4 and 5 for each of the model runs. As would be expected, the total number of passengers on the bus, the number of standees, the maximum queue, the average queue, and the average in-queue residence time increased with increased passenger demand. Conversely, the number of zero entries (i.e., the number of passengers that could board without waiting in the queue) decreased with increased passenger demand.

This information is useful for planning and evaluating the operations of a boarding platform. Table 4 indicates that, for passenger flows above 300/h, with a pay-enter method of fare collection, not all passengers will be able to board a bus and that the maximum number of persons that can board the 12 buses is 574 passengers. Similar data from Table 5 for the pay-leave method of fare collection are 800 and 845 passengers/h respectively.

The information about average and maximum queues can be used to design adequate loading platforms or to change operating procedures to avoid overcrowding on an existing platform. The values of average time per passenger in the queue can be compared with desired service standards and appropriate operational changes made if necessary.

With the use of GPSS, models can be developed to simulate the operation of other bus stops. The model developed here is an example, not a model for all cases. However, it can be adapted to other cases by changing the distributions of passenger arrival and service times as well as the time allocated for each bus to load passengers.

CONCLUSIONS

From the analysis of photographic studies of bus passengers described here, it can be concluded that

1. There is no difference in the average service time for each successive passenger to board, except that the first passenger may require less time due to the ready storage area on the steps between the bus door and the driver; and
2. The distribution of service times for individual passengers to pass through the vehicle door can be represented by an Erlang function in which the value of K seems to be equal to the number of doors on the vehicle and the minimum service time is approximately half the average service time.

These results can be used as inputs with simulation models to analyze a series of bus flow situations for the development of guidelines to assist the terminal designer and street transit operator in evaluating their existing or proposed system. Specific models can be developed to evaluate the effects of the method of fare collection (for example, on queue length), the average waiting time under varying rates of passenger arrivals, the use of both front and rear doors for boarding, or the use of the front door for boarding and the rear door for alighting.

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Differential Time-of-Day Transit-Fare Policies: Revenue, Ridership, and Equity

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This paper examines the financial, ridership, and equity implications of premium rush-hour fares of seven transit systems in New York State. Using 1973 data and demand equations that establish a relation between fare and ridership, calculations are made to estimate changes in ridership and revenue in each of the cities for various peak and off-peak fare combinations. Graphs are plotted for each of the cities to determine the fare combinations that maximize ridership without decreasing revenue more than 5 percent and still improve equity. The results showed that, in all of the cities studied, no differential fare combination increases both revenue and ridership simultaneously. Certain combinations improve equity while increasing either ridership or revenue with a less than 5 percent loss in the other. In Albany-Schenectady-Troy, Rochester, Syracuse, and Binghamton, combinations that increase passengers at the expense of a less than 5 percent decrease in revenue are attractive because of their flexibility. In New York City and Buffalo, combinations that increase revenue rather than passengers are attractive because no fare combination would increase passengers more than 5 percent without a loss of 15 percent or more in revenue.

Differential time-of-day transit fares (in which peak-hour riders pay a higher fare than do off-peak riders) have recently been proposed in many U.S. cities, and are suggested as a potential policy for transportation system management. These fares are attractive for three reasons:

1. Fare increases only in peak hours increase revenue without significant ridership losses, because peak-hour ridership is generally less sensitive to fare changes than is off-peak ridership;
2. Differential time-of-day fares encourage travelers to shift to off-peak periods, lessening peak-hour service requirements; and
3. Differential fares are more equitable because the cost of peak-hour service is carried more heavily by peak-hour users, for whom a large fleet must be provided.

This paper reports on a recent study in New York State to evaluate the ridership, revenue, and equity implications of such policies in seven transit systems.

