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Contents

Attitude Surveys, Transit Planning, and Automobile-Use Constraints

William F. Hoey and Herbert S. Levinson, Wilbur Smith and Associates, Los Angeles

This paper summarizes the procedures, findings, and implications of an attitudinal survey of existing and potential transit users. Employees at workplaces having different levels of transit accessibility and different industry classifications were sampled about (a) the characteristics of a desirable transit service, and (b) the conditions under which they would use such a service. The approach used here appears to be more cost-effective and more accurate than the traditional home interview or bus-rider attitude and market-research studies and was useful in market segmentation for transit-system planning purposes. Radical differences were found between transit users and nonusers in regard to acceptable transit-service levels. Even with a level of service acceptable to nonusers of transit, most automobile drivers conditioned a change of regular modes of travel to work on motor-fuel supply restraints.

This paper presents the results of a survey of employee attitudes and expectations undertaken as a part of the Greater New Haven Transit Study. It sets forth the objectives, procedures, findings, and transit planning implications obtained from employee attitude surveys at five locations (1). It shows how the present modal choice is related to transit-service planning features and how automobile-use constraints would affect transit use and planning.

SURVEY DESIGN AND OBJECTIVES

Previous studies have indicated that the best single potential for diversion of trips from automobiles to transit is the journey to work. The Greater New Haven Transit Study therefore featured employer surveys for trip data and attitudes, which were supplemented by visitor surveys for trip data at a number of major trip generators.

Survey Objectives

The objectives of the survey were

1. To produce data useful for expanding or restructuring the existing bus services,
2. To aid in developing patronage and revenue forecasts, and
3. To aid in assessing the impact of the transportation-management proposals under study by the staff of the Connecticut Department of Environmental Protection.

Minimizing Noncommitment Responses

Previous studies have found that transit attitude survey responses may be highly misleading, particularly in home interview surveys where respondents may give socially acceptable answers rather than their personal feelings on the subject (2). Also, respondents may be unfamiliar with the characteristics of the proposed transit system on which they are being asked to indicate their attitudes. This problem of potential noncommitment response may be solved by asking them about their willingness to ride public transport modes with which they have experience, and factoring down (or up) to existing ridership as a control value (3).

Accordingly, the attitude surveys used the following innovative techniques to obtain realistic responses:

1. A secret ballot survey with no interviewer participation,
2. A request that the respondents describe an acceptable transit system in terms of major operating parameters, and
3. A question as to how often and under what circumstances the respondents would use their acceptable transit system for work access.

Questionnaire Design

The employee survey questionnaire was designed so that it could be readily understood by recipients, require a minimum of time to complete, and be largely self-coding. The forms were intensively reviewed by participating agency personnel and were pretested for comprehension and completion time. The following information was requested, of which the first seven items were in both the employee and the attitude surveys:

1. Residence location,
2. Mode of access (multimode if applicable),
3. Working hours (for service planning),
4. Number of automobiles owned in the household,
5. Personal automobile (a question intended to identify priority for vehicle use),
6. Travel during the day (e.g., on lunch hour),
7. Age and sex,
8. Perceived cost of trip,
9. Longest acceptable walking distance,
10. Longest acceptable waiting time,
11. Longest acceptable journey-to-work time (door-to-door),
12. Maximum acceptable time difference between bus and transit (diversion curve data),
13. Highest acceptable fare,
14. Bad weather shelter impact,
15. Impact of standing load on bus, and
16. Circumstances of bus use.

Sampling Procedures

Surveys of employee attitudes toward public transportation were undertaken at five locations. Approximately 5800 employees were included in the attitude survey population. The sites surveyed included a major downtown office building housing law firms and such, a telephone company office building, industrial management offices on the fringe of downtown, a suburban college, and South Central Connecticut State College in New Haven. (All of the employers were cooperative and helpful in distributing and collecting the survey questionnaires.) Return rates ranged from 25 to 100 percent and averaged 46 percent.

