HIGHWAY RESEARCH RECORD

Number 213

Passenger Transportation

5 Reports

Subject Area

15 Transportation Economics
84 Urban Transportation Systems

HIGHWAY RESEARCH BOARD

DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

Washington, D.C., 1968 Publication 1558

Price: $1.80

Available from

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Foreword

There has been a growing recognition of the interfaces between modes of transportation and the substitutability of different modes of travel in urban areas. There has been increasing concern about effects of price changes on demand for travel in urban areas and between urban areas. The papers in this RECORD describe effects of price changes on travel demands.

In his paper on the effects of a 1966 fare increase on New York City's transit system, William Lassow describes changes in patronage on the New York City subway and bus lines after the fares were increased from 15 cents to 20 cents per ride. The paper describes effects of fare changes on transit usage by month, day, and time and in different areas of the city. The paper concludes that as a result of fare increases there was a decline in transit patronage, that this tended to be mitigated over time, and that the effects of fare increases are not the same on all classes of riders.

The paper by Sam R. L. Brown and Wayne S. Watkins is an effort to measure effects of fare changes on demand for air travel in the United States. The principal conclusion of the study is that the demand for air travel is elastic with the result that fare increases reduce the demand. The elasticity of demand is most pronounced in moderate-length trips where substitute forms of transportation are readily available. Another conclusion was that increases in income levels cause an increase in demand for air travel.

John F. Curtin examines the effects of price changes on the use of rapid transit in the San Francisco Bay Area. The study was part of the Northern California Transit Demonstration Project in which various aspects of price and fare differentials were examined. Some of the areas investigated were effects of fare differentials on distribution of traffic between surface and rapid transit service, the magnitude of shrinkage of traffic volumes in response to fare increases, and joint fares for trips involving more than one mode of transportation. The paper discusses model techniques used in the project and describes effects of fare differentials on demand and distribution between modes of travel.

In a similar paper, Edward A. Harvey describes the effects of fare changes on transit usage in the Philadelphia area. The paper summarizes information obtained by the Southeastern Pennsylvania Transportation Authority during the past seven years. A description is given of the transit system and pricing policies adopted along with the results of price changes. The paper relates the effects of price changes on projections of demand and fare potential in Philadelphia.

R. L. Carstens and L. H. Csanyi set forth in their paper a model for estimating transit demand and revenues. Variables considered by the model are quantity of transit service provided, average fare, size of city, and proportion of population not in working force. The model, while applicable only in communities in Iowa, offers insight into factors which may be applicable for transit operations in small urban areas. The model exhibits considerable price elasticity at low levels of service but relative inelasticity at high levels of service.

Contents

Effect of the Fare Increase of July 1966 on the Number of Passengers Carried on the New York City Transit System

WILLIAM LASSOW, Assistant to the Chairman, New York City Transit Authority

•IN July 1966, the basic subway and bus fare in New York City was increased from 15 to 20 cents. This paper explores the effect of the fare increase on the number of regular-fare passengers carried on the city-owned transit system during the year following the increase. It also examines the differential effects of the fare increase at varying times of day, by days of the week, and on different kinds of riders.

CITY-OWNED TRANSIT FACILITIES

Two public Authorities operate the transit facilities owned by the City of New York:

1. The New York City Transit Authority (NYCTA) operates all the rapid transit lines in the city, all the local bus lines in Brooklyn and Richmond (Staten Island), approximately half of those in Queens, and a few lines in Manhattan.
2. The Manhattan and Bronx Surface Transit Operating Authority (MaBSTOA), a subsidiary of NYCTA, operates all the local bus lines in the Bronx and most of those in Manhattan.

There are also five private companies providing about half the local bus service in the Borough of Queens, and one small company in Manhattan. These companies carry about 10 percent of all local bus riders in the city. Fares were correspondingly increased on these lines at the same time as on the city-owned lines.

This paper deals only with the two Authorities. The magnitude of their operations is given in Tables 1, 2 and 3. For convenience, all the rail rapid transit lines are referred to as "subway" although there are long sections on elevated structures, in open cut, and on embankment.

The total number of revenue passengers and the number of regular-fare passengers carried in the year ended June 30, 1967, is given in Table 2. The difference is the number of children riding at reduced-rate school fare. Since the fare paid by school children was not changed, the analysis of the effect of the fare increase is based entirely on regular-fare passengers as determined by the number of passengers entering the subway turnstiles or paying regular fares on buses.

There are wide differences among the number of passengers carried on regular weekdays, Saturdays and Sundays (Table 3). In this paper the effect of the fare increase on riding is measured by comparing the number of regular-fare passengers carried during the year after the fare increase, July 1, 1966, to June 30, 1967 (fiscal 1967), with the number in the corresponding period of the prior year (fiscal 1966). No attempt has been made to adjust for any secular trend that may exist because, based on the last few years, this trend appears to have been very slight. During these years, changes in riding have been under 1 percent per year downward on the subway lines, and about the same percentage upward on the bus lines. These changes are so much less than the observed effects of the fare increase, and any extension of such small trends is so

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 47th Annual Meeting.

TABLE 1

NEW YORK CITY-OWNED TRANSIT FACILITIES AS OF JUNE 30, 1967

Operated by	Route Miles		Passenger Vehicles	
	Subway	Bus	Subway Cars	Buses
NYCTA	237	554	6,726	2,325
MaBSTOA	–	324	–	1,959
Total	237	878	6,726	4,284

TABLE 2

NUMBER OF PASSENGERS, JULY 1, 1966, TO JUNE 30, 1967 (millions)

Operated by	Revenue Passengers			Regular-Fare Passengers		
	Subway	Bus	Total	Subway	Bus	Total
NYCTA	1,299	434	1,733	1,243	362	1,605
MaBSTOA	–	397	397	–	365	365
Total	1,299	831	2,130	1,243	727	1,970

speculative when there are so many other factors affecting transit riding, that it appeared to be an unnecessary refinement to adjust all the figures for trend for this study.

An adjustment based on the number of passengers using the World's Fair station and counts made on other stations and bus lines has been made in the fiscal 1966 data to eliminate the riding resulting from the New York World's Fair, which ran from April to October in 1964 and 1965.

GROSS EFFECT OF FARE INCREASE

Comparing fiscal 1967 as a whole with fiscal 1966, after eliminating the month of January in both years because of the 13-day transit strike in January 1966, there was an annual loss in regular passengers of 2.4 percent on the subway lines, and 9.8 and 10.0 percent on the bus lines of the NYCTA and MaBSTOA, respectively. While there has been some recovery of the lost riders, the effect of the fare increase still persists. For the first six months of fiscal 1968 subway riding was about 1 percent more than fiscal 1967 and bus riding was about the same.

It is interesting to note that while for the bus lines the loss of passengers was close to the result that would be produced by a commonly used formula for predicting the effect of a fare increase, the actual result for the subway lines was quite different. This formula states that for every 1 percent increase in fare there will be a 0.3 percent decrease in riding. According to this formula, the 33.3 percent increase in fare should therefore result in a 10 percent decrease in riding. Since the gross loss in riding is the composite of losses which vary among groups of riders, it is obvious that in a system as large and as complex as New York City, a gross prediction based on a simple formula may be misleading.

The total percentage loss figures (Table 4) conceal very substantial differences in the effect of the fare increase on the different days of the week, particularly on the subway lines. These differences are significant in understanding the fare increase effects because total figures are affected by changes in the number of regular weekdays, Saturdays and Sundays, the incidence of holidays, and other calendar incidentals which distort monthly and annual comparisons.

It is tempting to speculate about the causes for the differences in the foregoing percentages. The lower percentage decreases in subway passengers may be explained by the greater preponderance of journeys to and from work and other longer and more important trips for which no substitute means of transportation is easily available. Bus trips are shorter, less work-oriented, and may be more casual. This permits easier postponement or elimination of trips (shopping, for example) and the substitution of

TABLE 3

AVERAGE DAILY NUMBER OF REGULAR-FARE PASSENGERS, JULY 1, 1966, TO JUNE 30, 1967 (millions)

Operated by	Type	Regular Weekdays	Saturdays	Sundays
NYCTA	Subway	4.20	1.97	1.25
	Bus	1.14	0.81	0.49
MaBSTOA	Bus	1.15	0.85	0.50
Total		6.49	3.63	2.24

TABLE 4

PERCENTAGE DECREASE IN REGULAR PASSENGERS, FISCAL 1967 UNDER FISCAL 1966[1]

Operated by	Type	Regular Weekdays (%)	Saturdays (%)	Sundays (%)
NYCTA	Subway	1.9	4.1	1.0
	Bus	9.4	11.6	10.8
MaBSTOA	Bus	9.7	10.5	9.5

[1]Excluding January both years.

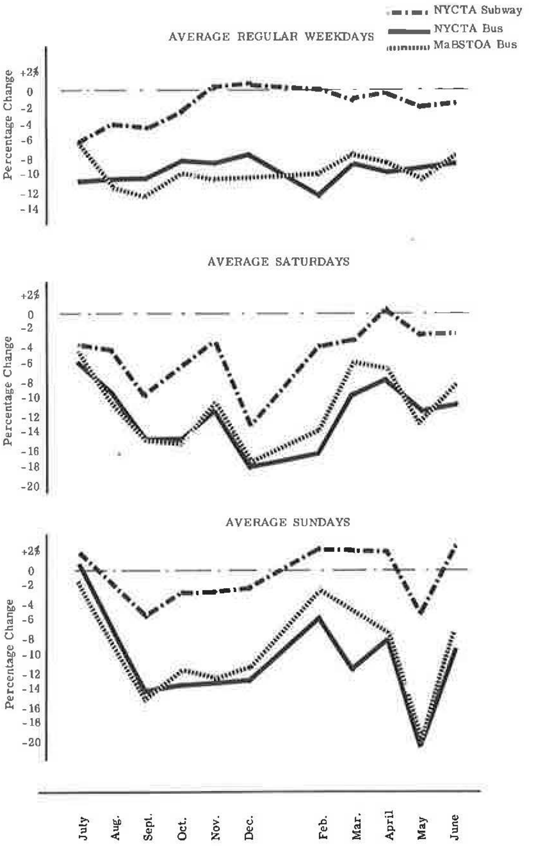

Figure 1. Percentage change in regular passengers by month (excluding January)—fiscal 1967 compared with fiscal 1966.

walking, or taking a taxi, particularly when two or more people are traveling together.

A possible explanation of the 1 percent decrease in subway patronage on Sundays may be that Sunday riders are mainly workers in the extensive New York City service industries and round-the-clock operations, and people traveling for social and recreational purposes. The former have to travel, while the latter may be those who, for one reason or another, do not have a private car available and are not deterred by the higher fare because their trips may be in the nature of special occasions and may involve long trips by the entire family.

However, these are only speculations and "reasonable" explanations because there are no data that would provide a more accurate basis for explaining the differences in the percentages.

The percentage change in the average number of regular passengers on weekdays, Saturdays, and Sundays is shown in Figure 1 by months (except January) for fiscal 1967 and fiscal 1966. While there are wide variations among the months, in each month the percentage of loss of riding on the subways is less than on the buses on each of the three types of days.

The average weekday percentages of loss of passengers are, as could be expected, more stable from month to month. Subway riding shows a higher initial percentage reduction on weekdays and Saturdays and a gradual slow recovery. There is a similar though smaller recovery in bus riding on weekdays, but no such change is evident on Saturdays and Sundays.

The smaller loss on the MaBSTOA buses in the early months of 1967 is probably a result of the immediate sharp decline in riding on these buses following the establishment of one-way traffic on Fifth and Madison Avenues in Manhattan in January 1966.

The sharp drop in Saturday riding in December was caused by the difference in the days on which Christmas and New Year's Day fell in the two years, and the drop in Sunday riding in May by more rainy Sundays in 1967.

DIFFERENTIAL EFFECTS OF FARE INCREASE

In the following sections comparisons of the effects of the fare increase are based on a more limited body of data, but are nevertheless believed to be significant and indicative of what happened. Up to this point the data used have been based on the total fare collections of the entire transit system. The following data are based on hourly counts made on two days a year of the passengers entering the turnstiles at every subway station.

This count is produced by having the railroad clerk (token seller) at each station booth record each hour, on the hour, the reading on the meter on each turnstile under his control. These readings show the number of turnstile operations or passengers

TABLE 5

TURNSTILE REGISTRATIONS—ALL SUBWAY STATIONS—TWO REPRESENTATIVE REGULAR WEEKDAYS 1966 AND 1965 (millions)

Day		Total Number of Turnstile Registrations
Wednesday, Oct. 20, 1965 (15-cent fare)		4.57
Wednesday, Oct. 5, 1966 (20-cent fare)		4.30
	Decrease	0.27
	Percent decrease	5.8%

entering the subway. Since turnstile meter readings are used primarily to account for the railroad clerk's receipts and are ordinarily recorded only at the start and end of each tour of duty, the collection and compilation of these hourly data for statistical and traffic analysis is a major additional task for the 4,000 railroad clerks who work in the 482 stations, with 835 change booths and 3,015 turnstiles.

There are some obvious problems in the use of these data. While the days selected are Wednesdays in May and October, which are as near to average or representative weekdays as can be selected, they are only two out of some 240 to 250 such days. Days without unusual weather or special events are selected, but there are normal statistical and other unanticipated and sometimes inexplicable daily variations in traffic. In addition, it is obviously unrealistic to expect each railroad clerk to read the turnstile meters precisely on the hour, particularly during busy periods. Instructions to do this are quite specific; supervisors do their best to enforce them, and at very busy stations other personnel assist, but at individual stations there are many occasions when the reported hourly figures are not correct. However, when station and hourly totals are combined there is a balancing of discrepancies, and totals are quite accurate enough for the following comparisons.

To check the reliability of the figures in Tables 5 through 9, which are based on the riding on these two typical days, a comparison was made with similar data derived from the average number of revenue passengers per weekday for both fiscal years. While the actual percentages showing the change from the prior year varied somewhat in the two sets of figures the rank order of the effects of the fare increase on the four groups studied in Tables 7 through 9 remains the same. Therefore, the absolute values of the percentages of decrease or increase in riding resulting from the fare increases shown in these tables must be used with extreme care. However, the general conclusions on the effects of the fare increase on different groups of riders are believed to be valid.

The analyses in Tables 5 through 9 are based on the counts made on the Wednesdays, October 20, 1965, and October 5, 1966. Counts made in March 1966 and 1967 were reviewed but were found to be distorted because the Easter holidays, with their effect on shopping, employment, and school holidays, fell in April in 1966 and in March in 1967. There are no comparable data available for the buses. Table 5 gives the traffic on the two days studied.

There figures differ from the average regular weekday figures given in Tables 3 and 4, which are based on the average of all regular weekdays for the entire year, while the figures in Tables 5 through 9 are based on one day in each year. However, it is believed that these two days are sufficiently representative of normal weekday riding patterns to permit their use to make valid comparisons to determine whether there were different effects of the fare increase on different kinds of riders. The following results were obtained by this method of analysis.

EFFECT OF FARE INCREASE BY TIME OF DAY

A comparison of the losses in subway riding by time of day is given in Table 6. As might be expected, the smallest effect of the fare increase is shown during the hours with the greatest number of work-based trips, that is, during the morning and evening rush hours and the midnight and early morning hours. Midday trips which probably have a smaller proportion of work-based trips and more shopping trips were more

TABLE 6

PERCENTAGE DECREASE IN TURNSTILE REGISTRATIONS BY TIME OF DAY—TWO REPRESENTATIVE REGULAR WEEKDAYS, 1966 AND 1965

Hours	Distribution of 1965 Turnstile Registrations (%)	Decrease (%)
7 a. m. -10 a. m.	31	2.4
10 a. m. -4 p. m.	21	8.0
4 p. m. -7 p. m.	30	5.0
7 p. m. -11 p. m.	10	14.6
11 p. m. -7 a. m.	8	3.7
Total—24 hours	100	5.8

TABLE 7

PERCENTAGE DECREASE IN TURNSTILE REGISTRATIONS AT 11 STATIONS IN LOWER MANHATTAN FINANCIAL DISTRICT—TWO REPRESENTATIVE REGULAR WEEKDAYS, 1966 AND 1965

Hours	Distribution of 1965 Turnstile Registrations (%)	Decrease (%)
7 a. m. -10 a. m.	7	1.8
10 a. m. -4 p. m.	20	6.1
4 p. m. -7 p. m.	62	3.4
7 p. m. -11 p. m.	8	27.9[a]
11 p. m. -7 a. m.	3	2.5
Total—24 hours	100	1.0

[a]Increase

seriously reduced. The greatest loss of riding was in the evening hours, which probably have the highest proportion of social and recreational trips for an evening's entertainment.

EFFECT OF FARE INCREASE ON JOURNEY TO WORK

The stations in the financial district of Lower Manhattan are used almost solely for work-oriented trips inasmuch as practically no one lives in this area. Therefore, there are very few people entering these stations in the morning hours and the turnstile registrations show the high concentration of riders entering the stations in the afternoon on their journey home from work. Table 7 gives the hourly distribution of the turnstile registrations for 11 stations in this area with a total of 243,000 riders on a Wednesday in October 1965, and the change from the prior year in the number of passengers.

The percentage of loss of riders was significantly lower at these stations than for the subway system as a whole—a total 1 percent decrease compared with 5.8 percent for all stations. The increase from 7 a.m. to 10 a.m. may reflect changes in the number of people working in these hours and is worthy of further study. It is not believed that the total number of workers in the area changed enough to account for the lower percentage of loss of riders for the 24 hours.

EFFECT OF FARE INCREASE ON RIDERS OF DIFFERENT ECONOMIC STATUS

The effect of fare increase on riders of different economic status is difficult to measure from the data available for this study. It is fairly easy to select stations in the depressed areas of the city, and 13 stations in Harlem, Bedford-Stuyvesant, and the South Bronx were selected and examined. It is difficult to select subway stations that serve mainly high-income residents. Therefore, comparison was made with 10 stations which are adjacent to the commuter railroad and bus terminals and are therefore used by large numbers of work-bound commuters, presumably of higher economic status, during the journey-to-work hours. These data are given in Table 8. On the October 1965 day studied, the stations in the low-income areas had 149,000 entering passengers, while the "commuter" stations had 449,000. Since the "low income" stations are in residential areas there is a concentration of entering passengers in the morning rush hour. The "commuter" stations are in the midtown area and entering passengers are therefore most numerous in the afternoon rush hour; but the influx of the commuters is shown by the high percentage of passengers entering in the morning rush hour—a much higher percentage than that given in Table 7 for the financial district for the same hours.