DATA SOURCES AND CALCULATIONS

The peak hour is defined as the time from 7 to 9 a.m. and 4 to 6 p.m. In some cities the afternoon peak begins at 3 p.m., but most of the travel at this time is nonwork trips. Ridership and revenue data (Table 1) were obtained from 1973 reports submitted to the New York State Department of Transportation (NYSDOT) by transit operators to qualify for operating assistance. Base data on peak-hour ridership were obtained from area transportation studies done by NYSDOT in previous years. Data on transit-demand elasticity were used to calculate changes in ridership and revenue. These relationships have been investigated by Hartgen and Howe (1) in a study of fare increases and by Donelly (2) in a study of fare decreases. The fare-decrease elasticities are generally lower than the fare-increase elasticities and vary with the magnitude of the fare decrease. Table 1 also shows typical values for a fare decrease to 25 cents. The relation of these elasticities to ridership and revenue is as follows:

$$R = R_B [1 + e(\Delta F/F)] \quad (1)$$

where

R = riders at new fare,
e = elasticity (increase or decrease depending on whether ΔF is positive or negative),
ΔF = change in fare,
F = existing fare, and
R_B = riders at existing fare.

$$rev = R(F + \Delta F)k \quad (2)$$

where rev = new revenue and K = ratio between 1973 riders and revenue (fare-expansion factor to estimate total revenue from a given nominal fare).

Each of the seven systems was analyzed, and the changes in revenue and ridership that would occur if differential time-of-day fares were implemented were calculated.

POLICIES

Each proposed differential-fare combination can be represented by its impact on revenue and ridership (Figure 1) as follows:

Objective	Impact
A	Increase both passengers and revenue (may not be possible)
B	Increase either passengers or revenue, with a less than 5 percent loss in the other
B_1	Increase passengers, with a less than 5 percent loss in revenue
B_2	Increase revenues, with a less than 5 percent loss in passengers
C	Maintain both passengers and revenue (a less than 5 percent loss in both)
D	Increase either passengers or revenue, with a more than 5 percent loss in the other
D_1	Increase passengers, with a more than 5 percent loss in revenue
D_2	Increase revenues, with a more than 5 percent loss in passengers
E	Decrease both passengers and revenue, with a less than 5 percent loss in one, and a more than 5 percent loss in the other
E_1	Decrease revenues more than 5 percent, with a less than 5 percent loss in passengers
E_2	Decrease passengers more than 5 percent, with a less than 5 percent loss in revenue
F	Decrease both passengers and revenue, with a more than 5 percent loss in both

While the specific levels of these objectives (e.g., 5 percent) are arbitrary, they illustrate the range that may be achieved by the implementation of differential time-of-day fares. The particular level chosen here (i.e., the 5 percent change) was selected because it isolates a small number of fare combinations that achieve real revenue or ridership increases while improving equity.

To determine the fare combinations that achieve each of the objectives, a series of graphs was constructed to show the passenger and revenue changes that would occur in each city (Figures 2 to 8). In these figures, off-peak fares are plotted along the horizontal axis and peak fares along the vertical. At the intersections (i.e., at each fare combination) are shown the associated percentage changes in passengers and in revenue that would occur from 1973 levels. A series of contours is then drawn to connect points of equal percentage change and delineate areas of the graph where the fare combinations achieve the objectives. These areas are indicated by the large letters A through F.

By definition here, equitable fare policies are those in which peak fares are higher than off-peak fares. For each of the above objectives, it is possible to identify fare combinations that are less equitable than the present flat fare by reducing peak and increasing off-peak fares, but doing so would increase the inequities of the present flat-rate system. It would also add more passengers to transit vehicles at times when there is no or little excess capacity while increasing the capacity of the system to handle the increase would eliminate any revenue gains made.