Survey forms were distributed through the personnel and accounting sections of participating firms. To avoid bias in the distribution of forms, each firm was instructed to conduct a 100 percent sample of its employees and was given sufficient forms for this purpose. The forms were sampled on a random basis to provide a minimum of 200 acceptable coded responses/employer, or where the number of sample returns was less than 200, all were coded. The sample sizes for the employee and attitude surveys were 3237 and 960 respectively, which were sufficient to provide good statistical reliability.

Table 1. Profile of transit commuters.

Characteristic	Workers Who Use Transit (%)		
	Downtown	Outlying[a]	Region
Have personal automobile	57.0	29.2	44.6
Two or more automobiles in household	41.8	14.2	25.1
One automobile in household	43.9	36.1	40.4
No automobile in household	14.3	49.7	30.1
Female	77.5	73.8	75.5
Male	22.5	26.2	24.5
Under 18 years of age	3.1	0.5	1.9
18 to 35 years of age	40.2	32.1	36.4
36 to 54 years of age	38.0	39.3	38.6
55 years of age or more	18.6	28.1	23.1
Workplace location	55.2	44.8	100.0

Notes: Sample size and employment represented are 793 and 4455, 2444 and 15 318, and 3237 and 19 773 for the downtown, outlying, and overall regions respectively. Percentages are based on samples expanded to total employment at each location surveyed.

[a] Includes downtown New Haven frame, viz., Yale-New Haven Hospital and Penn Central Railroad offices, and outlying survey locations.

Table 2. Attitude survey findings.

Characteristic	Acceptable Standard[a]	Respondents[b] (%)		
		Transit	Automobile Driver	All
Walking distance (time)	2 blocks (3 min)	73	68	69
	300 m (5 min)	45	31	30
Waiting time	5 min	84	86	87
	10 min	44	33	36
Total fare	25 cents	94	74	78
	35 cents	74	48	53
	Free fare essential	4	6	6
Time difference (assuming transit longer)	5 min	86	77	79
	10 min	59	42	43
	15 min	41	12	16
Bus shelter	Provided at each stop	17	58	49
Standing on bus	Up to 5 or 10 min	70	59	62

Notes: 1 m = 3.3 ft.
Number of respondents and employment represented are 112 and 754, 584 and 3358, and 960 and 5806 for the transit user, automobile driver, and all populations respectively

[a] Standard desired by indicated percentages of respondents.
[b] Accepting this level of service or better.

SURVEY FINDINGS

The employer survey found that a larger portion of the workers who use transit in Greater New Haven do so by choice than is the case in other areas. Transit users comprised 23.9, 4.1, and 8.8 percent of all workers in the downtown, outlying, and overall regions respectively. The characteristics of these transit users are given in Table 1. About 42 percent of the downtown workers who used transit and 14 percent of the nondowntown (downtown frame and outlying workplaces combined) transit users had two or more automobiles in their households. A personal automobile for use as needed was reported by 57 percent of downtown transit commuters (core only) and 29 percent of the others. Generally, transit surveys find that only about 15 percent of transit riders have both a driving license and an automobile available for their transit trip. Outlying and downtown frame employees were more likely to be transit dependent in that about half (49.7 percent) had no automobile in their family or household. They represent a more typical situation.

Women predominated among transit commuters (about 75 percent) in both downtown and outlying locations. This proportion (70 to 75 percent female) is typical of local public transportation in the United States. There was no apparent relation between transit use and the age of the rider.

The dominance of downtown New Haven as a bus-traffic generator was confirmed by the surveys. Approximately 24 percent of downtown New Haven employees used transit for access to work. In contrast, bus use by central business district (CBD) frame employees (i.e., those at Yale-New Haven Hospital and the Penn Central Railroad offices) was about 14 percent, and only 2.7 percent of employees working away from the CBD used transit to get to work.

User and Nonuser Expectations

Selected characteristics of an acceptable transit system, as reported by the attitude surveys, are summarized in Table 2. Transit-rider and automobile-driver responses are identified separately.