The greater impact of the fare increase on the lower income areas in every period of the day is evident from a comparison with the entire subway system as given in Table 6. The effect is even more pronounced when the low-income area stations are compared (Table 8) with the stations used by suburban commuters entering the subway system during the morning hours. The low-income-area figures are consistent with

TABLE 8

PERCENTAGE DECREASE IN TURNSTILE REGISTRATIONS AT 13 STATIONS IN LOW-INCOME AREAS AND 10 "COMMUTER" STATIONS—TWO REPRESENTATIVE WEEKDAYS, 1966 AND 1965

Hours	Low Income		"Commuter"	
	Distribution of 1965 Turnstile Registrations (%)	Decrease (%)	Distribution of 1965 Turnstile Registrations (%)	Decrease (%)
7 a.m.-10 a.m.	42	4.5	22	3.7[a]
10 a.m.-4 p.m.	21	9.3	20	1.3[a]
4 p.m.-7 p.m.	14	8.0	41	7.9
7 p.m.-11 p.m.	10	19.1	11	6.4
11 p.m.-7 a.m.	13	13.1	6	2.5[a]
Total—24 hours	100	8.6	100	2.7

[a] Increase

those for the entire subway system in showing the lowest effect of the fare increase during the daytime hours when people go to work.

EFFECT OF FARE INCREASE ON RIDERS PAYING MORE THAN ONE FARE, OR HIGHER FARES

It could be expected that passengers who pay more than one fare for a single trip, or a higher rate of fare, would be affected more seriously by the fare increase, with a resulting greater loss of subway riders. This was confirmed by study of the effect of the fare increase in three situations where riders paid more than one basic fare.

Feeder Bus Line Stations

The effects of the fare increase at ten stations in the outlying areas of the city where a large proportion of the 225,000 riders on the October 1965 average weekday entered the subway from feeder buses on their morning rush hour journey to work are given in Table 9.

The greater loss of riders among those paying two fares than among subway riders as a whole is evident. The percentage decrease is greater for the entire day, and for every hourly period except from 11 p.m. to 7 a.m.

Rockaway Line

A double fare is charged on the Rockaway Line. A comparison of the riding for fiscal 1967 shows a decrease of 6.8 percent. On the entire subway system the comparable figure is 2.4 percent.

Aqueduct Race Track Specials

Special trains are run to the Aqueduct Race Track at a fare that was raised from 50 to 75 cents. It is possible to make the trip on the regular trains, which take much longer, at the regular 20-cent fare. Comparing the average number of special train riders per racing day for each of the four months, March through June, in 1966 with the same months in 1967 shows a monthly loss of riding ranging from 19 to 30 percent.

TABLE 9

PERCENTAGE DECREASE IN TURNSTILE REGISTRATIONS AT 10 STATIONS WHERE A LARGE PROPORTION OF PASSENGERS COME FROM FEEDER BUS LINES—TWO REPRESENTATIVE REGULAR WEEKDAYS, 1966 AND 1965

Hours	Distribution of 1965 Turnstile Registration (%)	Decrease (%)
7 a.m.-10 a.m.	58	6.4
10 a.m.-4 p.m.	17	20.7
4 p.m.-7 p.m.	11	6.2
7 p.m.-11 p.m.	5	22.3
11 p.m.-7 a.m.	9	10.1[a]
Total—24 hours	100	7.3

[a] Increase

CONCLUSIONS

While the actual percentage of decline in riding may include minor effects of factors other than the 5-cent increase in the basic transit fare, there is no doubt about the profound effect of the fare increase in reducing riding. Based on the

analysis in this paper the following general conclusions can be drawn with a high degree of confidence:

1. As a result of the fare increase, transit riding in the 1967 fiscal year declined nearly 2.5 percent on the subways and nearly 10 percent on the buses below the level of the 1966 fiscal year. This represents a decrease of about 100,000 trips per weekday on the subways and more than twice that number on the buses.
2. The effect of the fare increase is persistent because, while these percentages are the average for the year, the percentage of loss at the end of the year was only a little lower than earlier in the year.
3. The effect of the fare increase was not the same on all classes of riders. For example, (a) weekday rush-hour trips, which are predominantly journey-to-work trips, were affected least; (b) weekday midday and evening trips and Saturday trips were affected most—these have a higher than average proportion of shopping, social, and recreational trips; (c) there was a greater than average decline in riding among lower income groups; and (d) the greater the amount of the fare increase, the greater the effect, i.e., the decline in riding among those who pay more than one fare for a trip, or who pay a higher rate of fare, was greater than the average for all riders.

A fundamental question that should be studied further is: what is the effect on the city as a whole of the reduction in the number of mass transit trips caused by the fare increase? We do not know how many, if any, of these trips were made by auto or taxi or other means of transportation, with perhaps an increase in downtown traffic congestion, or how many were not made at all, with a decline in the number of people shopping in the city, or just visiting, or attending a movie or concert, thus diminishing the city's attraction as a shopping, cultural, and recreational center. While we note and count the decrease in transit riding resulting from the fare increase, we have no measure of its broad social and economic significance.

Discussion

EUGENE L. GRANT, Professor of Economics of Engineering, Emeritus, Stanford University—Total revenue requirements of privately owned regulated public utility companies in the United States include operation and maintenance expenses, property taxes, depreciation, income taxes, and a fair return on a rate base that is related to the capital assets of the system. However, it is an accepted fact of life in the United States in the 1960's that no schedule of passenger fares in an urban mass transit system can be designed to cover all revenue requirements as they are defined today in our regulated gas, electric, telephone, or water utilities. The time when passenger revenues were able to cover all such "costs" is long since past.

The change from private to public ownership eliminated the property tax and income tax components from passenger revenue requirements in urban mass transit. Moreover, part or all of the capital costs (such as bond interest and repayment) now often are covered from general taxation; in some publicly owned systems, even part of the operation and maintenance cost is paid from general tax revenues. The total revenue objectives that are considered in setting passenger fares differ greatly among the various publicly owned mass transit systems. They are not necessarily the same in, say, the San Francisco Bay area and the New York City area.

Effect of Fares on Transit Riding

JOHN F. CURTIN, Partner, Simpson & Curtin, Philadelphia

•FARES are perhaps the most sensitive aspect of transit service—balancing uneasily between political pressures and the need for operating revenue. Political campaigns in major American cities have been won and lost over transit fare issues, and there is substantial evidence that patrons react to fare increases at the turnstiles as well as at the polls.

The correlation of price increase with loss of transit riding has been well established. Most utility commissions use a variation of the "shrinkage formula" devised by our firm more than 20 years ago when pressures of inflation first became manifest in fare increase proposals by transit companies.

But the corollary questions of price differential among competing transit services, and the effect of joint fares in coordinated transit operations, have not been so well explored. What is the "sub-modal split" of riding between surface and rapid transit connecting two points, when the fare is 15 cents on one and 25 cents on the other? How much added traffic is attracted to rapid transit when the feeder bus fare is dropped from 20 cents to 10 cents? When feeder and trunk lines are separate operations, how should the feeder line discount in the combination fare be shared between them?

These are fundamental questions of revenue and cost apportionment in developing coordination between surface and rapid transit systems. Auto travel switches freely between systems—from county roads to city streets to state highways—without motorists' awareness; division of motor fuel revenues among these systems is accomplished by legislative standards with varying degrees of sophistication. Transit, however, is more like a barrier-type toll highway; each link of the trip is a new fare confrontation—whether the journey fare is paid at one point or piecemeal. The mechanics of collection become involved, therefore, as well as price discount and revenue yield.

These considerations were a major part of the Northern California transit coordination study (NCTDP) recently completed for transit services in the San Francisco Bay Area. This HUD-sponsored analysis explored correlations among community goals, traffic, population, auto ownership, transit routes, operating costs and vehicle requirements, as well as single-vehicle and combination fares, for their influence on transit riding. The transit systems involved are the two present surface operations—San Francisco Municipal Railway (Muni) and Alameda-Contra Costa Transit District (AC Transit)—in conjunction with the Bay Area Rapid Transit District (BARTD), the 75-mile rapid transit network now under construction (Fig. 1).

PRESENT FARE STRUCTURES

The fare structures of these operating systems are quite dissimilar and not readily adaptable to coordination.

Muni has one of the lowest and simplest transit fare plans in the nation—a citywide 15 cent fare for adults, 5 cents for children and students, free transfer, no tokens and no zones. This fare has been in effect since 1952.

AC Transit has zone fares, but the first zone is so large as to approach an areawide flat fare plan. More than 80 percent of East Bay journeys are one-zone rides. The basic adult fare is 25 cents with a 20 cents token rate. Zone increments for the four additional zones are 5 and 10 cents each. Transbay fare between the central East Bay zone and downtown San Francisco is 50 cents cash or 45 cents on a commute ticket.

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 47th Annual Meeting.

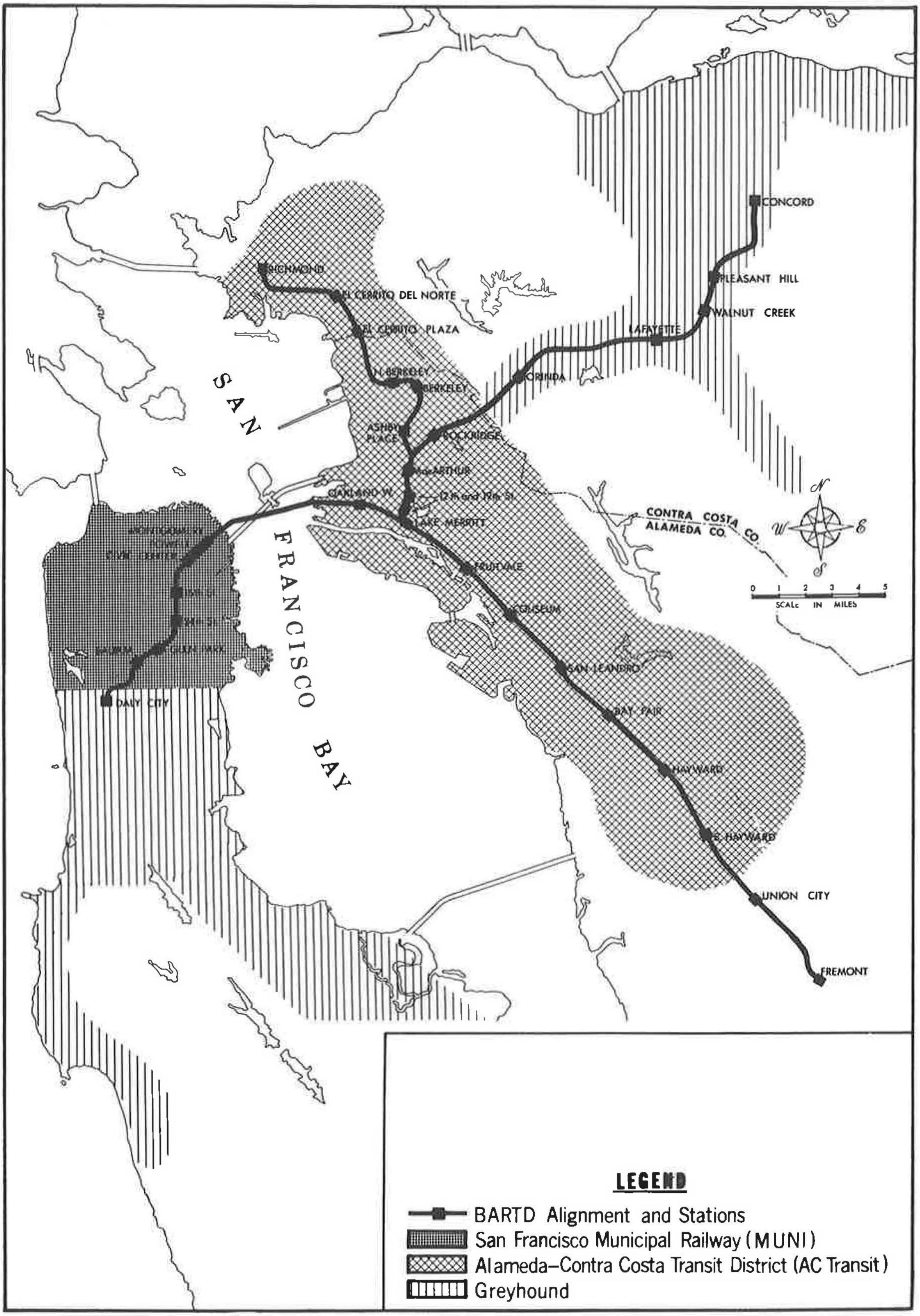

Figure 1. Transit services—San Francisco Bay Area.

BARTD will have a range of station-to-station rates based on distance, varying from 25 cents to $1.00.

Both Muni and AC Transit have pay-enter fare box collection on vehicles; BARTD is designing an automated system, based on stored-value or stored-trip tickets which are magnetically encoded and inserted by passengers in entrance and exit turnstiles.

There are no joint fare arrangements between Muni and AC Transit. O-D studies reveal a substantial interchange of passengers between the two, particularly at the San Francisco Transbay Terminal. Combination fares for multi-vehicle journeys between systems will become particularly significant when BARTD is superimposed on them.

Among the 22 largest metropolitan areas in the country, only Philadelphia and Washington have combination fare arrangements between suburban and local transit systems to any significant degree. In both cities, joint fare tickets are sold by drivers manually; neither the sale nor collection is automated.

TRANSIT TRAVEL IN 1975

Conventional systems techniques for traffic forecasting were utilized to develop a potential volume of 253,353 adult BARTD passengers on the average weekday in 1975, prior to adjustment for fare differentials. Similarly, AC Transit's AADT is projected at 57,485—down 54 percent from 1965—while Muni is expected to carry 353,377 adult riders, a drop of 8 percent from 1965 levels. The latter two figures for 1975 do not include feeder trips to BARTD stations, which are estimated at another 65 percent of BARTD's daily volume. When these are added, AC Transit is expected to carry a total of 12 percent more than its 1965 daily volume, but for trips of considerably shorter length. Muni system riders are also forecast to rise 22 percent overall, divided among Muni surface vehicles, a new Muni rapid transit system and feeder passengers to BARTD in San Francisco.

These projections of 1975 transit riding were calibrated from existing transit use, which is a product of the fare structure on the present carriers. These estimates of future travel, therefore, presupposed continuation of existing fare policies. To the extent that alternative fare plans developed for 1975 will result in higher or lower fares than now exist for comparable journeys, it was necessary to alter projected transit travel to reflect that change in travel costs.

ALTERNATE FARE PROPOSALS

Alternate fare proposals were considered first from the standpoint of public acceptance and policy considerations, then tested for their influence on traffic generation and revenue production. With several choices of fares on each of the three transit systems—as well as inter-system alternatives and possible variations in parking charges—it is evident that 500 or more combinations could be devised. The initial problem was to narrow the choice to those which might have greater public appeal, then determine the effectiveness of components in attracting passengers and revenue. Following this, the cost side of the equation was introduced and the iterative process of revenue and cost projections repeated until a reasonable balance was achieved to satisfy fiscal requirements for the three transit systems.

Several fare schedules for surface and rapid transit lines in the Bay Area were machine-tested by bracketing the range of acceptable alternatives, then narrowing the choice within that range. Four alternate fare plans were reviewed by BARTD, as summarized in Table 1, together with two alternatives for AC Transit and three for the Muni system.

BARTD Plans B-1 to B-4 were tested for previously determined station-to-station volumes on the BARTD system, in combination with various feeder surface fares. Each of these tests involved separate consideration and subdivision of BARTD patronage among single-vehicle BARTD trips, journeys on which passengers will come to BARTD by a Muni route (Muni-BARTD), by an AC route (AC-BARTD) and in various other combinations (i.e., Muni-BARTD-Muni, AC-BARTD-AC, Muni-BARTD-AC, AC-BARTD-Muni, BARTD-Muni, and BARTD-AC).

TABLE 1
ALTERNATE FARE PROPOSALS, BAY AREA TRANSIT SYSTEMS

(a) Alternate Fare Plans Considered for BARTD

Fare Category	Plan B-1	Plan B-2	Plan B-3	Plan B-4
Minimum adult fare (cents)	25	25	25	25
Minimum fare applicable to non-transbay trip of (miles):	8	8	5	4
Maximum adult fare ($)	1.00	1.00	1.00	1.00
Minimum transbay fare (cents)	35	50	50	50
Fare increment for transbay trip (cents)	10	10	4 miles added	4 miles added
Adult fare within San Francisco (cents)	25	25	25	25
Maximum fare on peninsula (Daly City-San Francisco) (cents)	25	25	30	35

(b) Alternate Fare Plans Considered for AC Transit

Fare Category	Plan A-1	Plan A-2
Adult single zone cash fare (cents)	25	25
Adult token fare (cents)	20	None
Transfers	Free	Free
Minimum transbay fare—cash/commute (cents)	50/45	50/45
Surface feeder to BARTD (cents)	10	25/round trip
Student and child fare (cents)	15	15

(c) Alternate Fare Plans Considered for Muni

Fare Category	Plan M-1	Plan M-2	Plan M-3
Adult surface fare (cents)	15	20	25
Surface transfers (cents)	Free	5 for first transfer only	Free
Adult Muni rapid fare (cents)	25	25	25
Adult combination surface rapid fare (cents)	25	30	30
Surface feeder to BARTD (cents)	5	10	25/round trip
Student and child fare (cents)	5	10	15

BARTD Fare Plans B-1 to B-4 were analyzed in combination with AC Transit alternate Plans A-1 and A-2, as well as Muni Plans M-1 to M-3—making a total of 24 complete multi-system analyses.

SUB-MODAL SPLIT BETWEEN SURFACE AND RAPID TRANSIT

New rapid transit systems in Toronto, Montreal and Chicago opened in the past two decades reveal that an overwhelming majority of the users of these systems are not new to transit. Studies on the Yonge Street Subway in Toronto show that 86 percent of the riders were previously surface transit users. Similarly, on the Congress Street rapid transit and the Skokie Swift demonstration in Chicago, diversion studies show the proportion of previous transit users at 85 percent on Congress Street and 75 percent on the Skokie Swift. These indications do not lessen the importance of rapid transit in terms of its primary task of winning people over from auto travel; however, they do point up the need for careful analysis of sub-modal split—the distribution of transit users between rapid and surface lines.