RESULTS

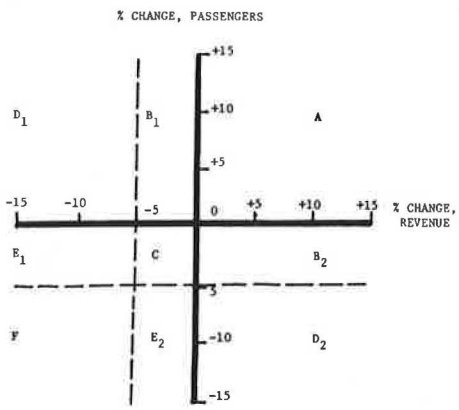
Because ridership and revenue levels are influenced by transit-demand elasticity, and because that elasticity varies from city to city (Table 1), the effect of differential fares will also vary among cities. Generally, elasticities are lower in larger cities; that is, there is a lower percentage change in ridership as a result of any change in fare. Elasticities generally increase with decreasing city size, but there is no proportional relationship between these variables. On the basis of elasticities, and, hence, the similarities in the behavior of passenger and revenue levels, the cities studied can be separated into three distinct groups.

Table 1. Ridership, revenue, and fare elasticities of cities in New York State.

System	Ridership, 1973 (000)				Revenue, 1973 ($000)			Fares, 1975 ($)			Fare Elasticity	
	Peak	Off-Peak	Total	Percent in Peak	Peak	Off-Peak	Total	Base	Average[a]	Ratio	Increase Fare	Decrease Fare to $0.25
Albany-Schenectady-Troy	4 631	6 395	11 026	42	1 852	2 558	4 410	0.40	0.40	1.000	-0.52	-0.28
Binghamton	802	869	1 671	48	264	287	551	0.40	0.33	0.824	-1.15	-0.56
Buffalo	10 479	17 097	27 576	38	5 089	8 304	13 393	0.40	0.486	1.214	-0.25	-0.13
Rochester	8 475	9 181	17 656	48	3 331	3 608	6 939	0.40	0.393	0.983	-0.54	-0.29
Syracuse	4 558	6 041	10 599	43	1 655	2 194	3 849	0.35	0.363	1.038	-0.56	-0.33
NYC Subway	575 494	648 962	1 224 456	47	185 531	209 215	394 746	0.35	0.3224	0.921	-0.23	-0.20
NYC Bus	122 997	169 854	292 851	42	50 222	69 355	119 577	0.35	0.4083	1.167	-0.26	-0.22

[a] Revenue/passenger.

Figure 1. Schematic diagram of policy objectives.



These are, in order of the elasticity levels: (a) New York City and Buffalo; (b) Albany-Schenectady-Troy (Capital District), Rochester, and Syracuse; and (c) Binghamton.

In New York City, the low elasticities of the subway provide a great deal of flexibility in determining fare policies. A large number of fare combinations, although producing passenger-volume decreases, keep these losses below 5 percent (area B_2 in Figure 2). Conversely, no fare combination would increase passenger levels more than 2 percent without producing a revenue decrease of 6 percent or more. Most of these results are are also applicable to the New York City bus system (Figure 3). The only equitable fares that do not produce reasonable passenger and revenue levels (objective B_2) on both the subway and the buses are 25-cent off-peak and 50-cent peak and 25-cent off-peak and 55-cent peak fares. These maintain both passengers and revenue on the bus system (objective C) or increase revenue with less than a 5 percent loss in passengers (objective B_1).

The low elasticities in Buffalo (Figure 4) would prevent any significant increases in passenger volumes if off-peak fares were reduced. It is not possible to increase ridership 5 percent without incurring revenue losses greater than 20 percent. On the other hand, fares can be higher than on other systems without sustaining large passenger losses: a 15 percent increase in fare-box income would be accompanied by an approximately 5 percent decrease in passenger levels. The low ridership elasticity in Buffalo provides a wide number of possible fare combinations that satisfy this objective (B_2).

Transit-demand elasticities in the Capital District, Rochester, and Syracuse are approximately equal and about twice as high as those in New York City and Buffalo. Consequently, the characteristics of the fare combinations that are possible in the latter cities are not present in the former. The large number of combinations, the flexibility, and the high level to which fares can be increased before producing diminished revenue returns are all absent. Similarly, the characteristics of the fare combinations in these three cities resemble each other: There are at most two fare combinations that are equitable and produce passenger increases (objective B_2), and there are a large number of profitable but inequitable combinations.

