANSIT BUSES?

- 1 ◯ AT LEAST 4 DAYS A WEEK
- 2 ◯ 1–3 DAYS A WEEK
- 3 ◯ 1–3 DAYS A MONTH
- 4 ◯ LESS THAN ONE DAY A MONTH

9. WHAT IS OR WAS THE MAIN REASON FOR THIS TRIP?

- 1 ◯ WORK
- 2 ◯ SCHOOL OR UNIVERSITY
- 3 ◯ SHOPPING
- 4 ◯ MEDICAL, DENTAL
- 5 ◯ PERSONAL BUSINESS
- 6 ◯ SOCIAL, RECREATION
- 7 ◯ OTHER ______________________

10. DO YOU HAVE A HANDICAP DISCOUNT CARD? 1 ◯ YES 2 ◯ NO

11. WAS A CAR AVAILABLE TO YOU TO MAKE THIS TRIP TODAY?

1 ◯ YES 2 ◯ NO

12. SEX: 1 ◯ MALE 2 ◯ FEMALE

13. AGE:

- 1 ◯ UNDER 5
- 2 ◯ 5–12
- 3 ◯ 13–17
- 4 ◯ 18–30
- 5 ◯ 30–59
- 6 ◯ 60–64
- 7 ◯ 65 AND OVER

14. HOUSEHOLD INCOME:

- 1 ◯ UNDER $7,000
- 2 ◯ $7,001–$15,000
- 3 ◯ $15,001–$25,000
- 4 ◯ $25,001–$35,000
- 5 ◯ OVER $35,000

15. ETHNIC BACKGROUND:

- 1 ◯ ASIAN
- 2 ◯ BLACK
- 3 ◯ MEXICAN OR HISPANIC
- 4 ◯ AMERICAN INDIAN
- 5 ◯ WHITE
- 6 ◯ OTHER ______________

COMMENTS: ____

____

____

PLEASE RETURN THIS FORM TO SURVEY TAKER. THANK YOU FOR YOUR COOPERATION.

THIS INFORMATION IS CONFIDENTIAL AND FOR STATISTICAL PURPOSES ONLY.

FIGURE C-2. AC TRANSIT ON-BOARD RIDERSHIP QUESTIONNAIRE (CONTINUED)

The San Diego Region's Comprehensive Planning Organization in cooperation with the transit operators is trying to understand your transit needs. You can help us by filling out the questions below and returning the form to the interviewer on this bus. Thank you.

№ 55902

OFFICE USE ONLY

1. THIS QUESTION FOR TRANSFER PASSENGERS ONLY

What route(s) did you transfer from? ________

Thank you for your help. Please do not fill out the rest of this form.

2. How did you get to the bus stop where you got on this bus? Walked ____ Blocks ○ (Number of) / Drove ○ / Was Driven ○ / Bicycled ○

3. Where did you come from? Home ○ / Work ○ / School ○ / Shopping ○ / Personal Business (Medical, Church, Etc.) ○ / Recreational or Social Activity ○ / Other ____ (Specify) ○

4. What is the address of this place that you came from?

________ Number and Street (or Intersection)

________ City ____ Zip

5. What is the nearest street intersection or building name where you will get off this bus?

________ Street Address/Intersection or Building Name

________ City

6. After you get off this bus, how will you get to the place you are going? Will Walk ____ Blocks ○ (Number of) / Will be Driven ○ / Will Drive ○ / Will Bicycle ○ / Will Transfer to Route(s) ____ (Specify) ○

On the bus you transfer to, where will you get off?

________ Nearest Street Intersection and/or Building Name

________ City

7. Where are you going? Home ○ / Work ○ / School ○ / Shopping ○ / Personal Business (Medical, Church, etc.) ○ / Recreational or Social Activity ○ / Other ____ (Specify) ○

8. What is the address of this place where you are going?

________ Number and Street (or Intersection)

________ City

9. Is this bus trip: The first half of a round trip by bus ○ / The second half of a round trip by bus ○ / A one-way bus trip ○

10. What type of fare did you pay to get on this bus? Monthly Pass: Regular ○ / Senior Citizen ○ / Student ○; Cash: Regular ○ / Senior Citizen ○ / Student ○

11. How many vehicles in running condition do you have in your household? None ○ / One ○ / Two ○ / Three or More ○

12. Check one: Male ○ / Female ○

13. Check one: Under 16 years ○ / 16 to 24 years ○ / 25 to 44 years ○ / 45 to 59 years ○ / 60 years or over ○

14. Which of the following apply to you? San Diego County Resident ○ / Student ○ / Employed ○ / Senior Citizen ○ / Visitor/Tourist ○ / Member of Armed Forces ○ / None of the Above ○

15. How many persons live in your home? One ○ / Two ○ / Three ○ / Four ○ / Five ○ / Six or More ○

16. What is the yearly total income of those persons living in your home? Less than $5,000 ○ / $5 - 7,000 ○ / $7 - 10,000 ○ / $10 - 15,000 ○ / $15 - 25,000 ○ / More than $25,000 ○

Please return to the interviewer on this bus.

THANK YOU

FIGURE C-3. SDTC ON-BOARD RIDERSHIP QUESTIONNAIRE

APPENDIX D

COST CENTERS ESTIMATES

TABLE D-1. SCRTD — COST CENTERS ESTIMATES OF SAMPLE ROUTES' DAILY TRANSIT COSTS (AS OF 6/30/79)

Line	Div.	In-Service Vehicle Miles	+	Total Vehicle Hours	+	Pull-Outs	+	Peak Vehicles	=	Daily Cost($)
2	2	2574(.51)		238(14.48)		28(16.18)		19(97.76)		7069
3	1	2106(.42)		214(13.56)		21(16.88)		17(88.53)		5646
3	7	1295(.42)		132(12.78)		16(14.77)		12(89.05)		3536
3	18	884(.45)		90(14.76)		10(18,17)		8(106.22)		2758
3	Total	---		---		---		---		11940
6	3	1872(.42)		169(14.56)		16(20.08)		13(99.05)		4856
6	5	2162(.40)		199(14.13)		23(16.50)		19(87.32)		5715
6	Total	---		---		---		---		10571
22	3	263(.42)		27(14.56)		2(20.08)		2(99.05)		742
25	3	1883(.42)		187(14.56)		24(20.08)		17(99.05)		5679
27	5	2311(.40)		208(14.13)		22(16.50)		16(87.32)		5624
28	1	3511(.42)		386(13.56)		51(16.88)		34(88.53)		10580
29	2	1261(.51)		185(14.48)		23(16.18)		17(97.76)		5356
29	18	1126(.45)		117(14.76)		13(18.17)		10(106.22)		3532
29	Total	---		---		---		---		8888
33	12	1483(.42)		115(15.37)		12(15.94)		9(82.76)		3327
34	18	613(.45)		51(14.76)		8(18.17)		5(106.22)		1705
35	8	4298(.42)		298(13.16)		44(14.65)		29(86.70)		8886
42	3	1692(.42)		196(14.56)		22(20.08)		18(99.05)		5789
42	7	1039(.42)		122(12.78)		14(14.77)		14(89.05)		3449
42	Total	---		---		---		---		9238
47	2	2053(.51)		200(14.48)		23(16.18)		16(97.76)		5879
73	5	1127(.40)		107(14.13)		9(16.50)		8(87.32)		2810
87	3	665(.42)		72(14.56)		5(20.08)		5(99.05)		1923
89	7	2018(.42)		249(12.78)		19(14.77)		20(89.05)		6091
91	2	1246(.51)		126(14.48)		14(16.18)		10(97.76)		3664
91	7	3542(.42)		373(12.78)		55(14.77)		37(89.05)		10362
91	Total	---		---		---		---		14026
95	2	3388(.51)		505(14.48)		55(16.18)		40(97.76)		13841
114	18	485(.45)		38(14.76)		3(18.17)		3(106.22)		1152
144	8	580(.42)		42(13.16)		22(14.65)		11(86.70		2072
154	15	1717(.38)		104(13.66)		8(20.75)		8(99.57)		3036
435	3	1141(.42)		91(14.56)		6(20.08)		6(99.05		2519
480	9	4788(.37)		254(15.41)		36(16.47)		23(87.91)		8301
607	5	1838(.40)		109(14.13)		8(16.50)		8(87.32)		3106
801	1	969(.42)		65(13.56)		12(16.88)		7(88.53)		2111
814	12	607(.42)		43(15.37)		14(15.94)		7(82.76)		1718
826	1	1796(.42)		144(13.56)		11(16.88)		10(88.53)		3778
828	5	2693(.40)		223(14.13)		15(16.50)		14(87.32)		5698
869	18	1616(.45)		107(14.76)		10(18.17)		7(106.22)		3232
873	6	934(.41)		65(13.36)		4(13.84)		4(87.16)		1655
873	12	1297(.42)		88(15.37)		5(15.94)		6(82.76)		2473
873	Total	---		---		---		---		4128

