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EVALUATION OF FARE STRATEGIES FOR THE CAPITAL METRO TRANSIT SYSTEM

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1. Introduction

This report presents the application of an evaluation framework based on market-specific elasticities to the analysis of several alternative fare scenarios for the Capital Metro service area, in terms of their impact on ridership and revenues. The scenarios include: 1) systemwide fare increase or decrease (including systemwide free fare), in order to illustrate the overall sensitivity to fare changes, 2) free off-peak for senior citizens, 3) free off-peak systemwide, and 4) geographically delineated free-fare zones. In addition, a comparison of the relative impacts of increased vehicle-miles (and other service characteristics) to those of lower fares is performed. The methodology, assumptions and results of each of these scenarios are discussed in detail hereafter.

2. Systemwide Fare Changes

This analysis illustrates the change in ridership and revenue that would result from a uniformly applied fare increase or decrease. The impacts are calculated for changes in 10% (of the current fare) increments up to a 50% increase, and decreases down to 100%. Note that the computed values were intended to generate the overall *trend* in ridership response to fare changes, rather than to evaluate this response for the specific levels considered. The elasticity values used for a given market segment were slightly higher (in general) for fare increases than for fare decreases; in addition, a separate free fare scenario was tested using elasticities derived from actual free fare experiments.

The ridership on regular fixed routes and on Park and Ride routes are divided into the following four primary market segments: 1) "full-fare" riders (i.e. those who pay the full cash fare, or pay the full price of a pass); 2) students; 3) senior citizens; and 4) the mobility impaired. Primary market segments 2, 3, and 4 are considered "half-fare" whether they pay cash or use a pass. The ridership on the 'Dillo is not divided into the above primary market segments because all passengers pay the same fare. The four primary market segments (and the 'Dillo ridership) are further divided into more specific segments defined on the basis of all appropriate combinations of the levels of the following factors: captive status (i.e. licence/car, licence/no car, and no licence), pass usage, trip length, and time of travel (i.e. peak vs. off-peak). These are summarized in Table 1. (See Albee and Mahmassani[1] for a more detailed

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[1] Albee, Kathryn E. and Mahmassani, Hani S.; "Transit Fare Elasticities and Free Fare Programs;" Technical Paper CMT-PRCNG-88-2; October 1988.

Table 1. Market Segments and Associated Elasticity Ranges.

MARKET SEGMENTS	ELAS.- INCREASE			ELAS.-DECREASE			ELAS.-FREE FARE		
Regular Routes									
FULL FARE	Lower	Middle	Higher	Lower	Middle	Higher	Lower	Middle	Higher
LC-NP-PK-ST	-0.09	-0.35	-0.60	-0.09	-0.32	-0.55	-0.05	-0.35	-0.64
LC-NP-PK-LT	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
LC-NP-OPK-ST	-0.18	-0.41	-0.63	-0.18	-0.41	-0.63	-0.08	-0.36	-0.64
LC-NP-OPK-LT	-0.12	-0.38	-0.63	-0.12	-0.38	-0.63	-0.08	-0.36	-0.64
LNC-NP-PK-ST	-0.09	-0.35	-0.60	-0.09	-0.32	-0.55	-0.05	-0.35	-0.64
LNC-NP-PK-LT	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
LNC-NP-OPK-ST	-0.18	-0.40	-0.62	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
LNC-NP-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
NL-NP-PK-ST	-0.09	-0.35	-0.60	-0.09	-0.32	-0.55	-0.05	-0.35	-0.64
NL-NP-PK-LT	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
NL-NP-OPK-ST	-0.18	-0.40	-0.62	-0.18	-0.40	-0.62	-0.08	-0.36	-0.64
NL-NP-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
LC-P-PK-ST	-0.09	-0.35	-0.60	-0.09	-0.32	-0.55	-0.05	-0.35	-0.64
LC-P-PK-LT	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
LC-P-OPK-ST	-0.18	-0.41	-0.63	-0.18	-0.41	-0.63	-0.08	-0.36	-0.64
LC-P-OPK-LT	-0.12	-0.38	-0.63	-0.12	-0.38	-0.63	-0.08	-0.36	-0.64
LNC-P-PK-ST	-0.09	-0.35	-0.60	-0.09	-0.32	-0.55	-0.05	-0.35	-0.64
LNC-P-PK-LT	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
LNC-P-OPK-ST	-0.18	-0.40	-0.62	-0.18	-0.40	-0.62	-0.08	-0.36	-0.64
LNC-P-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
NL-P-PK-ST	-0.09	-0.35	-0.60	-0.09	-0.32	-0.55	-0.05	-0.35	-0.64
NL-P-PK-LT	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
NL-P-OPK-ST	-0.18	-0.40	-0.62	-0.18	-0.40	-0.62	-0.08	-0.36	-0.64
NL-P-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
1/2 FARE--STUDENTS									
LNC-ST	-0.05	-0.33	-0.60	-0.05	-0.30	-0.55	-0.08	-0.36	-0.64
LNC-LT	-0.05	-0.33	-0.60	-0.05	-0.27	-0.48	-0.08	-0.36	-0.64
LC-ST	-0.05	-0.33	-0.60	-0.05	-0.30	-0.55	-0.08	-0.36	-0.64
LC-LT	-0.05	-0.33	-0.60	-0.05	-0.27	-0.48	-0.08	-0.36	-0.64
NL-ST	-0.05	-0.33	-0.60	-0.05	-0.30	-0.55	-0.08	-0.36	-0.64
NL-LT	-0.05	-0.33	-0.60	-0.05	-0.27	-0.48	-0.08	-0.36	-0.64
1/2 FARE--SENIOR CITIZENS									
LC-NP-ST	-0.23	-0.42	-0.60	-0.18	-0.38	-0.58	-0.08	-0.36	-0.64
LC-NP-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LNC-NP-ST	-0.23	-0.42	-0.60	-0.18	-0.38	-0.58	-0.08	-0.36	-0.64
LNC-NP-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
NL-NP-ST	-0.23	-0.42	-0.60	-0.18	-0.38	-0.58	-0.08	-0.36	-0.64
NL-NP-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LC-P-ST	-0.23	-0.42	-0.60	-0.18	-0.38	-0.58	-0.08	-0.36	-0.64
LC-P-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LNC-P-ST	-0.23	-0.42	-0.60	-0.18	-0.38	-0.58	-0.08	-0.36	-0.64
LNC-P-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
NL-P-ST	-0.23	-0.42	-0.60	-0.18	-0.38	-0.58	-0.08	-0.36	-0.64
NL-P-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64

Table 1. Market Segments and Associated Elasticity Ranges (ctd.).

1/2 FARE--MOBILITY IMPAIRED									
LC-NP-PK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.64
LC-NP-PK-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
LC-NP-OPK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
LC-NP-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
LNC-NP-PK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.64
LNC-NP-PK-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
LNC-NP-OPK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
LNC-NP-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
NL-NP-PK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.64
NL-NP-PK-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
NL-NP-OPK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
NL-NP-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
LC-P-PK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.64
LC-P-PK-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
LC-P-OPK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
LC-P-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
LNC-P-PK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.64
LNC-P-PK-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
LNC-P-OPK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
LNC-P-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
NL-P-PK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.64
NL-P-PK-LT	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
NL-P-OPK-ST	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.36	-0.64
NL-P-OPK-LT	-0.12	-0.36	-0.60	-0.12	-0.33	-0.54	-0.08	-0.36	-0.64
PARK AND RIDE									
FULL FARE									
LC-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
LNC-NP	-0.12	-0.36	-0.60	-0.12	-0.35	-0.57	-0.05	-0.35	-0.64
NL-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.05	-0.35	-0.64
LC-P	-0.09	-0.35	-0.60	-0.09	-0.33	-0.57	-0.05	-0.35	-0.64
LNC-P	-0.09	-0.35	-0.60	-0.09	-0.29	-0.48	-0.05	-0.35	-0.64
NL-P	-0.09	-0.35	-0.60	-0.09	-0.33	-0.57	-0.05	-0.35	-0.64
1/2 FARE--STUDENTS									
LNC	-0.05	-0.33	-0.60	-0.05	-0.27	-0.48	-0.08	-0.36	-0.64
LC	-0.05	-0.33	-0.60	-0.05	-0.27	-0.48	-0.08	-0.36	-0.64
NL	-0.05	-0.33	-0.60	-0.05	-0.27	-0.48	-0.08	-0.36	-0.64
1/2 FARE--SENIOR CITIZENS									
LC-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LNC-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
NL-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LC-P	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LNC-P	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
NL-P	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64

Table 1. Market Segments and Associated Elasticity Ranges (ctd.).

1/2 FARE--MOBILITY IMPAIRED									
LC-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LNC-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
NL-NP	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LC-P	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
LNC-P	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
NL-P	-0.12	-0.36	-0.60	-0.12	-0.30	-0.48	-0.08	-0.36	-0.64
'DILLO									
LC-NP-PK	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.65
LC-NP-OPK	-0.18	-0.41	-0.63	-0.18	-0.41	-0.63	-0.08	-0.42	-0.75
LNC-NP-PK	-0.14	-0.37	-0.60	-0.14	-0.35	-0.55	-0.05	-0.35	-0.65
LNC-NP-OPK	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.42	-0.75
NL-NP-PK	-0.13	-0.37	-0.60	-0.13	-0.34	-0.55	-0.05	-0.35	-0.65
NL-NP-OPK	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.42	-0.75
LC-P-PK	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.05	-0.35	-0.65
LC-P-OPK	-0.18	-0.41	-0.63	-0.18	-0.41	-0.63	-0.08	-0.42	-0.75
LNC-P-PK	-0.14	-0.37	-0.60	-0.14	-0.35	-0.55	-0.05	-0.35	-0.65
LNC-P-OPK	-0.18	-0.39	-0.60	-0.18	-0.37	-0.55	-0.08	-0.42	-0.75
NL-P-PK	-0.13	-0.37	-0.60	-0.13	-0.34	-0.55	-0.05	-0.35	-0.65
NL-P-OPK	-0.17	-0.39	-0.60	-0.17	-0.36	-0.55	-0.08	-0.42	-0.75

LEGEND

LNC=LICENSED-NO CAR
LC=LICENSED-CAR
NL=NO LICENSE
PK=PEAK
OPK=OFF-PEAK
P=PASS
NP=NO PASS
ST=SHORT TRIP
LT=LONG TRIP

explanation of the combinations of the specific market segments corresponding to each of the above primary segments.)

"Current", or base-case, ridership figures are representative of conditions preceding the September merger with the UT-shuttle system. Farebox data from one week in June was used to estimate the percentages of the primary market segments. It is assumed that the percentage of riders who are "full-fare," students, or senior citizens/mobility impaired remain relatively constant over the year. The percentage of riders using transfers or passes is also obtained from the farebox data and assumed to remain constant over the year. Sensitivity analyses have shown that the results are relatively robust with regard to small departures from these assumptions.

The methodology presented in this report treats senior citizens and the mobility impaired as separate market segments, although the farebox counts do not distinguish between these groups. Information from a Capital Metro market survey[2] was used to determine the relative proportions of the two groups.

In the farebox data base, "full-fare" refers to full *cash* price; in the segmentations presented in this report, "full-fare" refers to full *cash or pass* price. Pass users are coded in the farebox as one category whether the pass is a half-fare or full-fare pass. The proportion of pass usage that is "full-" or "half-fare" is assumed to be the same as that for pass sales. The pass sales reports for February-May, 1988, indicate an average of 36% half-fare passes and 64% full-fare passes. The percentage of pass users who transfer is assumed to be the same as that for cash users.

The current, or base-case, ridership value used in the analysis is the number of "linked revenue person-trips," which is equivalent to the total boardings (from the reports) less the number of transfers (cash and pass) and non-revenue trips. The number of transfers are subtracted because the transferring passenger is simply continuing the original trip, and most available model-derived elasticities are applicable to such complete linked trips, rather than to undifferentiated boardings. The number of non-revenue passengers is subtracted from the total boardings because ridership frequency of this group would not be influenced by fare changes.

The large sample of fare elasticities reported in the literature, and reviewed in a previous technical paper,[3] was synthesized, and ranges of elasticities were individually

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2 Nu-Stat, Inc., " CAPITAL METRO Marketing Baseline Study" (Draft); Spring 1988

3 Albee, Kathryn E. and Mahmassani, Hani S.;"Transit Fare Elasticities and Free Fare Programs"

assigned to all appropriate market segments. Reported elasticities were obtained from demand models (and would apply to a fare decrease or increase), before and after studies of fare decreases, before and after studies of fare increases, and UMTA (Urban Mass Transportation Administration) free fare demonstrations. The high and low ends of a range of applicable elasticities were determined for each specific market segment. The upper and lower bounds on the likely ridership and revenue impacts of contemplated fare changes could then be estimated. When the high end of the elasticity spectrum is used, the ridership impact is, by definition, greatest. As an illustration, when the high elasticity is applied to a fare increase, the largest decrease in ridership is obtained. Similarly, using the high elasticity in connection with a fare decrease would lead to a larger increase in ridership than when a low elasticity is used. Note that the high values correspond to the highest reported anywhere, and tend as such to be rather extreme and highly unlikely for the Capital Metro service area.

Unfortunately, this range is often quite large, as the results presented in this report illustrate, and may not be very helpful for policy-making purposes, other than to highlight the need for Austin-specific data. It is helpful to therefore consider less extreme, possibly more representative values towards the middle of the range of elasticities. The middle elasticity for each segment was obtained by averaging the corresponding high and low values. The resulting middle values appear to be towards the higher end of the spectrum encountered for U.S. properties that can be considered comparable to Austin. Therefore, actual values for Austin are likely to be in the lower to middle range of elasticities. Table 1 summarizes the upper and lower ends of the elasticity ranges associated with each market segment, as well as the middle values.

The corresponding revenue impacts are also evaluated. The current revenue is based on all "full-fare" (cash and pass) riders paying 50¢ on regular bus routes and $1.00 on Park and Ride routes, and "half-fare" (cash and pass) riders paying 25¢ on regular routes and 50¢ on Park and Ride routes. Everyone pays 25¢ on the 'Dillo. This analysis assumes that pass holders, on average, use their passes so as to "break-even." This assumption seems to be valid, on average, because the base-case revenue calculated by this method is very close to the reported revenue generated by the farebox and pass sales. In this analysis, the current revenue is $63,100 per week or $265,000 per month (based on 4.2 weeks per month), while the budget report for June, 1988 (the current ridership is based primarily on June data) indicates total farebox and pass sale revenues of $264,858.

For a given fare elasticity ε_k associated with market segment k, the new ridership resulting from a fare decrease (or increase) is determined by the following equation:

$$V_k' = V_{0k} (1 + \varepsilon_k \Delta f_k / f_{0k})$$

where:

V_k' = new ridership

V_{0k} = current ridership

ε_k = fare elasticity

Δf_k = change in fare (negative for fare decrease, positive for fare increase)

f_{0k} = current fare

The total ridership systemwide or for a primary market segment is then obtained by aggregating or summing the ridership in the corresponding specific market segments.

Figures 1-9 show the estimated ridership for each market segment as well as the total revenue that would result from each increment of fare change. For example, Fig. 1 plots this information for regular fixed routes on an average weekday assuming the low elasticities.

Figures 10-12 depict the total (Regular, 'Dillo and Park and Ride) ridership and revenue that would result from the incremental fare changes.

Figures 13 and 14 show the average weekday ridership, by market segment, for the systemwide fare scenario, under the "free fare experiments" elasticities. Figure 15 depicts the total average weekday ridership, by type of service, for the same scenario. Figure 16 presents similar information as Fig. 13 for weekend ridership. The corresponding revenue for all the free fare cases is zero.