A 35-cent off-peak and 40-cent peak fare appears to be the best combination for the Capital District (Figure 5). This policy would increase passengers 3 percent and decrease revenues 4 percent. This fare is more desirable in the long run than is a 35-cent off-peak and 45-cent peak or a 40-cent off-peak and 45-cent peak fare, which, although equitable, might be accompanied by lower passenger increases.

Like the Capital District, there are few options in Rochester (Figure 6). Accordingly, the attractive fare combinations, both equitable, are about the same: A 35-cent off-peak and 40-cent peak fare increases passenger volumes in Rochester by about 3 percent at the expense of a 4 percent drop in revenue; a 35-cent off-peak and 45-cent peak fare maintains both levels. The passenger and revenue situation in Syracuse (Figure 7) is approaching that which has already occurred in Binghamton where fare increases soon resulted in declining fare-box revenues. Serious argument should be made against higher fares because of their depressing effect on passenger volumes. Unfortunately, in Syracuse the fare options are limited, and, to preserve flexibility for future policy decisions, only two fare combinations are attractive: a 35-cent peak and 30-cent off-peak or a 40-cent peak and 30-cent off-peak fare.

Binghamton (Figure 8) has the highest elasticity among the cities studied, and will probably have its revenue and ridership levels affected more. Yet it has the fewest options available to it. The uniqueness of Binghamton's position is shown in Figure 8. The transit-demand elasticities are more than twice those of the next-lowest city, Syracuse (Table 1), and are responsible for a contour configuration that is unlike that of any other city. The revenue-change contours are elliptical, disappearing at 0 percent, and the passenger contours are closer than in any other city. Furthermore, large areas are under objectives E and F. Hence, it is impossible to increase fare-box revenue by any combination fare. At the same time, changing fares would create large-scale fluctuations in passenger levels, either up or down. Apparently because of the high elasticities, current fares are at levels at which further increases would probably result in revenue decreases, and passenger levels would be affected dramatically. The most profitable outcome possible for Binghamton is one in which passenger

Figure 2. Passenger and revenue effects of combination fares: New York City subway.

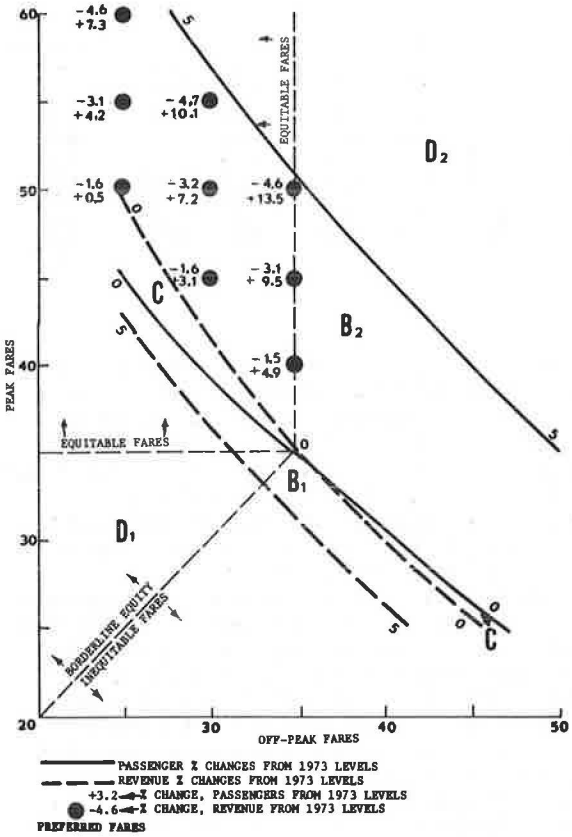


Figure 3. Passenger and revenue effects of combination fares: New York City public bus.