1. Walking distance or time—Automobile drivers and transit riders were similar in walking-distance tolerance. About 70 percent of each population group was willing to walk more than 2 blocks to a bus stop. Less than half of each were willing to walk more than 5 min (300 to 400 m; 1000 to 1300 ft). These data confirm the distance tolerance assumption used in estimating the population coverage of bus routes (300 m; 1000 ft).
2. Waiting time—Waiting time preferences were also similar for transit users and automobile drivers. About 85 percent of both groups would wait 5 min for a bus, but less than half would wait 10 min or more.
3. Fares—User charges for bus service were accepted by a consensus of the population. Only 6 percent of the survey respondents would ride buses only if there was no fare charge. Over 90 percent of the bus riders and over 70 percent of the automobile drivers would accept a 25-cent fare. (This represents a survey of the working population. Senior citizens and student populations are more sensitive to fares.) Over 70 percent of transit riders and over 50 percent of all respondents accepted the Connecticut Company basic fare of 35 cents. Automobile drivers were apparently more sensitive to fares than are present transit users. Less than half of the automobile drivers indicated that they would pay a 35-cent fare. This response implies that a fare reduction would increase system deficits, since a radical increase in service levels, as well as a fare reduction, would be necessary to attract motorists to transit.
4. Time difference—The higher transit service expectations of automobile drivers were reflected in the greater acceptance of longer transit travel time by transit users. Only about 40 percent of the automobile drivers would accept an extra 10 min of travel time by public transportation. For a typical 6-km (3.6-mile) trip at a realistic bus speed of 16 to 20 km/h (10 to 12 mph), the average trip may require about 20 min, and the door-to-door time (including walking and waiting) will be approximately 35 min, if bus service is frequent and direct. Automobile travel time for the same trip might be about 12 min, and the door-to-door (including parking and terminal) times approximately 20 min. Such a 15-min time difference would be accepted by fewer than 20 percent of the surveyed automobile drivers.

Transit users were more tolerant of time differences, possibly because many did not have the alternative of travel by automobile. Almost 60 percent would accept a trip time 10 min longer than that by automobile, and over 40 percent would accept a 15-min time difference. If people do not have private transport alternatives, the maximum acceptable transit travel times or fares limit their choices of housing and employment. Comparisons

Table 3. Projected use of acceptable bus system.

	Respondents (%)		
Projected Bus Use Frequency[a]	Transit	Automobile Driver	All
Daily instead of driving	87	39	45
Occasional use such as tune-up	0	12	9
Constrained use (gasoline \$0.25/L or rationed, parking surcharge of \$1.00, or combination thereof)	12	46	41
Unlikely (no answer to question on form)	1	3	5
Total	100	100	100

Notes: 1 L = approximately 0.25 gal. (English units were used in the original survey data.) Number of respondents and employment represented are 112 and 754, 584 and 3358, and 960 and 5806 for the transit user, automobile driver, and all populations respectively.

[a] Assuming a bus service with the desired walking distance, waiting time, speed, and such is provided.

Table 4. Impact of constraints on automobile use.

	Automobile Drivers Taking Bus[a]	
Constraint	Number	Percent
Gasoline cost of \$0.25/L or more	40	24.3
Gasoline rationed to 40 L/week	20	12.1
Gasoline rationed and cost of \$0.25/L or more	50	30.3
Subtotal gasoline-related	110	66.7
Parking cost increased by \$1.00	1	0.6
Free bus and parking cost increased	13	7.9
Gasoline cost of \$0.25/L or more and parking cost increased \$1.00	9	5.4
Gasoline rationed, cost of \$0.25/L or more, and parking cost increased by \$1.00	15	9.1
Gasoline rationed and parking cost increased by \$1.00	4	2.4
Gasoline rationed or cost of \$0.25/L or more, parking cost increased by \$1.00, and bus ride free	13	7.9
Subtotal parking-related	55	33.3
Total	165	100.0

Note: 1 L = approximately 0.25 gal.

[a] Unexpanded responses, all locations combined, constrained mode change by automobile drivers only.

with private automobile travel time are of limited significance for these riders because total trip times constrain their transit use.