Table 2 summarizes the ranges of marginal subsidies per new passenger associated with the systemwide fare decrease and free fare scenarios. This subsidy is calculated by dividing the additional cost by the number of riders (more specifically, the number of linked revenue trips, as previously defined). The additional cost considered in this calculation consists exclusively of the revenues lost because of the lower fares. It does *not* include the cost of providing additional service to accommodate overcrowding that would develop along certain routes at certain times of the day, especially under the middle and high elasticity scenarios. The estimation of such cost requires a more detailed perspective which is outside the scope of the present analysis. Therefore, the

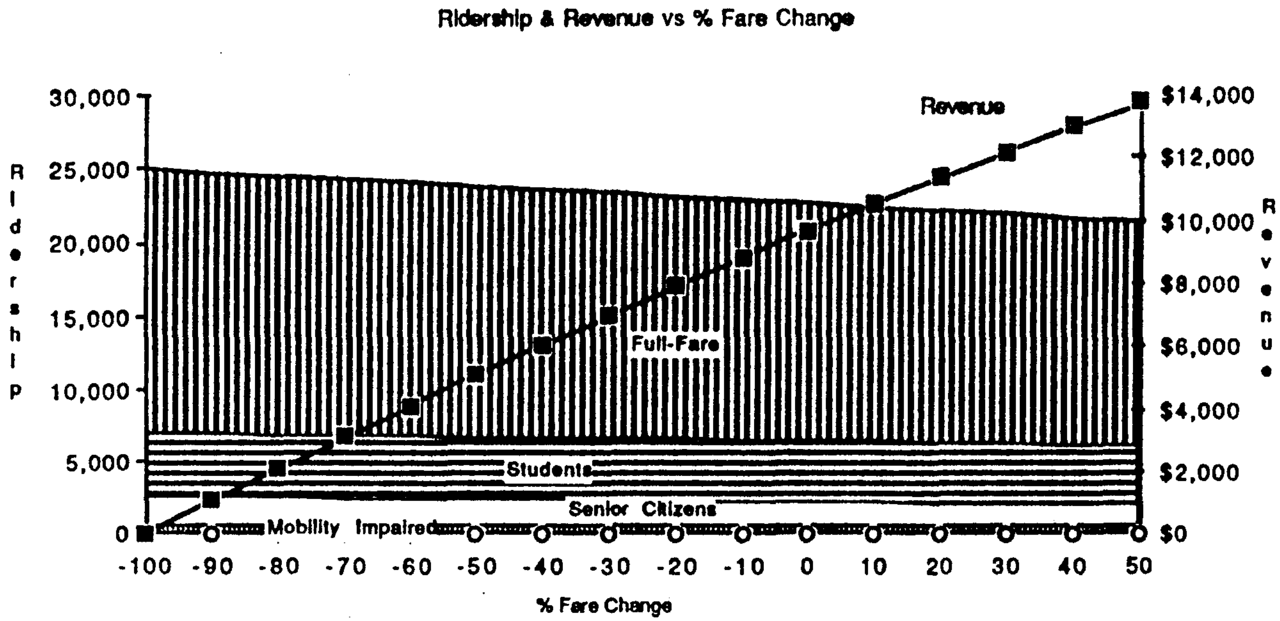


Figure 1. Average Weekday Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Regular Routes, under the Low Fare Elasticities.

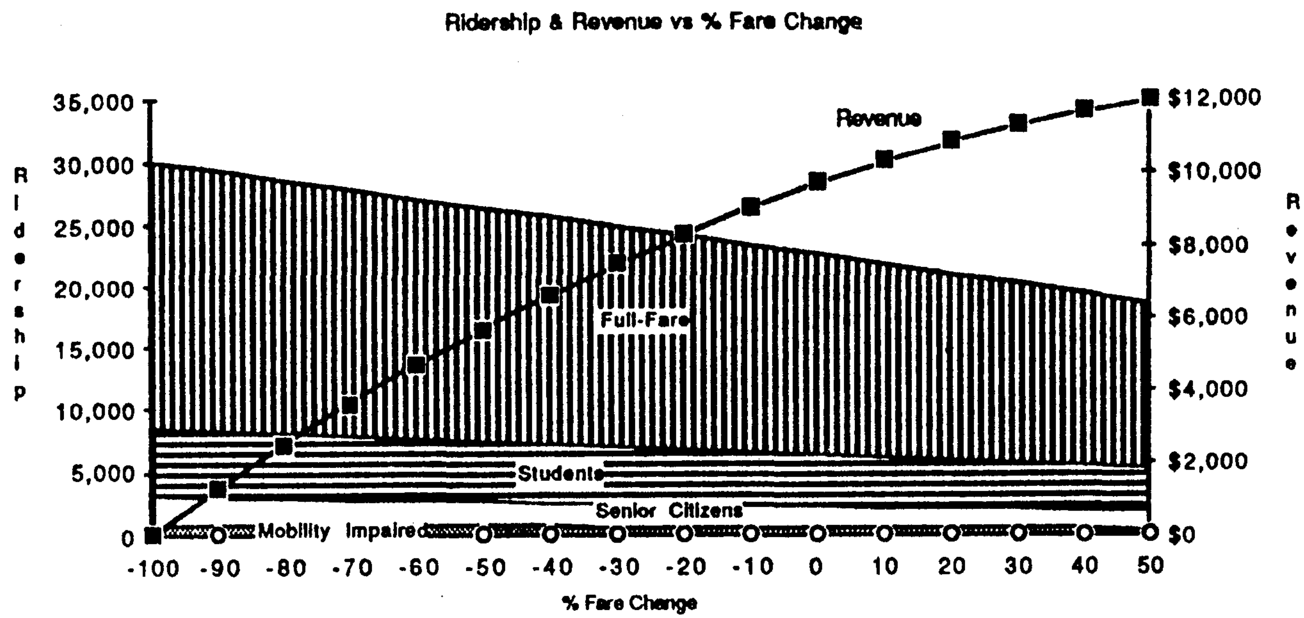


Figure 2. Average Weekday Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Regular Routes, under the Middle Fare Elasticities.

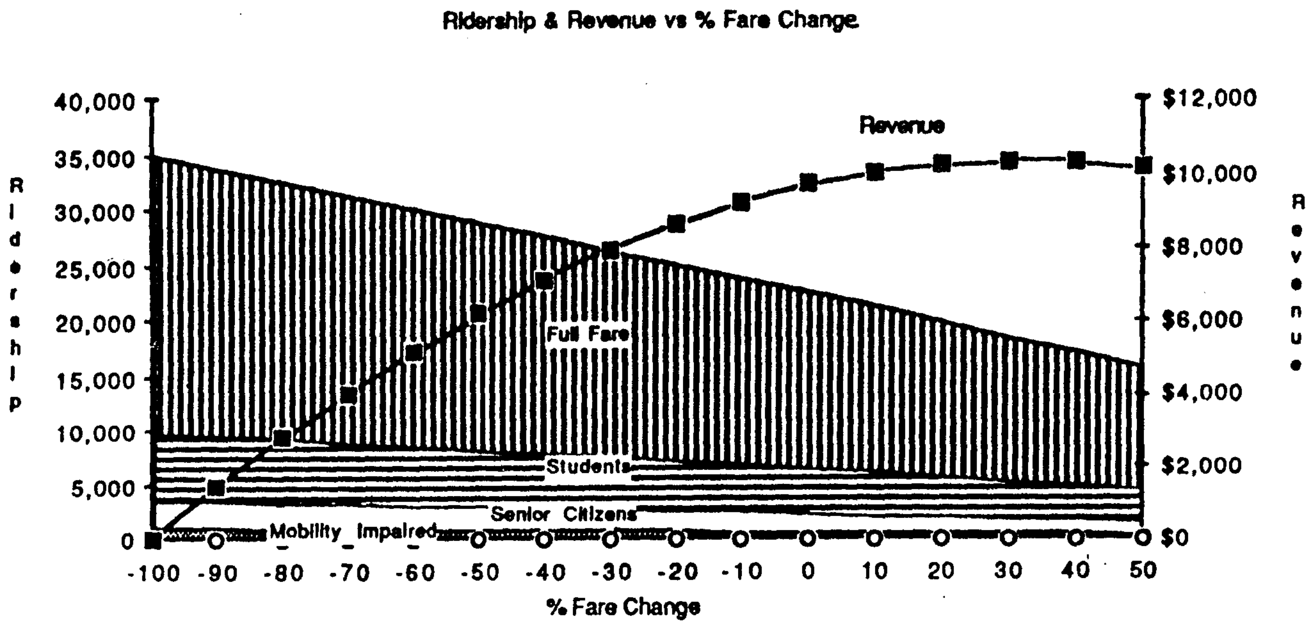


Figure 3. Average Weekday Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Regular Routes, under the High Fare Elasticities.

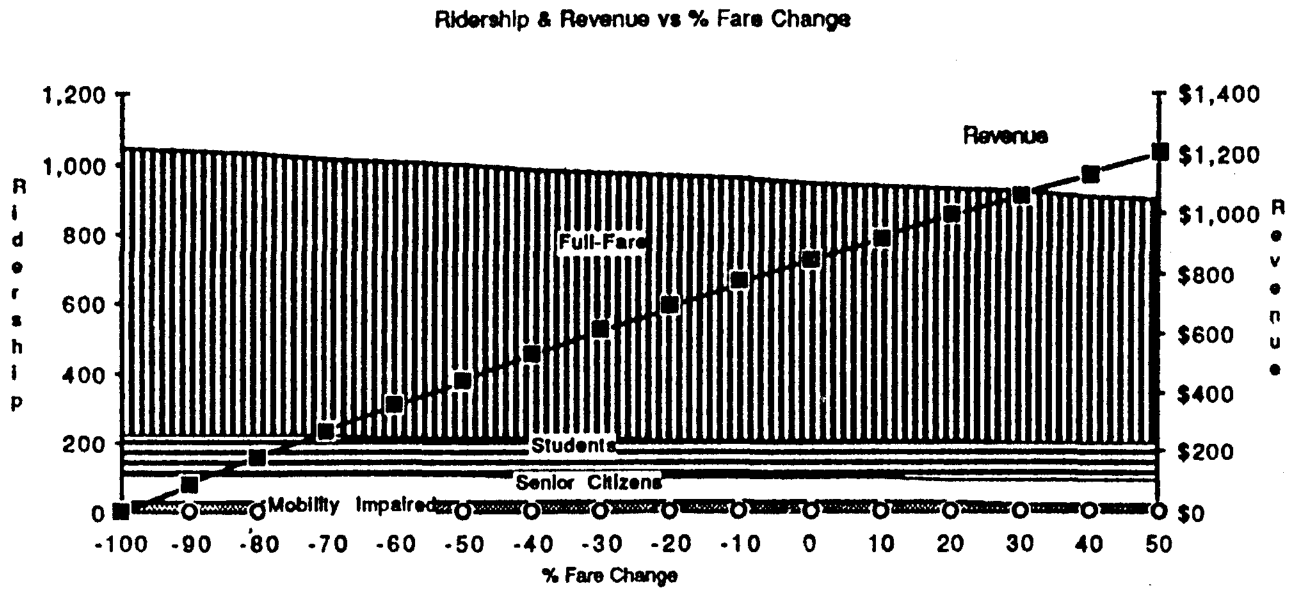


Figure 4. Average Weekday Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Park and Ride Routes, under the Low Fare Elasticities.

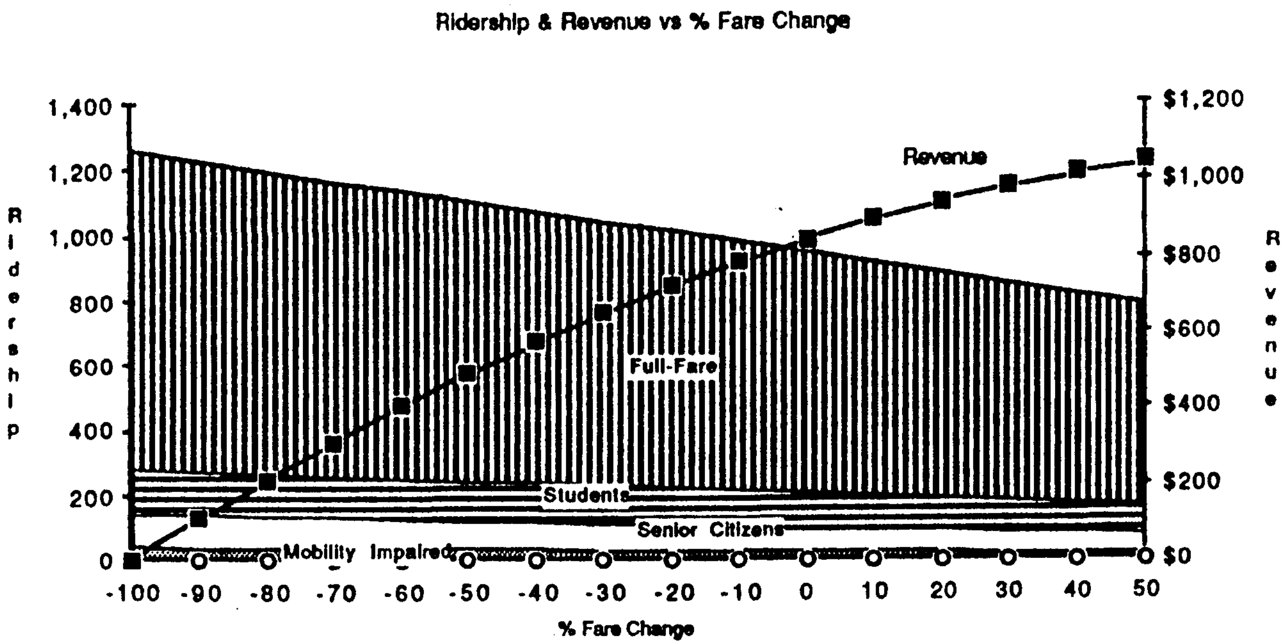


Figure 5. Average Weekday Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Park and Ride Routes, under the Middle Fare Elasticities.

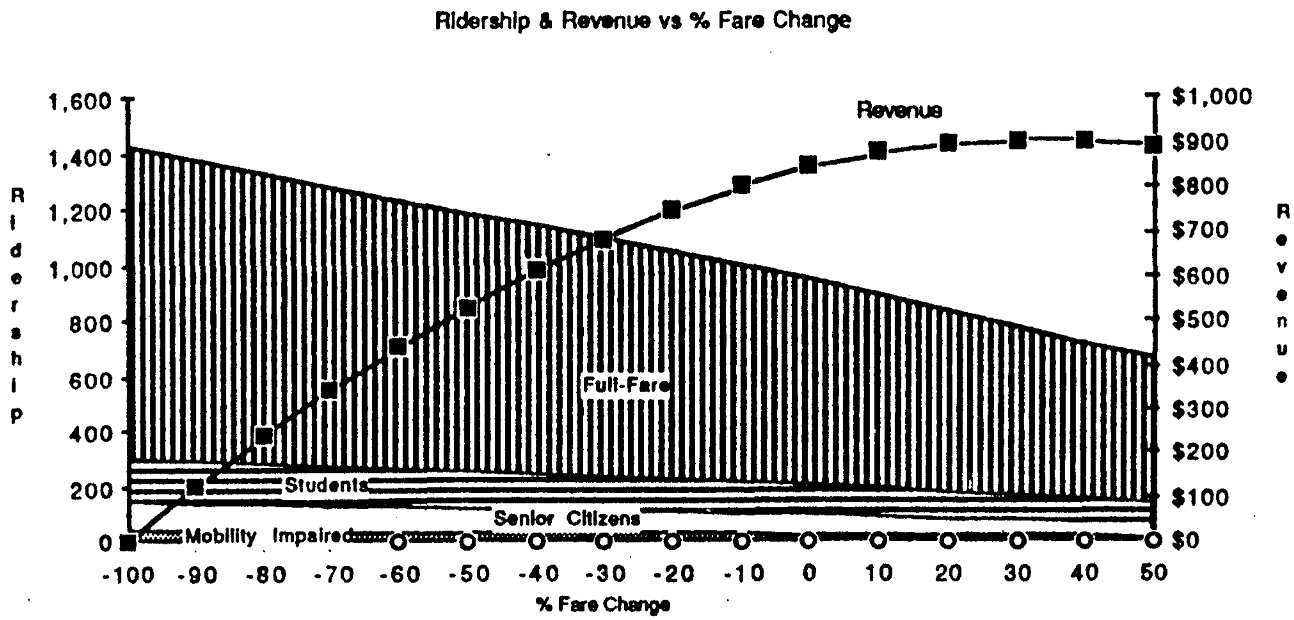


Figure 6. Average Weekday Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Park and Ride Routes, under the High Fare Elasticities.