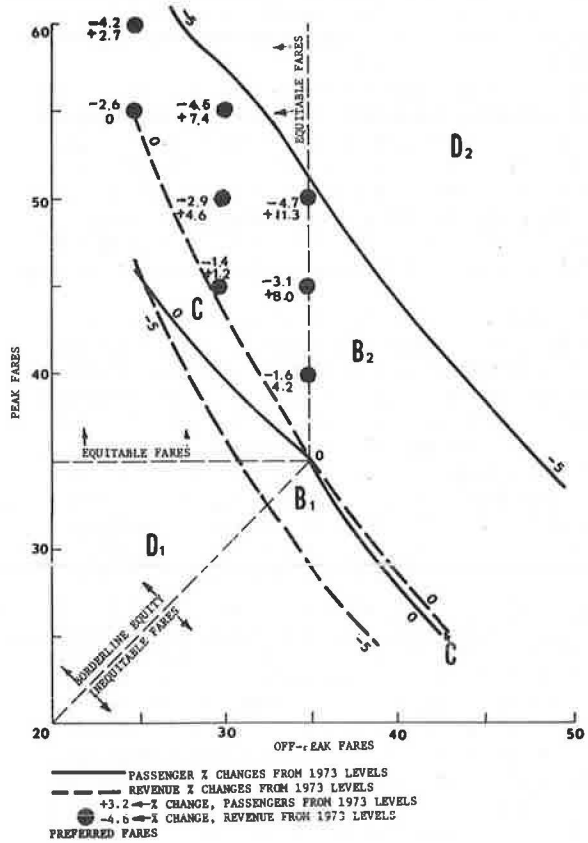


Figure 4. Passenger and revenue effects of combination fares: Buffalo.

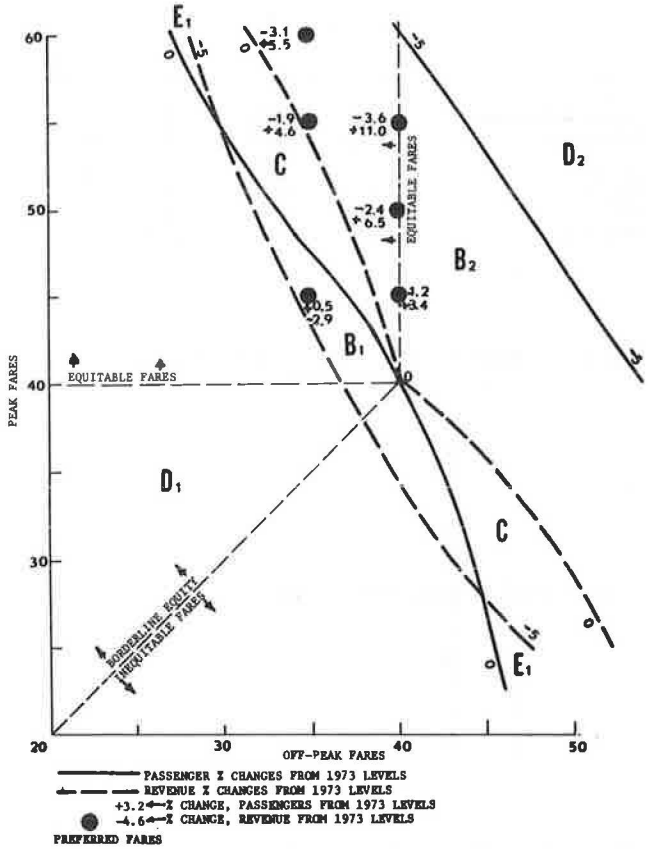


Figure 5. Passenger and revenue effects of combination fares: Capital District (Albany-Schenectady-Troy).