Some further attention has been given to transit diversion in Philadelphia where estimates have been made for distribution of transit riders between surface and grade-separated lines reflecting the relative convenience of surface transit for short trips and passenger reluctance to go down into a subway or up to an elevated structure (1).

The gross transit market in San Francisco derived for 1975 was developed initially on the basis of factors which affect total transit use and assigned to specific transit

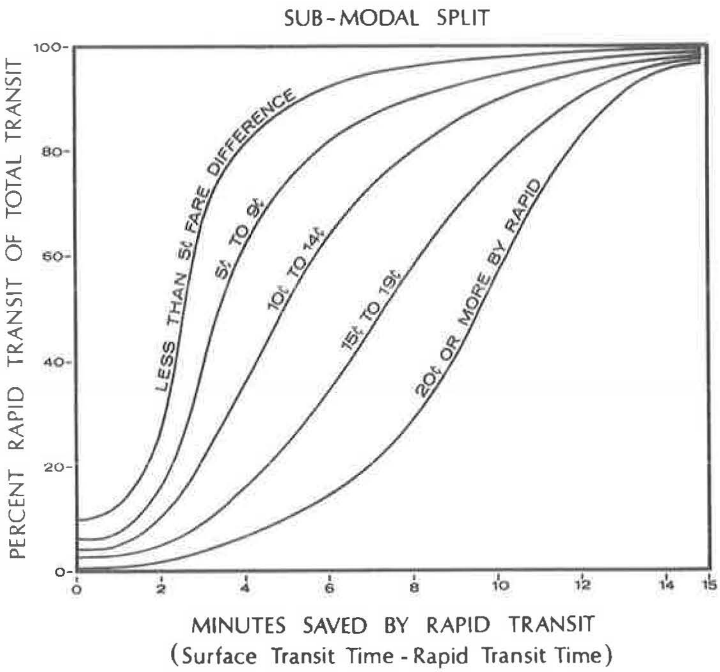

Figure 2. Effect of fare and time differentials on rapid transit use.

lines on the basis of the route or combination of routes representing the minimum time path from origin to destination. Thus, for example, a short trip of a mile or mile and one-half was originally assigned to the rapid transit system as opposed to a surface alternative whenever the trip time on the rapid transit line was slightly less than the surface route, regardless of fare differences.

However, diversion studies reveal that an important element of the "sub-modal split" equation is the fare differential between rapid transit and surface lines. With rapid transit fares higher than surface travel, a significant group of rapid transit patrons will prefer the slower surface alternative. Only when time savings on rapid transit are large (15 minutes or more) do most riders prefer that service to the alternative surface lines, despite a fare differential.

Based on experience in other cities with rapid transit, a family of time differential diversion curves was developed, stratified by fare differences between rapid and surface transit (Fig. 2). Each curve represents a 5-cent fare difference and expresses the proportion of rapid transit usage in relation to time savings by rapid transit over surface alternates. Thus, a trip which had a 5-minute saving on rapid transit with 10 cents additional fare was analyzed differently from a trip with the same time saving but with a 20-cent fare differential.

This process resulted in a series of internal redistributions of traffic between rapid transit and surface routes. While the aggregate volume of riding on the Bay Area transit systems in 1975 was not affected, there was some shifting to surface lines of trips which, strictly on a time comparison basis, had been assigned to the rapid transit system.

Traffic Reduction Due to Fare Increase

As previously indicated, the effect of fare increase (and of fare decrease) on transit riding has been analyzed periodically over the past two decades. Figure 3 illustrates the experience of 77 bus fare changes, revealing a high correlation coefficient ($R = 0.92$).

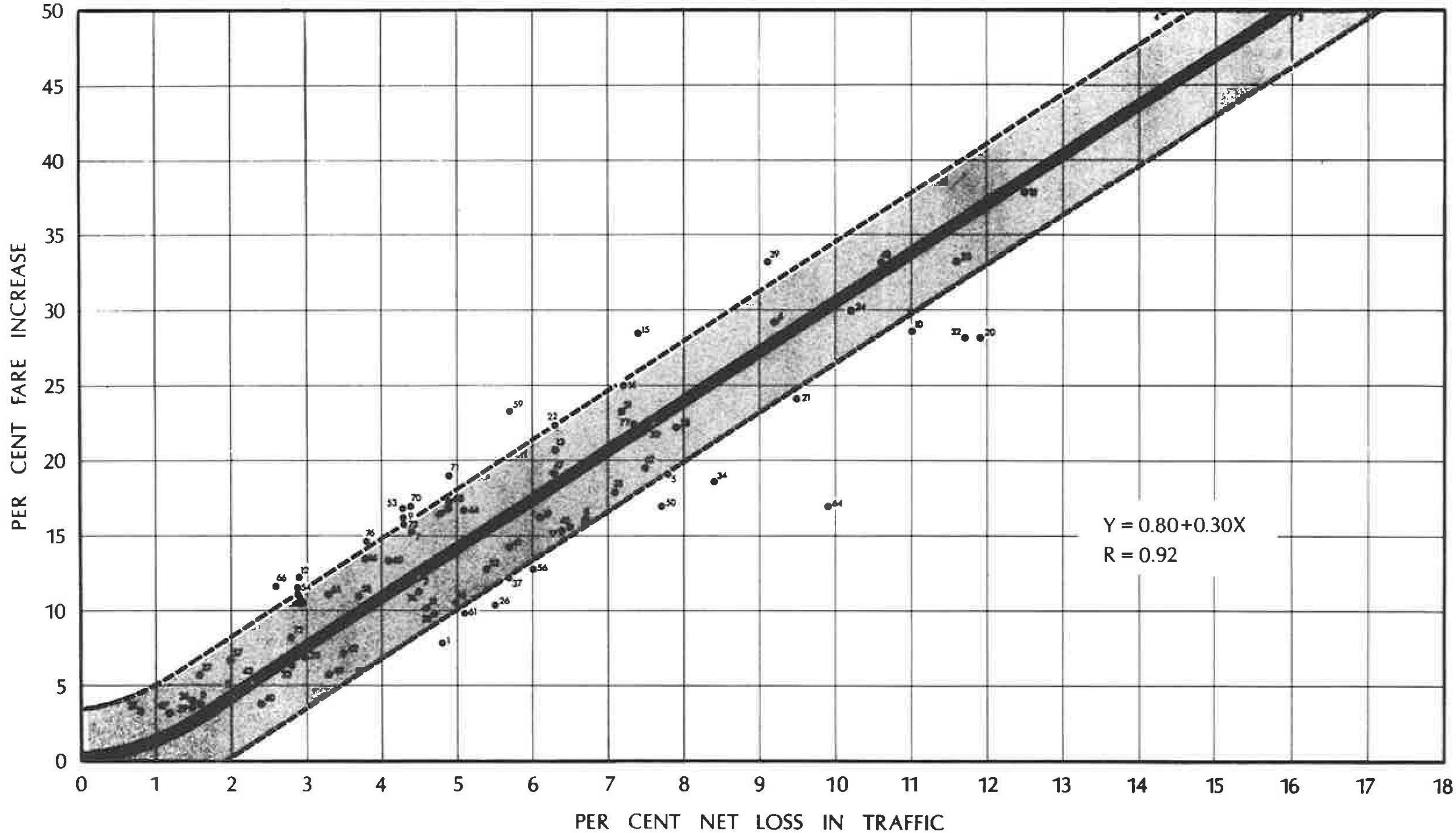

Figure 3. Shrinkage in passenger traffic due to fare increases—transit systems throughout the United States.

Universally, fare increases in the range here being considered for the Bay Area systems have produced revenue gains for the transit systems involved. It is not until the minimum or basic fare level reaches 30 to 35 cents that diminishing returns may offset the revenue yield. But it is also a universal phenomenon that some passenger riding is lost due to each fare increase, no matter how nominal that increase may be.

The factor expressing the rate of passenger loss attributable to fare increase is known among utility commissions as "loss ratio" or "shrinkage ratio." It is applied to the percentage increase in fare to determine the rate of passenger loss as a result of the higher price.

The loss ratios for fare increases in a group of representative cities are given in Table 2. The last fare change in San Francisco, which occurred in June 1952, raised the adult rate from 10 to 15 cents. Prior to the fare increase, traffic had been declining slowly at a rate of 1.87 percent; this drop was accelerated after the fare increase to a rate of 11.04 percent. The net traffic decline due to the 50 percent fare increase, therefore, was 9.17 percent, resulting in a loss ratio of 0.18.

In light of prior experience in San Francisco and other fare changes throughout the United States, it was estimated that a loss ratio of 0.20 would be applicable in the Bay Area for fare increases establishing a minimum fare of 25 cents or less.

There was an additional element to be considered in predicting the impact of fare changes on the BARTD and Muni rapid transit systems. For those particular facilities, a lower shrinkage loss was anticipated because of the superior quality of service and passenger amenities represented in rapid transit compared to existing forms of transit in the Bay Area. Patrons will be required to pay more than they do now, but they will be getting a faster and more comfortable journey in more attractive vehicles. While an increase in fares for rapid transit journeys above existing surface fares can be expected to have some effect on riding, it will be less than the passenger loss which would result from a higher fare on existing routes and service. In calculating the impact of a rate increase from the existing surface transit fare to a proposed higher rapid transit fare, therefore, a loss ratio of 0.10 was applied.

Rapid transit journeys in many cases will involve access by surface transit vehicles to rapid transit lines and/or the use of surface lines for reaching the final destination after leaving rapid transit. These surface feeder legs were treated as a part of the rapid transit trip, and the loss ratio of 0.10 was applied to the entire journey. The 0.20 loss ratio was used only for journeys completed entirely on surface routes.

TABLE 2

PASSENGER "LOSS RATIO" RESULTING FROM FARE INCREASES ON MAJOR TRANSIT SYSTEMS INCREASING FARES TO LEVELS UP TO 25 CENTS

Date	City	Cash Fare Increase (cents)		Loss Ratio
		From	To	
June 1952	San Francisco	10	15	0.18
July 1953	New York	10	15	0.20
July 1966	New York	15	20	0.18
Oct. 1955	Boston (surface)	13	15	0.19
	(rapid transit)	18-20	20	
Feb. 1958	Portland	20	25	0.28
Dec. 1963	Salt Lake City	20	25	0.12
June 1958	Connecticut Co.	15	20	0.28
Oct. 1963	Atlanta	20	25	0.28
July 1957	Cincinnati	20	25	0.24
Jan. 1954	Philadelphia	15	18	0.14
Oct. 1958	Baltimore	20	25	0.08
Jan. 1954	NYC omnibus	10	13	0.30
July 1957	Chicago	20	25	0.30

	Daly City	24th Street	Downtown San Francisco	Downtown Oakland	MacArthur	Orinda	Walnut Creek	Concord	Berkeley	El Cerrito	Richmond	Fruitvale	San Leandro	Hayward
24th Street	$0.25													
Downtown San Francisco	0.35	$0.25												
Downtown Oakland	0.75	0.60	$0.55											
MacArthur	0.75	0.70	0.60	$0.25										
Orinda	0.90	0.80	0.75	0.40	$0.35									
Walnut Creek	1.00	0.90	0.85	0.65	0.60	$0.25								
Concord	1.00	1.00	1.00	0.75	0.75	0.55	$0.35							
Berkeley	0.85	0.75	0.70	0.30	0.25	0.55	0.75	$0.85						
El Cerrito	0.90	0.80	0.75	0.40	0.30	0.65	0.80	0.95	$0.25					
Richmond	0.95	0.90	0.85	0.55	0.50	0.75	0.90	1.00	0.35	$0.25				
Fruitvale	0.80	0.70	0.60	0.25	0.30	0.60	0.75	0.85	0.40	0.55	$0.65			
San Leandro	0.90	0.80	0.75	0.40	0.50	0.65	0.85	0.95	0.60	0.70	0.75	$0.30		
Hayward	1.00	0.90	0.85	0.60	0.65	0.80	0.95	1.00	0.75	0.80	0.85	0.50	$0.30	
Fremont	1.00	1.00	1.00	0.85	0.85	1.00	1.00	1.00	0.95	1.00	1.00	0.75	0.65	$0.50

FARE PLAN FORMULA

25¢ First 4 Miles
25¢ +4¢/mile - 4 to 10 Miles
50¢ +3¢/mile - 10 to 15 Miles
65¢ +2¢/mile - over 15 Miles
$1.00 Maximum Fare

TRANSBAY - Mileage plus 4 Miles with 50¢ Minimum

PENINSULA - 25¢ Fare within San Francisco
35¢ Maximum Fare

Figure 4. Fare Plan B-4—prospective BARTD fares, typical stations.

SUMMARY OF PASSENGERS AND REVENUE FOR 1975

The passenger and revenue volumes projected for the three Bay Area transit systems on the machine run of fare schedules ultimately recommended are summarized in Tables 3 and 4. Table 3 deals solely with adult riding and revenues, while Table 4 includes child and student riding and advertising income, as well as adult patronage.

The BARTD operation, based on Fare Plan B-4 (Fig. 4), is forecast to carry 53.9 million adult riders, of whom 36 percent will be transbay passengers, about 40 percent San Francisco riders and the balance--approximately 24 percent—riders on the East Bay portion of the BARTD system.

In terms of adult patronage, the Muni system is expected to carry two-thirds of 1957 Bay Area transit patrons. Under the

TABLE 3

BAY AREA TRANSIT SYSTEMS
(1975 Annual Adult Passengers and Revenue Under Machine Run VI)

System (Fare Plan)	Passengers	Revenue ($)
BARTD (B-4):		
Transbay	19,419,900	14,014,305
East Bay	12,643,740	5,041,365
San Francisco	21,796,200	5,678,400
BARTD total	53,859,840	24,734,070
Muni (M-3):		
Richmond rapid	17,245,559	4,311,390
Sunset rapid	14,377,088	3,594,273
Twin Peaks rapid	10,886,684	2,721,672
Muni rapid total	42,509,331	10,627,335
Surface only	57,848,190	14,357,921
Surface—BARTD	43,234,124	5,045,329
Surface—Muni rapid	45,705,200	2,048,610
Muni surface total	146,787,514	21,451,860
Muni system total	189,296,845	32,079,195
AC Transit (A-2):		
Surface only	18,614,044	4,952,517
Surface—BARTD	24,621,170	2,973,321
AC system total	43,235,214	7,925,838
Total	286,391,899	64,739,103

TABLE 4

BAY AREA TRANSIT SYSTEMS
(1975 Annual Adult, Child and Student Passengers, Passenger and Advertising Revenues Under Machine Run VI)

System (Fare Plan)	Adult, Child and Student Passengers	Passenger and Advertising Revenue ($)
BARTD (B-4)	56,552,832	25,723,433
Muni rapid (M-3)	44,634,798	11,052,428
Muni surface (M-3)	163,862,047	24,253,232
Muni system total	208,496,845	35,305,660[a]
AC Transit (A-2)	60,414,714	10,607,791[b]
Total	325,464,391	71,636,884

[a]It is estimated that special and charter revenues will add $300,000 annually to the line passenger and advertising revenues shown here.

[b]It is estimated that charter revenues will add $800,000 annually to the line passenger and advertising revenues shown here.

projected arrangement, Muni will operate its own surface and rapid transit service, as well as feeders to BARTD.

Derivation of passenger and revenue estimates for AC Transit were based on the techniques previously described, using a loss ratio of 0.20 for AC Transit riding under Fare Plan A-2 and a corresponding ratio of 0.10 for combination journeys with BARTD.

JOINT FARE DISCOUNT

Serious consideration was given to the added volume of riding induced by offering a fare discount for combination journeys. Six discount proposals were analyzed for joint fare reductions ranging from 5 to $12\frac{1}{2}$ cents on the surface systems (Table 5). The revenue yields to feeder line and trunk route under various amounts of discount were readily determinable. Derivation of passenger volumes and revenue yield under these combination proposals was based on the two adjustments previously described: (a) a shift of passengers among alternate routes of BARTD and the surface systems on the basis of passenger convenience, time and fare differentials, followed by (b) shrinkage or increase of passenger volumes in combination journeys as a result of the discount in fare.

It was in devising an acceptable formula for sharing the fare discount among affected transit systems that the fare analysis became obscured. The amount to which a surface system is entitled for carrying a joint fare rider may be developed in relation to the length of ride and fare charged for non-feeder trips on that particular local system.

TABLE 5

SURFACE AND BARTD-FEEDER FARES AND DISCOUNTS UNDER SEVERAL FARE PLANS

Fares and Discounts	Fare Plan					
	A	B	C	D	E	F
(a) BARTD-Muni						
Fare (cents):						
Muni surface	15	15	20	20	25	25
Single-vehicle BARTD	25	25	25	25	25	25
Muni-BARTD	35	35	35	35	40	37.5
Muni-BARTD-Muni	35	40	35	45	50	37.5
Discount (cents):						
Muni-BARTD	5	5	10	10	10	12.5
Muni-BARTD-Muni	5	0	10	0	0	12.5
Payment (cents):						
BARTD to Muni	2.5	2.5	2.5	2.5	0	2.5
(per passenger)	2.5	0	2.5	0	0	2.5
Total annual discount on surface feeders ($)	1,884,698	1,669,777	3,922,932	3,462,165	3,377,730	4,839,600
BARTD to Muni discount share ($)	946,648	834,889	985,340	865,541	0	972,437
(b) BARTD-AC Transit						
Fare (cents):						
AC surface	–	–	20	20	25	25
Single-vehicle BARTD	–	–	25	25	25	25
AC-BARTD	–	–	35	35	40	37.5
AC-BARTD-AC	–	–	35	45	50	37.5
Discount (cents):						
AC-BARTD	–	–	10	10	10	12.5
AC-BARTD-AC	–	–	10	0	0	12.5
Payment (cents):						
BARTD to AC	–	–	5	5	0	2.5
(per passenger)	–	–	5	0	0	2.5
Total annual discount on surface feeders ($)	–	–	2,166,510	1,955,550	2,024,930	2,817,690
BARTD to AC discount share ($)	–	–	1,083,250	977,770	0	565,620

An alternate approach would relate the amount to be received by the local system for carrying the feeder line passengers to the average cost per passenger on the entire surface operation. Another fundamental approach would be to relate the average length of ride for feeder passengers on a particular local system to the length of ride on the rapid transit line to which feeder passengers are delivered.