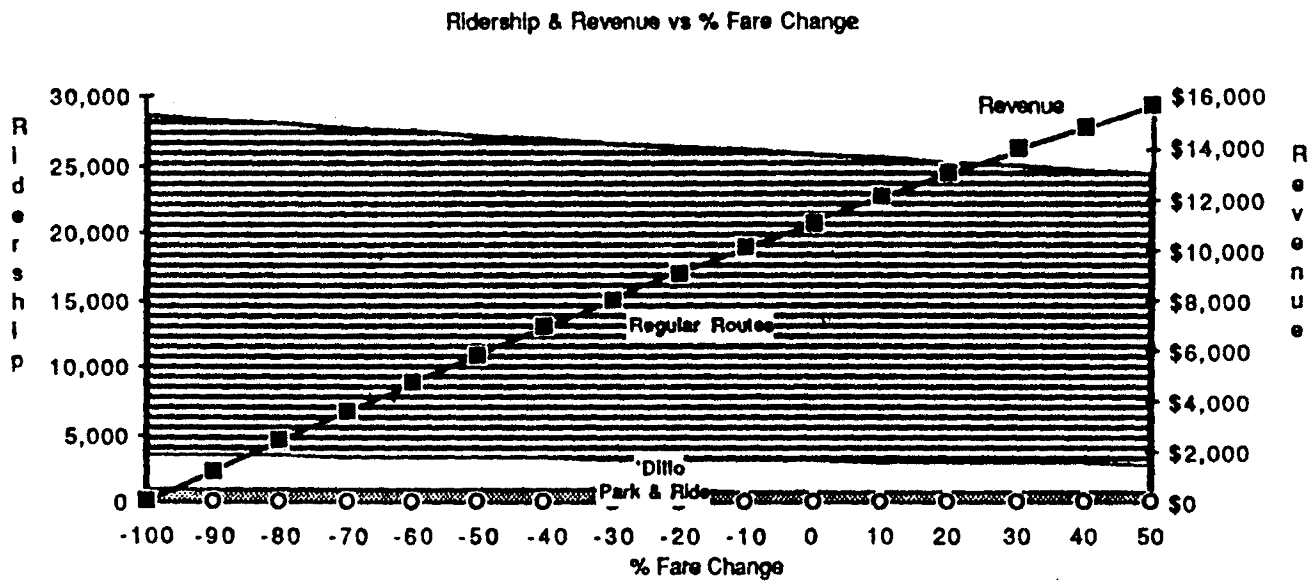


Figure 7. Average Weekday Ridership, by Route Type, and Total Revenue vs. Percent Fare Change under the Low Fare Elasticities

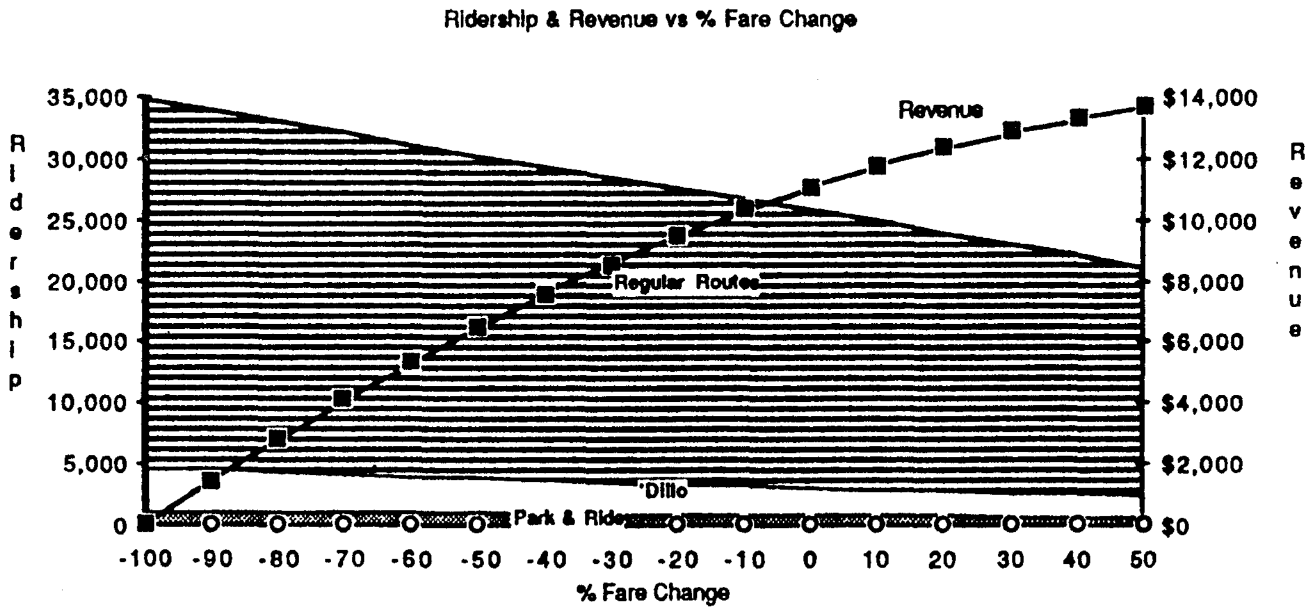


Figure 8. Average Weekday Ridership, by Route Type, and Total Revenue vs. Percent Fare Change under the Middle Fare Elasticities

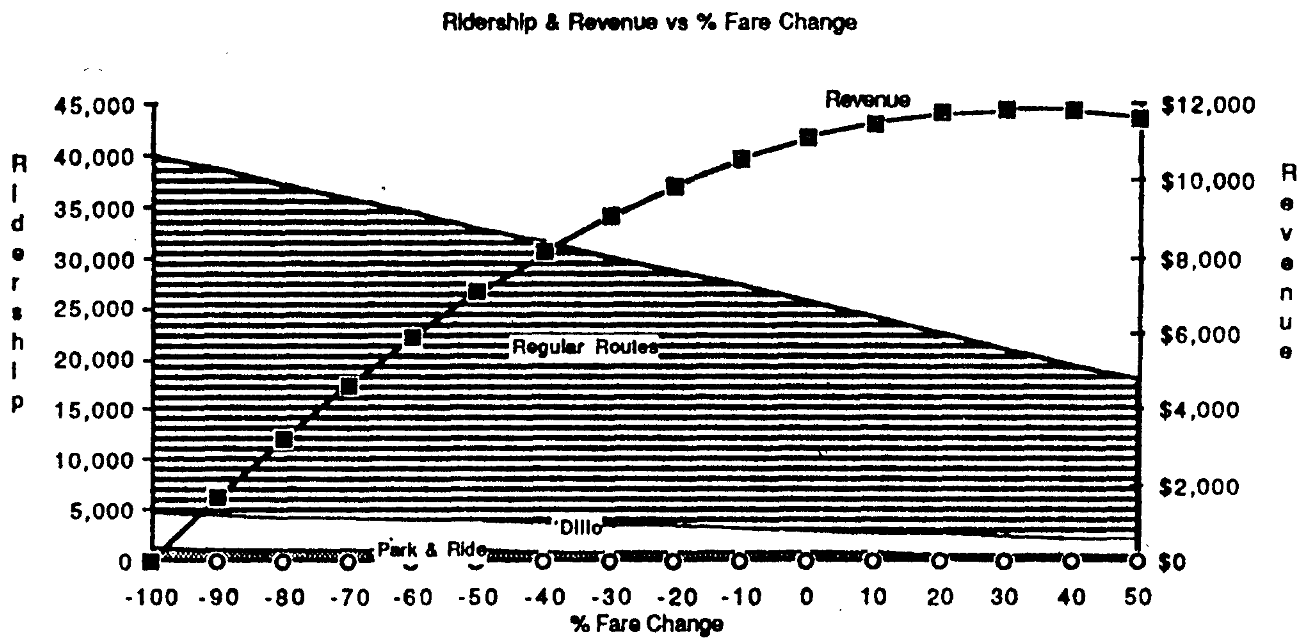


Figure 9. Average Weekday Ridership, by Route Type, and Total Revenue vs. Percent Fare Change under the High Fare Elasticities.

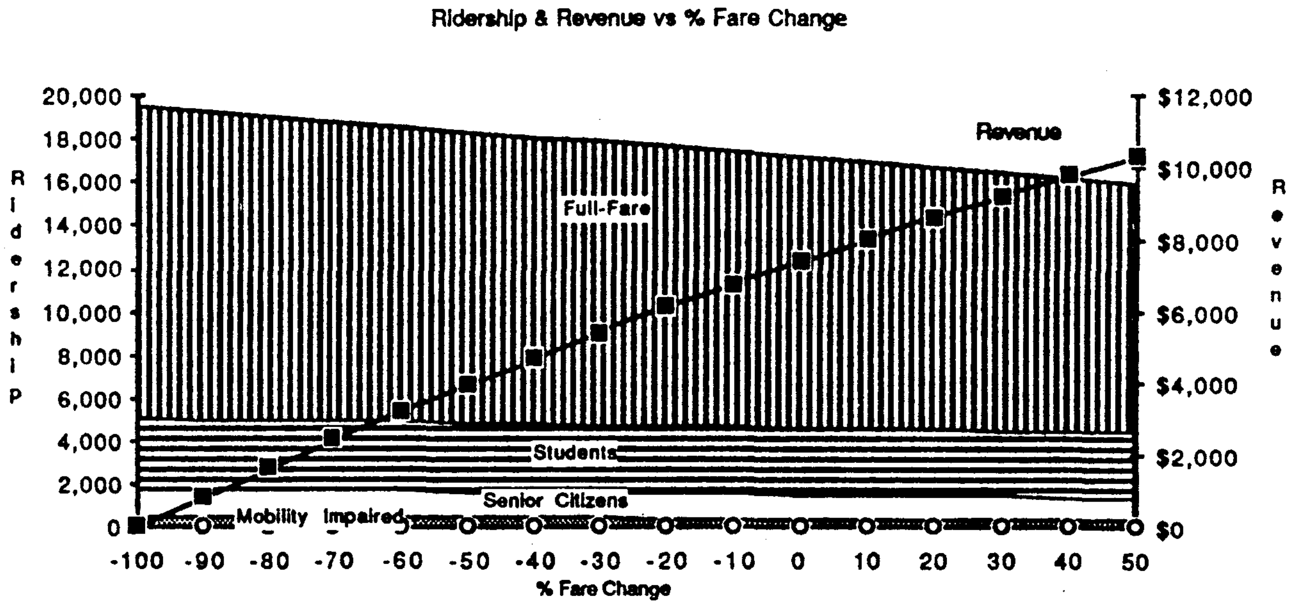


Figure 10. Weekend Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Regular Routes, under the Low Fare Elasticities.

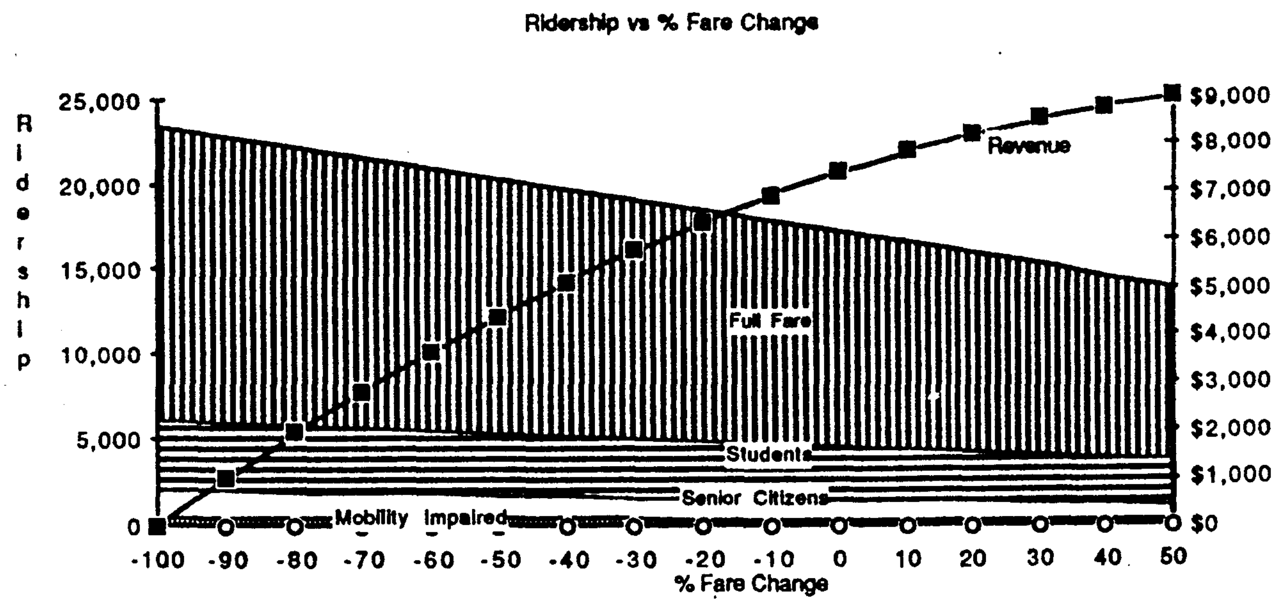


Figure 11. Weekend Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Regular Routes, under the Middle Fare Elasticities.

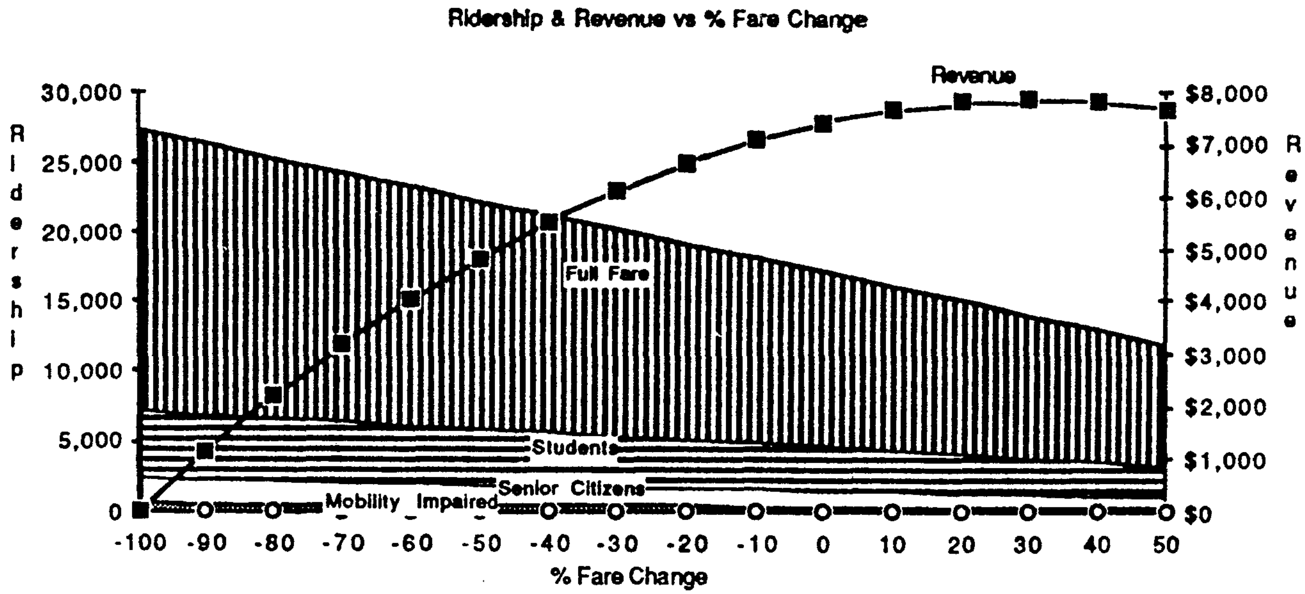


Figure 12. Weekend Ridership, by Market Segment, and Total Revenue vs. Percent Fare Change for Regular Routes, under the High Fare Elasticities.