TABLE D-2. SCRTD — UNIT COST ESTIMATES (AS OF 6/30/79)

Line	Div.'s	Cost	Cost/ Passenger	Cost/Bus Hour	Cost/Bus Mile	Cost/ Passenger-Mile
2	2	$ 7069	$ .36	$28.49	$2.56	$.14
3	1,7,18	11940	.36	26.78	2.43	.14
6	3,5	10571	.34	28.72	2.29	.11
22	3	742	.46	11.40	1.17	.26
25	3	5679	.59	30.37	2.64	.19
27	5	5624	.33	27.04	2.43	.14
28	1	10580	.35	27.40	2.81	.14
29	2,18	8888	.39	28.95	3.52	.16
33	12	3327	.80	28.83	2.23	.14
34	18	1705	1.60	33.43	2.78	.20
35	8	8886	.84	29.82	2.07	.08
42	3,7	9238	.50	29.54	2.77	.17
47	2	5879	.53	29.39	2.55	.20
73	5	2810	.25	26.26	2.29	.71
87	3	1923	.81	26.71	1.68	.62
89	7	6091	.29	24.46	2.77	.17
91	2,7	14026	.43	28.10	2.62	.12
95	2	13841	.46	27.41	3.25	.21
114	18	1152	1.43	30.31	2.17	.50
144	8	2072	2.39	49.33	2.67	.15
154	15	3036	1.19	29.19	1.62	.36
435	3	2519	1.21	27.68	1.97	.34
480	9	8301	1.77	32.68	1.42	.11
607	5	3106	1.82	28.49	1.51	.21
801	1	2111	1.39	32.47	1.89	.15
814	12	1718	3.13	39.95	1.80	.18
826	1	3778	.61	26.24	1.90	.26
828	5	5698	.73	25.55	1.95	.21
869	18	3232	1.98	30.20	1.78	.44
873	3,12	4128	2.19	25.46	1.68	.25

TABLE D-3. AC TRANSIT — COST CENTERS ESTIMATES OF SAMPLE ROUTES' DAILY TRANSIT COSTS (AS OF 6/30/79)

Line	Div.	Vehicle Miles	+	Vehicle Hours	+	Overhead Expansion	=	Daily Costs ($)
A	2	1141 (.25)		65.59 (18.40)		1.298		1937
G	3	840 (.30)		42.32 (18.20)		1.298		1317
K/R/S	4	5438 (.29)		251.19 (18.62)		1.298		8118
U	6	2973 (.21)		115.44 (18.93)		1.298		3647
11	2	338 (.25)		37.49 (18.40)		1.298		1005
22/24	6	980 (.21)		63.47 (18.93)		1.298		1827
31	3	150 (.30)		8.57 (18.02)		1.298		259
32	6	273 (.21)		16.23 (18.93)		1.298		473
46/87	4	403 (.29)		37.27 (18.62)		1.298		1052
51/58	2	3427 (.25)		315.31 (18.40)		1.298		8643
54	4	711 (.29)		62.02 (18.62)		1.298		1767
65	2	635 (.25)		61.07 (18.40)		1.298		1665
70	3	600 (.30)		49.51 (18.02)		1.298		1392
72	2	3436 (.25)		279.45 (18.40)		1.298		7789
79	4	560 (.29)		47.38 (18.62)		1.298		1356
80/81	4	2050 (.29)		141.19 (18.62)		1.298		4184
82/83	4	5411 (.29)		409.51 (18.62)		1.298		11934
84	4	388 (.29)		31.19 (18.62)		1.298		900
90/92	4	1317 (.29)		91.14 (18.62)		1.298		2698
306	2	591 (.25)		37.00 (18.40)		1.298		1075

TABLE D-4. AC TRANSIT — UNIT COST ESTIMATES (AS OF 6/30/79)

Line	Div.	Cost	Cost/ Passenger	Cost/Bus Hour	Cost/Bus Mile	Cost/ Passenger-Mile
A	2	$1937	$1.78	$29.53	$1.70	$ .23
G	3	1317	2.55	31.12	1.57	.20
K/R/S	4	8118	1.93	32.32	1.49	.12
U	6	3647	3.58	31.59	1.23	.38
11	2	1005	.81	26.81	2.97	.52
22/24	6	1827	3.22	28.79	1.86	.59
31	3	259	1.87	30.22	1.73	.18
32	6	473	1.60	29.14	1.73	.12
46/87	4	1052	1.33	28.23	2.61	1.20
51/58	2	8643	.33	27.41	2.52	.14
54	4	1767	1.42	28.49	2.49	.69
65	2	1665	.63	27.26	2.62	.35
70	3	1392	.83	28.11	2.32	.27
72	2	7789	.66	27.87	2.27	.20
79	4	1356	1.25	28.62	2.42	.55
80/81	4	4184	.67	29.63	2.04	.44
82/83	4	11934	.59	29.14	2.21	.14
84	4	900	2.47	28.86	2.32	.84
90/92	4	2698	1.46	29.60	2.05	.44
306	2	1075	2.67	29.05	1.82	1.50

TABLE D-5. SDTC — ESTIMATES OF SAMPLE ROUTES' DAILY TRANSIT COSTS (AS OF 6/30/78)

Line	Vehicle Miles	+	Vehicle Hours	=	Daily Costs ($)
2	1038.4 (.43)		106.3 (20.76)		2653
3	1055.6 (.43)		118.1 (20.76)		2906
5	2420.6 (.43)		146.0 (20.76)		4072
20	2939.2 (.43)		124.0 (20.76)		3838
21	998.8 (.43)		55.2 (20.76)		1575
27	948.8 (.43)		78.2 (20.76)		2031
43	879.6 (.43)		63.3 (20.76)		1692
51	259.2 (.43)		17.5 (20.76)		475
80	1077.2 (.43)		63.0 (20.76)		1771
90	1153.4 (.43)		63.8 (20.76)		1820

TABLE D-6. SDTC — UNIT COST ESTIMATES
(AS OF 6/30/78)

Line	Cost	Cost/ Passenger	Cost/Bus Hour	Cost/Bus Mile	Cost/ Passenger-Mile
2	$2653	$ .49	$26.13	$2.68	$.23
3	2906	.50	25.80	2.88	.22
5	4072	.70	37.17	2.24	.15
20	3838	1.55	32.47	1.37	.11
21	1575	2.59	29.87	1.65	.39
27	2031	.98	27.20	2.25	.21
43	1692	1.80	27.95	2.02	.50
51	475	1.78	27.93	2.02	.45
80	1771	1.24	29.49	1.72	.19
90	1820	1.16	29.69	1.65	.11