5. Bus shelters—The difference in expectations between the present transit user and the automobile driver was particularly delineated by their attitude on shelters. Only 17 percent of the transit users indicated a need for a bus shelter at their stop. Over half of the automobile drivers would use a bus in bad weather only if a shelter were available.

6. Standing on the bus—About 70 percent of the transit riders were willing to stand for 5 or 10 min on their bus trips. A smaller majority of automobile drivers (59 percent) were also willing to stand for this time on each trip. These attitudes are consistent with observed passenger behavior in peak hours at maximum load points.

Potential System Use

The attitude surveys also attempted to identify potential users of the transit system, assuming that a service that meets level-of-service expectations could be provided. Table 3 summarizes the projected use of an acceptable (i.e., custom-designed) bus system by the survey respondents.

Of present transit users, 87 percent would use a bus system that meets their specifications. (The other 13 percent may represent errors in the data or responses from motorists who were using buses because of temporary automobile unavailability.)

A majority of present automobile drivers would normally continue to drive even if an acceptable bus system were available to them. This response is consistent with driver behavior observed during the energy crisis of 1973-74. Even so, the diversion to transit of the 39 percent who would change their travel mode could represent an increase of approximately 88 percent in downtown transit trips. (A radical improvement in transit service would be necessary on most routes to achieve this level of use.)

Transit Planning Implications

The attitude surveys imply that potential transit consumers who now use automobiles would accept a bus system with the following features: (a) routes 4 blocks apart at most; (b) short headways, ideally as short as 5 min in peak hours; (c) a basic zone fare of 25 cents; (d) travel times no more than 10 min longer than by automobile; (e) shelters at almost all bus stops; and (f) seats for all passengers, except on the last 5 or 10 min of heavily used local runs.

These features describe a marketable public transportation product. They provide planning objectives for service improvements, even though they may not be economically realistic in terms of potential revenues, public funding resources, and geographic or development factors or both.

1. Route spacing—Routes can feasibly be spaced at 4-block intervals in an urban area with a gross population density approaching 3900 persons/km^2 (10 000 persons/mile^2), a condition that is met by most of New Haven. Suburban areas with population densities of approximately 800 persons/km^2 (2000 persons/mile^2) cannot be fully covered by bus service although, within such areas, it may be feasible to serve a series of high-density apartments or condominium developments if they are located within 300 to 500 m (1000 to 1500 ft) of a major or arterial street.

2. Fares—The dominant automobile-user preference for a 25-cent fare may reflect a desire for a convenient single-coin fare, rather than a monetary limit. This fare preference is inconsistent with known data on transit-fare elasticity and with current automobile operating costs. Successful commuter buses have been operating in the New Haven area at fares of \$0.50 to \$1.25/ride. The 25-cent fare may, however, be desirable for in-city shuttle service and for special promotions.

3. Travel times—If the maximum allowable time difference is 10 min, normal local bus services, with their 16 to 20-km/h (10 to 12-mph) average speeds, cannot compete with automobile trips unless the total trip time is less than 10 min. This implies a local bus-service limit of about 3.2 km (2.0 miles) when waiting and other access times are minimized. Express services, especially park-and-ride buses that operate nonstop between outlying parking facilities and the CBD, can be competitive for greater distances if the buses are given priority at locations where traffic queues form during peak hours.

Automobile-Use Constraints as Transit Incentives

Even if an acceptable transit service is provided, automobile users have a residual preference for the private automobile as a transportation mode. If public policy objectives such as improved air quality or energy conservation require diversion of automobile users to transit, strong incentives will be required.

Table 4 summarizes the impacts of various constraints to automobile use on potential bus ridership. Of the energy-environmental constraints listed in the attitude survey, the measures with the strongest impacts reflect gasoline cost or supply. Parking-related measures, with or without free bus service, had little impact on respondents' choice of mode unless coupled with a gasoline price increase or rationing.