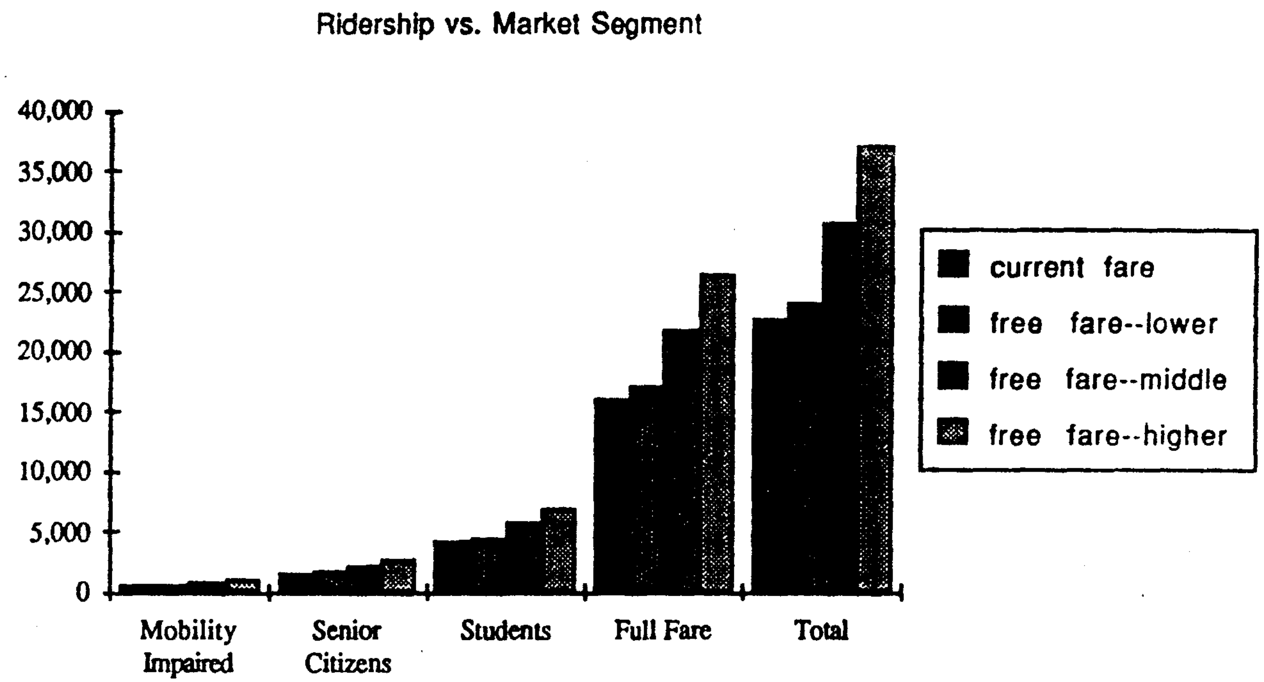


Figure 13. Average Weekday Regular Route Ridership, by Market Segment, for Current Fare and Free Fare under Low, Middle and High Free Fare Elasticities.

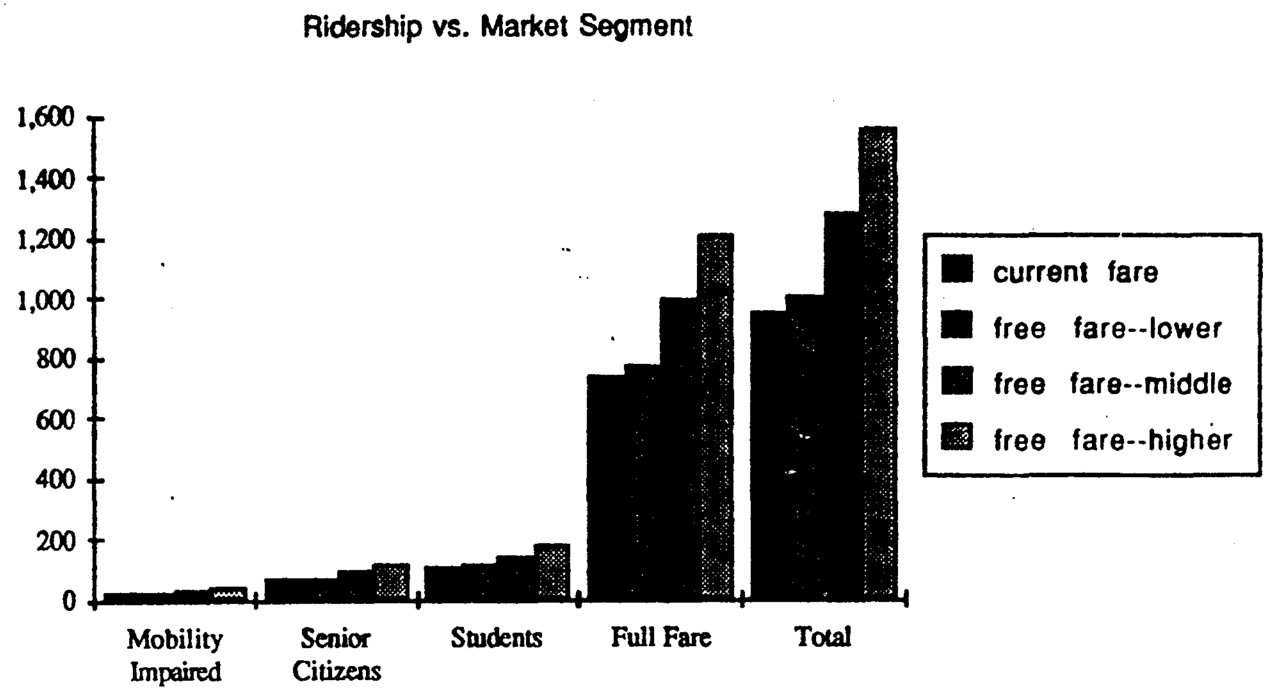


Figure 14. Average Weekday Park and Ride Ridership, by Market Segment, for Current Fare and Free Fare under Low, Middle and High Free Fare Elasticities.

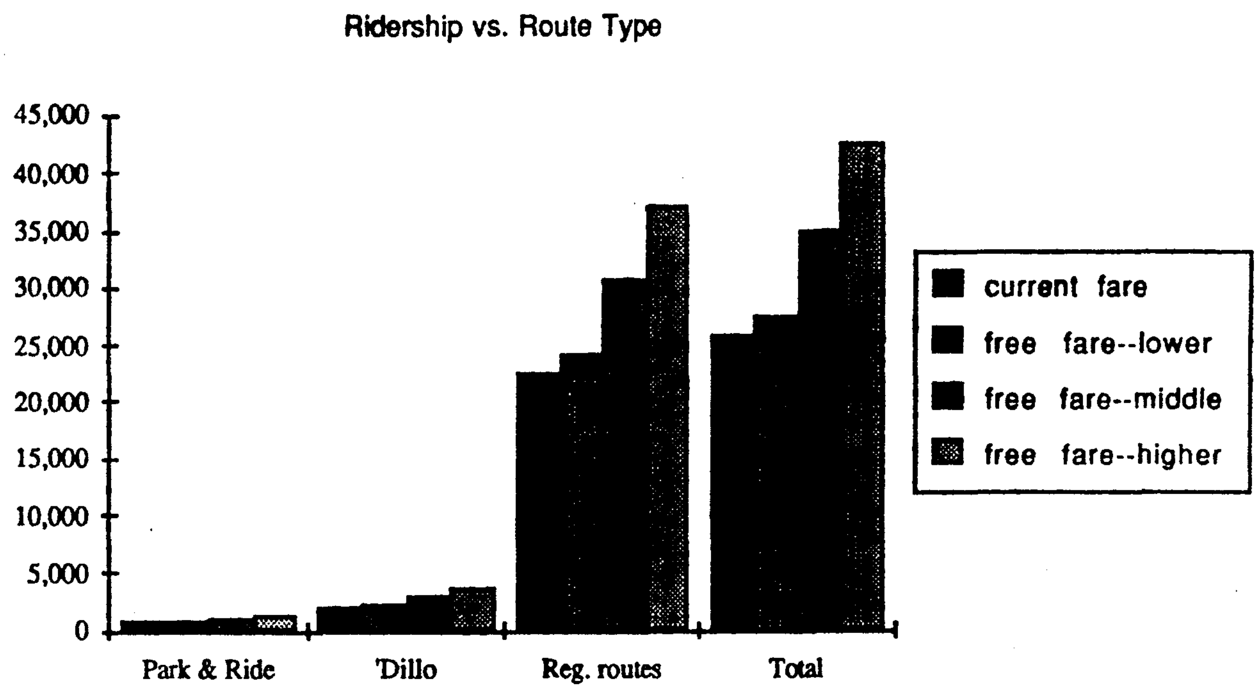


Figure 15. Systemwide Average Weekday Ridership, by Route Type, for Current Fare and Free Fare under Low, Middle and High Free Fare Elasticities.

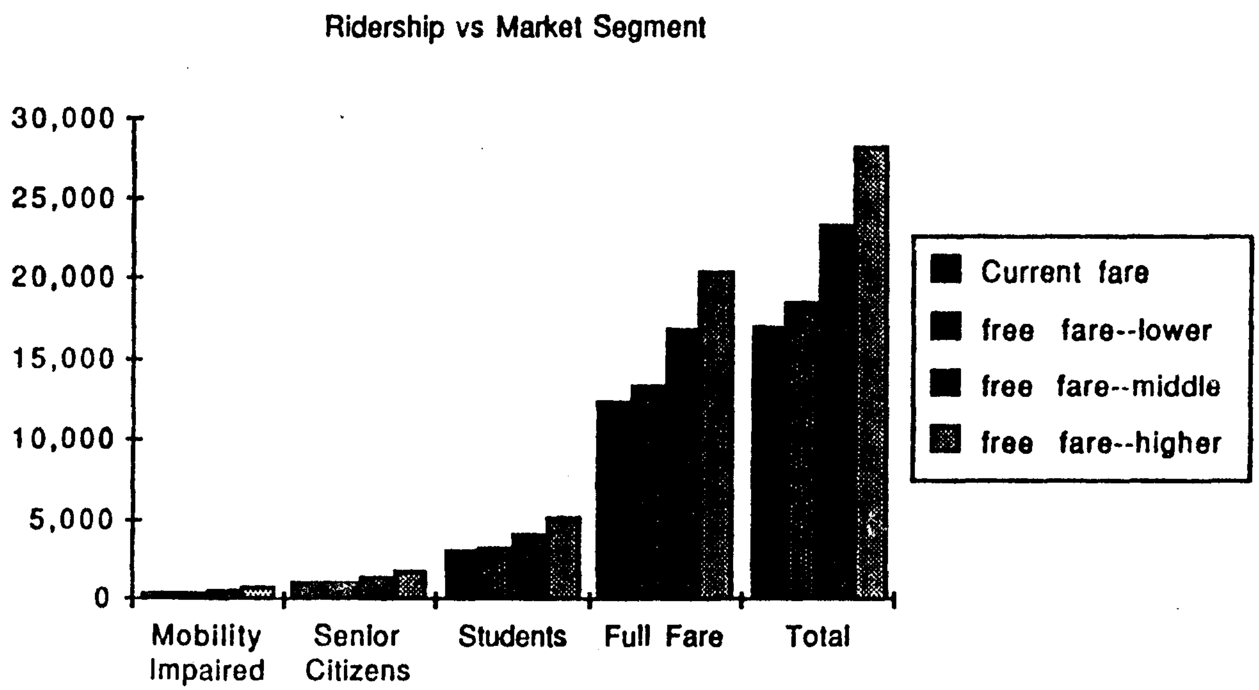


Figure 16. Weekend Regular Route Ridership, by Market Segment, for Current Fare and Free Fare under Low, Middle and High Free Fare Elasticities.

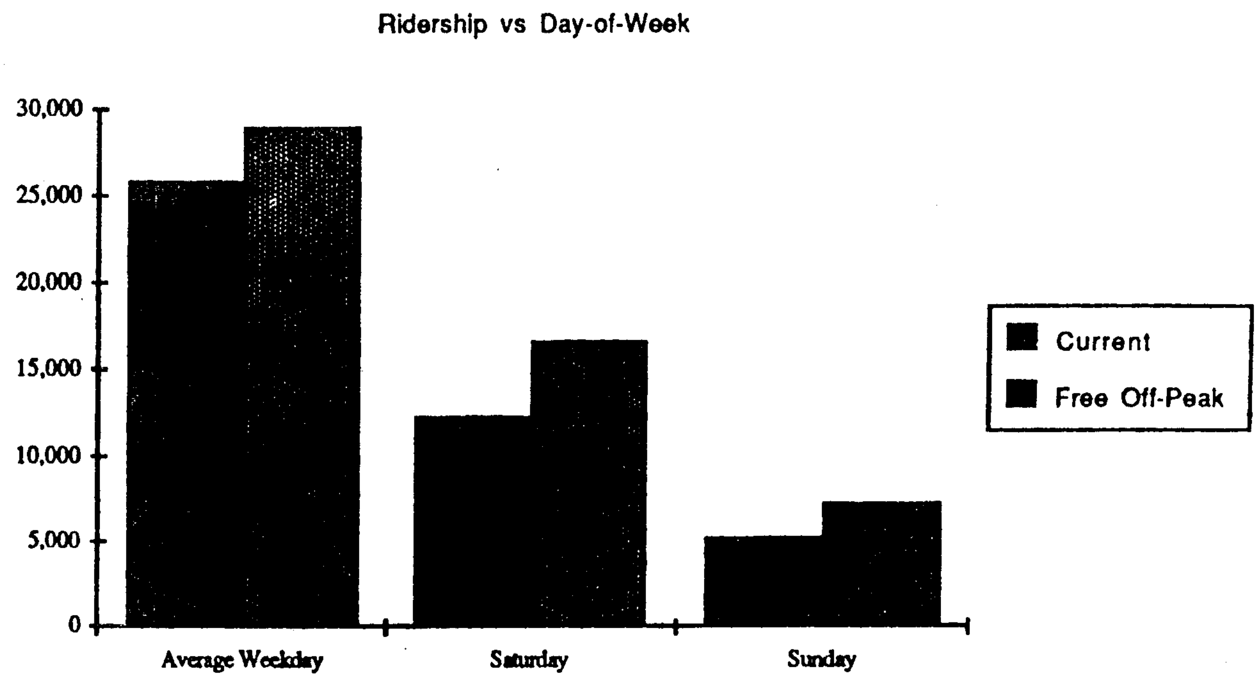


Figure 17. Systemwide Ridership, by Day-of-Week, before and after Implementing Off-Peak Free Fares.

Table 2. Range of Marginal Subsidy per New Rider for Systemwide Fare Increase and Free Fare for the Three Elasticity Levels.