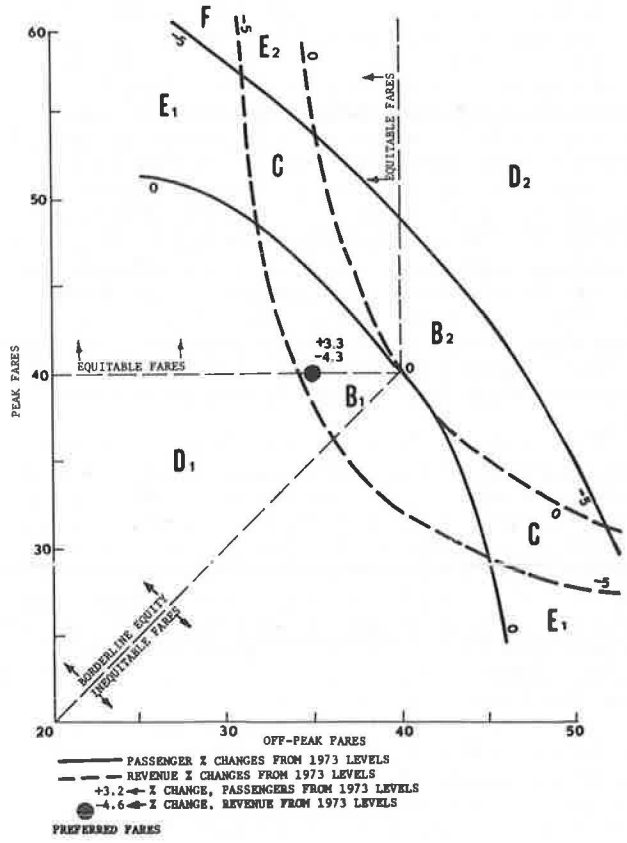


Figure 6. Passenger and revenue effects of combination fares: Rochester.

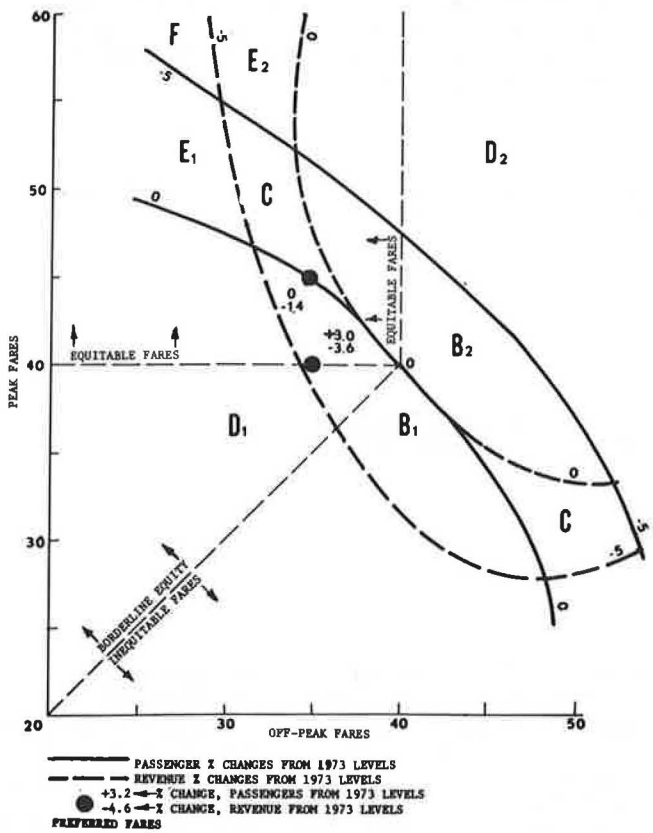


Figure 7. Passenger and revenue effects of combination fares: Syracuse.