While surface feeder legs will ordinarily involve short rides, a higher than normal proportion of BARTD feeder trips will be peak-hour travel—trips occurring at a period of the day when it is necessary for the surface systems to add manpower and vehicles in order to take care of BARTD patrons. On the basis of cost of service, therefore, it may be held that the surface lines are entitled in many instances to full fares for feeder patrons carried to rapid transit.

These basic elements—length of haul on the one hand and proportion of peak-hour traffic on the other—are important counterbalancing considerations. A wide variety of formulas can be devised provided there is agreement among the carriers on objectives. In this instance, the three transportation agencies will have to give more detailed study to policy on feeder service and its several complexities before a formula can be evolved. To a considerable degree, the final arrangement will depend on how much feeder surface operation to BARTD is required and how much is realized in fare-box revenue in the aggregate from that service.

In order to complete the fare analyses and revenue yield calculations, an arrangement was tested whereby the discount represented in the surface feeder fare to BARTD below the present fare levels on each surface system would be divided equally between BARTD and Muni or AC Transit, as the case may be. Thus, using existing fares as the basis, a passenger riding a Muni surface line to reach BARTD and/or after leaving BARTD would pay 10 cents to Muni. BARTD would pay Muni an additional $2\frac{1}{2}$ cents for each such rider, representing 50 percent of the discount in the feeder fare below the present 15 cent fare level on the Muni system. On AC Transit, the basic fare is 20 cents while the feeder patron to BARTD would pay 10 cents. This discount of 10 cents would be borne equally by AC Transit and BARTD, requiring a payment of 5 cents per passenger by BARTD to AC Transit.

The effect of this discount-sharing proposal is pointed up in the six fare plans summarized in Table 5. In this series, Plans A and B were not applied to AC Transit, since they involved a 15 cent minimum fare—5 cents below the present AC Transit rate.

As shown in Table 5, the amount of payment from rapid transit to the feeder systems varied from nothing under one proposal to more than $2 million on two others, offset to a substantial degree, however, by higher gross revenue on the rapid transit line.

As ultimately worked out, a 25 cent minimum fare for adult riders was recommended on all three systems. Further, the recommended amount which the passenger would pay for feeder surface ride to BARTD would be $12\frac{1}{2}$ cents, or one-half the basic adult fare on either of the surface operations. In another phase of the NCTDP study dealing with fare collection, it was recommended that this be accomplished by selling the feeder transportation on the basis of 25 cents for a surface round trip.

OPERATING COST ANALYSIS

The end result of the foregoing fare analyses was a distribution of riding and revenue among the three Bay Area transit systems in 1975. To evaluate the proposed fare structures, singly and in combination, it was necessary to determine their sufficiency in meeting projected operating expenses. This was accomplished by projecting the cost of carrying prospective passenger volumes under each fare plan—first, by determining the amount of service required for that patronage, and then by estimating the cost of that service. Various methods were developed for determining both of these sets of facts.

The number of adult passengers by lines under each projected fare plan served as the basis of deriving vehicle-miles and hours of service to be operated on each surface route in 1975. Service levels on existing routes were analyzed by class of lines to determine the mileage provided in relation to riding volumes.

TABLE 6

PROJECTED 1975 RESULTS OF OPERATIONS
(Three Bay Area Transit Systems)

Category	1965	1975	Percent Change
Revenue passengers:			
BARTD	–	56,552,832	–
Muni	141,724,908	208,496,845	+ 47.1
AC Transit	52,905,464	60,414,714	+ 14.2
Total	194,630,372	325,464,391	+ 67.2
Passenger & advertising revenues ($):			
BARTD	–	25,723,433	–
Muni	19,820,932	35,605,660	+ 79.6
AC Transit	13,268,079	11,407,791	- 14.0
Total	33,089,011	72,736,884	+119.8
Cost of operations ($):			
BARTD	–	13,596,360	–
Muni	27,966,377	43,525,177	+ 55.6
AC Transit	14,827,112	17,055,659	+ 15.0
Total	42,793,489	74,177,196	+ 73.3
Net Revenues ($):			
BARTD	–	10,589,016	–
Muni	- 7,991,711	- 6,947,080	+ 13.1
AC Transit	- 1,463,421	- 5,082,248	-247.3
Total	- 9,455,132	- 1,440,312	+ 84.8

Future surface transit costs were then determined by calibrating cost allocation models on the basis of the three independent variables developed—vehicle-miles, vehicle-hours and passenger revenue—as follows:

Muni bus:

$$C = 3.359H + 0.3862M + 0.11456R$$

Muni trolley coach:

$$C = 6.108H + 0.3803M + 0.09462R$$

Muni cable car:

$$C = 11.058H + 2.461M + 0.19624R$$

AC Transit bus:

$$C = 6.209H + 0.2541M + 0.03865R$$

Sensitivity tests on cost allocation formulas revealed a satisfactory level of accuracy for planning purposes. The result was to produce individual route cost figures for the AC Transit and Muni surface systems in arterial, cross-town and feeder service.

The projected results of operations for the three systems in 1975 under the recommended fare structures are summarized in Table 6. The influence of the proposed fare increases is revealed by relative gains estimated for revenue passengers and passenger revenue. The latter is projected to increase by nearly 120 percent, while revenue passengers are expected to rise more than 67 percent. As shown, high costs due primarily to more extensive operations will require this entire increase, leaving the three systems in a slight deficit position overall.

As a final step, the future cost/revenue margin for each of the 120 surface routes, as well as for the several rapid transit trunk lines, was derived. This important measure will enable system managers to analyze the prospective operations of each route in terms of its own self-liquidating capabilities, its contribution to feeding rapid transit and other arterial lines, as well as less tangible warrants of cost effectiveness.

REFERENCE

1. Mass Transportation Diversion Curves, Subway-El vs. Surface Lines (RR Excluded). Penn Jersey Tech. Memo. Series TM 14-9, 1960.

Discussion

R. L. CARSTENS, Associate Professor, Department of Civil Engineering, Iowa State University—The author's report on methodology employed to forecast modal choice is a helpful contribution to the understanding of travel characteristics in urban areas. This very complex decision-making process is even more difficult to quantify when a choice of alternative forms of transit is available.

The writer would agree that the fare charged for transit service influences a choice among alternative travel modes. Examples reported by the author and shown in Figure 3 indicate that the percent loss in patronage resulting from a fare increase is about one-third of the percent fare increase. Stated otherwise, this experience has indicated a shrinkage ratio of about 0.33 or a price elasticity of -0.33 for transit patronage. The author states quite correctly that this correlation has been well established.

The writer has investigated transit operating experience in 13 cities in Iowa starting with 1950 but covering shorter time periods (depending upon the availability of data) in most cities. These 13 communities vary in size from about 20,000 to more than 200,000 population. In most of them, particularly in recent years, the quantity of transit service has been quite low. For comparisons among cities, the quantity of service is expressed as a service factor, S, as follows:

$$S = \frac{\text{Annual revenue miles of transit service}}{\text{Population in transit service area}}$$

There have been frequent changes in the quantity of service afforded by the transit operations studied, and these changes often have occurred concurrently or nearly concurrently with fare changes. Since previous research had established a relationship between the level of service and transit patronage, it was possible to isolate the probable effect of service changes. Having done this, elasticities were then calculated to relate changes in transit patronage with fare changes. These were found to vary widely for the 30 substantial fare changes that occurred in 12 cities during the period studied. A median elasticity was -0.67, or about twice that developed from the author's data.

Although the pattern of variation in elasticities was very scattered, at least one relationship was evident to help explain the differences among cities. The level of service appears to exert a most important influence on price elasticity in that the effect of a fare increase upon patronage was found to be markedly more pronounced when the level of service was low. Various other factors, many of which it was not possible to identify, undoubtedly were of importance in particular cities. The writer believes, however, that the low levels of service common in cities in Iowa account primarily for the fact that elasticities are so much higher than those encountered in other studies.

Several specific examples of extremely elastic behavior of transit patronage were noted in the study, most of these occurring when the service level was quite low. Recent experience in Iowa City is an example. Here, the average fare had been about $0.20 with a $0.25-base fare and a substantial number of reduced-rate school fares. Then, in November 1966, a uniform fare of $0.10 was introduced. Patronage immediately nearly doubled and continued to gain gradually until the increase in ridership amounted to more than 100 percent after the reduced fare had been in effect for a year. A comparison of patronage during the fourth quarter of 1967 with the same period in 1965 indicates an increase of 127 percent in patronage. Some increase in service occurred during the intervening period with the service factor changing from about 5.4 in 1965 to approximately 5.8 in 1967. Discounting the probable effect of the added service and comparing these two quarterly periods, a decrease of 48 percent in fare apparently induced an increase of 98 percent in patronage.

An implication of shrinkage ratios greater than 1.0 is that, depending on the magnitude of the change, a fare decrease might increase revenue while a fare increase may actually result in a decline in passenger revenues. In general, however, the considerable price elasticity of transit patronage when levels of service are low has resulted in changes in passenger revenues that were quite small following fare changes in most cities in Iowa.

Elasticities on the order of those presented by the author were encountered in Iowa only when service factors were about 20 or higher. Service at this level would probably be limited today to large transit-oriented urban centers or those smaller cities with a large number of captive riders. It would appear that some reevaluation may be in order for our understanding of the correlation between price increases and loss of patronage.

EUGENE L. GRANT, Professor of Economics of Engineering, Emeritus, Stanford University—An important aspect of the choice of a passenger fare schedule on an urban mass transit system is the total amount of revenue that must be secured from the passengers. The aimed-at total passenger revenue objectives differ considerably among different publicly owned transit systems. Fares may be intended merely to cover current out-of-pocket outlays for operation and maintenance with the remainder of the costs to be met from general taxation or other sources. Or they may be set to cover part or all of the capital costs as well.

The Demand for Air Travel: A Regression Study of Time-Series and Cross-Sectional Data in the U.S. Domestic Market

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•REGULATORY agencies have a good deal of influence over rates and fares charged for the regulated service. Accordingly, the Civil Aeronautics Board has a strong and abiding interest in the effect of fares on demand for air travel, and the staff conducts economic and statistical research addressed to the questions: How will fare changes affect growth of traffic? What is the proportionate effect on air passenger demand of a given percentage change in fares, other things equal?

This paper is a progress report of staff studies of these questions, studies necessarily limited by the data available and by the methods employed. The statistical method employed is that of ordinary least squares, and the conclusions depend on the basic assumptions for the valid application of that method. The data do not yet permit study of the segments of demand—business and nonbusiness, for example—nor of the varied response of traffic to the structure of promotional fares. We hope and expect that these lacks will be remedied in the future. General average elasticities, short term and long term, and according to length of trip, which the present study does yield, may perhaps find some use in the meantime, and may help to stimulate collection of better data and application of improved methods.

Presumably everyone will agree that the Marshallian law of demand applies to air travel: people will buy more at lower prices and less at higher prices, if other things are not different or do not change. But other things, such as population, incomes, and tastes, are different and do change, and the task of the researcher is somehow to hold them constant in order to gauge the net effect of fares. The statistical method of multiple regression can be applied to the available data in at least two ways: by analysis of time series, and by analysis of cross-sectional data for city-pair markets.

TIME SERIES

Figure 1 illustrates the framework of the problem. In the upper panel, a demand curve, D_1, having a uniform elasticity is drawn to scales of fares per mile and billions of passenger-miles per quarter-year. The same curve is also shown as it would be a year later, D_2, shifted to the right because of the growth of population and income and because the tastes or preferences of the public become more favorable to air travel as time passes. Two supply curves, S_1 and S_2, drawn on the assumption that plenty of seats are available, are shown intersecting demand curves D_1 and D_2. Now the historical record will show a number of passenger-miles sold at the fare P_1 and a larger quantity sold a year later at the lower fare P_3. To find the effect of fares alone on traffic one must correct for the shift of the curve, and measure the increase of traffic against the decreases of fares as if both P_1 and P_2 had actually been observed. This is what regression analysis tries to do.

The lower panel of the chart shows the same demand and supply curves drawn to the logarithms of fares per mile and passenger-miles. The elasticity of demand is then

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 47th Annual Meeting.

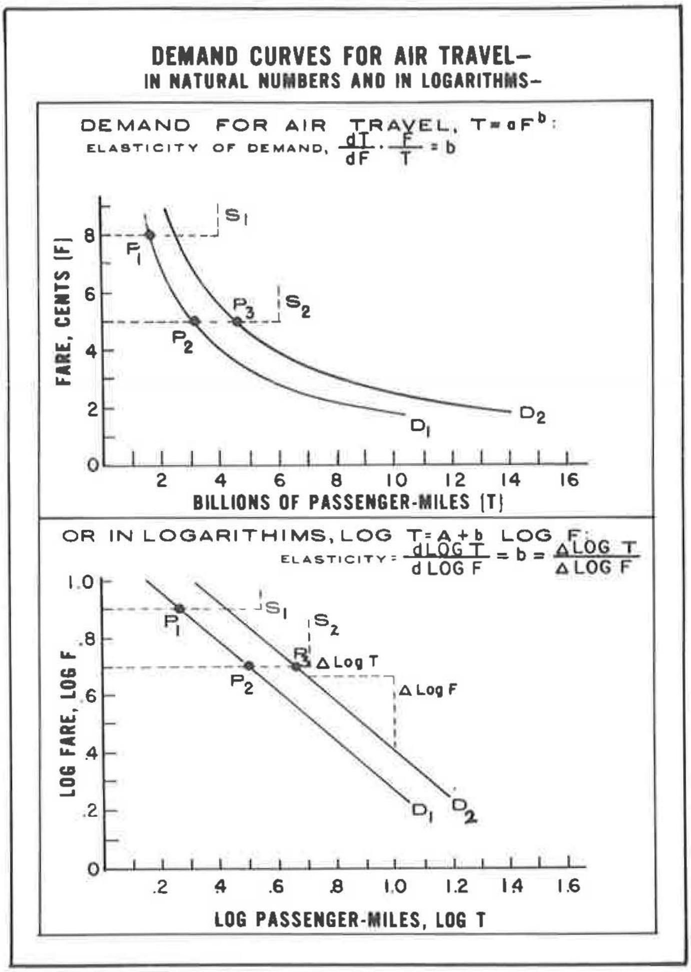


Figure 1.

simply the slope of the logarithmic line, measured as "change in log traffic over change in log fares," that is, Δ log T $\div$ Δ log F. This use of logarithms gives better statistical results than other formulations we have tried.

Figure 2 shows the simple time-series history of air passenger traffic, fares, and income and gives the quarterly traffic figures for passenger-miles and the corresponding series for average real fares per mile. The latter series is computed: total passenger revenues are divided by passenger-miles, the Federal excise tax added, the result seasonally corrected and deflated by the Consumer Price Index. This is, therefore, a general average of all fares paid by the public, reflecting effects of discount fares and the growing proportion of coach traffic, as well as the changing tax and the relative rise of other prices.

It is worth noting that the period of slow, halting growth of traffic from 1957 to 1962 corresponds almost exactly to the period of rising fares. Furthermore, rapid growth of traffic resumed in 1962 and continued into 1966 and 1967 when fares resumed their downward trend.

In the lower panel of Figure 2 are shown the same series of traffic and fares, but plotted as percentage changes from the corresponding period of the preceding year.

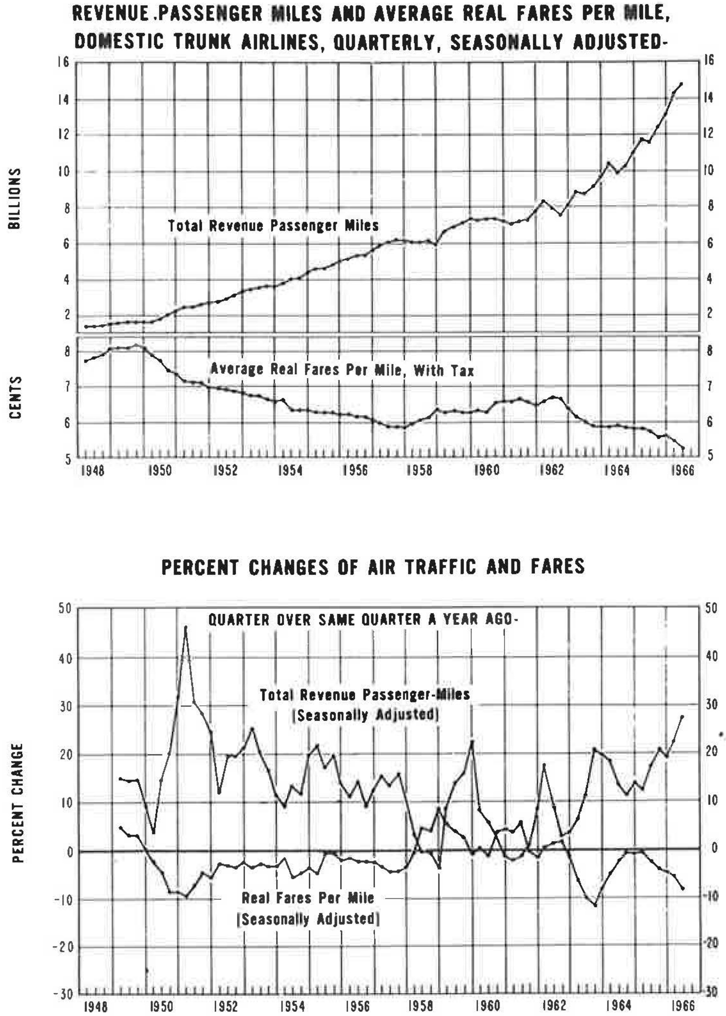


Figure 2.

Again, there appears a clear inverse correspondence between changes of traffic and changes of fares.

Two series of the U.S. Department of Commerce are available to measure the increasing demand for air travel as the economy expands and incomes rise: disposable personal income and gross national product. The personal income series has generally been preferred in this study as better reflecting general economic changes likely to influence both business and nonbusiness demand for air travel. Both the GNP and the income series are plotted with air traffic in Figure 3. Whether looked at as aggregate levels (upper panel) or as percentage changes (lower panel), both series show a fairly clear correspondence with air travel.