1. Gasoline related—The most effective single public policy incentive to transit use would involve increasing the price of motor fuel to over $0.25/L ($1.00/gal) in 1975 dollars. This incentive could be implemented through a federal motor fuel tax comparable to those levied in most Western European countries. The revenue from such a tax might be used to reduce other federal taxes or might be rebated to the cities and counties where the taxes were collected, in order to reduce their property tax burdens.

Gasoline rationing that set a 40-L (10-gal)/week limit on driving would also have a strong impact on transit use. However, rationing involves many more administrative and enforcement costs than do fuel-tax measures, which can be collected from relatively small numbers of refiners and distributors.

2. Parking related—Parking surcharges were seen as much less effective than fuel taxes or rationing as incentives to transit use. An increase in parking fees of $1.00/d in 1975 was seen as influencing modal choice by less than 1 percent of the survey respondents who indicate a willingness to change mode in response to public policy measures. To be effective in diverting automobile users to transit, parking surcharges would have to be coupled with motor fuel constraints.

CONCLUSIONS

The Greater New Haven Transit Study research used a relatively simple, unsophisticated questionnaire and analysis to point the way to a public transit service with increased consumer marketability. Its methods and findings have potential application for transit service planning in medium-sized communities throughout the United States—in adapting service to tap markets, developing transportation-system management programs, and restraining automobile use.

The survey showed that existing transit riders have much lower expectations about bus service attributes than do automobile drivers. Thus, radically improved service concepts and levels will be necessary to divert motorists to transit use and may be feasible only in selected corridors. If energy, environmental, or public policy considerations require large-scale diversions of commuters to transit, then selected automobile disincentives may be necessary. Increased motor fuel taxation appears to be a more effective disincentive than parking taxes and controls, at least in medium-sized cities.

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Abridgment

Marketing Approach Using Product Diffusion Knowledge to Measure Consumer Transit Attitudes

Martin L. Schwartz, Miami University, Ohio

This paper suggests a method that can be used to develop a measuring instrument that will (a) determine specifically why shoppers do not use the urban bus system, and (b) be sufficiently sensitive to identify whether the problem is a bus system design problem or a promotion problem.

A measuring instrument that provides these capabilities could be used by transit marketing managers to more effectively allocate their resources toward the goal of increasing bus patronage. Marketing managers will always be constrained by limited resources. Consequently, they must decide how to allocate corporate funds so as to maximize the return on their investment. Transit marketing managers are expected to make trade-offs between (a) methods of removing the barriers to adoption of the bus system, (b) the capital investment required to effect their removal, and (c) the number of potential customers who would be affected by the removal. The measuring instrument should be capable of providing information on all of the items used in the trade-off except the capital investment. The instrument should be capable of identifying the barriers to adoption, of determining whether those barriers can be removed by advertising alone or whether system redesign is also required, and it should be capable of identifying the number of individuals affected by each barrier identified.

THEORETICAL CONSTRUCT

Communication knowledge, integrated by Rogers and Shoemaker (1, pp. 102 and 158), was used as the theoretical construct to identify the criterion and predictor variables of a measuring instrument with sufficient sensitivity to meet these objectives. The theoretical construct used to obtain the predictor variables assumes that adoption rate is a function of perceived attributes of innovation, the type of innovation decision to be made, the nature of the social system, and the extent of change agents' promotion efforts. Only perceived attributes need to be measured since the other variables can be assumed to be constant or can be constrained by the sampling procedure.

The nature of the social system can be constrained by selecting only one market segment for participation in a study. The market segment used in this study consisted of middle-class, suburban women shoppers. This particular segment was selected because it is the key to using bus capacity more efficiently during off-peak hours. At present, buses run almost empty when work commuters are not using them. The other variables—the type of innovation decision used, the type of communication channels used, and the extent of change agents' promotion efforts—are also assumed to be constants.