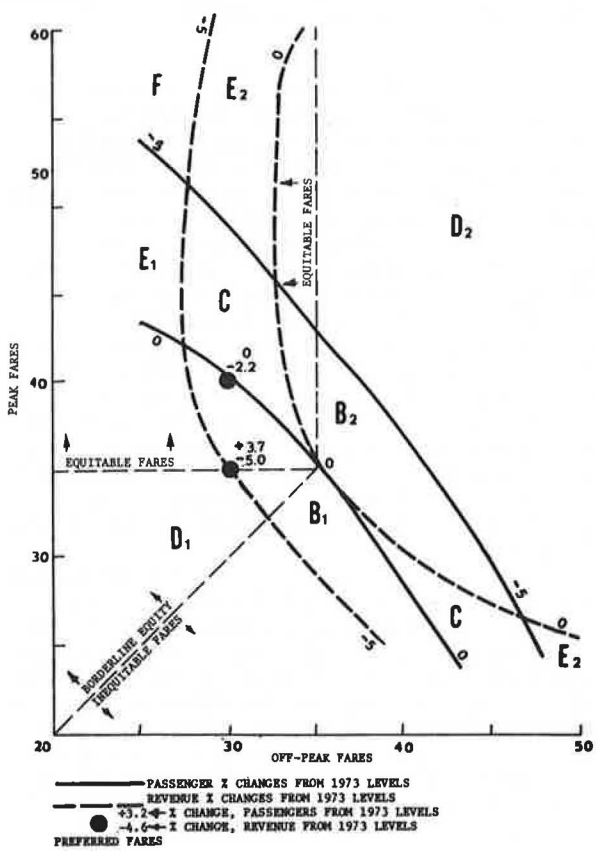
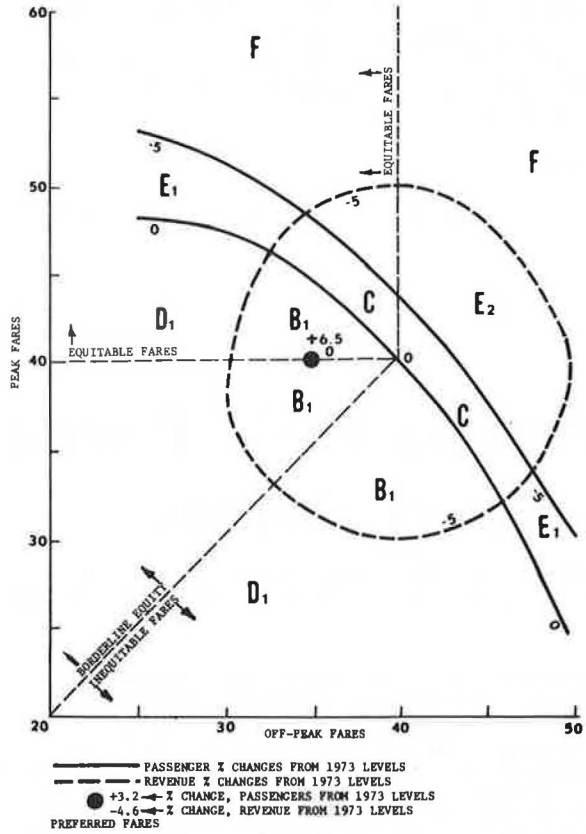


Figure 8. Passenger and revenue effects of combination fares: Binghamton.



volumes increase 5 percent or more and revenues remain constant or decline slightly (between 0 and 5 percent). That objective (B_1) is possible with a 35-cent off-peak and 40-cent peak fare that would maintain revenues while increasing passenger volumes by about 7 percent. An all-day 35-cent fare would be less equitable but is a reasonable alternative situation (Figure 8).

SUMMARY AND CONCLUSIONS

Differential time-of-day fares were analyzed for seven New York State cities with three criteria: to increase revenue, to increase ridership, and to improve the equity of fares for peak versus off-peak users. For the systems studied, no differential fare combination, either equitable or not, could be found that would increase both ridership and revenue simultaneously. Riders can be attracted during off-peak hours by charging fares that are lower than current (1973) levels, but only by incurring higher deficits. However, for all seven systems, there are certain differential-fare policies that markedly improve equity and at the same time increase either ridership or revenues with less than a 5-percent loss in the other.