Faster aircraft have meant shorter trip times and thus better service, over the years, and must have stimulated growth. However, many attempts with time series to find a relationship between rising flying speed and growth of traffic have not been successful. The cross-section studies described later have been more productive.

The rise of "coach" service and the decline, both relative and absolute, of "first class" are outstanding historical trends. Looking first at the lower panel of Figure 4,

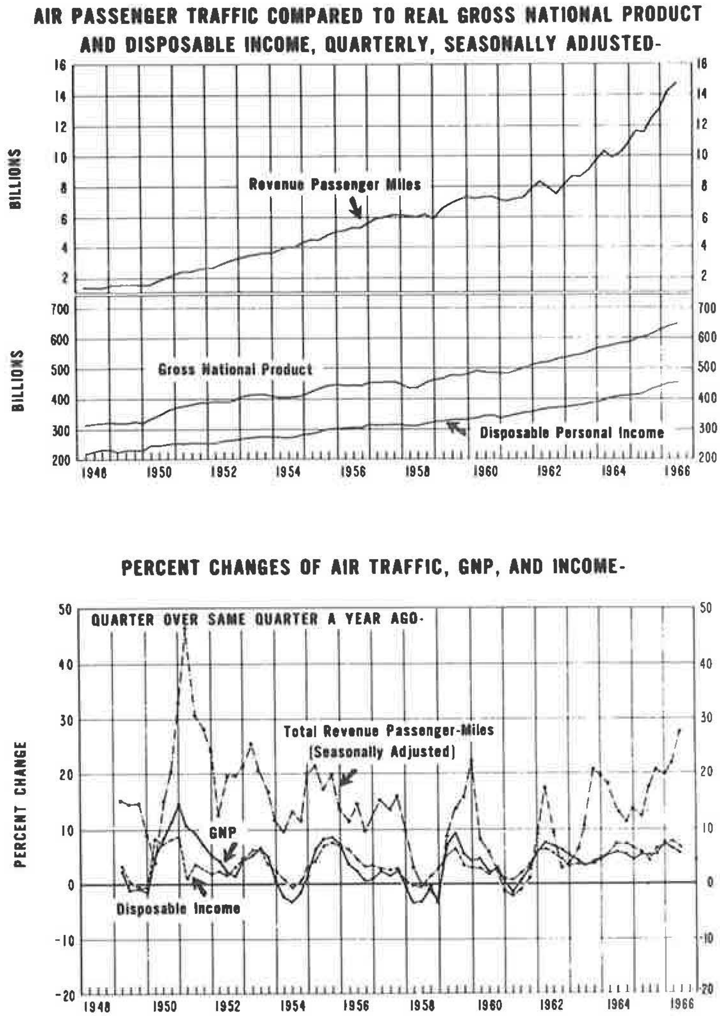


Figure 3.

coach traffic grew from nothing in 1948 to overshadowing importance by 1966. Growth has been both fast and steady, at 20 percent or more per year, since the beginning of the jet era in 1958-59. First class traffic, though holding its own in recent years, is actually less than it was a decade ago, and as a proportion of the total has declined precipitously.

The upper panel of Figure 4 shows the history of average real fares per mile, first class and coach, as trends and as percentage changes over the year. The outstanding facts are their fairly close correspondence over the period, but also the narrowing of the absolute margin between the classes of service since 1960 (1).

Returning now to the basic problem illustrated in Figure 1, the curve of total demand for air travel may be thought of as sloping downward to the right as average fares per mile decline. As time passes, the entire curve moves to the right with the growth of total income and population, with the improvement of service, and as preferences of the public grow more favorable. An econometric model to measure the net effect of fares on traffic may be devised by linking traffic, as a dependent variable, to population,

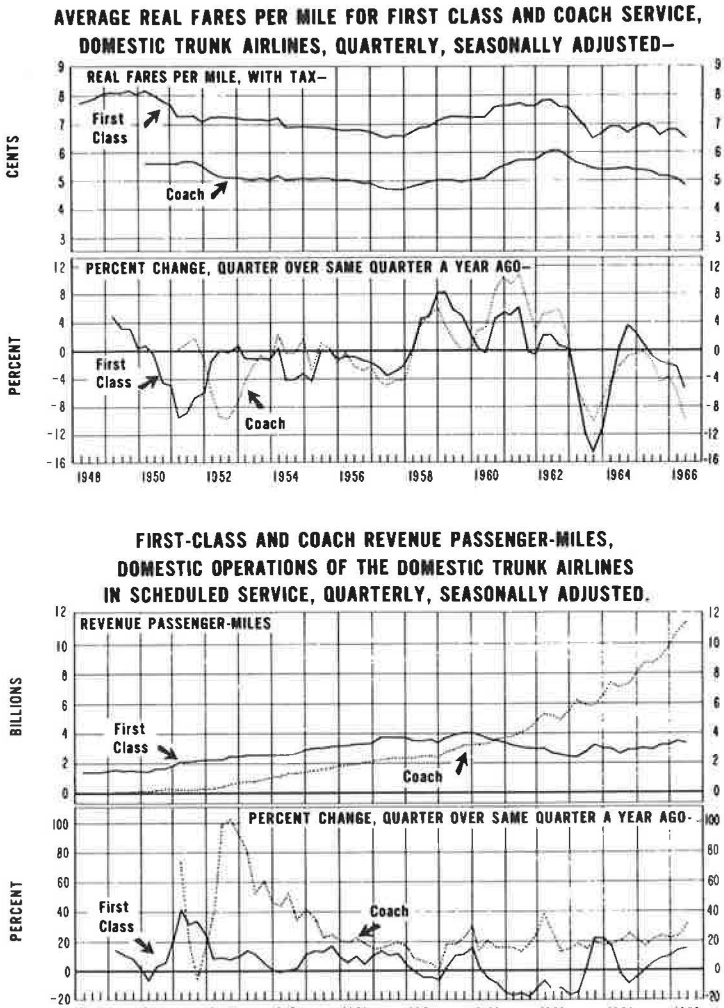


Figure 4.

income, improving quality of service and preferences of the public, and fares in real dollars. Then the "weights" or coefficients to be attached to each of the determining factors may be estimated by the method of least squares. The coefficient for fares is the desired estimate of the relationship of traffic to fares, after allowing for, or holding constant, the effects of the other factors.

Growing population can be most conveniently allowed for by dividing the traffic and income series by population, to yield a curve of demand per capita, related to income per capita. Improving quality of service and more favorable preferences of the public may both be thought of as changing gradually with time, so that time may be used as a proxy for these determinants. If T = passenger-miles per capita; F = average fares per mile, in real dollars; Y = real disposable income per capita; and t = clock time, or net trend, a proxy; then we may write a functional expression

$$T = f(F, Y, t) \tag{1}$$

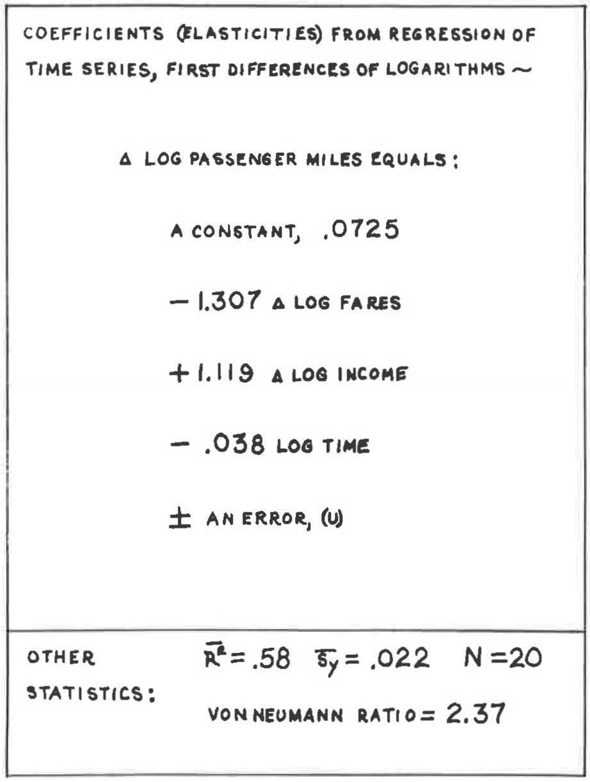


Figure 5. Air travel related to fares and income, 1946-1966.

Now this study assumes that the relationship of quantity demanded in the market to fares, incomes, and other determining factors is multiplicative, so that when logarithms of all the variables are taken the relationships become linear, and the basic function may be written

$$\log T = K + a \log F + b \log Y + c \log t + u \tag{2}$$

where u is a term for the error.

The linear-in-the-logarithms formulation of the demand function has proved relevant and useful over the years for many empirical studies of demand, and this is the principal justification for its adoption in this one. The characteristics and usefulness of the log-linear demand function are discussed in several standard works (2-6). Also, its residuals or errors perform better than those of straight linear models. However, the logarithmic model yields only one elasticity coefficient for each factor for each regression, which may be regarded as an average elasticity over the range of the data.

Now for good statistical reasons, the basic function is fitted to the first differences of the logarithms of traffic, fares, and income. That is, the percentage change of traffic from one year to the next is related to the corresponding percentage change of fares and percentage change of income. The model is then expressed

$$\Delta \log T = K + a \Delta \log F + b \Delta \log Y + c \log t + u \tag{3}$$

The coefficients, estimated by ordinary least squares applied to annual data 1946 through 1966 (data for 1966 were adjusted for the long airline strike) are

$$\Delta \log T = 0.0725 - 1.307 \Delta \log F + 1.119 \Delta \log Y - 0.038 \log t + u \quad (4)$$
$$\quad\quad\quad\quad (0.291) \quad\quad\quad (0.383) \quad\quad\quad (0.040)$$

$\bar{R}^2 = 0.576$, $\bar{S}y = 0.022$, Von Neumann ratio = 2.37, N = 20, origin of time = 1937. This equation is that used to project air traffic ten years ahead (7).

The results are summarized in Figures 5 and 6. The constant term and the coefficient for log time (K + c log t) together imply a trend rate of increase of passenger-miles per capita, if fares and incomes were constant, of something less than 5 percent per year, the net effect of changing tastes and improving service. The short-period fare elasticity of -1.307 has a standard error of 0.291. The chances are, therefore, 2 out of 3 that the true elasticity is -1.307 ± 0.291, or between -1.016 and -1.598. The chances are 19 out of 20 that the true value of the fare elasticity lies between -0.725 and -1.889. The short-period income elasticity of +1.119 has a much larger standard error of 0.383. The chances are 2 out of 3 that the true value lies between +0.736 and +1.502, etc. The coefficient for log time is not quite as large as its standard error. However, in the nature of the laws of growth there is virtual certainty that it has a negative sign.

Because they relate changes of traffic from one year to the next to changes of fares and income over corresponding periods of one year, these results may be taken as

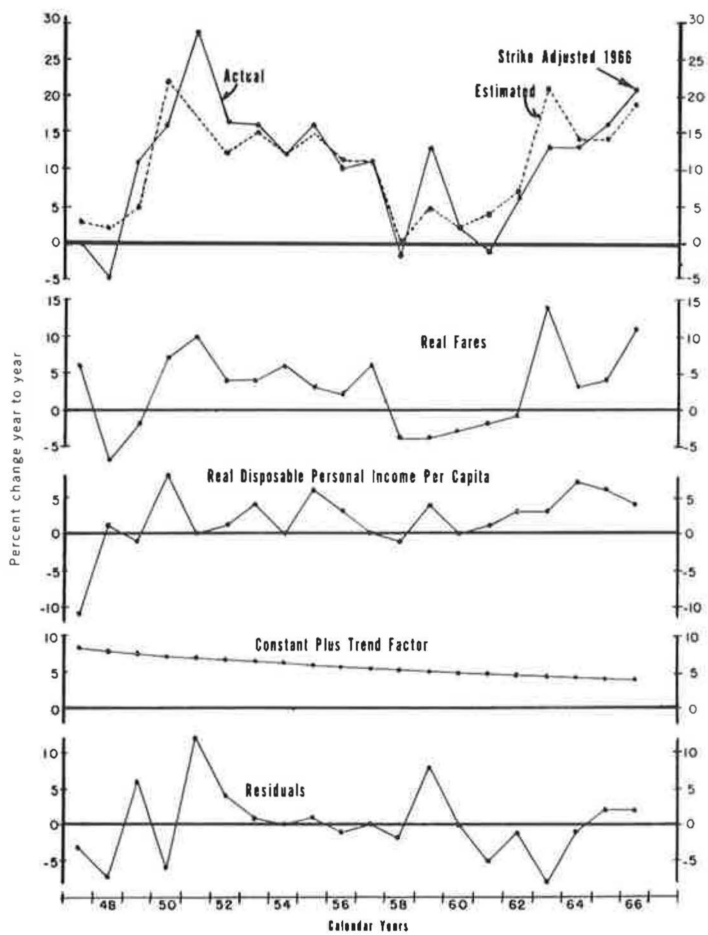


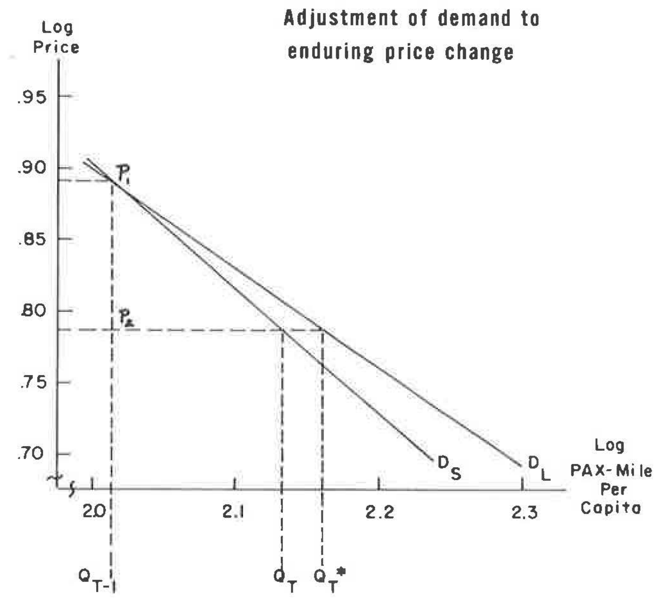
Figure 6. Percent change in RPM's per capita, actual and casual factor estimates.

estimates of short-term elasticities. Over the longer run, fares probably have larger effects on traffic, and a good deal of interest attaches to longer-period elasticities. Nerlove has devised a method of estimating long-term elasticities from time series based on a simple assumption concerning the "elasticity of adjustment" of quantity demanded to changes of price (8). Defining p_t as the logarithm of real price and q_t as the logarithm of quantity demanded, the assumption is

$$q_t - q_{t-1} = \gamma \left(q_t^* - q_{t-1} \right), \quad 0 < \gamma \leq 1 \tag{5}$$

In this difference equation the left side is the change of quantity demanded from time t-1 to time t, the expression within parentheses on the right is the difference between quantity demanded in the long run q_t^* and quantity demanded at time t-1, and γ is the elasticity of adjustment. The equation says that the percentage increase of quantity demanded in the short period is a constant proportion γ of the percentage increase of quantity demanded after the price (or income) change has had time to work itself out completely.

In Figure 7, D_L represents the long-run curve of demand and D_S a short-run curve. If price changes from P_1 to P_2 quantity demanded will increase from Q_{t-1} to Q_t, and eventually to Q_t^* if everything else remains constant and the price change has time to take full effect. Actually, more price and income changes are occurring from time to



Coefficient of adjustment:

1. $Q_T - Q_{T-1} = \gamma \left[Q_T^* - Q_{T-1} \right];$

2. $\gamma = \dfrac{Q_T - Q_{T-1}}{Q_T^* - Q_{T-1}}$

3. $\gamma = \dfrac{2.125 - 2.010}{2.160 - 2.010} = .77$

4. $D_L = \dfrac{D_S}{\gamma}$

5. $D_L = \dfrac{1.31}{.77}$

6. $D_L = 1.7$

Figure 7. The long-term effect of price on the demand for air transportation.

time so that we can never get observations on the true long-run curve, D_L. But Nerlove's model makes it possible to estimate the elasticity of D_L indirectly. He defines the long-run demand function

$$q_t^* = a\,p_t + b\,Y_t + c \qquad (6)$$

where a and b are the fare elasticity and income elasticity, respectively. By substituting Eq. 6 into Eq. 5, gathering terms, and simplifying, we obtain

$$q_t = a\gamma p_t + b\gamma Y_t + c\gamma + (1-\gamma)\,q_{t-1} \qquad (7)$$

which is not a demand function at all but an expression that can be estimated statistically. The coefficient for q_{t-1} can be reduced to the value of γ, and the long-term price and income elasticities a and b then divided out of the coefficients for current price and income.

Nerlove's formulation was fitted to the logarithms of the levels of the variables for the period 1946-1966. The method of ordinary least squares was applied with and without a separate variable for time, taken also as a logarithm with origin at 1937. The results were as follows:

Variables	Regression Coefficients	Standard Errors
Constant	-2.120	0.515
Log fare/mile	-0.809	-1.307
	(0.322)	(0.214)
Log DPI/capita	1.072	0.292
	(0.431)	(0.296)
Log RPM_{t-1}	0.669	0.234
	(0.089)	(0.096)
Log time	—	0.934
		(0.172)
R^2	0.99	0.99
Sy	0.026	0.015
N	20	20
Von Neumann ratio	1.25	2.23
γ = 1 - coefficient RPM_{t-1}	0.331	0.766
Long-run fare elasticity	-2.44	-1.71
Long-run income elasticity	+3.24	0.381

The fare coefficients are in both cases significantly larger than those obtained in the Δ-log model employing the same data. The regression without a variable for time trend gives evidence of significant serial correlation of the residuals (compare the Von Neumann ratio), and the standard errors are therefore probably unreliable. Including the trend variable, however, eliminates serial correlation of the errors and results in a firmer estimate of the long-term fare elasticity. However, the time trend and the income variable are highly intercorrelated and the regression analysis has not been able to disentangle their separate effects on traffic, judging by the radical change of the income coefficient when time trend is brought into the analysis.

CROSS-SECTIONAL DATA

Discussing the effort to estimate the elasticity of demand for air travel from time series, Caves remarked that a cross-sectional study of particular city-pair markets might yield acceptable evidence (9). Here we report such an attempt.