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APPENDIX E

SPECIFICATION OF VEHICLE HOUR FACTORS

TABLE E-1. SPECIFICATION OF SCRTD'S PEAK AND BASE VEHICLE HOUR FACTORS

SPECIFICATION OF SCRTD'S PEAK AND BASE VEHICLE HOUR FACTORS								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		PEAK		BASE		PEAK	BASE	n=
Line	Division	Pay Hours	Vehicle Hours	Pay Hours	Vehicle Hours	PH/VH	PH/VH	(5)/(6)
2	2	143:00	108:45	147:20	129:45	1.315	1.135	1.158
3	1	116:47	86:33	133:12	127:37	1.349	1.044	1.292
3	7	92:03	60:03	81:44	75:17	1.533	1.086	1.412
3	18	56:45	35:00	61:41	53:35	1.621	1.15	1.408
6	3	136:20	93:40	118:17	99:40	1.456	1.187	1.227
22	3	15:58	10:00	18:46	16:56	1.597	1.108	1.441
25	3	144:20	106:00	83:00	79:00	1.367	1.050	1.301
27	5	114:22	90:00	137:21	124:44	1.271	1.101	1.154
28	1	256:40	184:23	206:13	201:53	1.392	1.022	1.363
29	2	118:30	84:45	103:30	101:15	1.398	1.022	1.367
29	18	70:40	52:30	89:30	77:30	1.346	1.155	1.166
33	12	66:00	46:05	84:20	76:55	1.432	1.096	1.306
34	18	35:10	26:00	27:20	25:08	1.353	1.088	1.244
35	8	220:35	150:00	181:54	169:43	1.471	1.072	1.372
42	3	126:00	94:45	112:00	101:40	1.330	1.102	1.207
42	7	89:50	71:00	61:00	50:42	1.265	1.203	1.054
47	2	129:37	96:33	103:37	97:35	1.343	1.062	1.426
73	5	58:10	50:05	61:43	57:30	1.161	1.073	1.082
87	3	32:30	25:00	40:38	37:28	1.300	1.085	1.199
89	7	112:17	92:01	175:35	157:21	1.220	1.116	1.093
91	2	96:09	67:03	69:25	59:01	1.434	1.176	1.219
91	7	330:54	223:37	148:44	139:45	1.480	1.064	1.390
95	2	230:04	156:33	259:11	243:00	1.470	1.067	1.378
114	18	22:00	15:00	31:11	26:55	1.467	1.159	1.266
144	8	101:18	32:13	9:49	9:49	3.144	1.000	3.144
154	15	55:28	40:00	64:11	61:44	1.387	1.040	1.334
435	3	37:48	30:00	71:43	62:21	1.260	1.150	1.095
480	9	171:40	113:10	138:10	133:19	1.517	1.036	1.464
607	5	52:21	40:00	90:27	79:19	1.309	1.140	1.148
801	1	60:20	40:30	25:20	24:40	1.490	1.027	1.451
814	12	55:24	22:36	23:48	22:03	2.450	1.079	2.269
826	1	57:14	47:29	111:48	99:55	1.205	1.119	1.077
828	5	81:33	67:44	155:44	141:25	1.204	1.101	1.093
869	18	50:00	38:11	65:18	58:44	1.310	1.112	1.178
873	6	28:04	20:00	52:08	48:57	1.403	1.065	1.317
873	12	36:40	27:30	84:56	74:54	1.333	1.134	1.176
Sample Average		98:28	70:41	95:17	88:49	1.393	1.07	1.302

TABLE E-1. SPECIFICATION OF SCRTD'S PEAK AND BASE VEHICLE HOUR FACTORS (CONTINUED)

SPECIFICATION OF SCRTD'S PEAK AND BASE VEHICLE HOUR FACTORS (cont.)							
		(8)	(9)	(10)	(11)	(12)	(13)
		s=	PEAK FACTOR	BASE FACTOR	VEHICLE HOUR FACTOR		
Line	Division	(2)/(4)	n(1+s)/1+ns	1+s/1+ns	Daily Average	Peak	Base
2	2	.838	1.080	.933	14.48	15.64	13.51
3	1	.678	1.156	.894	13.56	15.68	12.12
3	7	.798	1.194	.845	12.78	15.26	10.80
3	18	.653	1.213	.861	14.76	17.66	12.54
6	3	.940	1.105	.901	14.56	16.09	13.12
22	3	.591	1.238	.859	14.56	18.03	12.51
25	3	1.340	1.110	.853	14.56	16.16	12.42
27	5	.722	1.084	.939	14.13	15.32	13.27
28	1	.913	1.162	.852	13.56	15.76	11.58
29	2	.837	1.171	.857	14.48	16.96	12.41
29	18	.677	1.098	.937	14.76	16.21	13.83
33	12	.599	1.172	.897	15.37	18.01	13.79
34	18	1.034	1.107	.890	14.76	16.34	13.13
35	8	.884	1.120	.873	13.16	14.74	11.49
42	3	.932	1.097	.909	14.56	15.97	13.24
42	7	1.400	1.022	.969	12.78	13.06	12.39
47	2	.989	1.177	.825	14.48	17.04	11.95
73	5	.871	1.042	.963	14.13	14.72	13.61
87	3	.667	1.111	.926	14.56	16.18	13.49
89	7	.585	1.057	.967	12.78	13.51	12.36
91	2	1.136	1.092	.896	14.48	15.81	12.97
91	7	1.600	1.121	.806	12.78	14.33	10.31
95	2	.644	1.200	.871	14.48	17.38	12.61
114	18	.557	1.156	.913	14.76	17.06	13.48
144	8	3.282	1.189	.378	13.16	15.65	4.98
154	15	.648	1.179	.884	13.66	16.11	12.07
435	3	.481	1.062	.970	14.56	15.46	14.12
480	9	.849	1.207	.824	15.41	18.60	12.70
607	5	.504	1.094	.953	14.13	15.46	13.46
801	1	1.642	1.133	.781	13.56	15.37	10.59
814	12	1.025	1.382	.609	15.37	21.24	9.36
826	1	.475	1.051	.976	13.56	14.25	13.23
828	5	.479	1.061	.971	14.13	14.99	13.72
869	18	.650	1.101	.934	14.76	16.25	13.79
873	6	.409	1.206	.916	13.36	16.11	12.23
873	12	.367	1.122	.954	15.37	17.25	14.66
Sample Average		.796	1.148	.882	14.17	16.11	12.55

TABLE E-2. SPECIFICATION OF AC TRANSIT'S PEAK AND BASE VEHICLE HOUR FACTORS

		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		PEAK		BASE		PEAK	BASE	n=
Line	Division	Pay Hours	Vehicle Hours	Pay Hours	Vehicle Hours	PH/VH	PH/VH	(5)/(6)
A	2	31:30	24:30	42:39	42.20	1.286	1.008	1.277
G	3	38:30	30:30	24	23:23	1.262	1.026	1.230
K/R	4	168:30	116:30	148:44	130:25	1.446	1.142	1.266
U	6	86	81	44	41	1.062	1.062	1.00
11	2	19	18	12:37	12	1.056	1.06	1.00
22/24	6	21:50	18	64:30	47:28	1.794	1.359	.879
31	3	10:30	8	7:08	6:38	1.313	1.075	1.221
32	6	22	18	16	12	1.222	1.333	.917
46/87	4	12:30	11	23:23	21	1.136	1.113	1.021
51/58	2	166	142	200:34	195:30	1.169	1.026	1.139
54	4	33:30	29:30	31:12	29	1.136	1.076	1.056
65	2	37:18	35:18	34:27	32:42	1.057	1.057	1.00
70	3	25:30	23:30	19:50	18:30	1.085	1.072	1.012
72	2	125:22	102	172:24	162:05	1.229	1.064	1.156
79	4	33:37	27:36	27:13	24:53	1.218	1.094	1.114
80/81	4	62:41	42:30	98:30	95:50	1.475	1.028	1.435
82/83	4	217	187	280:30	264:30	1.160	1.061	1.094
84	4	13	11	13:50	12:50	1.182	1.078	1.097
90/92	4	53	47	57:20	54:50	1.128	1.046	1.079
306	2	24:30	23:30	14:18	13:40	1.043	1.043	1.000
Sample Average		60:05	48:55	66:39	62:01	1.228	1.075	1.142

TABLE E-2. SPECIFICATION OF AC TRANSIT'S PEAK AND BASE VEHICLE HOUR FACTORS (CONTINUED)