		Fare Decrease	Free Fare
		(Δ cost/Δ passenger gained)	
Regular Routes			
Avg. Wkday	(lower)	$3.62-$4.02	$6.52
	(middle)	0.92- 1.31	1.21
	(higher)	0.39- 0.78	0.67
Weekend	(lower)	2.68- 3.12	5.39
	(middle)	0.78- 1.18	1.21
	(higher)	0.33- 0.73	0.68
'Dillo			
Avg.Wkday	(lower)	1.22- 1.45	4.13
	(middle)	0.21- 0.44	0.67
	(higher)	0.21- 0.44	0.36
Park & Ride			
Avg. Wkday	(lower)	7.82- 8.64	15.67
	(middle)	1.95- 2.74	2.55
	(higher)	0.94- 1.75	1.39

subsidy estimates should be considered as minimum values, with the likelihood of serious underestimation increasing for higher elasticity values. The results in Table 2 illustrate that the cost-effectiveness of fare decreases as a means of inducing ridership is critically dependent on the underlying fare elasticities. It should be stressed further that the high elasticity case is a highly unlikely one for Austin, and is provided here only for illustrative purposes, so as to obtain an absolute upper bound on the potential ridership impact. As noted earlier, the Austin situation can be reasonably expected to lie somewhere between the low and the middle elasticity values.

3. Fare-Free During the Off-Peak

This analysis uses the base-case ridership and revenue values from the above scenario, in connection with the free-fare elasticities, which are applied only to the off-peak market segments. No other fare changes were assumed. The free off-peak period is considered to be between 9:00 A.M. and 3:00 P.M., after 6:00 P.M. until the end of the day's service, and all day Saturday and Sunday.

Figure 17 compares the estimated ridership before and after the free off-peak strategy is implemented, assuming an elasticity in the middle of the range. This comparison is made for average weekday, Saturday and Sunday. The corresponding revenue loss would be 32.3% ($11,100 to $7,510) for an average weekday, and 100% for Saturday ($5,280 to $0) and Sunday ($2,290 to $0). The resulting marginal subsidies are as follows:

$1.13/new passenger on an average weekday

$1.19/new passenger on Saturday, and

$1.20/new passenger on Sunday.

The average marginal subsidy is $1.15/new passenger for the week. Similar analyses were conducted for the lower and higher ends of the elasticity spectrum, resulting in an average marginal subsidy of $5.21/new passenger (low elasticity) and $0.64/new passenger (very high elasticity) for the week.

4. Free Off-Peak for Senior Citizens

An estimate of the increase in senior citizen and overall ridership under the scenario where senior citizens may ride free during the off-peak would provide an interesting test of the estimation process and an opportunity to calibrate the elasticities to the local context. Because Capital Metro has adopted such a policy as of November 1, 1988, it would be useful to compare the estimated ridership increases with the actual eventual increases. Unfortunately, the latter will be difficult to determine due to the lack of adequate observed "before data," as senior citizens and mobility impaired riders were not separated in the farebox counts prior to this program.

The same base-case ridership and revenue values as those described above, as well as the "free-fare" elasticities are used in this analysis. No fare change was assumed for any other market segment. In addition, this analysis did not consider the ridership impacts on the 'Dillo. The number of senior citizens who ride the 'Dillo is relatively small compared to the total who ride the regular routes and Park and Ride routes.

Figure 18a compares the estimated senior citizen ridership before and after the free off-peak for senior citizens strategy is implemented, assuming an elasticity in the middle of the range. This is shown for average weekday, Saturday and Sunday. Figure 18b presents the corresponding total ridership under these scenarios. Figure 19 presents a similar comparison for the estimated revenue. The resulting marginal subsidies are as follows:

$0.69/new passenger on an average weekday

$0.70/new passenger on Saturday, and

$0.69/new passenger on Sunday.

The average marginal subsidy is $0.69/new passenger for the week. Similar analyses were conducted for the lower and higher ends of the elasticity spectrum, resulting in an average marginal subsidy of $3.08 new passenger (low elasticity) and $0.39/new passenger (very high elasticity) for the week.

5. **Free Zones**

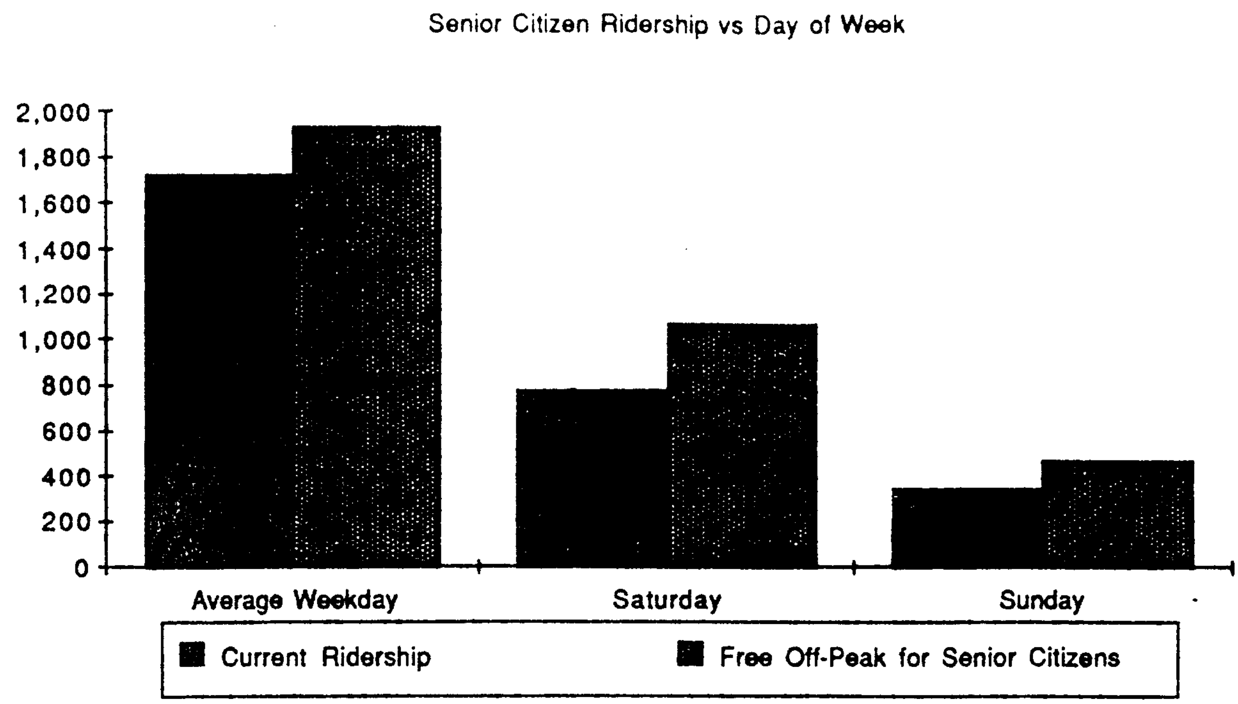
This analysis illustrates the application of the fare impact assessment methodology to geographically-based fare strategies. In particular, we consider the scenario of a central zone where no fares would be charged for trips originating and ending in that zone. Three alternative geographic definitions of such a free zone are considered (see map in Fig. 20):

1) the CBD only,

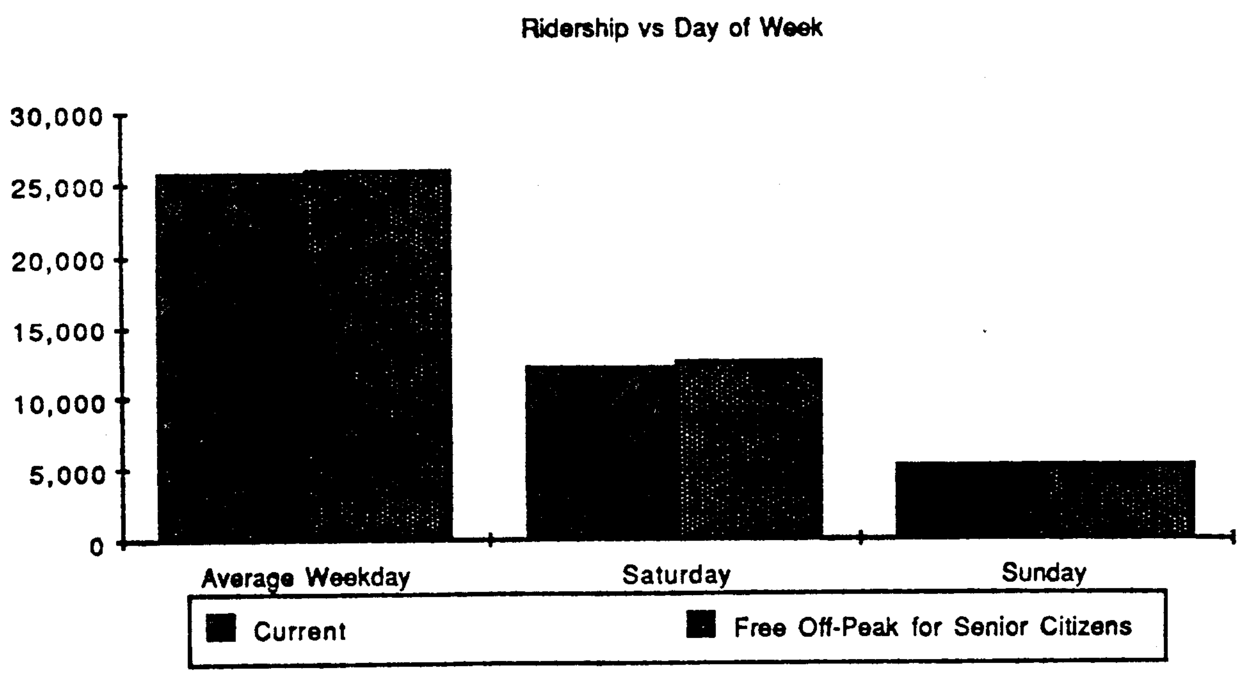
2) the CBD, UT, Zilker Park, and Barton Springs area, and

3) the area from Oltorf (on the South) to 38-1/2 (North), and Exposition (West) to Airport/Pleasant Valley (East).

The boundaries for alternative 1 were selected to include only the CBD. Alternative 2 includes all of alternative 1, the UT area, Palmer Auditorium, and Zilker Park. These "tourist" areas were included to aid Austin visitors. Alternative 3 was selected as a somewhat large area that still allows simple implementation. Care was

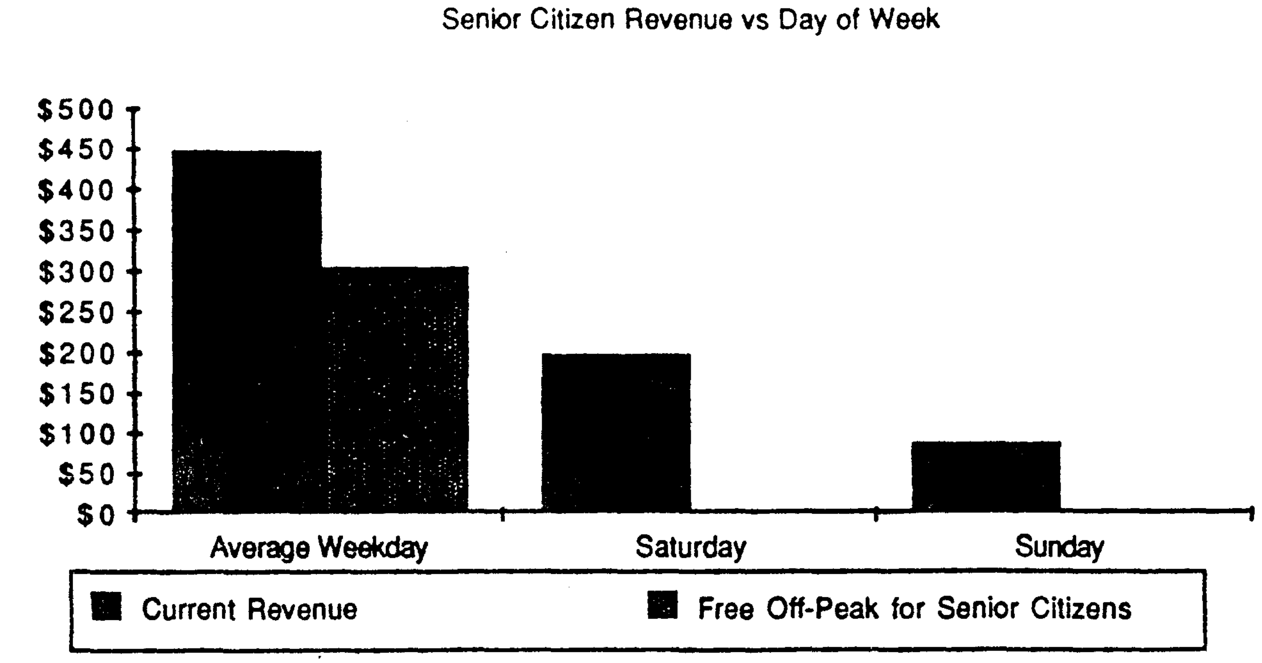


18a. Senior Citizens Only

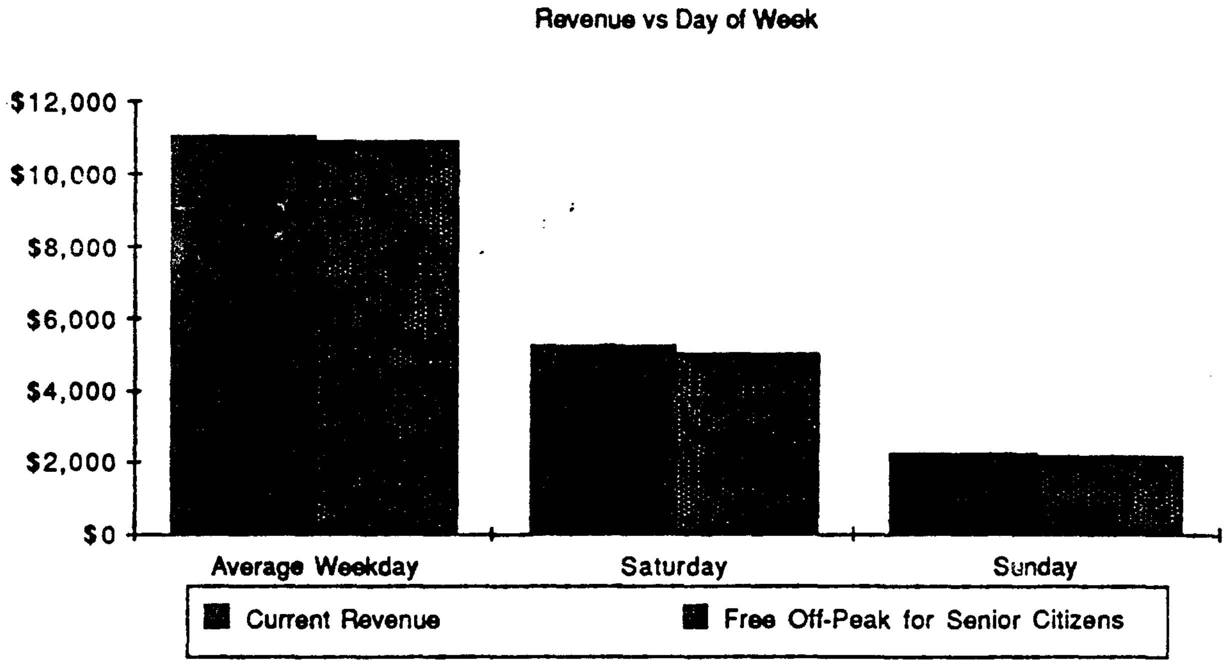


18b. Systemwide

Figure 18. Ridership, by Day-of-Week, before and after Implementing Free Off-Peak Free Fares for Senior Citizens.



19a. Senior Citizens Only



19b. Systemwide

Figure 19. Revenue, by Day-of-Week, before and after Implementing Free Off-Peak Free Fares for Senior Citizens.