The theoretical construct used to obtain criterion variables is discussed by Schwartz in another paper in this Record. The construct connotes that an individual passes through a number of stages prior to adopting or finally discontinuing (or both) the use of a product or service. Individuals within each of these stages have been categorized as nontriers, triers, rejecters, adopters, and discontinuers of the bus system. The reasons that urban transit has not been tried, the causes of rejection, and the causes of discontinuance can be determined by randomly measuring and comparing the extent to which individuals in the various stages of the decision process perceive that urban transit possesses specific attributes.

QUESTIONNAIRE DESIGN

The questionnaire developed here has several attributes that differ from most previous questionnaires used to determine the barriers to the adoption of transit. First, it is targeted toward the very specific market segment of middle-class female shoppers. Second, the independent variables are developed from Rogers' five perceived attributes of innovation. Third, the independent variables are designed to be very product specific. Fourth, the dependent variables operationalize five of the stages of the Rogers and Shoemaker individual innovation decision process (1, p. 102).

The taxonomy to develop pertinent and product-specific questions to be asked of respondents was based on the Rogers and Shoemaker perceived attributes of innovation (1, p. 158) (relative advantage, compatibility, complexity, observability, and trialability) to ensure that they were adequately represented in the questionnaire. When they were not adequately represented by transit attributes studied previously, new questions were formulated.

Bus transit was treated as the entire system and not as only the bus when these attributes were developed. Obtaining bus route information and traveling to the bus stop are as much a part of the bus system as are the attributes of the bus itself.

The final list of attributes is shown by Schwartz in another paper in this Record. These attributes were converted to questions and scaled using a five-point semantic differential. Possible answers ranged from not at all to extremely. Observability was the only variable that was not directly measured by an interval scale (for purposes of this study, the semantic differential was assumed to be intervally scaled). It was measured instead by an I don't know category. If a respondent indicated I don't know for an attribute, it was assumed to mean that she had not observed it or that she did not remember having observed it (which is the same thing as not having observed it in a study that assumes that decisions are made cognitively).

VALIDATION OF THE QUESTIONNAIRE

Validation of the measuring instrument was obtained by using factor analysis, Student's t-test, chi-square tests, discriminant analyses, and classification analyses to ensure that the attitudes measured by the questionnaire conformed to the theory on which the questionnaire was based.

Validation by Factor Analysis

A factor analysis using the varimax method was performed to determine the extent to which three of the five attributes of innovation—relative advantage, compatibility, and complexity—were represented by clearly identifiable factors in the minds of respondents. Observability was not included in the analysis because it was measured in a different manner from the other attributes. Willingness to try was not included because it was used in this study as an effect rather than as a cause. (This study attempted to determine why shoppers did not use the bus on a trial basis rather than determining the extent to which shoppers preceived the bus to be triable.)

The factors obtained indicate that respondent thought patterns fall into factors that can be interpreted as relative advantage, compatibility, and complexity. The concepts of compatibility and relative advantage were reppresented not by one factor, but by several factors, each reflecting a different facet of the attribute. For example, compatibility consisted of several factors that included (a) compatibility of the bus with culturally derived structural needs such as shopping with friends, combining shopping with other social activities, and time orientations; (b) compatibility of the bus with aesthetic, proxemic, and comfort needs such as closeness of the bus seats, the odor of the bus, the dirtiness of the bus, the bumpiness of the ride, and the possibility of having to stand while on the bus; and (c) compatibility of the bus with societal needs such as reducing air pollution, traffic congestion, and highway accidents and conserving natural resources.

Relative advantage consisted of several factors including the speed of the car as compared to that of the bus, the cost of taking the bus, the inconvenience of going to or from the bus stop, the risk of criminal assault, and the convenience of not having to park a car.

Complexity consisted of one factor that was composed of the inconvenience of finding out which bus to catch and where and when to catch it, the difficulty of obtaining bus route information and bus schedules, the difficulty of understanding route maps, the difficulty of identifying the proper bus to board, the difficulty of finding out where to catch the bus when shopping, and the difficulty of remembering bus numbers, bus stops, and bus schedules when shopping. The factors obtained in this analysis support the validity of the measuring instrument.