		(8)	(9)	(10)	(11)	(12)	(13)
		s=	PEAK FACTOR	BASE FACTOR	VEHICLE HOUR FACTOR		
Line	Division	(2)/(4)	n(1+s)/1+ns	1+s/1+ns	Daily Average	Peak	Base
A	2	.579	1.160	.908	18.40	21.34	16.70
G	3	1.304	1.088	.885	18.02	19.61	15.95
K/R	4	1.133	1.177	.949	18.62	21.92	17.67
U	6	1.975	1.00	1.00	18.93	18.93	18.93
11	2	1.5	1.00	1.00	18.40	18.40	18.40
22/24	6	.379	.909	1.034	18.93	18.93	18.93
31	3	1.206	1.089	.892	18.02	19.62	16.07
32	6	1.5	.965	1.052	18.93	18.93	18.93
46/87	4	.524	1.014	.993	18.62	18.88	18.49
51/58	2	.726	1.076	.945	18.40	19.80	17.38
54	4	1.017	1.027	.973	18.62	19.12	18.11
65	2	1.079	1.00	1.00	18.40	18.40	18.40
70	3	1.270	1.01	.99	18.02	18.20	17.90
72	2	.630	1.091	.944	18.40	20.07	17.36
79	4	1.109	1.051	.943	18.62	19.57	17.57
80/81	4	.449	1.266	.882	18.62	23.57	16.43
82/83	4	1.414	1.037	.948	18.62	19.31	17.65
84	4	.858	1.05	.957	18.62	19.55	17.82
90/92	4	.857	1.041	.964	18.62	19.38	17.97
306	2	1.719	1.00	1.00	18.40	18.40	18.40
Sample Average		.789	1.075	.941	18.52	19.60	17.76

TABLE E-3. SPECIFICATIONS OF SDTC'S PEAK AND BASE VEHICLE HOUR FACTORS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PEAK		BASE		PEAK	BASE	n=
Line	Pay Hours	Vehicle Hours	Pay Hours	Vehicle Hours	PH/VH	PH/VH	(5)/(6)
2	80:00	49:00	66:21	57:21	1.633	1.157	1.411
3	71:00	46:00	81:07	72:07	1.544	1.125	1.372
5	139:30	70:30	96:30	75:30	1.979	1.278	1.549
20	96:00	65:00	65:00	59:00	1.477	1.102	1.340
21	27:00	17:00	43:24	38:24	1.588	1.130	1.405
27	36:00	30:00	51:22	48:22	1.200	1.062	1.130
43	33:00	23:00	47:25	40:25	1.435	1.173	1.223
51	7:00	6:00	11:53	11:23	1.167	1.044	1.118
80	37:00	25:00	43:00	38:04	1.48	1.130	1.310
90	48:30	39:30	29:16	24:16	1.228	1.206	1.018
Sample Average	57:30	37:06	53:30	46:45	1.53	1.14	1.337

TABLE E-3. SPECIFICATIONS OF SDTC'S PEAK AND BASE VEHICLE HOUR FACTORS (CONTINUED)

	(8)	(9)	(10)	(11)	(12)	(13)
	s=	PEAK FACTOR	BASE FACTOR	VEHICLE HOUR FACTOR		
Line	(2)/(4)	n(1+s)/1+ns	1+s/1+ns	Daily Average	Peak	Base
2	.854	1.186	.841	20.76	24.62	17.45
3	.638	1.199	.874	20.76	24.89	18.14
5	.934	1.225	.791	20.76	25.43	16.41
20	1.102	1.138	.849	20.76	23.63	17.62
21	.443	1.250	.890	20.76	25.95	18.47
27	.620	1.076	.952	20.76	22.34	19.77
43	.569	1.131	.925	20.76	23.48	19.21
51	.527	1.074	.961	20.76	22.29	19.94
80	.657	1.167	.891	20.76	24.22	18.49
90	1.628	1.007	.989	20.76	20.90	20.53
Sample Average	7.94	1.164	.87	20.76	23.78	18.60

APPENDIX F

AN ANALYSIS OF ALTERNATIVE APPROACHES TO APPORTIONING "PULL OUT" AND "PEAK VEHICLE" FACTOR

The allocation problem presented by the "pull out" and "peak vehicle" factors is graphically illustrated in Figures F-1 and F-2. Each factor is measured by the shaded areas of the graph. Whereas the entire area of the bimodal distribution shown in Figure 4-1 represents "vehicle miles" and "vehicle hours," only a portion of the graphs in Figures F-1 and F-2 measure "pull outs" and "peak vehicles." There is no time scale associated with these latter two factors from which to gauge how many units of "pull outs" and "peak vehicles" belong in each period.

Three alternative rationales were considered in apportioning "pull outs" and "peak vehicles." The necessary calculations for apportioning these two factors between time periods under each alternative are presented in both figures. Alternative I calls for allocating the increment of pull outs and peak buses above the base level to the peak period, with the residual falling into the off-peak period. The rationale is that all costs incurred by buses which augment the base level of service should be attributed solely to the peak period, and the remainder should become the responsibility of off-peak users. As Kahn (1971, p. 101) explains, "it might appear that peak users are responsible not for the entire overhead, but for that portion by which their consumption exceeds off-peak consumption - that is, that efficiency requires that they pay the entire costs of only the "peak" or the protuberance of the mountain above the surrounding plateau, not of the entire mountain." A problem with this allocation approach is that whenever the peak increment is relatively small, base period users would bear a large share of the "peak vehicle" and "pull out" related expenses (e.g., costs for clerical and building services, planning, accounting, scheduling, etc.). For example, eight of SCRTD's thirty sample lines operate the same number of buses during the peak and base; thus, Alternate I would allocate no "pull out" or "peak vehicle" related costs to the peak since the increment ($a_o \cdot 2t_2$ and $a_v \cdot t_2$ in Figures F-1 and F-2) above the base would be zero. Clearly, the first alternative would allocate a disproportionate share of non-capital overhead expenses to base period users.

The second alternative shown in these two figures proposes pro-rating "pull outs" and "peak vehicles" on the basis of each time period's relative share of total "vehicle hours." The idea behind this alternative is to employ the "vehicle hour" measure as a surrogate of service intensity in apportioning the two parameters. In the Arthur Anderson study of bus route costing, support was lent to the apportionment of overhead (i.e., units of "pull outs" and "peak vehicles") on the basis of bus hours, "on the hypothesis that bus hours are the principle determinant of crew numbers, and most overheads will in the long term be approximately proportional to crew numbers" (McGlenahan and Kaye, 1975, p. 36). In principle, this approach holds the "pull out" and "peak vehicle" factors constant, effectively reducing SCRTD's "cost centers" equations to two-factor models based primarily on "vehicle hours" and "vehicle miles." The major shortcoming of this alternative is that off-peak users would be penalized with disproportionately high non-capital overhead charges in cases where there is an even split in vehicle hours between time periods yet significantly more buses operate in the peak period than the base. Five of SCRTD's thirty sample lines experience this pattern of operations.

Alternative III represents a hybrid of the prior two rationales. As illustrated in both figures, this approach allocates the entire increment of "pull outs" and "peak buses" above the base to the peak period and pro-rates the residual according to "vehicle hours." Clearly, the additional overhead expenses represented by the increment of "pull outs" and "peak vehicles" above the base are the responsibility of peak patrons. Likewise, the base component of overhead expenses linked to these two measures are incurred jointly by users from both time periods. However, the "pull out" and "peak vehicle" measures have no intrinsic attributes which enable one to causally apportion the base (i.e., non-increment) component. The "vehicle hour" factor offers a reasonable yardstick for apportioning this component since it reflects service intensities over a daily time span. This rationale - the assignment of the entire increment to the peak and the pro-rating of the residual between time periods - is by far most liberal among the alternatives in allocating non-capital overhead costs to the peak period.

In order to evaluate the allocation implications of each of the alternatives, a sensitivity analysis was performed. Using the expressions displayed in Figures F-1 and F-2, "pull outs" and "peak vehicles" were apportioned between the peak and base periods for all thirty sample lines and comparisons were made between alternate approaches.