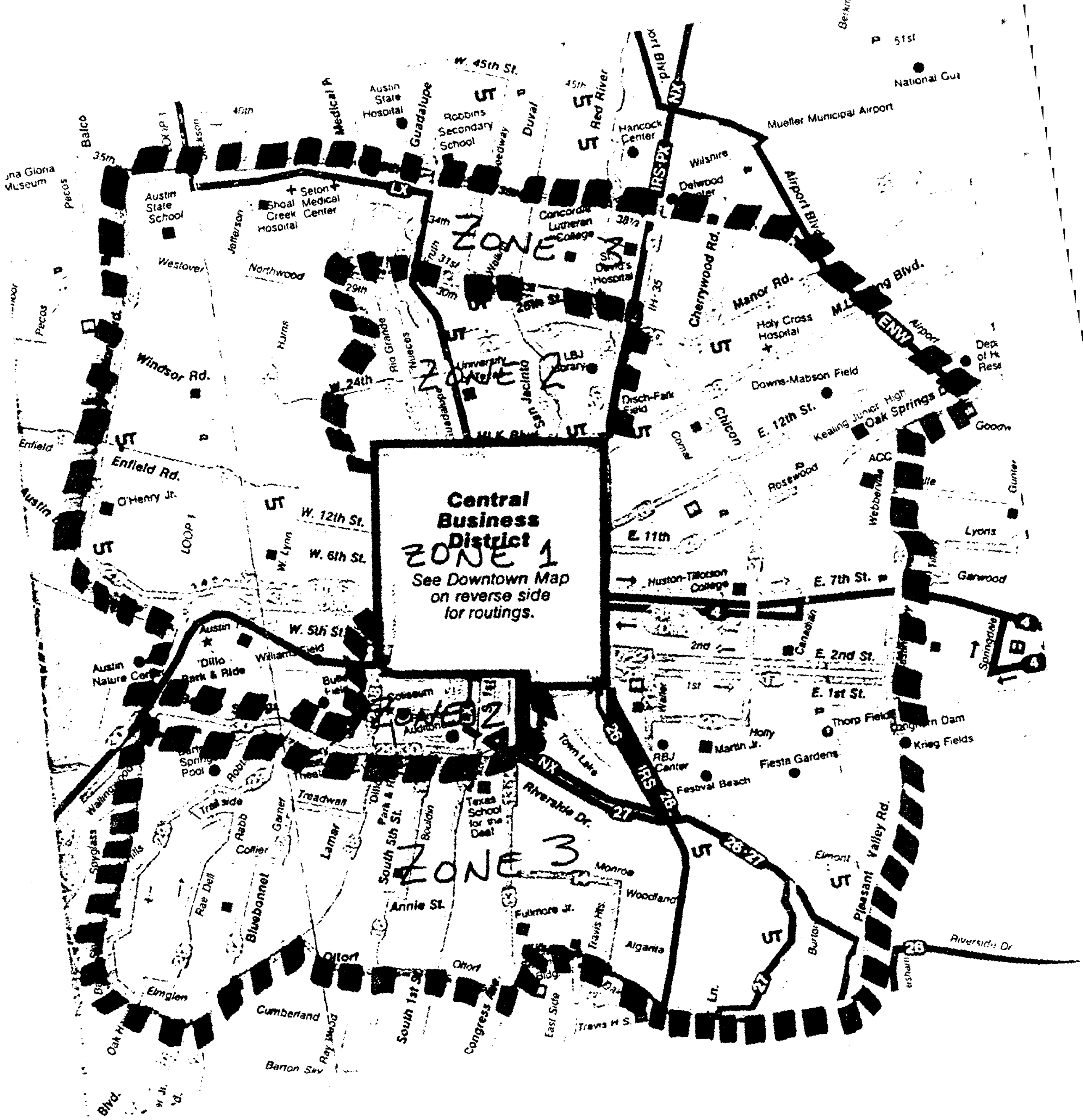


Figure 20. Free Zone Alternatives

taken to avoid having routes that cross into (or out of) the free zone several times. For simplicity, all 'Dillo routes are assumed to be free in all three alternatives. Because Park and Ride routes offer a premium service, the free zones do not apply to them. Furthermore, they do not serve trips with both ends in the free zone.

The three zone alternatives were analyzed with and without those Capital Metro routes which duplicate, in part, the University of Texas (UT) shuttle routes and serve the campus area. These would be routes 5 and 15. Routes 9, 21, and 26 also duplicate UT-Shuttle routes, but are not included because they do not serve the UT campus. (Route 26 does go past campus as route 5, but travels via the CBD, not express on Interstate 35 as the UT shuttle does.) Under the recent Capital Metro/UT shuttle system merger, all shuttle routes must be open to the general public, with no cash fare required (though not excluding pre-payment). Because students could use routes 5 and 15 as well as the designated shuttles, it would be reasonable to extend the free portion of these routes to the point where they diverge from the shuttle routes. The free zones are also analyzed without those routes in the event that the Capital Metro route structure is revised to eliminate the duplication.

In this analysis, the same base-case ridership and revenue values were used to maintain consistency with the above three studies. However, because of August route restructuring, more recent data (October 4, 1988) was utilized to determine the percentage of the total ridership that is on each route group (as it exists after August, 1988). The farebox data was used to obtain the respective fractions of full- and half-fare patrons, in order to calculate the average fare, per route. The average fare, for the purposes of this analysis, is the total revenue divided by the number of linked revenue-trips for each route. This value ranged from 36.4¢ to 44.2¢. For the route groups which were affected by the restructuring, an estimated value of 40.3¢ was used (calculated in a manner that preserves the overall average fare of 42.8¢ per linked revenue trip).

To analyze the free fare zone concept, it is necessary to estimate the fraction of trips on each route that take place within the free zone. In the absence of route-level origin-destination data, some reasonable simplifying assumptions were made to estimate the needed fractions. In particular, it is assumed that boardings are uniformly distributed along a given route. Similarly, a passenger getting on at a particular point is equally likely to get off at any subsequent point along that route. Under these assumptions, the proportion of riders whose trip is entirely within the free zone can be calculated. The details of the derivation are given in Appendix A.1.

An average elasticity of -0.50, based on "free CBD only" elasticities reported in the literature, is applied to the above proportion of riders to determine the new ridership and revenue for alternative 1. The reported average systemwide free fare elasticity is approximately -0.35; therefore, as the area of the free zone increases, the (absolute value of the) fare elasticity decrease. For alternative 2, an elasticity of -0.45 was used; for alternative 3, which covers the largest area of the three, an elasticity of -0.40 was assumed. Note that this last value falls between the systemwide and the CBD-only free fare elasticities, the rationale being that alternative 3 is, larger than the CBD but smaller than the whole system service area.

In order to implement a free central zone system, Capital Metro could follow the examples of Portland, Oregon and Seattle, Washington. Passengers traveling toward the free zone pay their fare upon boarding the bus. On routes leaving the free zone, passengers pay as they exit the bus. Thus, when passengers board (or alight) in the free zone, they may use either the front or rear door because no fare needs to be paid. The utilization of both doors also contributes to decreased boarding/alighting times, which offset the increased time required by the greater number of passengers that might be expected to ride the bus. When a passenger traveling toward the free zone (paying on entrance) wishes to travel beyond the free zone (paying on exit), a transfer is requested upon boarding, and is to be returned to the driver upon exit as proof of fare payment. Similarly, a passenger who boards the bus outside the free zone and wishes to transfer to another bus in the CBD will request a transfer upon boarding the first bus but will return it to the driver of the *second* bus, when getting off outside the CBD. A sign or cover could be placed over the farebox while in the free zone to remind regular passengers and inform new riders that no fare is required to board the bus. Seattle and Portland have found that this system works well, and there is very little passenger confusion.

In the Capital Metro system, Route 21 could cause a potential implementation difficulty in connection with alternatives 1 and 2. Because it is a "loop route", it is difficult to determine when the passenger is travelling toward the free zone or away from it. Two possible solutions are: 1) Issue the passenger some type of card which indicates boarding location, to be returned to the driver upon exit. If the entire trip was in the free zone, no fare is paid; otherwise, the regular fare is paid. 2) Make all of route 21 free, as in alternative 3.

Figure 21 shows the current ridership as well as the resulting ridership for each alternative (including routes that overlap UT shuttle routes) for each route type as

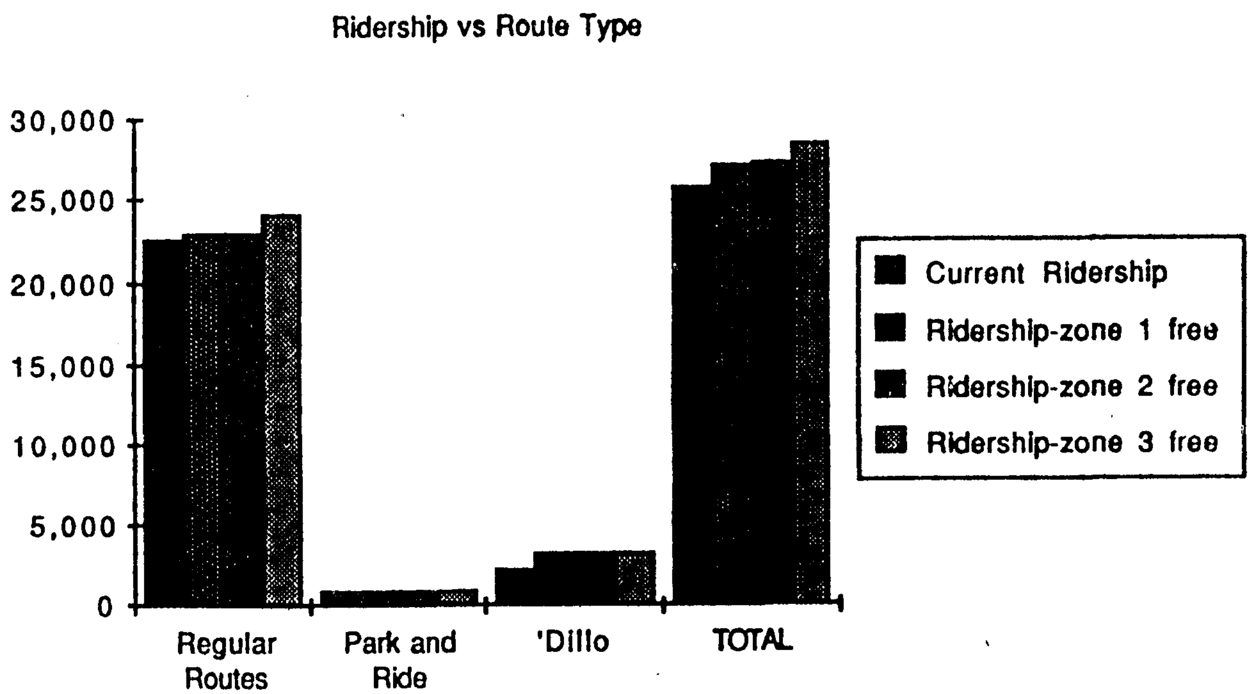


Figure 21. Average Weekday Ridership, by Route Type, for Each Free Zone Alternative.

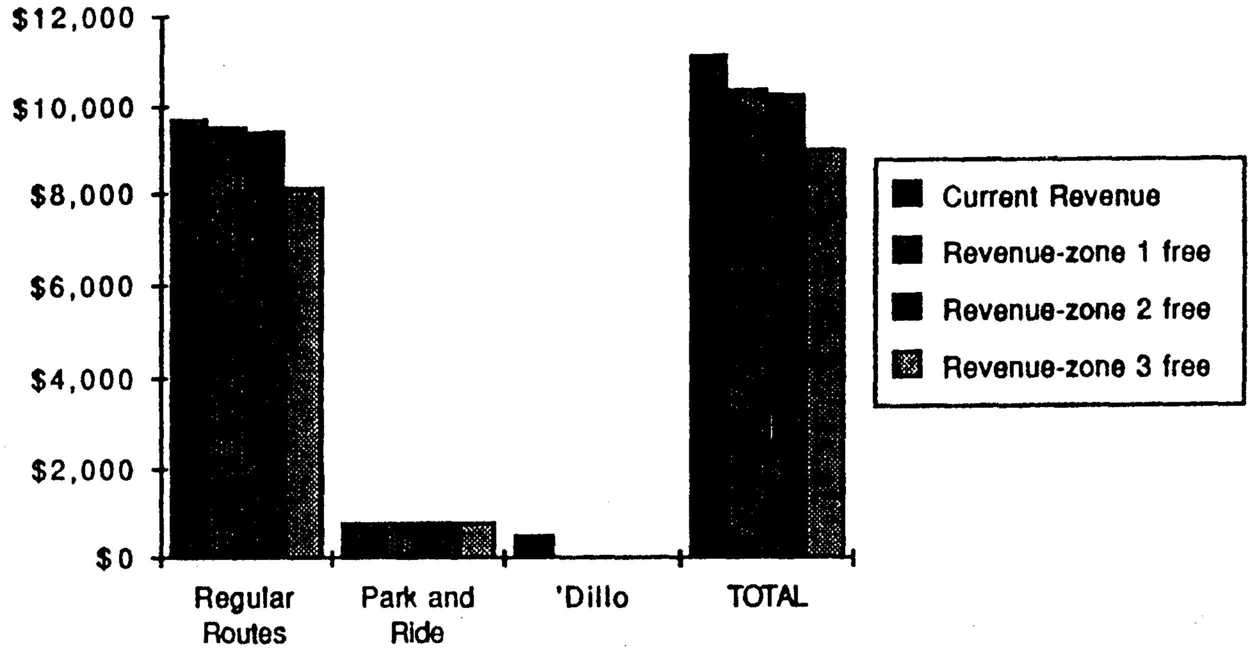


Figure 22. Average Weekday Revenue, by Route Type, for Each Free Zone Alternative.

well as systemwide. Figure 22 shows the corresponding revenue. Because all 'Dillo and no Park and Ride routes are included, the revenue for the 'Dillo is zero for the three alternatives, whereas the revenue remains constant (at the current value) for Park and Ride under all three alternatives. Very similar graphs are obtained when the routes overlapping the UT shuttle routes are excluded.

The marginal subsidies per new rider are shown below for each alternative:

Alternative 1 $0.56/new passenger

Alternative 2 $0.60/new passenger

Alternative 3 $0.82/new passenger

These figures are not significantly affected by the inclusion or exclusion of the routes that duplicate the UT Shuttle.

The above results are intended primarily to illustrate the application of the methodology to specific scenarios in the study area. With the methodology now in place, alternative geographic definitions of the free zone, as well as different strategies with spatial and temporal elements can be analyzed.

6. Comparative Evaluation of Service Improvements and Fare Decrease

In a previous technical paper[4], reported elasticities with respect to service changes were reviewed along with those corresponding to fare changes. The elasticities associated with service quality attributes, such as frequency of service, travel time, and number of transfers, are in all cases greater in magnitude than those associated with fare changes. In other words, a 10% improvement in travel time is likely to result in a greater percent increase in ridership than a 10% fare reduction. However, in order to properly evaluate the relative effectiveness of various improvements, it is necessary to translate them into a common basis of comparison. This can be accomplished by examining the relative impact on ridership of a given dollar amount, invested alternatively in a particular improvement in service and in subsidizing a fare decrease, respectively. Many experts agree that $1000, for example, spent on service improvements may increase ridership to a greater extent than $1000 lost as result of a fare decrease. While translating a given fare decrease into an overall revenue loss is straightforward, estimating the costs of service changes is somewhat more elaborate, requiring the use of cost allocation formulas. Because the Capital Metro costs for vehicle miles and vehicle hours are readily available, service improvements in the form of vehicle-mile increases were analyzed first. An elasticity of 0.69 is used to quantify

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[4] Albee, Kathryn E. and Mahmassani, Hani S., "Transit Fare Elasticities and Free Fare Programs"

ridership response to vehicle mile increase. A range of fare elasticities (from -0.05 to -0.35) was tested to determine at which point fare changes would result in a similar ridership impact as increased vehicle miles.