Average fares per mile vary a good deal among city-pair markets, principally because of differences in the availability of lower-priced coach service. This fact suggests an effort, by cross-sectional regression analysis, to isolate the net effect of fares on traffic and to estimate fare elasticities in much the same way as income elasticities are estimated from family-budget studies. There are strong reasons for

making the attempt. Fare elasticities from cross-section data are more likely to yield longer-term elasticities, representing more complete adjustment of demand to differences of price, than are elasticities estimated from time-series data. Two city-pair markets, alike in other respects, of which one has enjoyed for several years a low-fare air service while the other has not, are likely to show a more complete adjustment of traffic to this difference than would occur after one year's experience of a similar fare difference in a single market.

In the cross-section approach, differences of air travel among the principal city-pair markets during 1960 and 1964 are explained by differences in average fares, in elapsed trip time, in quality of service—number of stops on the route, for example—population and income levels in the members of each city-pair, distance, and community of interest between the cities. The coefficients of a logarithmic regression equation provide estimates of the elasticities associated with each factor. Figure 8 is an effort to make clearer the rationale of this type of analysis.

Data for the cross-sectional study pertain to the 300 city-pair markets ranked from the top according to air passenger-miles traveled in 1960. The same selection of city-pairs was employed for 1964. In point of traffic, these comprise about two-thirds of total domestic air travel and may be considered broadly representative. The model is specified as follows:

Let

T = traffic, passengers on the route

F = fares per mile

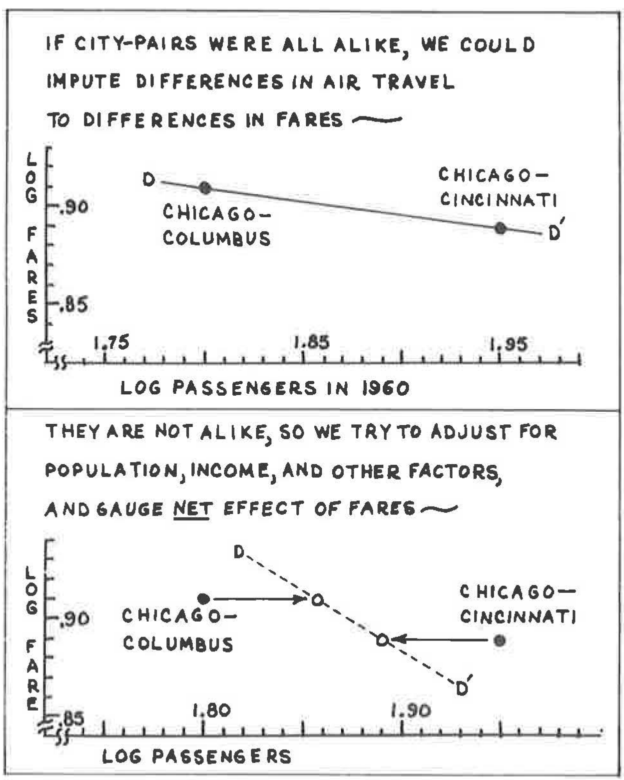


Figure 8. Cross-sectional analysis: rationale.

h = quality of service

D = distance

C = community of interest

Y_{ij} = income products

S = sales promotion resulting from competition

Again assuming log-linear relationships, the complete model may be written

$$\log T = K + \alpha \log F + \beta \log h + \gamma \log D + \delta \log C + \epsilon \log Y_{ij} + \zeta \log S + u \quad (8)$$

An additional variable for time may be included when data for two different periods of time, 1960 and 1964, are comprised by the analysis.

The dependent variable for the regression analyses is:

Passengers (T)—the total number of O-D passengers traveling between two cities (from the CAB's Origin and Destination Surveys), adjusted to exclude those passengers traveling between the two cities as the domestic portion of an international journey.

The independent variables are:

Fare per mile (F)—average weighted fare divided by distance and computed from first class and coach, prop and jet fares, weighted by first class and coach, prop and jet passengers.

Time per mile (h)—average elapsed time (including ground times) on the four best flights available, East-West and West-East in January and December 1960 and 1964.

Number of stops (h)—("0-1" classification, with "non-stop flights" the omitted variable) a "One Stop" flight has one stop on all four of the "best" flights; "2 or more stop" flights have two or more stops on all four of the "best" flights.

Distance (D)— the number of statute miles, city center to city center, by great circle routes (Origin and Destination Surveys, CAB).

Phone messages (C)—average number of business-day calls between the two cities of each city-pair, October 1963.

International passengers (C)—those passengers who are using the city-pair merely as the domestic portion of an international journey.

Income (Y_{ij})—product of the aggregate incomes in the SMSA's of each city-pair.

Competition index (S)—("0-1" classification) the traffic carried by the second largest carrier in a market as a percentage of the largest carrier's traffic. The three intervals are 0-19 percent (omitted variable), 20-59 percent, and 60-99 percent.

Dummy variable for time—a "0-1" classification with 1960 = 0, 1964 = 1.

The principal weakness of the data is that for lack of information it takes no account of discount fares, chiefly family-plan fares in 1960 and family-plan and military standby fares in 1964. The estimated average fares are therefore biased upward. The effect of this bias cannot be estimated with the present quality of data for fares on city-pair routes.

(Figure 9 shows one of the interesting simple correlations between air traffic and a community-of-interest variable, air passengers against long-distance telephone messages.)

The regression analysis was performed for the 300 city-pairs for 1960 and 1964 together—600 observations. Separate regressions were also performed for the data for 1960 and for 1964. The overall results of the three analyses are best put in tabular form (Table 1).

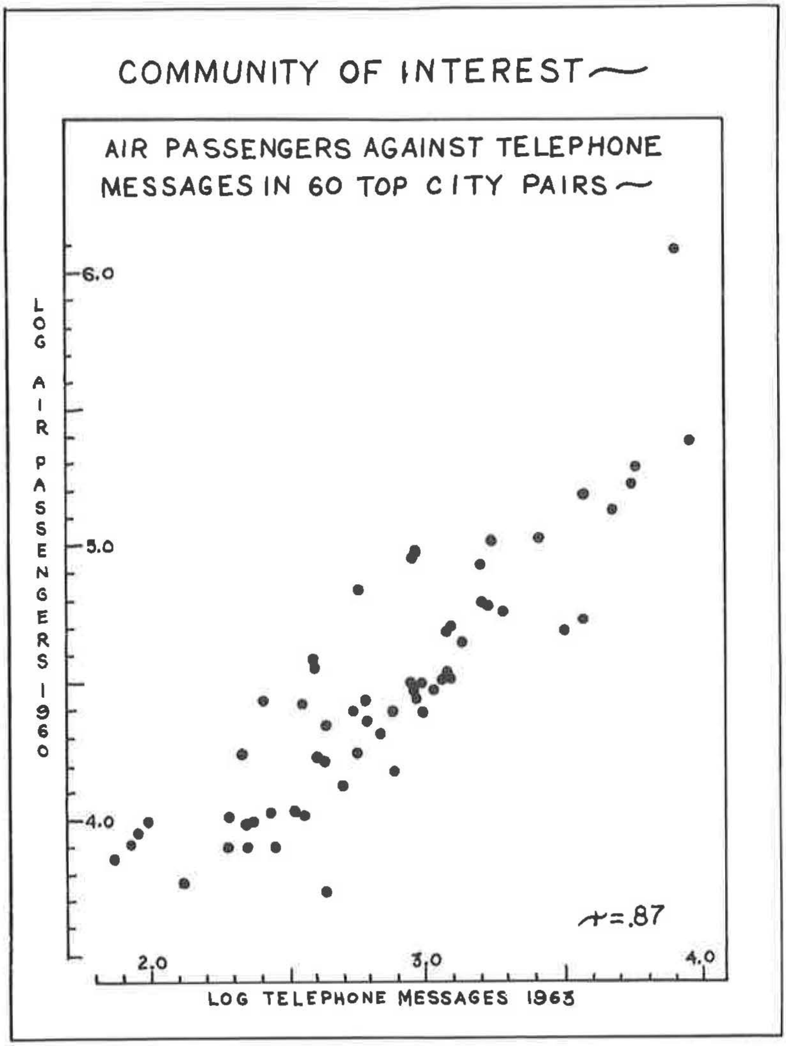


Figure 9.

The cross-section results show a fairly high degree of explanation of the dependent variable, R^2, exceeding 0.8. All of the coefficients have the expected signs and all are significant, ranging from 2.1 to 11.5 times their standard errors. The coefficient for fares is -1.74, interestingly close to the long-term fare elasticity obtained by employing Nerlove's formulation for estimating long-term elasticities from time series. The standard error of the fare coefficient is 0.226, which implies that the chances are 2 out of 3 that the true cross-sectional or long-term elasticity lies between -1.52 and -1.97, and 19 out of 20 that it lies between -1.29 and -2.42.

The coefficient for journey time per mile is smaller, -0.51 with a standard error of 0.140. However, when the variables for 1 stop and 2+ stops are omitted from the analysis, the coefficient for journey time increases (numerically) to -1.09, with a standard error of 0.121. If the major deterrent effect of "stops" on traffic is the lengthening of trip time, as seems likely, the true coefficient for journey time is probably closer to unity than to -0.5.

TABLE 1

PRINCIPAL REGRESSION RESULTS: CROSS-SECTIONAL ANALYSIS OF AIR TRAVEL IN 300 DOMESTIC CITY-PAIRS, LOGARITHMIC MODEL

Item	1960 and 1964	1960	1964
Observations (N)	600	300	300
R^2	0.87	0.88	0.86
Sy	0.164	0.157	0.171
Coefficients and standard errors of variables:			
Constant	6.669	7.096	6.891
Fare per mile (F)	-1.741	-1.689	-1.953
	(0.226)	(0.298)	(0.402)
Journey time per mile (h)	-0.512	-0.578	-0.562
	(0.140)	(0.217)	(0.202)
1 stop (h)	-0.151	-0.156	-0.132
	(0.022)	(0.031)	(0.033)
2+ stops (h)	-0.302	-0.283	-0.330
	(0.055)	(0.066)	(0.107)
Distance (D)	-0.858	-0.926	-0.882
	(0.097)	(0.138)	(0.148)
Phone messages (C)	0.307	0.284	0.321
	(0.028)	(0.039)	(0.041)
International pax (C)	0.127	0.134	0.122
	(0.011)	(0.015)	(0.015)
Income products (Y_{ij})	0.183	0.167	0.205
	(0.023)	(0.029)	(0.036)
Sales competition (S_1)	0.082	0.073	0.097
	(0.018	(0.025)	(0.027)
Sales competition (S_2)	0.056	0.048	0.063
	(0.017)	(0.023)	(0.024)
Clock time[a]	0.107		
	(0.018)		

[a]Expressed as "0" for 1960, "1" for 1964.

TABLE 2

FARE AND JOURNEY TIME ELASTICITIES BY DISTANCE GROUPS

Distance (miles)	N	R^2	Fare Elasticity and Standard Error	Journey Time Elasticity and Standard Error
0-300	56	0.63	-0.110	-0.899
			(1.005)	(0.698)
301-1,100	286	0.88	-2.805	-0.623
			(0.273)	(0.153)
1,101-over	258	0.83	-0.658	-1.659
			(0.475)	(0.273)
0-500	136	0.76	-2.311	-0.739
			(0.416)	(0.336)
501-1,000	170	0.86	-1.768	-0.670
			(0.460)	(0.195)
1,001-1,500	120	0.86	-2.284	-1.461
			(0.546)	(0.310)
1,501-2,000	84	0.89	0.466	-1.114
			(0.766)	(0.435)
2,001-over	90	0.90	0.024	-1.850
			(0.922)	(0.506)

Note: Regressions summarized here did not include the 0-1 variables for number of stops on the best flight. All other variables earlier described were included.

The coefficient for clock time, where "0" was assigned to 1960 and "1" to 1964, indicates a trend rate of growth of nearly 28 percent over the 4-year period, or between 6 and 7 percent per year with all other variables held constant. Actual growth over this period, which was one of rising income and of rising and then falling fares, was more than 42 percent. The evaluation of net trend given by the analysis is thus plausible.

In general, the results of the separate cross-section analyses are consistent with each other and with the combined regression. The fare coefficient is somewhat higher (numerically) in 1964 than in 1960, but the difference is not great. Other coefficients are even more closely comparable, and so are the general statistics of the equations, though the 1960 analysis exhibits a standard error of estimate nearly 10 percent smaller or better than that for 1964.

In an effort to gauge the effect of distance, the data were broken into various distance groupings. Besides a routine classification in 500-mile intervals, a different classification was tested based on the hypothesis (a) that competition between air travel and other modes is not important for short trips of 300 miles or less since auto and other surface modes have the great advantage, (b) that competition between air and other modes is strongest for trips of 301 to 1,100 miles, and (c) that over 1,100 miles air travel has so great an advantage that competition is again unimportant. One should expect then, low fare elasticities in the shortest and longest distance groups, high fare elasticities in the middle group. Table 2 gives condensed results of these regressions by distance group.

In general, the results confirm the hypothesis that fare elasticities are low or insignificant in the shortest distance groups, though lengthening the interval from 300 to 500 miles changes the picture a great deal. In the middle group up to 1,100 miles, fare elasticities are high and then decline to insignificance at the longest distances. Elasticities with respect to journey time appear to increase (numerically) fairly steadily as length of trip increases.

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Impact of Fare Change on Railroad Commuter Ridership

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This paper summarizes the experience gained by the Southeastern Pennsylvania Transportation Authority in demonstration projects that have been conducted during the past 7 years. It also covers various programs developed by different segments of the transportation system in the SEPTA area. The paper describes the Philadelphia area system of the rail commuter, suburban and long-haul passenger service, and defines the delineation of this service as between public-private and entirely private systems. A description of the objectives of the pricing policies adopted on the system is followed by a description of the results of the implementation of the pricing policies that have evolved from the objectives. A discussion of the impact of flexible fare schedules on various segments of the transportation market in the Philadelphia area includes the characteristics of the traveler and the description of the types of transportation provided to accommodate them. A recap of the results of the operational demonstration program conducted between 1960 and 1967 in the SEPTA area covers the effect of various fare changes on ridership levels in different segments of the Philadelphia Transportation System.

The final section of the paper draws conclusions from the results of these demonstration programs. It then relates these conclusions to program projections for the Philadelphia Transportation System with estimates of ridership potential, fare potential, and the impact of the system as a whole on the Philadelphia region.

•A DISCUSSION of the economics of railroad passenger service is fast becoming akin to a dissertation on "Americana." The substantial decline and, in most cases, irrevocable elimination of those services in many areas is a fact which needs no substantiation. Without addressing the merits, the railroad industry has argued that the decline is the result of the public's abandoning them as a passenger carrier rather than vice versa. The resulting "chicken or the egg" exercise before the regulatory agencies in the hallowed halls of ivy or in the trade magazines has not abated the aforementioned decline.

The development and the decline of railroad passenger service has taken place within the framework of private enterprise. Although regulated through its total cycle, the prime responsibility remained in the private sector, qua railroad.

It should be assumed that railroad management would be willing to retain, promote, and improve passenger service wherein it contributes to the total corporate financial structure in direct proportion to the corporate commitment of management, labor, and capital necessary to operate such service. It is understandable that railroad management will be less than enthusiastic in retaining a service that does not contribute its

Paper sponsored by Committee on Passenger Transportation Economics and presented at the 47th Annual Meeting.

share to or, worse, is a burden upon the corporate structure. Accordingly, it follows that the decision to establish, retain, or abandon a particular segment of passenger service was made initially by management within the framework of its own corporate economics.

Although the regulatory agencies, reviewing management decisions, provided an overview of the "public convenience and necessity," they also were mandated to give consideration to the viable economics of the involved carrier—an extremely difficult "line to walk," at best, to which the aforementioned resulting trend attests.

Implicit in the trend of passenger service is the effect on commuter as well as long-haul operations. The rather clumsy distinction is a product of the lack of a clearly defined, generally accepted criteria to differentiate one from the other. With few exceptions, railroad management makes no distinction organizationally and, furthermore, mixes labor, equipment, and facility generally without regard to difference, but specifically in an effort to lessen the economic burden on the corporate purse.

PHILADELPHIA AREA PROGRAM

In the past decade the Philadelphia area has been actively involved in a program to revitalize its regional rail commuter service on the Pennsylvania and Reading railroads. That program has clearly defined that segment of the passenger services which will be considered "commuter" in nature, and has established a new relationship between the public and private sectors. In addition, it has added a new dimension with which to evaluate the economics for the retention and improvement of that service.

As noted, prior to 1958 the expansion and development of the rail commuter systems serving the Southeastern Pennsylvania region was solely the responsibility of the private sector. That responsibility was met to varying degrees, depending upon the magnitude of the burden on the total railroad corporate financial structure as well as the availability of profits from other than passenger operations which offset those burdens. Prior to 1958, the public policy of the region was primarily protected by the regulatory process which governs the two carriers, both Pennsylvania and Reading railroads. In retrospect, it is fair to characterize the expression of such a public policy as one founded on the result of an adversary proceeding dealing primarily with individual train-off cases and fare increases. The situation that existed in 1958 demonstrated graphically the inadequacy of this approach wherein (a) annual ridership on both the Pennsylvania and Reading railroads was declining at a rate of approximately 4.5 percent; (b) highway congestion was already at an intolerable level during peak periods of the day; and (c) although additional highway facilities were soon to be opened, it was not anticipated that they could, for any substantial period of time, alleviate these conditions. In the face of rising costs and declining ridership, there appeared no totally acceptable plan or solution in the private sector alone that could reverse these trends.

In 1958, Philadelphia entered into a pilot program, referred to as "Operation Northwest," wherein service was purchased from both the Pennsylvania and Reading railroads. In subsequent years the public sector's participation has expanded via purchase of service and demonstration projects and presently envelops the total rail commuter systems on the Pennsylvania and Reading railroads.

Thus the region, in a series of steps, placed under contract that service which it was in threat of losing. By doing so, it defined more clearly the service which the railroad could consider as "commuter" pursuant to the urban-suburban needs; and it evolved a partnership of the public-private sector, melded the public interest and private enterprise, and established a public enterprise. The economics of the region's needs for better mass transportation telescoped the economics of the individual carriers.