For all thirty SCRTD routes studied, the proportion of "pull outs" assigned to the peak period was: Alternative I - 56.7 percent; Alternative II - 48.2 percent; and Alternative III - 81.5 percent. Alternative II assigned the lowest share of "pull outs" to the peak for eighteen of the thirty sample routes. However, for seven sample routes in which the same number of buses operated throughout the day, Alternative I apportioned no units of "pull outs" to the peak; that is, the "pull out" increments were zero, resulting in a total assignment to the base period. The variance in the time-of-day assignment of "pull outs" between sample routes was much larger for the first and third alternative in comparison with Alternative I. This was the case since routes with a large amount of peak pull-out activity supplementing the base received relatively high apportionments under Alternatives I and III while those with no incremental services were assigned zero units of "pull out." Given these results, a decision was made to allocate SCRTD's "pull outs" between time periods based solely upon a pro-rating of "vehicle hours" (i.e., Alternative II).[1] Since SCRTD's "pull out" factor

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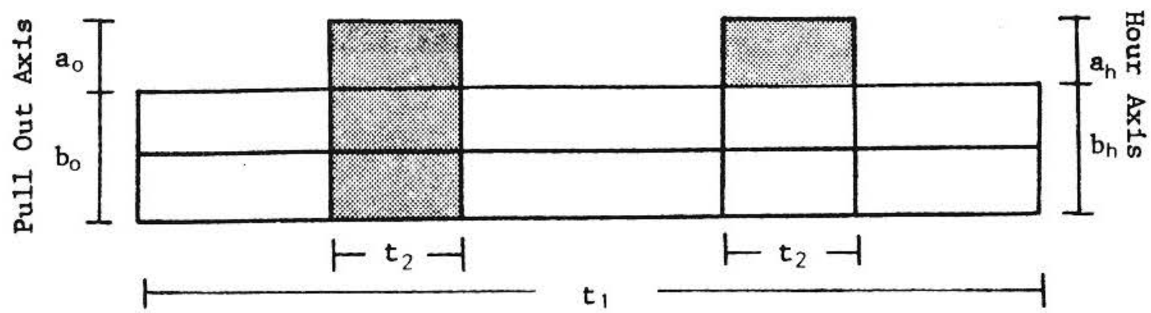
[1]This is again a conservative approach. The "pull out" factor, by virtue of its definition as the difference between morning plus evening pull outs minus midday ones, is not particularly compatible with the allocation approaches of Alternatives I and II. The addition of <u>both</u> the morning and evening pull outs substantially inflates the incremental portion of the measure. Accordingly, the peak period is apportioned a relatively large share of the factor under these two alternatives, except when the base activities equal those in the peak. In the latter case, the base is allotted all pull outs. The second alternative neutralizes these extremes, thus emerging as a superior measure for apportioning pull outs.

encompasses less than 6 percent of total costs, the net difference between using any of the three alternatives is marginal at best. Based on the comparative analysis of approaches, however, Alternative II appears to yield the most reasonable results.

In the sensitivity analysis of the "peak vehicle" factor, Alternative I apportioned 62.4 percent of the sample "peak buses" to the based period, while Alternative's II and III assigned 53.2 and 39.4 percents respectively. Stated another way, the first approach favored charging the majority of overhead expenses to the base period users while the third alternative promoted just the opposite. Alternative II struck a middle ground between these extremes. Since Alternative I assigned the most "peak vehicles" to the peak period for only four of the thirty sample routes (i.e., those with at least twice as many buses in the peak as in the base), it was eliminated from any further consideration.

Generally, the third alternative allocated around twenty percent more "peak vehicles" to the peak than did the second approach. For half the thirty lines sampled, the allocation differential between these two alternatives was less than ten percent. Only six express and commuter lines received decisively larger allocations of "peak vehicles" during the peak period under Alternative III. It can be argued, however, that such services should bear relatively larger shares of overhead expenses since administrative staffs, accounting functions, etc. are scaled to ridership levels during the peak. In that over 26 percent of SCRTD's total expenses are associated with the "peak vehicle" factor and given the relative sensitivity of the third rationale to the overhead expense burden imposed by expanded commuter services, Alternative III was chosen to allocate "peak vehicles."



Alternative	Daily Measure	Base Allocation	Peak Allocation
I	$b_o(t_2)+a_o(2t_2)$	$b_o(t_2)$	$a_o(2t_2)$
II	"	$b_o(t_2)\cdot\left[\frac{b_h(t_1)-b_h(2t_2)}{b_h(t_1)+a_h(2t_2)}\right]$	$\left\{a_o(2t_2) + b_o(t_2)\cdot\left[\frac{a_h(2t_2)}{b_h(t_1)+a_h(2t_2)}\right]\right\}$
III	"	$\left\{\left[b_o(t_2)+a_o(2t_2)\right]\cdot\left[\frac{b_h(t_1)-b_h(2t_2)}{b_h(t_1)+a_h(2t_2)}\right]\right\}$	$\left\{\left[b_o(t_2)+a_o(2t_2)\right]\cdot\left[\frac{a_h(2t_2)}{b_h(t_1)+a_h(2t_2)}\right]\right\}$

WHERE:

t_1 = 24 hour time period

t_2 = Total duration of each peak

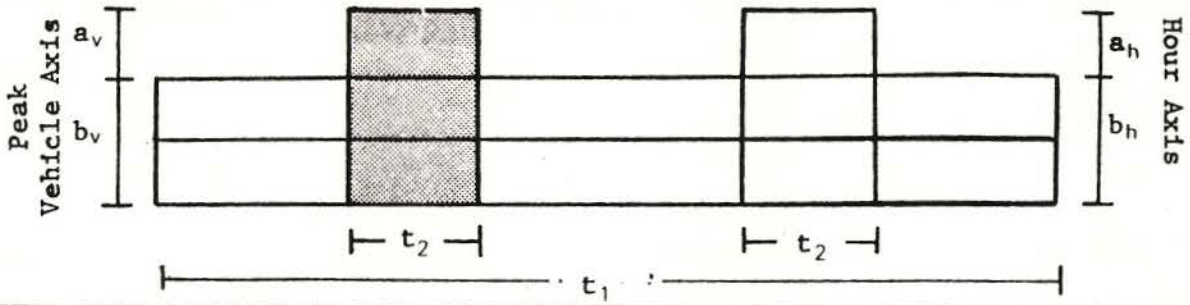
a_o = Increment of Pull Outs above the base for each peak

b_o = Pull Outs during the base period

a_h = Increment of Vehicle Hours above the base for each peak

b_h = Vehicle Hours during the base period

FIGURE F-1. ALTERNATIVE APPROACHES TO APPORTIONING THE PULL OUT FACTOR



Alternative	Daily Measure	Base Allocation	Peak Allocation
I	$b_v(t_2)+a_v(t_2)$	$b_v(t_2)$	$a_v(t_2)$
II	"	$b_v(t_2)\cdot\left[\frac{b_h(t_1)-b_h(2t_2)}{b_h(t_1)+a_h(2t_2)}\right]$	$\left\{a_v(t_2) + b_v(t\ )\cdot\left[\frac{a_h(2t_2)}{b_h(t_2)+a_h(2t_2)}\right]\right\}$
III	"	$\left\{(a_v+b_v)t_2\cdot\left[\frac{b_h(t_1)-b_h(2t_2)}{b_h(t_1)+a_h(2t_2)}\right]\right\}$	$\left\{(a_v+b_v)t_2\cdot\left[\frac{a_h(2t_2)}{b_h(t_2)+a_h(2t_2)}\right]\right\}$