This analysis is used to determine the ridership impact of an expenditure, ranging from $0 to $10,000 per day (in $1,000 increments), to subsidize a systemwide fare decrease, versus spending the same amount on an increase in the vehicle miles of service. The net cost involved in reducing fares is simply the lost revenue. However, the net cost for increasing vehicle miles includes the direct cost per additional vehicle mile as well as the indirect cost per additional vehicle hour, and is partially offset by the increased revenue generated by the new ridership (the average fare per rider is assumed to remain constant). The two formulas for new ridership are as follows (see appendices A.2 and A.3 for derivations):

Ridership resulting from increasing vehicle miles:

$$V' = \frac{NC}{[(VM_O/\varepsilon * V_O) * (C_{vm} + C_{vh}/S_{avg}) - R_O/V_O]} + V_O$$

where:

- V' = new ridership
- NC = net cost
- VM_O = current vehicle miles
- ε = vehicle miles elasticity (a value of 0.69 is used here based on reported data
- V_O = current ridership (or volume)
- C_{vm} = cost per vehicle mile
- C_{vh} = cost per vehicle hour
- S_{avg} = average vehicle speed
- R_O = current revenue

Ridership resulting from decreasing fares:

$$V' = \frac{(1/\varepsilon - 1) - \sqrt{(1 - 1/\varepsilon)^2 - 4 * (NC/R_0 - 1)/\varepsilon}}{2/(V_0 * \varepsilon)}$$

where:

V' = new ridership

ε = fare elasticity (ranges from -0.05 to -0.35)

NC = net cost

R_o = current revenue

V_o = current ridership (volume)

It should be noted of course that indiscriminate increase in vehicle-miles can be just as misguided as across-the-board reductions in fare. Indeed, recent experience in the Capital Metro area has indicated that a reduction of up to 12 percent in total vehicle-miles of service has not had any significant ridership impacts. This was largely due to the nature of the vehicle-miles that were eliminated: carefully selected, well-targeted unproductive service. It should therefore be stressed that the level of detail in this particular analysis is rather coarse, and it does not recognize the specific factors that must be taken into into account when fine-tuning a particular system. The purpose of this analysis is to illustrate the kind of trade-offs present in considering appropriate fare structures and pricing strategies, and to demonstrate that the latter should be addressed in connection with service considerations. Nevertheless, recognizing the above concerns, three scenarios of service improvements are analyzed:

1) Across-the-board systemwide increase in vehicle-miles; in other words, the analysis is performed at the aggregate systemwide level.

2) Targeted service improvement: only a portion of the system is targeted to receive the total increase in vehicle-miles.

3) Redeployment of existing vehicle-miles, with no additional cost. It is assumed that the top ten routes in the system receive a given percent increase in vehicle-miles, which are redeployed from the remaining routes. It is intended for illustrative purposes only, as additional considerations must be taken into account before recommendations on specific routes can be made. Such recommendations are outside the scope of this particular study.

Figure 23 depicts the estimated ridership resulting from a given net dollar investment in either increased vehicle miles systemwide, or in subsidizing a decrease in fares (with the same cost), for a range of assumed fare elasticities. (Note that the net cost for increasing vehicle miles includes the amount spent on increased service *less* the revenue increase.) The plots in this figure indicate that the superiority of one strategy over the other (in terms of greater ridership impact for a given investment) depends on the magnitude of the underlying fare elasticity. If the absolute value of the latter is less than about 0.15, then the increased vehicle-miles strategy would be more effective than a fare decrease. The marginal subsidy per new rider for the vehicle-miles increase remains constant at $2.61 net/new passenger across the total net cost levels considered.

Figure 24 presents similar information as Fig. 23, except that now the increase in vehicle-miles is targeted to five among the more productive route groups in the system (1/13/40, 2/10, 3/17/25, 6, and 7/27). The resulting subsidy (of $1.68/new passenger) is, as expected, considerably less than for the untargeted case, illustrating the potential of carefully selected service improvements to increase ridership.

Figure 25 presents the results of the redeployment of service strategy, from less productive to more productive portions of the system. The figure plots the new ridership under this strategy on the routes targeted for the increased vehicle-miles as well as on the "other" routes (with decreased vehicle miles), against the percentage of the total vehicle-miles that are redeployed. The 10 targeted route groups include the five mentioned earlier, as well as: 4/18, 5/26, 8, 12/20, 15/16/39. Note that because there is an increase in ridership with no additional funds spent on the redeployment, there is actually an increase in revenue. In other words, this strategy leads to increased ridership and revenue at the same time.

For comparison purposes, Table 3 shows the systemwide decrease in fares (assuming a fare elasticity $\varepsilon = -0.20$) required to achieve the same ridership obtained from a given percent of redeployed vehicle miles, and the corresponding revenue implications.

% v-miles redeployed	% ridership increase	% revenue increase	% fare decrease	% revenue increase
3	1.16	1.17	6.3	5.1
6	2.31	2.34	12.5	10.3
9	3.47	3.51	18.7	15.7
12	4.63	4.68	25.0	21.2
15	5.79	5.84	31.2	26.9
18	6.94	7.01	37.5	32.8
21	8.10	8.18	43.7	38.8
24	9.26	9.35	50.0	45.0
27	10.42	10.52	56.2	51.3
30	11.57	11.69	62.5	57.8

Table 3. Percent Fare Decrease Needed to Achieve Same Ridership Impact as Given Percent of System Vehicle-Miles Redeployed.

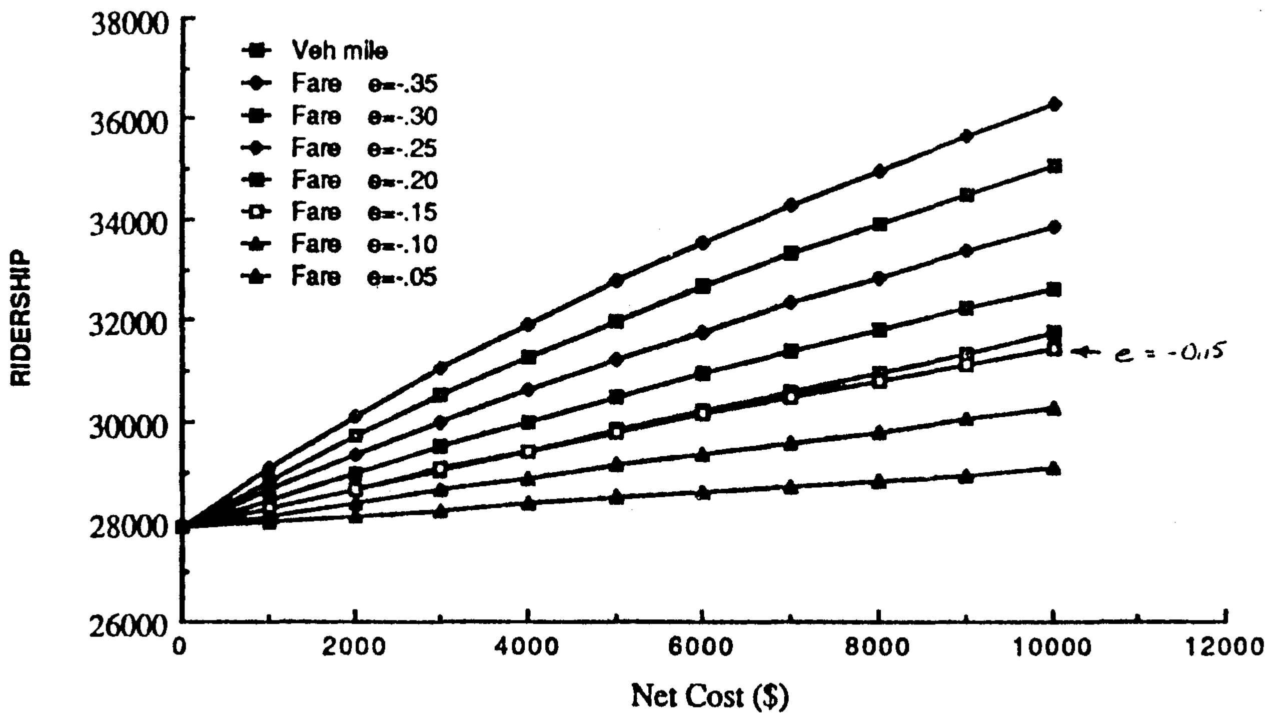

Figure 23. Average Weekday Systemwide Ridership vs. Net Cost of Aggregate Vehicle Mile Increase and Net Cost of Systemwide Fare Decrease under a Range of Fare Elasticities.

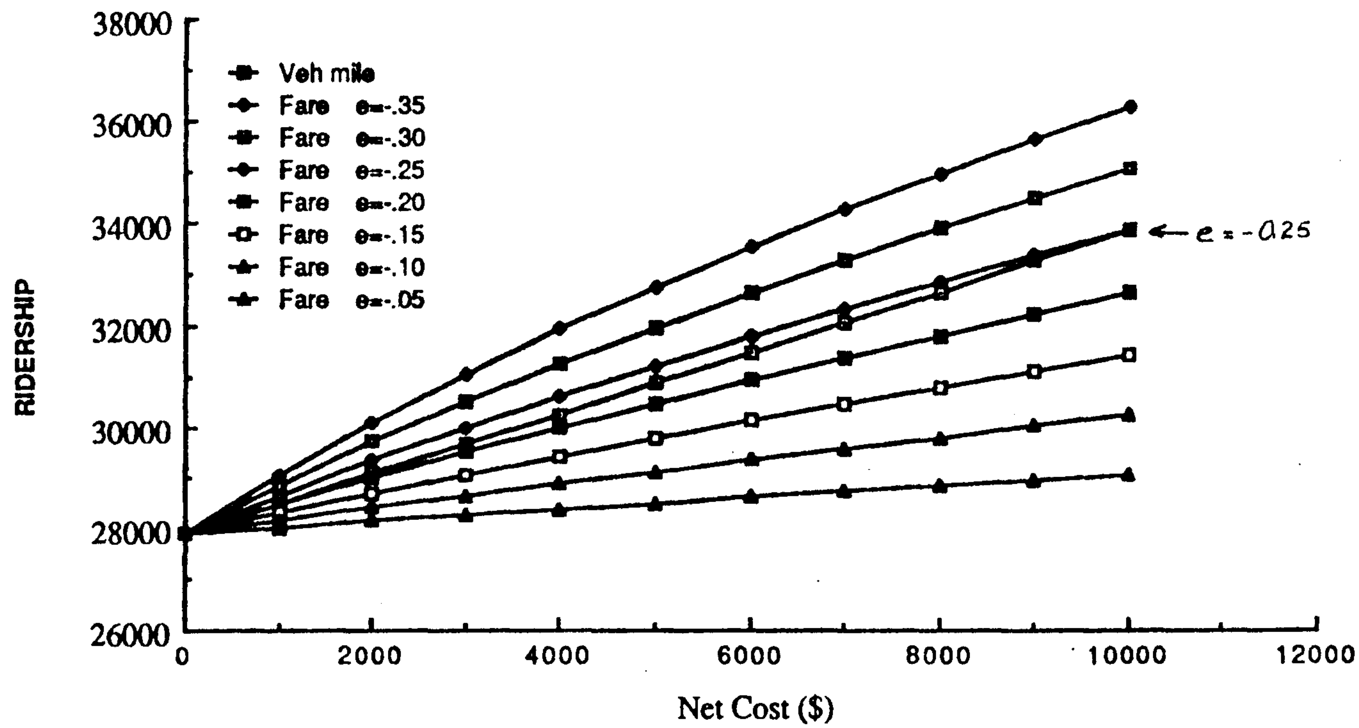

Figure 24. Average Weekday Systemwide Ridership vs. Net Cost of Targeted Vehicle Mile Increase and Net Cost of Systemwide Fare Decrease under a Range of Fare Elasticities.

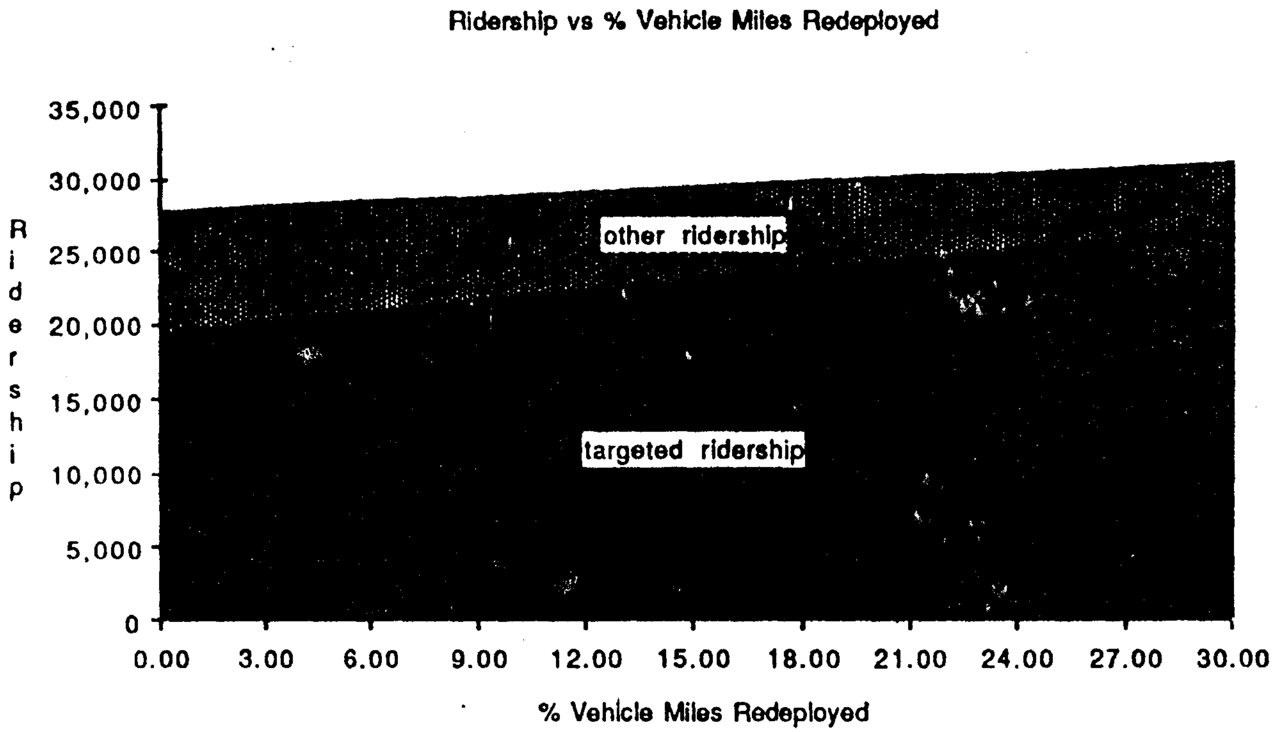

Figure 25. Average Weekday Systemwide Ridership vs. Percent of Targeted Route Vehicle Miles Redeployed from Other Routes.

7. Summary and Conclusions

This report has illustrated the application of an approach based on borrowed elasticities for various market segments to the evaluation of alternative fare policies in the Capital Metro area. In interpreting the results, it must be kept in mind that:

1) The elasticities used are not based on any local data; reported values in other cities exhibit considerable variability. For this reason, we used a range of values to illustrate the sensitivity of the results to the assumed elasticities.

2) The analysis is aggregate in nature, and does not capture details of particular routes.

Regarding the first item above, it is our belief that fare elasticities in Austin are likely to be closer to the -0.15 ~ -0.20 range, which corresponds to the lower-middle end of the spectrum. This is based on comparisons with situations judged to possess similar characteristics as Austin, taking into account the manner in which the reported elasticities have been derived. The transit system in Austin has been around for some time in its present form, and it is unlikely that the present fare structure is seriously deterring a sufficient number of potential riders, whose trips can be served at competitive levels of service, to justify a high fare elasticity. Furthermore, there is evidence from other cities to indicate that elasticities for fare decreases are smaller than for increases. This would place the maximum systemwide potential impact of fare elimination at about 20 to 25%.