PROGRAM ECONOMICS AND OBJECTIVES

Public Policy: Regulation vs Participation

The region's decision to participate with the railroads in the revitalization of the area's commuter service required a new framework of reference with which to evaluate, express, and implement public policy. The region analyzed the impact of an

improved railroad commuter system on such concerns as regional economic growth and land use, i.e., protect and improve CBD property investment, suburban residential, commercial and industrial investment, and land use as tax ratables; and such concerns as regional mobility and accessibility in balance, i.e., obviate existing highway congestion, provide access to social and economic opportunity to those otherwise isolated, provide emergency backup alternates, obviate exorbitant replacement costs, and provide time and schedule for evolution of a total regional transportation system.

The touchstone of this analysis was growth. Assuming the validity of the region's decision to retain the commuter system, it followed that it must also contribute to that effort with growth of its own. A common denominator to quantifying growth is ridership.

Present Railroad Commuter System: Capacity

To evaluate this region's rail commuter system in the context of growth required extensive program experimentation and analysis of the system's present and potential capacity, and of the efforts necessary to achieve capacity. The declining trend in commuter patronage, prior to the region's program involvement, had fortunately outstripped the facility and equipment retirement cycle of railroad management.

Quantitatively, the region enjoys a network of 217 route-miles of private right-of-way track facilities extending in every direction from the region's core (Fig. 1). This system serves approximately 200 stations on 12 separate lines and is over 90 percent electrified. The fleet of equipment assigned to the operations has varied over the

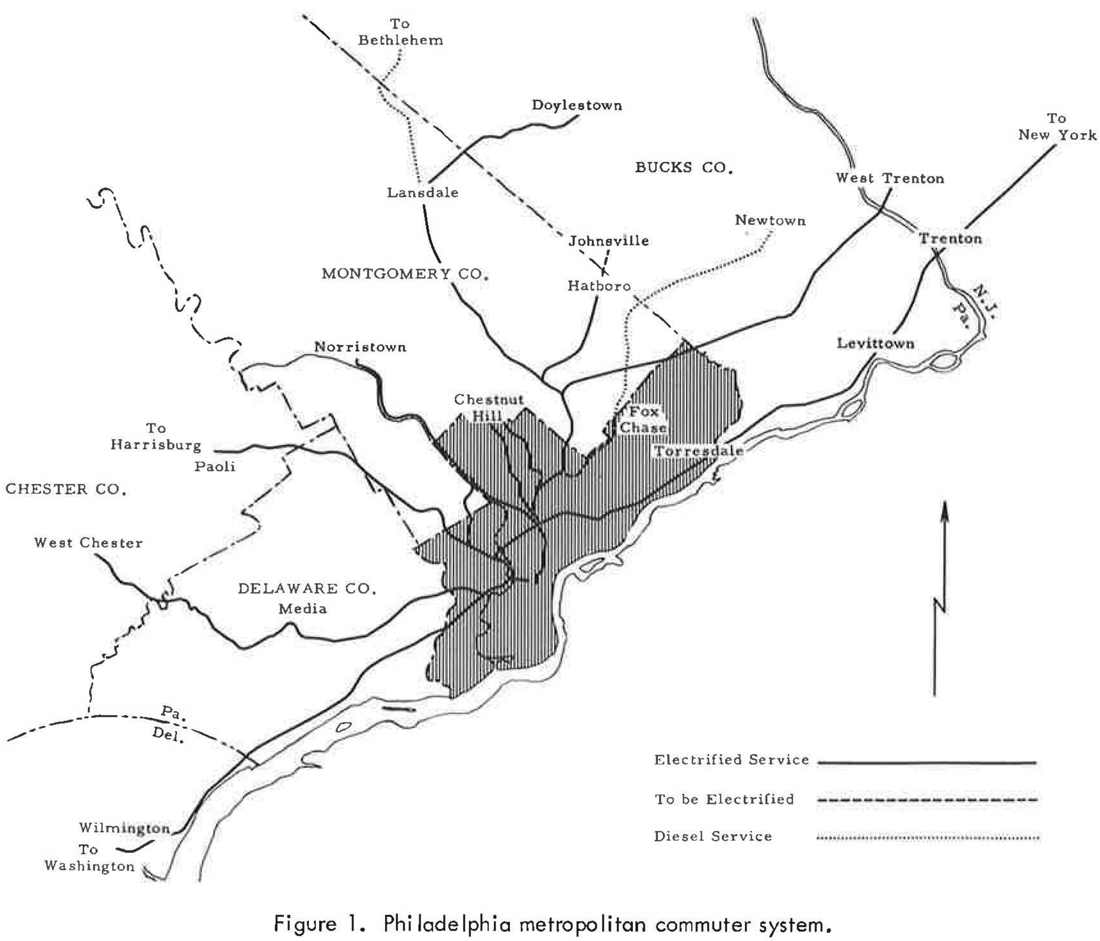

Figure 1. Philadelphia metropolitan commuter system.

program years, but, on the average, numbers approximately 450 cars, providing some 38,000 seats, before shopping. Weekday scheduled trains have, in the main, increased with each schedule change during the program effort (1958, approximately 600; 1968, approximately 800 weekday scheduled trains).

A qualitative review is necessarily more subjective. However, it should suffice to note:

1. There has been no expansion of the basic system for a period of 50 years.
2. No new stations have been established in over 30 years.
3. Sixty percent of the equipment is over 30 years old and a substantial portion of that is over 50 years old.
4. Only 30 percent of the assigned fleet has been replaced or rehabilitated in the last 10 years.
5. Less than 30 percent of the equipment is air conditioned.
6. Approximately 48 percent of weekday scheduled service is provided during the four peak hours (7-9 a.m., 4:30-6:30 p.m.).

In summary, the regional program enjoyed the benefits and suffered the burdens of revitalizing a system with which the community was quite familiar and which had not substantially changed quantitatively for 30 years, but, in relative terms, had been on a decline qualitatively for a decade or more prior to 1958. It was, however, a system that in 1958 had a considerable unused capacity.

Pricing Policy: Pre- and In-Program

It is of particular moment to note that prior to 1958 there were few, if any, logical threads which can rationalize the carriers' pricing policy and the relative economics for the commuter service they rendered. Although the fare structure had as a basis a fixed terminal, plus a mileage increment, it allowed limited consumer flexibility. In view of the service and facility committed, the fare was not competitive; furthermore, it failed to provide sufficient revenues to offset the costs of the service. There were a few attempts at selected fare reductions to encourage ridership increase. However, these were limited in scope and were subsequently erased in the overall effort for fare increases to offset the passenger service losses.

The initial program assumptions rationalizing pricing policy reflected that:

1. Payment of tax dollars should inure to the commuting public in reduced fares, as well as increased service; and
2. There was a relative unawareness on the part of commuters of the cost of his auto transportation other than the immediate out-of-pocket cost.

Accordingly, initial program pricing policy established fares slightly higher than other available mass transit modes, and commensurate approximately with the cost of parking in the CBD on an all-day (commuter) basis. Subsequent program efforts toward the goal of total system contracts evolved different basic policies on the pricing of service. The policy ran the gamut of:

1. Reducing suburban fares (SEPACT I),
2. Reducing and increasing fares (SEPACT III), and
3. Retaining carrier's existing fares (PRR contract January 1966 to June 1967).

Initially, and through all subsequent program steps, payments of public funds were made to the carriers to reduce their deficits incurred in providing improved commuter service.

Programming Pricing Policy

The region's use of pricing policy to obtain a growth objective in its commuter service has had an excellent result to date. It would be less than candid to suggest that the separate project efforts were the result of a vast premeditated plan. It was the program's initial inability (for a number of reasons) rather than its failure to design the total effort toward the desired objectives that holds us in good stead today. (No

small credit should be given the cooperative sufferance of the region and carriers alike through the program's evolution.)

Accepting the premise that enhancement of rail commuting services and facilities would most effectively conserve total public transportation funds, the effective use of pricing policy vis-a-vis improved service levels, new equipment, expanded parking, etc., became most essential. It became apparent that a sound, but flexible, fare structure to implement the pricing policy was equally essential to achieving the program objectives.

FARE STRUCTURE AND RIDERSHIP

Fare Structure Criteria

Extensive program effort was expended to determine the criteria for an effective fare structure. That effort included marketing studies, operational design, and data collection and review. The results of the program marketing efforts indicated the necessity and the benefits of a fare structure with flexibility.

There was evidence that, although weekday ridership counts did not vary in substantial amounts from day to day, there was a constantly changing composition of actual riders. (The study result of the Reading market area indicated that only 35 percent to 57 percent of the average daily work purpose ridership could be considered "hard core.") Accordingly, peak-hour commutation pricing should acknowledge a regular rider as one who rides as little as three times a week.

The peak-period rider is most aware of his transportation cost, has a work purpose, and cites the following as the reasons for rail use over other modes: (a) speed, (b) avoidance of traffic congestion, (c) rail as more direct route, (d) elimination of parking problem, and (e) greater comfort. To that end, the peak rider appears most inelastic to fare charged, given a quality of service reflective of his needs.

The off-peak rider has a low awareness of fare charges, is a part of a highly competitive transportation market, has a shopping, recreational or cultural trip purpose, travels primarily from 9:30 to 11:30 a.m. and 2:30 to 4:00 p.m.; and, as an occasional rider, is highly susceptible to promotion and advertising. Accordingly, the competitive nature of this market group demands a relatively greater amount of total management effort and pricing incentive to develop.

Evolution of the program to include the total commuter operations of both railroads has evidenced that the fare structure must and can aid in the effort of maximizing the effective use of a rail commuter operation.

The 12 separate lines of the regional system so fan the area as to allow a high accessibility to the market, not only in terms of the large number of separate communities directly served, but also in terms of the availability of several lines or services to the same market segment. Operational design, e.g., express and local service configuration, and facility design, e.g., railhead terminal storage and/or turnaround facilities allow and demand an effort to constantly increase the average length of ride per rail trip.

Equally important in obtaining the maximum use of the rail system capacity is the achievement of a better ratio of off-peak to peak-hour use. Train profitability studies graphically demonstrate the relatively low incremental cost of operating off-peak vs peak service. Accordingly, increased patronage and revenues during off-peak periods tend to contribute to and are necessary to a better balance of the economics of rail commuter service.

Consequently, the program has sought a fare structure which provides:

1. A zone system with only three major ticket types, i.e., one-way, peak; 10-trip commutation, peak; and a "bargain" one-way, off-peak.
2. The 10-trip, peak commutation ticket is the base of the structure (100 percent). The one-way peak is established at approximately 120 percent of base per ride and the "bargain," one-way off-peak is established at approximately 85 percent of base per ride.
3. The pricing formula establishes a basic user charge plus a mileage increment that declines as the mileage from the CBD terminal increases.

4. The 10-trip commutation ticket allows a saving to the peak-hour commuter who uses the system with a greater frequency than the commuter who uses the system as a backup to his normal mode and who purchases the one-way peak ticket. The lower bargain, one-way, off-peak ticket reflects the lower cost of that service and the higher unused capacity that exists. (The term "bargain" also provides a public relations and advertising sales point to attract a highly competitive market; this approach is difficult to quantify and should be held in good perspective.)

Fare Change and Ridership

The program has run the gamut of fare reductions and increases and, in the context of that mentioned, it should surprise no one that in each situation ridership continued to increase (Fig. 2).

Generally, program fare reductions, combined with service improvements, had a much greater effect in reversing the declining trend of rail commuter ridership and establishing, in fact, a growth trend. However, also in a general application, fare increases combined with service improvements failed to have an adverse effect on the growth trend.

Fare Reductions—Initial program efforts were limited to segments or individual lines of the two systems. Fare reductions and service improvements in these limited service areas produced substantial percentage increases over prior line ridership records. The initial and immediate success of these efforts failed to have a substantial effect on system ridership, but did spur the program to establish more and more coverage of the system. With the termination of the region's first demonstration project, SEPACT I, covering approximately 20 percent of the systems' services, ridership increases by line were of sufficient magnitude to halt and begin to reverse the systems' declining trend. The use of fare reductions was accordingly very effective in its limited goal, but its implementation created low fares on high service lines and high fares on low service lines, with a system impact of:

1. The abandonment by many patrons of their local stations for the use of closer-in stations or stations on other lines, which offered more favorable fare and service levels;
2. A lower average revenue per passenger resulting from the fare reductions and the shorter average length of ride; and
3. The virtual offsetting of revenue gains, realized from increased patronage, wherein system costs could not be pared operationally to reflect the market change.

The response to market studies in areas provided reduced fares and increased service, reflected favorably on the fare effort, but only secondarily to the response for improved service and its benefits.

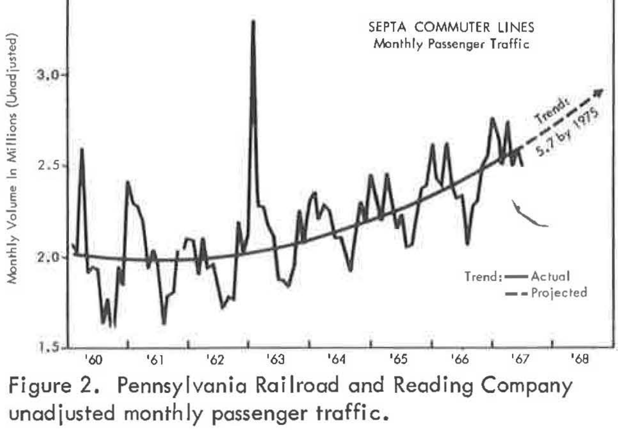

Figure 2. Pennsylvania Railroad and Reading Company unadjusted monthly passenger traffic.

A recent market study indicated that a 50 percent fare reduction would cause 60 percent of actual users to increase rail usage, but 35 percent of that group would be unaffected. It further noted that only 23. 5 percent of potential users would increase rail usage, while 74. 3 percent of that group would be unaffected with a 50 percent fare reduction.

Fare Increases—The region had its first opportunity to establish coverage of a complete commuter operation in SEPACT III, "Operation Reading." This demonstration project allowed the

program to adjust, in part, the imbalance created in earlier efforts and provided a better base against which to evaluate the total impact of fare change, generally, and fare increases, specifically.

During an 18-month period fares were increased on the average of 13 percent, with a resulting increase in actual ridership of 4.8 percent, or a ridership increase of 9 percent if annualized phases (before and after project) are compared.

This project effort, involving an operationally self-sufficient system, evidenced substantial benefits from a better balanced, if higher, fare structure. Average length of ride increased from 13.8 to 14.6 miles and a change in ratio of peak to off-peak ridership mix of 56.4/43.6 percent to 54.5/45.5 percent respectively was established.

Market studies indicated that diversion of ridership would take place from fare increases in excess of 20 percent. In addition, it was suggested that a 100 percent fare increase would not alter the rail habit of 51.7 percent of actual users, whereas 42.1 percent would reduce rail usage. Of potential users, 66.7 percent stated they would never use the railroad in the event of a 100 percent fare increase.

CONCLUSIONS

The Philadelphia area program to revitalize its rail commuter system has evolved through a series of steps that supports the conclusions that:

1. Retention and improvement of a transportation facility and service which is vital to a region's viability, but which is unsound economically within its own framework, cannot succeed solely within the present regulatory process.
2. The public's participation in the revitalization of such facilities and services must ultimately be programmed to meet regional transportation objectives, but remain cognizant of relative economics of the involved carrier.
3. Programming for system growth, although primarily oriented to facility and service improvement, must also establish pricing policies to offset long-term wage and material escalation.
4. Timely and properly supported fare increases need not deter from regional goals, and should never be evaluated by less than a total plan standard.
5. Pricing policy should be implemented through a fare structure which maximizes system use, as well as responds to the total market requirements.

ACKNOWLEDGMENT

The author gratefully acknowledges research support from the demonstration programs Project No. PA-MTD-1 (SEPACT I), Project No. PA-MTD-4 (SEPACT II), and Project No. PA-MTD-5 (SEPACT III), and the operational data received from the purchase of service program supported locally in Southeastern Pennsylvania.

A Model for Estimating Transit Usage In Cities in Iowa

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Reasonably accurate forecasts of transit patronage and revenues often are needed for solutions to urban transportation problems. This study developed a model for estimating annual totals for patronage and revenues using the following as independent variables: quantity of transit service provided, average fare, size of city, and proportion of population not in the working force.

Data utilized in developing the model were collected from 13 transit operations in Iowa covering 114 annual periods from 1955 through 1965. The model is thus applicable only for communities in Iowa, but offers an insight into factors that may be applicable generally for transit operations in small urban areas.

•PEOPLE in the United States are increasingly conscious of the role of mass transportation in urban areas. The public realizes that an efficient transit system not only helps alleviate traffic congestion but is vital to that segment of the population that has no alternate form of transportation available. Furthermore, there is growing public recognition of the need and the justification for public financial support in many cities, if this important public service is to remain available. Enactment by the U. S. Congress of the Mass Transportation Act of 1964 resulted from its concern for the problems of mass transportation and its determination to solve these problems. Local concern is evidenced by the large number of cities that have sought federal assistance under the Act.

The current problems of mass transportation result primarily from the marked changes in travel habits of urban populations. Such changes have occurred largely since World War II. During the war, patronage of transit was at an all-time high in the United States. Almost 19 billion revenue passengers were carried during 1945 (1). Also in 1945, there were 130 billion vehicle-miles of travel by motor vehicles on urban streets (2). After the removal of wartime restrictions on motor-vehicle travel, transit patronage declined rapidly. In 1950, fewer than 14 billion revenue passengers were carried on transit lines of the United States while urban motor-vehicle travel increased to 218 billion vehicle-miles. Despite the fact that urban area populations have increased markedly since 1950, transit usage has continued to decline. The trend toward suburbanization, continued economic prosperity, and the increase in automobile ownership resulting from these factors have all continued to lead to a substantial growth in motor-vehicle travel and further decline in transit patronage. During 1965, transit lines carried fewer than 6.8 billion revenue passengers (about 36 percent of the number carried in 1945) while there were 424 billion vehicle-miles of urban travel by motor vehicle (over three times that in 1945).