WHERE:

t_1 = 24 hour time period

t_2 = Total duration of each peak

a_v = Increment of Peak Vehicles above the base for each peak

b_v = Peak Vehicles during the base period

a_h = Increment of Vehicle Hours above the base for each peak

b_h = Vehicle Hours during the base period

FIGURE F-2. ALTERNATIVE APPROACHES TO APPORTIONING THE PEAK VEHICLES FACTOR

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APPENDIX G

ESTIMATED PEAK AND BASE ROUTE COSTS

TABLE G-1. ESTIMATES OF SCRTD ROUTE COSTS DURING THE PEAK PERIOD

Line	Div.	(VM)	+	(VH)	+	(PO)	+	(PB)	=	Peak Cost ($)
2	2	1174.0 (.51)		108.75 (15.64)		12.76 (16.18)		14.62 (97.76)		3935
3	1	929.0 (.42)		86.55 (15.68)		9.26 (16.88)		11.50 (88.53)		2924
3	7	574.6 (.42)		60.05 (15.26)		7.10 (14.77)		8.95 (89.05)		2060
3	18	394.2 (.45)		35.0 (17.66)		6.05 (18.17)		5.49 (106.22)		1468
6	3	907.0 (.42)		82.10 (16.09)		8.24 (20.08)		9.64 (99.05)		2882
6	5	1047.5 (.40)		96.75 (15.57)		11.18 (16.50)		14.77 (87.32)		3400
22	3	95.3 (.42)		10.0 (18.03)		.72 (20.08)		0.87 (99.05)		321
25	3	1079.0 (.42)		106.0 (16.16)		13.76 (20.08)		13.99 (99.05)		3828
27	5	968.5 (.40)		90.0 (15.32)		9.22 (16.50)		11.54 (87.32)		2933
28	1	1676.0 (.42)		184.33 (15.76)		24.35 (16.88)		27.89 (88.53)		6489
29	2	574.5 (.51)		84.75 (16.96)		10.48 (16.18)		13.16 (97.76)		3186
29	18	454.7 (.45)		52.50 (16.21)		5.25 (18.17)		6.45 (106.22)		1836
33	12	555.8 (.42)		46.08 (18.01)		4.50 (15.94)		6.02 (82.76)		1633
34	18	311.7 (.45)		26.0 (16.34)		3.93 (18.17)		4.27 (106.22)		1095
35	8	2016.6 (.42)		150.0 (14.74)		23.35 (14.65)		25.14 (86.70)		5580
42	3	816.0 (.42)		94.75 (15.97)		10.61 (20.07)		12.85 (99.05)		3342
42	7	606.1 (.42)		71.0 (13.06)		8.17 (14.77)		11.82 (89.05)		2355
47	2	1021.9 (.51)		96.55 (17.04)		11.43 (16.18)		11.89 (97.76)		3514
73	5	524.6 (.40)		50.08 (14.72)		4.19 (16.50)		4.88 (87.32)		1442
87	3	266.1 (.42)		25.0 (16.18)		2.0 (20.08)		2.34 (99.05)		788
89	7	744.6 (.42)		92.02 (13.51)		7.01 (14.77)		11.50 (89.05)		2684
91	2	662.7 (.51)		67.05 (15.81)		7.45 (16.18)		8.20 (97.76)		2320
91	7	2179.7 (.42)		223.62 (14.33)		33.85 (14.77)		32.64 (89.05)		7527
95	2	1327.4 (.51)		156.55 (17.38)		21.55 (16.18)		25.15 (97.76)		6205
114	18	173.6 (.45)		15.0 (17.06)		1.07 (18.17)		1.28 (106.22)		489
144	8	444.6 (.42)		32.17 (15.65)		16.86 (14.65)		11.05 (86.70)		1891
154	15	675.1 (.38)		40.0 (16.11)		3.15 (29.75)		3.69 (99.57)		1334
435	3	370.7 (.42)		30.0 (15.46)		1.95 (20.08)		2.41 (99.05)		897
480	9	2198.0 (.37)		113.17 (18.60)		16.53 (16.47)		18.64 (87.91)		4829
607	5	616.1 (.40)		40.0 (15.46)		2.68 (16.50)		4.12 (87.32)		1269
801	1	602.0 (.42)		40.5 (15.37)		7.46 (16.88)		6.58 (88.53)		1584
814	12	307.3 (.42)		22.6 (21.24)		7.08 (15.94)		7.00 (82.76)		1301
826	1	578.5 (.42)		47.48 (14.25)		3.54 (16.88)		5.44 (88.53)		1461
828	5	872.2 (.40)		67.73 (14.99)		4.86 (16.50)		5.91 (87.32)		1960
869	18	636.7 (.45)		38.18 (16.25)		3.94 (18.17)		3.21 (106.22)		1319
873	6	271.0 (.41)		20.0 (16.11)		1.16 (13.44)		1.57 (87.16)		586
873	12	348.4 (.42)		27.50 (17.25)		1.61 (15.94)		2.20 (82.76)		828

TABLE G-1. ESTIMATES OF SCRTD ROUTE COSTS DURING THE ~~PEAK~~ BASE PERIOD ~~(CONTINUED)~~

Line	Div.	(VM)	+	(VH)	+	(PO)	+	(PB)	=	Base Cost ($)
2	2	1400.0 (.51)		129.0 (13.51)		15.23 (16.18)		4.39 (97.76)		3132
3	1	1177.0 (.42)		127.0 (12.12)		11.74 (16.88)		5.50 (88.53)		2718
3	7	720.4 (.42)		75.0 (10.80)		8.90 (14.77)		3.05 (89.05)		1516
3	18	534.7 (.45)		53.0 (12.54)		3.95 (18.17)		2.51 (106.22)		1244
6	3	965.0 (.42)		86.0 (13.12)		7.75 (20.08)		3.36 (99.05)		2022
6	5	1114.5 (.40)		102.25 (12.59)		11.82 (16.50)		4.23 (87.32)		2308
22	3	167.7 (.42)		16.0 (12.51)		1.28 (20.08)		1.13 (99.05)		408
25	3	804.0 (.42)		79.0 (12.42)		10.24 (20.08)		3.01 (99.05)		1823
27	5	1342.5 (.40)		124.0 (13.27)		12.78 (16.50)		4.46 (87.32)		2783
28	1	1835.0 (.42)		201.0 (11.58)		26.65 (16.88)		6.11 (88.53)		4089
29	2	686.5 (.51)		101.25 (12.41)		12.52 (16.18)		3.83 (97.76)		2184
29	18	671.3 (.45)		77.0 (13.83)		7.75 (18.17)		3.54 (106.22)		1884
33	12	927.2 (.42)		76.0 (13.79)		7.50 (15.99)		2.98 (82.76)		1084
33	18	301.2 (.45)		25.0 (13.13)		4.07 (18.17)		.73 (106.22)		615
35	8	2281.4 (.42)		169.0 (11.49)		20.64 (14.65)		3.85 (86.70)		3536
42	3	875.8 (.42)		101.0 (13.24)		11.39 (20.08)		5.15 (99.05)		2444
42	7	432.8 (.42)		50.0 (12.39)		5.83 (14.77)		2.18 (89.05)		1082
47	2	1032.0 (.51)		97.0 (11.95)		11.56 (16.18)		4.10 (97.76)		2273
73	5	602.4 (.40)		57.5 (13.61)		4.81 (16.50)		3.12 (87.32)		1375
87	3	398.9 (.42)		37.0 (13.49)		3.0 (20.08)		2.66 (99.05)		990
89	7	1273.4 (.42)		157.0 (12.36)		11.99 (14.77)		8.50 (89.05)		3409
91	2	583 3 (.51)		59.0 (12.97)		6.35 (16.18)		1.80 (97.76)		1341
91	7	1362.3 (.42)		139.75 (10.31)		21.15 (14.77)		4.36 (89.05)		2713
95	2	2060.6 (.51)		243.0 (12.61)		33.45 (16.18)		14.85 (97.76)		6108
114	18	311.4 (.45)		26.0 (13.48)		1.93 (18.17)		1.72 (106.22)		708
144	8	135.4 (.42)		9.0 (4.98)		5.13 (14.65)		0 (86.70)		177
154	15	1041.9 (.38)		61.0 (12.07)		4.85 (20.75)		4.31 (99.57)		1662
435	3	770.3 (.42)		62.0 (14.12)		4.05 (20.08)		3.59 (99.05)		1636
480	9	2589.8 (.37)		133.0 (12.70)		19.47 (16.47)		4.35 (87.91)		3350
607	5	1221.9 (.40)		79.0 (13.46)		5.32 (16.50)		3.88 (87.32)		1979
801	1	366.0 (.42)		24.0 (10.59)		4.54 (16.88)		.42 (88.53)		522
814	12	299.7 (.42)		22.0 (9.36)		6.91 (15.94)		0 (82.76)		448
826	1	1217.5 (.42)		99.0 (13.23)		7.46 (16.88)		8.09 (88.53)		522
828	5	1820.7 (.40)		141.0 (13.72)		10.14 (16.50)		8.09 (87.32)		3537
869	18	979.3 (.45)		58.0 (13.79)		6.06 (18.17)		3.79 (106.22)		1753
873	6	663.0 (.41)		48.0 (12.23)		2.84 (13.84)		2.43 (87.16)		1110
873	12	948.6 (.42)		74.0 (14.66)		4.39 (15.94)		3.80 (82.76)		1869