Fare increases are not reversible: Those who leave the transit system when fares go up may never return, or return only after long periods. For this reason, it is preferable to encourage differential-fare policies that maintain or increase ridership at a slight loss in revenue, rather than the reverse. In four of the systems, Albany-Schenectady-Troy, Rochester, Syracuse, and Binghamton, there are differential-fare policies that will achieve this objective and also improve equity. In the largest systems, New York City subway, New York City

public bus, and Buffalo, there are differential-fare policies that increase revenues and also improve equity.

Generally, increased peak-hour fares in combination with low off-peak fares will have a negative impact on either revenue or passenger levels. No program can produce a revenue increase without a corresponding decrease in passenger volume.

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Approach to the Planning and Design of Transit Shelters

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For a transit patron, the transit shelter is one of the most easily recognizable elements of the transit system, but, at present, this type of transit-interface facility is considered simply for its cosmetic value. This attitude creates a weak link between the transportation system and its users and can threaten the viability of the urban transit system. This paper presents the theses that transit shelters have a more significant role in the community and in the transit system than being just a windbreak or weather-protection device; that they are an interface point with the system and should protect, comfort, inform, and guide the user; that they should blend into the surroundings but still be visible; and that they should not be isolated or passive agents. The paper sets forth an innovative approach to the planning and design of shelters and describes what a shelter facility is versus what it ought to be. It also describes the types of activities that are involved in the development of the transit shelter and the types of functional, social, financial, physical, and user issues that should be considered. The benefits that can be derived through the use of this approach are discussed.

A transit stop is a primary interface between the patron and the transit system. A well-designed stop will encourage ridership and provide comfort, security, information, and a place to rest. When a patron arrives at a stop and there is no bus in sight, a commonplace occurrence, he or she waits and watches automobile traffic pass by. This increases the illusion or reality that transit is inferior to the automobile in terms of travel time. However, if the patron is comfortable and occupied while awaiting the arrival of the bus, the passage of time may lose some of its significance.

To help increase the viability of the transit system in this respect, shelters have been recommended. These shelters need not be isolated passive agents but can and should be fully integrated into both the immediate environment and the balance of the transit system. In addition, they should be active agents in encouraging the use of the system. The traditional hardware approach to shelter and bus stops is a beginning, but recognition that the shelter and stops are parts of a complex design issue is very important. Figure 1 illustrates conceptually the manner in which the hardware and the environment are parts of a system that actively seeks to integrate the community, the transit system, and the patron.

As the interface among these, the shelter and stop have several important roles that may differ from residential location to activity-center location to employment-center location. These differences may affect the emphasis that given roles might have, although no role should ever be ignored if the shelter is to successfully serve the community, the transit system, and the patron.

Well-designed transit-shelter facilities should include more than a windbreak and a roof and be similar to transit facilities such as airport terminals or union stations. Although capital investment and space limitations will restrict options, the environment of a bus stop and shelter ideally should reflect the following (Figure 2).

1. Shelters provide security. The environment of the bus stop should be designed in a manner that encourages people to use the facility and provides them with a sense of security. At night a well-lighted stop permits bus drivers to see waiting patrons and provides patrons with the ability to see their environment. Lighted open spaces, rather than dark and confining areas, increase the users' feeling of well-being. The availability of a telephone or police and fire call box or both can also increase personal security.
2. Shelters provide a rest area. A relatively large number of transit riders are to some extent restricted in their mobility. Rest facilities, including benches to sit on and racks on which to place packages, increase the attractiveness of the system. If a person is already tired from walking to a bus stop, he or she is probably a less than completely satisfied customer. Benches and parcel racks, and perhaps a drinking fountain, would certainly be welcomed.
3. Shelters provide for the needs of the handicapped. Consideration should be given to the needs of people using wheelchairs, walkers, crutches, and other aids. As transit systems and vehicles seek to serve the handicapped better, the emphasis should be not on accentuating differences and difficulties, but rather on ameliorating them. Curb cuts at appropriate points near and en route to shelters, smooth pavements, wide access, low-level signs, and grab rails should be included to make use of the facility possible for people restricted to wheelchairs.