Cities in Iowa exhibit similar travel trends. Urban street traffic is increasing rapidly at the same time that transit patronage is decreasing. For example, the number of revenue-producing transit trips in Des Moines in 1965 was 23 percent of the number in 1950. Comparable figures were 48 percent in Dubuque and 18 percent in

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Burlington, the only other cities for which 1950 data were available for this study. The substantially reduced revenues accompanying the declines in patronage have obviously created serious financial problems for transit operators.

In 1967, 17 cities in Iowa had franchised transit service. Buses were utilized exclusively except for a cable railway in Dubuque. An indication of the financial problems encountered in several of these cities is afforded by events occurring during 1965 and 1966. During this two-year period, four cities faced abandonment of their transit operation. In all four cities, programs involving public ownership or public subsidy were adopted to prevent loss of service. Operations in two other cities were subsidized by the public prior to 1965. In most other cities, franchised transit operations are partially subsidized by earnings from school bus contracts, from charter services, or from non-transportation operations.

PURPOSE OF STUDY

This study was undertaken to gain an understanding of the characteristics of a community or of a transit operation that account for the considerable differences in transit service use among different urban areas. An understanding of these characteristics is essential to make realistic forecasts of future trends in transit usage.

Numerous other studies have been concerned with forecasts of travel mode in urban areas. These generally have produced mathematical expressions that are solved to yield a percentage of total personal travel that will utilize mass transportation. This dependent variable is referred to as the modal split. Several independent variables have been employed by various researchers. Among the most common are costs of service of competing travel modes, quality of transportation service, urban-area population, population density, automobile ownership, and several indicators of socioeconomic status. For the most part, these models were developed for application only to a tract of land within a specific area and used for assigning traffic as part of an urban transportation study.

However, modal splits for travel in cities in Iowa are very low. Nine recent comprehensive origin-destination studies made by the Iowa State Highway Commission show that from 1.5 percent to 10.7 percent of all person-trips on average weekdays were made by bus passengers. More than 6.5 percent of all person-trips were made by transit in only one city, Dubuque, and the median value for the nine cities was only 2.5 percent. Thus a conventional modal-split study in Iowa involves the use of such low numbers of bus passengers that the results are of dubious statistical reliability. Furthermore, comprehensive origin-destination surveys have not been made for several smaller cities so that not all the data necessary for a conventional modal-split model are available. For these reasons, this study was designed to produce a model that estimated transit patronage directly rather than as a percentage of total personal travel.

DEVELOPMENT OF MODEL

A mathematical expression or model to estimate transit patronage was derived by regression analysis. Linear, semilog, and log-log forms employing from two to six independent variables were tested for accuracy in reproducing historical data. To simplify calculations and to facilitate comparisons between cities, the average annual number of revenue transit rides per person resident in the area served by a transit operation was used as the dependent variable.

Data Utilized

All available data for 13 transit operations in Iowa for the period 1950 through 1965 were obtained for this study. Because of the limited data for years prior to 1955, only the data for the years 1955 through 1965 were utilized. By using a total of 114 different annual operating periods (an average of 8.8 years for each city), the analysis reflects changes in transit riding habits with time as well as differences among cities.

The transit operations included in this study are located in the cities listed in Table 1. Also given are populations of these cities according to the latest decennial or special

TABLE 1

CITIES INCLUDED IN STUDY

Central City of Transit Operation	Population, Latest Census	Latest Census Year
Des Moines	206,739	1966
Cedar Rapids	103,545	1965
Sioux City	89,159	1960
Dubuque	62,853	1966
Council Bluffs	52,957	1966
Iowa City	41,602	1965
Ames	34,826	1965
Ottumwa	33,871	1960
Clinton	33,331	1965
Burlington	33,285	1965
Fort Dodge	31,707	1967
Marshalltown	22,521	1960
Muscatine	22,194	1966

census. Service areas of seven transit operations also include one or more incorporated places in addition to the central cities given in Table 1.

Variables

Multiple regression models were developed using the data for 114 annual periods for 13 transit operations. A number of different independent variables were used; two described the transit operation itself and the remainder described demographic characteristics of the transit service areas. Some of these variables are given in Table 2 along with their correlations in linear equations with annual rides per capita. Definitions of the variables included in the model developed are given in the following paragraphs.

A revenue passenger is any patron making a single trip for which a fare has been paid for travel on a vehicle operating as part of a regularly scheduled intracity transit operation. However, a single trip may involve transfer between vehicles. Other services, such as chartered trips or buses operated under contract exclusively to transport children to and from school, are not included.

The quantity of vehicle travel involved in providing the service utilized by revenue passengers is recorded in revenue miles. This variable reflects both the quality and the quantity of service, because quantity most commonly is increased either by providing more frequent service so that waiting times are reduced, or by providing service on additional or extended routes so that walking distances are reduced.

The average fare is calculated by dividing the total annual passenger revenue by the number of revenue passengers carried. Thus, this includes the effects of school fares, added charges for transfers, zone fares, and other variations in charges for individual rides.

The nonworker-worker ratio for a city is defined as the number of persons who are not members of the working force divided by the number in the working force. Persons not in the working force include housewives, children, the aged, and the disabled. These groups tend to depend more upon public transportation than members of the working force and are a substantial proportion of total ridership of transit in Iowa. They are the so-called captive riders who lack an alternative to transit for personel travel and, with other captive riders, make up a majority of regular transit patrons in most cities. Thus, the nonworker-worker ratio is useful in the model for indicating differences among cities in the propensity for people to use transit.

TABLE 2

CORRELATION OF VARIOUS VARIABLES WITH ANNUAL RIDES PER CAPITA IN LINEAR EQUATIONS

Variable	Correlation
Revenue miles of service per resident of the service area	0.96
Nonworker-worker ratio, corrected for population of central city	0.52
Population of central city	0.52
Persons per registered automobile in county of central city	0.47
Median family income in central city corrected for population	-0.44
Average fare, corrected for population of central city	-0.39
Population density in central city, persons per square mile	0.30

Equations

The equation that best reproduces historical data for transit patronage and in which all regression coefficients are significant at the 0.01 level is

$$R_c = -33.97 + 1.46W + 0.033C + 3.00S \quad (1)$$

where

R_c = revenue transit rides annually per resident of a transit service area;

W = working force factor = N (log P);

C = city size and cost factor = $\frac{(\log P)^3}{F}$;

S = service factor = $\frac{M}{P_s}$;

N = nonworker-worker ratio for the central city of a transit service area;
P = population of the central city of a transit service area;
F = average fare, dollars;
M = revenue miles of transit service provided in one year; and
P_s = population of all incorporated places in a transit service area.

Or, where R = total revenue rides annually = $R_c P_s$,

$$R = 3.00M + P_s\,(-33.97 + 1.46W + 0.033C) \quad (2)$$

Further, if Y = total annual passenger revenue in dollars = RF,

$$Y = 3.00MF + 0.033P_s\,(\log P)^3 - P_s F\,(33.97 - 1.46W) \quad (3)$$

Eq. 1 has a coefficient of multiple correlation, r, of 0.984 and a standard error of estimate of 2.69 rides per capita per year. A comparison of actual and calculated values of R for 114 annual periods is shown in Figure 1.

Single-Variate Relationships

It may be noted from Table 2 that the correlation between the service factor and transit patronage is extremely high. This relationship is shown in Figure 2. The coefficient of correlation is 0.96 for the expression $R_c = -1.30 + 1.89S + 0.081S^2$.

Although it is apparent from Table 2 that factors such as family income, population density, and automobile registration are correlated with transit usage, they are less significant indicators than the factors used in Eq. 1. For example, the regression coefficient for automobile registration was not significant in any of the expressions derived, and in most such expressions had a sign opposite to its positive correlation. This is caused by the strong correlation of this variable with most independent variables used. Indeed, many of the variables given in Table 2 are interdependent and not actually independent when used together. However, as shown in Figure 3, automobile registration and transit patronage are related. Data for two cities, Iowa City and Ames, have not been included in the figure. Populations of both of these cities include a large proportion, about 40 percent, of university students. Thus, their characteristics are atypical in many respects, including the relationship between population and automobile registration. Figures on registration are available only on a countywide basis in Iowa, but in all counties with transit operations included in this study, the majority of the county population is resident in the transit service area. The expression

$$R_c = -8.05 + 2.19A^3 - 0.0055A^6$$

has a coefficient of correlation of 0.75.

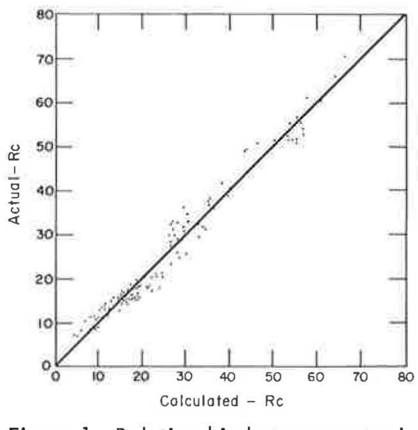

Figure 1. Relationship between actual and calculated values for annual transit patronage per capita.

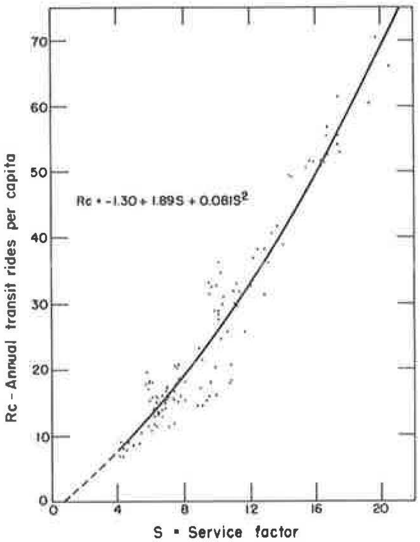

Figure 2. Relationship between level of service and annual transit rides per capita.

Applicability of Model

It must be emphasized that this model has been derived from a study of available data covering transit operations only in Iowa cities. Since these cities have fairly uniform economic and physical characteristics, the applicability of the model should be limited to cities possessing those characteristics. For example, it is probably not applicable to very large metropolitan areas, or other small urban areas outside of Iowa where economic factors, population densities, automobile ownership rates, and other demographic characteristics substantially differ from those typical of Iowa cities.

The model was derived for use as a forecasting tool with general applicability for cities in Iowa. Obviously, other factors will influence a modal choice in a particular city. Parking availability is an example of a factor that might significantly influence the choice between private automobiles and transit for personal travel. The construction of freeways that substantially reduce peak-hour congestion diverts some travel from transit to private automobile. Various other factors will uniquely influence transportation in a given urban area and also ought to be considered. Generally, however, the independent variables utilized adequately describe the propensity of residents of an urban area in Iowa to choose travel by public transit.

DISCUSSION OF MODEL

Significant characteristics of the 1965 transit operations included in this study are summarized in Table 3. For comparison, national averages for bus service in 1965 also are shown where these are available (1). As may be noted, there is considerable variation in these characteristics even though cities in Iowa are quite similar in many respects.

Effect of Change in Service Factor

An analysis of Eq. 3 permits speculation concerning solutions to the problems of marginal patronage and revenues. For example, the equation indicates that additional service will increase revenues at the ratio of three average fares per revenue mile of service, when other variables remain unchanged. If the operating cost per mile for transit service is less than three times the average fare, as is common in the cities included in this study, then increased service should be a profitable undertaking. It may be assumed that additional service would take the form of more frequent service on existing routes of proven passenger potential, special services for which a need exists, or extensions of service into new areas of indicated demand. Actual instances of service increases during the period covered by this study generally confirm this expectation. However, the increased patronage often is very slow to be realized, with a year or more apparently required in some instances before travel habits are adjusted to improved or increased transit service. This factor, of course, often will nullify the profit potential of increased service.

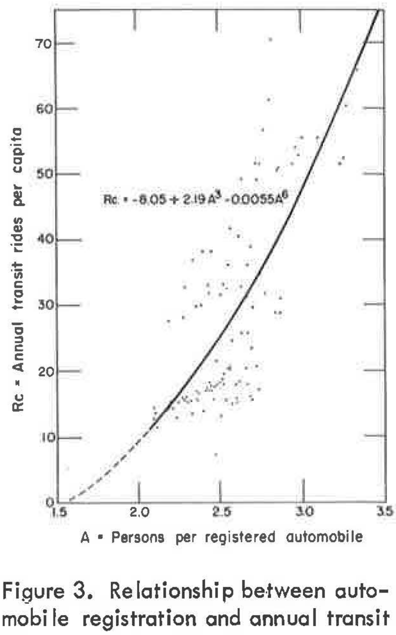

Figure 3. Relationship between automobile registration and annual transit rides per capita, 11 cities.

TABLE 3
SOME CHARACTERISTICS OF TRANSIT SERVICES IN 13 CITIES IN IOWA, 1965

Characteristic	Mean	Median	Range	National Average
Transit usage annually per service area resident, revenue rides	19.95	15.16	6.84-51.58	N. A.[a]
Revenue miles annually per service area resident	8.62	8.04	4.20-15.98	N. A.[a]
Revenue passengers per revenue mile	2.17	1.91	1.63-3.23	3.09
Average fare, dollars	0.193	0.192	0.126-0.253	0.205
Passenger revenue per revenue mile, dollars	0.41	0.39	0.29-0.68	0.64

[a]Not available.

Price Elasticity

The elasticity of revenue with respect to the average fare is somewhat more complex. Increases in fares lead to decreased patronage (Eq. 2), but the proportional decrease depends largely upon the level of service. At high levels of service, S, equal to about 15 annual revenue miles per service area resident, elasticity is about - 0. 3 to - 0. 4 depending on city size (an increase of 1 percent in average fare results in a decrease of 0. 3 to 0. 4 percent in patronage). This is consistent with the rule-of-thumb elasticity of - 0. 33 cited by Fitch (4). When S is about 7. 8 (varying among cities in accordance with the expression $S' = 11.30 - 0.49W$), the elasticity is - 1. 0. At this level of service, increased or decreased fares theoretically will cause no change in passenger revenues. At lower levels of service, transit in Iowa exhibits considerable price elasticity. Under these conditions of service, an increase in fares may lead to an actual decrease in revenue. Fare reductions, on the other hand, should induce sufficient increases in patronage to raise passenger revenues when service levels are low. This conclusion, deduced from Eq. 3, has not been verified by actual experience. It obviously runs counter to the solution of raising fares, usually adopted to increase the profitability of a marginal transit operation in which service has been reduced to low levels. Experience shows that many transit patrons in Iowa have a choice of transportation mode, and many travel by other means when faced with fare increases by an operation providing low levels of service. Only when transit is accompanied by shorter waiting times and reduced walking distances implied by high levels of service does it appear to be relatively price inelastic.

Demographic Characteristics as Indicators of Transit Usage

A model was developed earlier in this study that included several variables that measure demographic characteristics of the communities served by transit (3). However, the model presented here uses several fewer variables, is simpler in form, and reproduces historical data with comparable accuracy. As pointed out earlier, many socioeconomic indicators significantly indicate transit patronage. However, these indicators are closely correlated with characteristics of service and fare structure, which are better indicators. A brief discussion of transit-riding characteristics in Dubuque illustrates the apparent influence of some of the factors that are indicative of modal choice. Since 1957, the trend of transit usage has actually been rising in this service area, which includes East Dubuque, Illinois. In recent years patronage was at a substantially higher level on a per capita basis than in any other urban area included in this study. Patronage averaged 51. 6 revenue transit trips per person during 1965. The level of service during that year was the highest and the average fare the lowest for transit operations studied. At the same time, Dubuque is one of the few cities in Iowa with more than 4, 000 residents per square mile, its nonworker-worker ratio is the highest in the state when adjusted for city size, and Dubuque County has a much higher number of persons per registered automobile than any other urban county in Iowa. Clearly, these demographic characteristics of a community are indicators of the level of transit patronage parallel to the service and fare characteristics of that community's transit operation.

CONCLUSIONS

The model developed from this study permits reasonably accurate forecasts of transit patronage for cities in Iowa. While the model results from analysis of data only for

Iowa cities, the same factors could have limited application as indicators of transit patronage in other cities.

Summary of Results of Analysis

Conclusions from an analysis of the equations derived are summarized as follows:

1. The quantity of transit service, measured in revenue miles, is much the stronger indicator of transit usage. Patronage is related to revenue miles of service in a 3-to-1 ratio under typical conditions. However, increases in ridership resulting from increases in service often are slow to materialize, so that this is not necessarily an easy road to profitability.
2. The elasticity of transit patronage with respect to the average fare varies considerably, depending primarily on the quantity of transit service. At high levels of service, elasticity is about - 0. 3 to - 0. 4, depending on city size. However, patronage is considerably more price elastic at low levels of service.
3. The proportion of the population outside of the labor force is an indicator of the level of transit patronage. The nonworker-worker ratio measures this variable.
4. Other factors being equal, per capita patronage of a transit operation centered in a large city is higher than that of an operation in a small city.
5. The level of transit patronage in an urban area may be strongly influenced by the quantity of service provided and by the fare structure, within limits that depend upon demographic characteristics of the area.

Need for Further Research

Further research is needed to clarify the relationship of transit patronage with the quantity of service and the fare structure in small urban areas. Conclusions deduced from the model developed in this study have not all been verified by some other studies. For example, several demonstration projects in Massachusetts developed comparatively little additonal patronage with either increased service or reductions in fare (5). However, in some instances local service increases were profitable, showing that, if carefully selected, such improvements can be self-sustaining. This conclusion is further supported by experience reported from Memphis, which demonstrated that extensions of service into areas not previously served can prove profitable under certain conditions (6). Other studies reported in the literature, some with contradictory conclusions as to the price elasticity of transit patronage, concern large metropolitan areas with high levels of service and results that probably cannot be related directly to Iowa's much smaller urban areas.

Information more pertinent to this study is afforded by recent experience in Iowa City. This transit operation introduced a uniform ten-cent fare late in 1966. During the last quarter of 1967, patronage was more than double that during the comparable period in 1965 when the average fare was $0. 193. Passenger revenues were about 25 percent higher over this period in 1967 than in 1965. Increases in revenues did not occur, however, until the reduced fare had been in effect for a year, a further indication of the substantial time lag during which travel habits are adjusted to reflect changes in transit service.

Obviously, a better understanding of these relationships is essential if the marginal profitability of the typical transit operation is to be improved. Or, if profitability is not possible or desirable, further knowledge is necessary to establish the amount of public support that, with a given level of service and fare structure, will best help attain the transportation objectives of urban area residents.

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