TABLE G-2. ESTIMATES OF AC TRANSIT ROUTE COSTS DURING THE PEAK AND BASE PERIODS

		Peak Cost Estimates						Base Cost Estimates				
Line	Div.	(VM) ·	+	(VH)	=	Peak[a] Cost ($)		(VM)	+	(VH)	=	Base[b] Cost ($)
A	2	.25 (418)		21.34 (24.18)		831		.20 (722)		16.70 (41.79)		1105
G	3	.30 (840)		18.02 (42.32)		1317		0		0		0[c]
K/R/S	4	.29 (5438)		18.62 (251.00)		8118		0		0		0
U	6	.21 (2973)		18.93 (115.44)		3647		0		0		0
11	2	.25 (203)		18.40 (22.70)		614		.25 (135)		18.40 (15.10)		391
22/24	6	.21 (374)		18.93 (24.36)		729		.21 (605)		18.93 (39.43)		1098
31	3	.30 (150)		18.02 (8.57)		259		0		0		0
32	6	.21 (273)		18.93 (16.23)		473		0		0		0
46/87	4	.29 (403)		18.88 (37.27)		1052		.29 (403)		18.49 (37.27)		1052
51/58	2	.25 (1442)		19.80 (147.88)		4116		.25 (1985)		17.38 (182.77)		4527
54	4	.29 (711)		19.12 (62.02)		1767		.29 (711)		18.62 (62.02)		1767
65	2	.25 (329)		18.40 (31.73)		887		.25 (305)		18.40 (29.39)		778
70	3	.30 (351)		18.20 (29.18)		833		.30 (249)		17.90 (20.67)		558
72	2	.25 (1327)		20.07 (108.04)		3323		.25 (2108)		17.36 (171.66)		4466
79	4	.29 (295)		19.57 (25.05)		755		.29 (266)		17.57 (22.58)		601
80/81	4	.29 (630)		23.57 (43.41)		1610		.29 (1420)		16.43 (97.90)		2574
82/83	4	.29 (2447)		19.31 (185.35)		5756		.29 (2964)		17.65 (224.50)		6178
84	4	.29 (179)		19.55 (14.45)		442		.29 (209)		17.82 (16.86)		458
90/92	4	.29 (608)		19.38 (42.10)		1318		.29 (709)		17.97 (49.13)		1380
306	2	.25 (375)		18.40 (23.50)		694		.25 (215)		18.40 (13.50)		381

NOTES:

[a]Cost estimates include an expansion factor of 1.278 to account for overhead expenses attributable to the peak period (see Section 4.5.2).

[b]Cost estimates include an expansion factor of 1.020 to account for overhead expenses attributable to the base period (see Section 4.5.2).

[c]Routes with a zero base period cost apportionment are express services operating solely during the peak.

TABLE G-3. ESTIMATES OF SDTC ROUTE COSTS DURING THE PEAK AND BASE PERIODS

PEAK COST ESTIMATES

Line	(VM)	+	(VH)	+	Capital Costs[a]	=	Peak Cost ($)
2	478 (.43)		49.0(24.62)		130		1542
3	411 (.43)		46.0(24.89)		142		1464
5	1169 (.43)		70.5(25.43)		200		2495
20	1778 (.43)		75.0(23.63)		220		2758
21	308 (.43)		17.0(25.95)		77		651
27	364 (.43)		30.0(22.34)		100		928
43	320 (.43)		23.0(23.48)		83		761
51	89 (.43)		6.0(22.29)		23		196
80	427 (.43)		25.0(24.22)		87		876
90	715 (.43)		39.5(20.9)		89		1222

BASE COST ESTIMATES

Line	(VM)	+	(VH)	+	Capital Costs[b]		Base Cost($)
2	560 (.43)		57.35(17.45)		23		1264
3	644 (.43)		72.12(18.14)		25		1610
5	1252 (.43)		75.50(16.41)		28		1777
20	1567 (.43)		67.0(17.62)		30		1884
21	691 (.43)		38.33(18.47)		16		1019
27	584 (.43)		48.22(19.77)		19		1223
43	560 (.43)		40.25(19.21)		16		1030
51	170 (.43)		11.38(19.94)		5		307
80	650 (.43)		38.07(18.49)		16		998
90	439 (.43)		24.27(20.53)		11		698

NOTE:

(a) Capital Costs attributed to the peak period are estimated using an expansion Factor of 1.034 (see Section 4.5.2)

(b) Capital Costs attributed to the base period are estimated using an expansion factor of 1.006 (see Section 4.5.2)

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APPENDIX H

ELASTICITY ESTIMATES

TABLE H-1. SCRTD ELASTICITY ESTIMATES

USER GROUP	TIME OF DAY								
	PEAK			OFF-PEAK			ALL DAY		
	MIN	AVG	MAX	MIN	AVG	MAX	MIN	AVG	MAX
Income									
Under $5,000	-.03	-.05	-.07	-.06	-.08	-.10	-.04	-.07	-.08
$5,000 - $9,999	-.03	-.05	-.08	-.08	-.10	-.15	-.05	-.07	-.10
$10,000 - $19,999	-.04	-.06	-.09	-.08	-.10	-.15	-.06	-.08	-.12
$20,000	-.04	-.07	-.10	-.09	-.15	-.20	-.06	-.09	-.15
Age:									
5-13	-.03	-.04	-.06	-.05	-.07	-.10	-.04	-.06	-.08
14-18	-.03	-.04	-.06	-.06	-.08	-.10	-.04	-.06	-.09
19-23	-.04	-.05	-.07	-.08	-.10	-.13	-.05	-.07	-.10
24-31	-.05	-.07	-.08	-.09	-.12	-.15	-.07	-.08	-.13
32-45	-.06	-.07	-.09	-.09	-.13	-.17	-.07	-.10	-.15
46-52	-.06	-.08	-.10	-.10	-.15	-.20	-.08	-.11	-.17
53-62	-.07	-.10	-.15	-.10	-.17	-.25	-.09	-.13	-.20
63	-.40	-.50	-.70	-.25	-.40	-.60	-.20	-.30	-.50
Gender:									
Male	-.05	-.07	-.09	-.09	-.17	-.25	-.07	-.13	-.14
Female	-.04	-.05	-.08	-.06	-.13	-.20	-.09	-.15	-.17
Entire	-.04	-.09	-.10	-.07	-.15	-.20	-.06	-.10	-.15

TABLE H-1. SCRTD ELASTICITY ESTIMATES (CONTINUED)