Table 4 presents a summary of the impact of the various strategies considered in this report under the high, low and middle fare elasticity values. Each strategy is summarized in terms of three principal criteria: its maximum impact on ridership (total potential number of new trips), the associated cost (revenue loss), as well as the marginal subsidy per new rider, which is a cost-effectiveness measure.

The analysis of the various strategies presented in this report indicate that some potential exists for increasing ridership by reducing and/or eliminating fares. However, this potential is limited, with only relatively small increases possible through fare-related strategies. The cost per new rider is highly dependent on the underlying fare elasticity, as shown in Table 4. In general, targeted fare strategies, especially to specific geographic areas and time periods, as well as to particular socio-economic groups, are more cost-effective than universal indiscriminate reductions.

More importantly, greater impact on ridership can be achieved through service improvements. The most effective demonstrations reviewed are those where promotional fare programs were accompanied by major improvements in service

Table 4: Summary of Ridership and Revenue Impacts of Various Fare Strategies

	Maximum Impact New Riders		Total Cost ($)		Marginal Subsidy Per New Rider	
	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
Low Fare Elasticity						
Systemwide Free Fare	1,680	1,400	11,100	7,570	6.62	5.39
Free Off-Peak	700	1,400	3,590	7,570	5.14	5.39
Free Off-Peak/Seniors	45	90	140	280	3.06	3.14
Middle Fare Elasticity						
Systemwide Free Fare	9,160	6,340	11,100	7,570	1.21	1.19
Free Off-Peak	3,180	6,340	3,590	7,570	1.13	1.19
Free Off-Peak Seniors	210	410	140	280	0.69	0.70
Free Zones:						
Alternative 1	1,340		750		0.56	
Alternative 2	1,440		860		0.60	
Alternative 3	2,560		2,100		0.82	
Very High Fare Elasticity						
Systemwide Free Fare	15,000	11,280	11,100	7,570	0.74	0.67
Free Off-Peak	5,660	11,280	3,590	7,570	0.63	0.67
Free Off-Peak/Seniors	370	720	140	280	0.39	0.39
Independent of Fare Elasticity						
Redeployed	1,620†		0($650 profit)		0.00	
Targeted	5,950*		10,000*		1.68	
Systemwide Service Increase	3,840*		10,000*		2.61	

† The ridership increase depends on percent redeployed (see Fig. 25); number given here is for 15% redeployed.

* These figures depend on the amount to be invested (see Figs. 23 and 24); amounts shown here are for illustrative purposes.

coverage and/or quality. Elasticities associated with service quality attributes in most transit systems are known to be significantly larger than those associated with fares. The comparative analysis presented in this report illustrated how a meaningful basis of comparison can be established between fare decreases and service improvements. Only overall vehicle-miles were considered in this analysis. Yet the results clearly illustrate that service changes can provide a more cost-effective approach to increasing ridership. The results also illustrate the importance of carefully targeting these improvements to areas where the potential impact is greatest. Furthermore, *it should be noted that the benefits of service improvements are not limited to more trips, but also include better quality trips for new as well as existing riders. Trips induced by lower fares alone provide no benefits to existing trips.*

Other important considerations in the evaluation of a free-fare policy include: the nature of the attracted trips, the extent to which consistent with the agency's mission, overcrowding on certain portions of the system, vandalism, potential safety issues, degradation of perceived image, possible turn-off of choice (i.e., non-captive) customers, and low driver morale (reported in the Denver experiment). These were discussed in more detail in a previous technical paper[5] .

Based on the results presented in this report, as well as the analysis and synthesis of the findings of the study to date, the recommendations of the study team at this stage are as follows:

1) The basic fare structure presently adopted by Capital Metro on its regular fixed routes, park-and-ride, and 'Dillo System is generally adequate and does not warrant major revision. The 50¢ base fare is among the lowest in the nation (see Table 5, and is a simple fare to communicate and process. The lower fares to the selected groups are also appropriate and fair, and contribute to the agency's broader mission.

2) Pre-payment plans, such as passes, should be encouraged and more heavily promoted as a means of eliminating transactions associated with riding, encouraging habitual loyal ridership, providing discounts to regular volume users.

3) Transfers should remain free. Transfers are an inconvenience imposed on the rider by a route structure that does not allow for direct service for a substantial fraction of all trips. This is the case in the Capital Metro service area where some transferring is built in by design in the partially implemented time-transfer plan.

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[5] Albee, Kathryn E. and Mahmassani, Hani S., "Transit Fare Elasticities and Free Fare Programs"

However, in light of driver complaints and difficulty in enforcing some of the provisions of the present transfer system, we recommend that an alternative mechanism for the transfers be developed and adopted. More importantly, the reported difficulties would significantly diminish if the confusion created by the present route numbering and pairing system is eliminated. Regarding the transfer passes, one suggestion to simplify the drivers' task in handling and checking transfers is as follows: each day, only transfers of a particular color, or marked with a particular symbol or letter, would be valid. This color (letter or symbol) would not be known until the beginning of the day, thereby preventing fraudulent use. This would eliminate the waste associated with transfers that can be used by the agency on one day only, and would save drivers' time otherwise necessary to check the date on every transfer. Furthermore, the route number would be pre-printed in large print on each transfer, allowing easy checking by drivers for "legal" transfers. Ideally, each transfer pass would also have pre-printed on it a time of expiration, so the driver would only have to hand the transfer to the passenger. For convenience and simplicity, these would be at the following times: 10 a.m., 1 p.m., 4 p.m. 7 p.m., and end of service; if a rider desiring to transfer would have less than two hours left on the next expiration, then he/she should be given a later one. For example, if the next expiration is 10:00 a.m., and the present time is 9:15 a.m., then the passenger is automatically given the transfer that is valid until 1:00 p.m. The driver would have packets of the preprinted transfers to use. When it is time to change to a later expiration, the driver would simply reach for the next packet. Alternatively, the present tear-away format could be retained, though it would add to the required driver transactions.

4) It would not be wise at this stage to rush into aggressive free-fare experimentation. In most-free-fare demonstration projects, the impacts have fallen short of expectations. The reported increases proved ephemeral, were not sustained throughout the demonstration, and were in most cases virtually completely reversed upon reinstatement of the regular fares. The increases were not generally consistent with the mandates of the sponsoring agencies, as those additional trips were diverted in large part from short walking trips. In addition to the mixed results achieved elsewhere, and the limited systemwide potential, it would be premature to implement such free fare programs in the Capital Metro area before the recommendations of the service plan update have been developed and implemented. In other words, free fares should not be used as a panacea to avoid improving the route structure and the directness and quality of service. If free transportation is judged to be a desirable political and

Table 5. Survey of Fixed Route Transit Fares as of August 1, 1986

	UNITED STATES		CANADA	
Number in Sample with Fares of:	Number of Reporting Systems	Percent	Number of Reporting Systems	Percent
.00	1	0.4%	0	0.0%
.10	1	0.4%	0	0.0%
.15	0	0.0%	0	0.0%
.20	0	0.0%	0	0.0%
.25	12	4.3%	0	0.0%
.30	1	0.4%	0	0.0%
.35	9	3.2%	0	0.0%
.40	10	3.6%	0	0.0%
.45	1	0.4%	0	0.0%
.50	72	25.9%	0	0.0%
.55	7	2.5%	0	0.0%
.60	60	21.6%	0	0.0%
.65	9	3.2%	0	0.0%
.68	0	0.0%	1	12.5%
.70	9	3.2%	0	0.0%
.75	50	18.0%	0	0.0%
.80	7	2.5%	0	0.0%
.85	8	2.9%	1	12.5%
.90	3	1.1%	0	0.0%
.95	1	0.4%	1	12.5%
1.00	15	5.4%	3	37.5%
1.10	0	0.0%	1	12.5%
1.15	0	0.0%	1	12.5%
1.20	0	0.0%	0	0.0%
1.25	1	0.4%	0	0.0%
1.50	1	0.4%	0	0.0%
Total	278	100.0%	8	100.0%

Note: Table summarizes basic adult cash fares for fixed-route service, weekday base period not including zone fares, transfer charges or premiums. Each reporting system counted only once. For multi-mode systems with different fares for modes, the motor bus fare is used. Systems not operating fixed-route service are not included.

Source: American Public Transit Association; "Transit Fare Summary: Fare Structures in Effect on August 1, 1986" social objective by the community, then it would be better to time the implementation of such a wish in connection with major route restructuring and service improvement. However, our perception of the political environment in which this and other transit systems must operate is one of fiscal conservatism and business-like accountability, which does not appear to be consistent with what will undoubtedly be viewed as a give-away.

5) With regard to the targeting of special socio-economic groups with fare-related programs, such actions are appropriate as long as they are consistent with the agency's mandate and its broader social objectives. Such targeted programs are generally more cost-effective than uniform measures, and can contribute to the formation of a steady and loyal ridership base for the service.

Appendix

A.1 Derivation of proportion of passengers whose trip would be completely within the free zone:

The general expression for the proportion of riders whose trip would be completely within the free zone is given by the following expression:

$$N = p(F_{off} \mid F_{on}) * p(F_{on}) \qquad (1)$$

where:

N = percentage of riders on a specific route group whose complete trip would be in the free zone

$p(F_{off}|F_{on})$ = conditional probability of a passenger deboarding in the free zone (F_{off}) *given* that passenger got on the bus in the free zone (F_{on}); i.e. the proportion of all passengers who board in the free zone on that route who will also deboard in the free zone

$p(F_{on})$ = probability that a given passenger will board the bus in the free zone (F_{on}); i.e. the proportion of all passengers along a route group who board in the free zone.

The assumption of uniform ridership distribution makes evaluation of this last term rather simple, as it is taken as the ratio of the length of route group in the free zone to the total length of route group):

$$p(F_{on}) = F/T \qquad (2)$$

where F and T are defined below.

A schematic drawing will help explain the formula for $p(F_{off}|F_{on})$:

________"L"______|__"F"___|______"R"________

"L" = the length of the route "left" of the free zone
"F" = the length of the route in the free zone
"R" = the length of the route "right" of the free zone
"T" = the total length of route

The uniform distribution assumption implies that one-half of the passengers will be travelling "left" and the other one-half will travel "right." If a passenger boards at the "right" border of the free zone and travel "right," there is a probability of zero of deboarding within the free zone. If a passenger boards at the "left" border of the free zone and travels "right," the probability of deboarding within the free zone is: F/(F+R). To determine the "expected" probability of a randomly selected passenger who boards in the free zone also deboarding in the free zone, a midpoint value was used. Therefore:

$$p(F_{off} \mid F_{on} \text{ and travelling "right"}) = (F/2)/[(F/2) + R]$$

Similarly, for a passenger traveling "left":

$$p(F_{off} \mid F_{on} \text{ and travelling "left"}) = (F/2)/[(F/2) + L]$$

Therefore:

$$p(F_{off} \mid F_{on}) = (1/2) * [p(F_{off} \mid F_{on} \text{ and travelling "right"}) + p(F_{off} \mid F_{on} \text{ and travelling "left"})]$$

$$= (1/2)*\{(F/2)/[(F/2) + R] + (F/2)/[(F/2) + L] \qquad (3)$$

Combining (2) and (3):

$$p(F_{off} \mid F_{on}) * p(F_{on}) = (1/2)*\{(F/2)/[(F/2)+R]+(F/2)/[(F/2)+L] * (F/T)$$

or:

$$N = p(F_{off} \mid F_{on}) * p(F_{on}) = \frac{(F/2)^2}{T} * \left[\frac{1}{F/2 + L} + \frac{1}{F/2 + R}\right]$$

A.2 Derivation of new ridership generated from increasing vehicle miles:

The net cost for increasing vehicle miles is given by the following general expression:

$$NC = C_{vm} * \Delta VM + C_{vh} * \Delta VH - \Delta R \qquad (1)$$

where:

NC = net cost

C_{vm} = cost per vehicle mile

ΔVM = increase in vehicle miles

C_{vh} = cost per vehicle hour

ΔVH = increase in vehicle hours

ΔR = increase in revenue

This general equation should be altered to determine new ridership in terms of known values. The formulas necessary for this alteration are given below:

$$\varepsilon = \frac{(V'-V_O)/V_O}{(VM'-VM_O)/VM_O}$$

where:

ε = vehicle miles elasticity

V_O = current ridership

V' = new ridership

VM_O = original vehicle miles

VM' = new vehicle miles ($\Delta VM = VM' - VM_O$)

rewriting:

$$\Delta VM = \frac{(V' - V_0) * VM_0}{V_o * \varepsilon} \qquad (2)$$

Also,

$$\Delta VH = \Delta\ VM/S_{avg} = [(V' - V_O) * VM_O]/(V_O * \varepsilon * S_{age}) \qquad (3)$$

where:

S_{avg} = average speed (miles per hour)

finally:

$$\Delta R = (V' - V_o) * R_o/V_o \qquad (4)$$

where:

R_o = current revenue

Substituting (2), (3) and (4) into (1):

$$NC = C_{vm} * (V' - V_o) * VM_o/V_o * \varepsilon + (C_{vh} *(V' - V_o) * VM_o)/(V_o * \varepsilon * S_{avg}) - (V'-V_o)*R_o/V_o$$

Solving for V':

$$V' = \frac{NC}{[(VM_o/\varepsilon*V_o) * (C_{vm} + C_{vh}/S_{avg}) - R_o/V_o]} + V_o$$

A.3 Derivation of new ridership generated by decreasing fares:

The net cost for decreasing fares is given by the following general expression:

$$NC = V_o * f_o - V' * f' \qquad (1)$$

where:

- NC = net cost
- V_o = current ridership
- V' = new ridership
- f_o = current fare
- f' = new fare

Other necessary formulas

$$f_o = R_o/V_o \qquad (2)$$

where:

- R_o = current revenue
- V_o = current ridership

$$\varepsilon = \frac{(V' - V_0)/V_0}{(f' - f_0)/f_0} \qquad (3)$$

where:

ε = fare elasticity

Substituting (2) into (3), and rewriting:

$$f' = R_O/V_O + (V' - V_O) * R_O/(V_O^2 * \varepsilon) \qquad (4)$$

Substituting (2) and (4) into (1):

$$NC = V_O * R_O/V_O - V' * [R_O/V_O + (V' - V_O) * R_O/(V_O^2 * \varepsilon)]$$

Rewriting:

$$(V')^2 * R_O/(V_O^2 * \varepsilon) + V' * [R_O/V_O - V_O * R_O/(V_O^2 * \varepsilon)] + (NC - R_O) = 0$$

Simplifying (multiply both sides by V_O/R_O):

$$(V')^2/(V_O * \varepsilon) + V' * (1 - 1/\varepsilon) + (V_O * NC/R_O - V_O) = 0$$

This formula is now in the form of the quadratic equation:

$ax^2 + bx + c = 0$,

such that:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where:

$x = V'$

$a = 1/(V_O * \varepsilon)$

$b = 1 - 1/\varepsilon$

$c = V_O * NC/R_O - V_O$

or:

$$V' = \frac{-(1 - 1/\varepsilon) \pm \sqrt{((1 - 1/\varepsilon)^2 - 4 * [1/(V_0 * \varepsilon)] * [V_0 * NC/R_0 - V_0]}}{2 * [1/(V_0 * \varepsilon)]}$$

To determine if the radical should be added or subtracted, the V' was evaluated for NC = 0. When the radical was subtracted, V' = V_0.

Simplifying:

$$V' = \frac{(1/\varepsilon - 1) - \sqrt{(1 - 1/\varepsilon)^2 - 4 * (NC/R_0 - 1)/\varepsilon}}{2/(V_0 * \varepsilon)}$$