User Group	Trip Length: less than 1.0-4.0 Minimum	Average	Maximum	4.0-15.0 Minimum	Average	Maximum	15.0-25.0 and greater Minimum	Average	Maximum
Income:									
Entire System	-.04	-.07	-.13	-.06	-.09	-.17	-.09	-.15	-.20
under 5,000	-.08	-.11	-.15	-.05	-.07	-.09	-.07	-.08	-.10
5,000-9,999	-.06	-.09	-.13	-.07	-.10	-.13	-.09	-.12	-.16
10,000-19,999	-.05	-.08	-.11	-.09	-.12	-.15	-.13	-.16	-.20
20,000 and over	-.04	-.06	-.09	-.10	-.14	-.17	-.15	-.19	-.23
Age:									
5-13	-.10	-.13	-.17	-.06	-.08	-.10	-.09	-.11	-.14
14-18	-.10	-.12	-.15	-.08	-.11	-.13	-.11	-.13	-.16
19-23	-.08	-.11	-.13	-.10	-.13	-.15	-.14	-.16	-.19
24-31	-.08	-.09	-.10	-.13	-.15	-.17	-.17	-.20	-.23
32-45	-.06	-.07	-.08	-.13	-.15	-.17	-.20	-.22	-.25
46-52	-.05	-.06	-.07	-.15	-.17	-.20	-.20	-.24	-.28
53-62	-.04	-.05	-.06	-.08	-.13	-.18	-.14	-.17	-.20
63 and over	-.03	-.04	-.05	-.06	-.12	-.18	-.12	-.16	-.20
Gender:									
Male	-.04	-.07	-.10	-.09	-.16	-.23	-.18	-.22	-.27
Female	-.07	-.12	-.17	-.06	-.11	-.16	-.07	-.13	-.20

TABLE H-2. AC TRANSIT ELASTICITY ESTIMATES

	Time of Day								
User Group	Peak			Off-Peak			All Day		
Income:	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Under $5,000	-.06	-.10	-.14	-.10	-.15	-.20	-.08	-.15	-.17
5,000-9,999	-.08	-.12	-.17	-.14	-.19	-.24	-.11	-.17	-.20
10,000-19,999	-.10	-.15	-.20	-.17	-.24	-.28	-.14	-.20	-.25
20,000 and over	-.13	-.19	-.25	-.23	-.28	-.33	-.16	-.23	-.28
Age:									
5-13	-.06	-.08	-.10	-.09	-.13	-.18	-.07	-.11	-.15
14-18	-.06	-.09	-.10	-.13	-.16	-.20	-.09	-.13	-.17
19-23	-.08	-.11	-.15	-.15	-.20	-.26	-.13	-.18	-.23
24-31	-.10	-.14	-.18	-.18	-.23	-.28	-.15	-.20	-.25
32-45	-.13	-.18	-.23	-.22	-.26	-.30	-.17	-.22	-.27
46-52	-.13	-.18	-.23	-.22	-.26	-.30	-.17	-.22	-.27
53-62	-.17	-.21	-.25	-.24	-.28	-.33	-.20	-.24	-.28
63 and over	-.60	-.85	-1.0	-.34	-.43	-.50	-.40	-.50	-.70
Gender:									
Male	-.09	-.14	-.20	-.24	-.27	-.30	-.10	-.18	-.28
Female	-.07	-.13	-.16	-.17	-.20	-.23	-.08	-.14	-.20
Entire	-.08	-.13	-.17	-.20	-.25	-.30	-.08	-.17	-.25

TABLE H-2. AC TRANSIT ELASTICITY ESTIMATES (CONTINUED)

User Group	Trip Length: less than 1.0-4.0 Minimum	Average	Maximum	4.0-15.0 Minimum	Average	Maximum	15.0-25.0 and over Minimum	Average	Maximum
Income:									
Entire System	-.09	-.14	-.22	-.13	-.18	-.26	-.17	-.23	-.30
Under 5,000	-.14	-.19	-.25	-.11	-.14	-.16	-.16	-.17	-.20
5,000-9,999	-.11	-.16	-.21	-.15	-.17	-.21	-.18	-.21	-.25
10,000-19,999	-.10	-.14	-.18	-.17	-.21	-.25	-.21	-.25	-.29
20,000 and over	-.07	-.09	-.13	-.19	-.23	-.27	-.24	-.29	-.33
Age:									
5-13	-.11	-.21	-.27	-.21	-.15	-.19	-.17	-.20	-.23
14-18	-.15	-.19	-.25	-.13	-.17	-.21	-.20	-.22	-.26
19-23	-.13	-.18	-.23	-.16	-.21	-.24	-.22	-.25	-.29
24-31	-.12	-.16	-.20	-.19	-.23	-.27	-.25	-.29	-.32
32-45	-.11	-.15	-.19	-.19	-.23	-.27	-.29	-.31	-.35
46-52	-.09	-.13	-.17	-.23	-.27	-.31	-.30	-.33	-.37
53-62	-.08	-.11	-.15	-.14	-.19	-.25	-.22	-.25	-.29
63 and over	-.06	-.09	-.22	-.13	-.19	-.25	-.19	-.24	-.23
Gender:									
Male	-.08	-.13	-.19	-.18	-.24	-.30	-.24	-.30	-.36
Female	-.13	-.20	-.26	-.11	-.16	-.22	-.15	-.22	-.29

TABLE H-3. SDTC ELASTICITY ESTIMATES

User Group	Time of Day								
	Peak			Off-Peak			All Day		
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
Income:									
Under 5,000	-.14	-.17	-.20	-.23	-.26	-.30	-.18	-.22	-.25
5,000-9,999	-.16	-.20	-.24	-.27	-.31	-.34	-.21	-.25	-.29
10,000-19,999	-.18	-.23	-.27	-.30	-.34	-.37	-.24	-.28	-.32
20,000 and over	-.20	-.26	-.30	-.34	-.37	-.40	-.27	-.32	-.35
Age:									
5-13	-.10	-.15	-.20	-.17	-.23	-.29	-.13	-.18	-.24
14-18	-.10	-.15	-.20	-.20	-.27	-.33	-.15	-.21	-.26
19-23	-.14	-.19	-.24	-.24	-.30	-.35	-.19	-.23	-.28
24-31	-.18	-.22	-.27	-.27	-.32	-.37	-.23	-.27	-.32
32-45	-.18	-.22	-.27	-.29	-.34	-.39	-.24	-.29	-.33
46-52	-.20	-.25	-.30	-.33	-.37	-.42	-.26	-.31	-.36
53-62	-.24	-.28	-.33	-.38	-.41	-.45	-.31	-.35	-.39
63 and over	-.80	-1.0	-1.5	-.50	-.60	-.80	-.60	-.75	-.90
Gender:									
Male	-.20	-.26	-.32	-.34	-.39	-.45	-.28	-.33	-.37
Female	-.15	-.21	-.27	-.27	-.30	-.33	-.24	-.26	-.29
Entire	-.13	-.22	-.28	-.30	-.34	-.37	-.16	-.24	-.33

TABLE H-3. SDTC ELASTICITY ESTIMATES (CONTINUED)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980 -341-428/388

User Group	Trip Length								
	less than 1.0-4.0			4.0-15.0			15.0-25.0 and over		
	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum
Income:									
Entire system	-.15	-.22	-.30	-.20	-.27	-.35	-.25	-.32	-.40
Under 5,000	-.20	-.28	-.36	-.17	-.21	-.24	-.25	-.27	-.30
5,000-9,999	-.17	-.23	-.28	-.23	-.25	-.28	-.27	-.30	-.34
10,000-19,000	-.15	-.20	-.25	-.26	-.30	-.35	-.30	-.34	-.39
20,000 and over	-.10	-.13	-.17	-.28	-.33	-.38	-.34	-.39	-.44
Age:									
5-13	-.23	-.30	-.37	-.17	-.22	-.28	-.26	-.29	-.33
14-18	-.20	-.27	-.35	-.19	-.24	-.30	-.29	-.32	-.36
19-23	-.18	-.25	-.33	-.23	-.28	-.34	-.30	-.34	-.39
24-31	-.16	-.23	-.30	-.26	-.31	-.37	-.34	-.38	-.42
32-45	-.16	-.23	-.30	-.28	-.34	-.40	-.38	-.41	-.45
46-52	-.14	-.21	-.27	-.33	-.38	-.43	-.40	-.43	-.47
53-62	-.12	-.18	-.24	-.20	-.26	-.33	-.30	-.34	-.38
63 and over	-.10	-.15	-.20	-.20	-.26	-.33	-.27	-.32	-.37
Gender:									
Male	-.13	-.20	-.28	-.28	-.32	-.37	-.31	-.38	-.45
Female	-.20	-.28	-.36	-.17	-.22	-.28	-.24	-.31	-.38