Validation by Student's t-Tests and Chi-Square Tests

To determine whether adopters are significantly more probus in their perceptions of 60 attributes of the bus system than are nontriers, rejecters, and discontinuers, either in combination or alone, Student's t-tests and chi-square tests were used to test the following null hypotheses: (a) Adopters of the bus system for shopping are not significantly more probus than are nonusers (nontriers, rejecters, and discontinuers), either in combination or alone; (b) adopters of the bus system for any purpose are not significantly more probus than are nonusers (nontriers, rejecters, and discontinuers), either in combination or alone; and (c) attributes of the bus system are not significantly more observable to users of the bus system (adopters, occasional users, and triers) than they are to nontriers of the bus system.

The first two hypothesis tests on a sample of 159 respondents resulted in the following percentage of attributes for which adopters of the bus are significantly more probus than are nonusers:

Group	Percentage of Attributes
Adopters versus nonusers for shopping	53
Adopters versus nonusers for any purpose	60
Adopters versus nontriers for shopping	50
Adopters versus nontriers for any purpose	35
Adopters versus rejecters for shopping	30
Adopters versus rejecters for any purpose	35
Adopters versus discontinuers for any purpose	27

At a 0.001 level of significance, all of the null hypotheses were rejected. There were no attributes for which nonusers were significantly more probus than adopters. Adopters were significantly more probus for relative advantage, compatibility, and complexity attributes than were nontriers, rejecters, and discontinuers, either in combination or alone. There was not one bus system attribute for which nonusers of the bus system were significantly more probus than were adopters of the bus system, either for shopping or for nonshopping purposes.

The third hypothesis was also rejected. At the 0.05 level of significance 92 percent of the attributes were significantly more observable to users of the bus for shopping than they were to nontriers of the bus for shopping. None of the attributes was more observable to nontriers than to users of the bus system.

Validation by Discriminant and Classification Analyses

To determine the degree of sensitivity of the measuring instrument to differences between adopters and nonusers, discriminant and classification analyses were performed. One attribute from each of the five factors was selected by trial and error for incorporation into the discriminant and classification models. The classification analysis results indicated that 85.7 percent of the respondents can be correctly classified by their perceptions of bus system attributes.

The canonical correlation squared was used to estimate the proportion of variance of bus user or nonuser behavior explained by the attributes of the bus system. Forty-six percent of the variance between adopter and nonuser behavior can be explained by the five attributes selected for inclusion in the discriminant model. These results are acceptable for the purpose of validating the questionnaire, especially since the number of discriminating variables that could be incorporated into the model was limited by missing data constraints.

CONCLUSIONS

The measuring instrument developed and tested in this paper can be used to

1. Identify why many consumers have never tried to use an urban bus;
2. Identify the specific causes for consumer rejection after having tried the bus;
3. Identify the specific causes for consumer discontinuance after having adopted the bus for an extended period of time;
4. Identify why occasional users do not use the bus more frequently;
5. Identify whether individuals who are trying to use the bus are predisposed to become adopters or predisposed to become rejecters of the bus system;
6. Determine which barriers to adoption of the bus system can be removed by promotion alone and which require system redesign; and
7. Assist in determining how to best allocate resources in order to increase bus patronage.

REFERENCE

1. E. Rogers and F. F. Shoemaker. Communication of Innovations. The Free Press, 1971.

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Consumer Reaction to Transit Marketing in Boulder, Colorado

Martin L. Schwartz, Miami University, Ohio

The results of a questionnaire used to measure resistances to the adoption of urban transit during off-peak hours in Boulder, Colorado, are discussed. The findings have implications for transit marketing managers regardless of the cities in which they are located. The questionnaire was administered to middle-class women, aged 20 to 65. A systematic cluster sample was used to identify potential respondents, and a 55 percent usable response rate was obtained. The results suggest that the barriers to trial of transit are different from the causes of rejection of transit after trial, from the causes of discontinuance of transit after adoption, and from the causes of low-frequency use by occasional users. The causes of rejection after trial are also different from the causes of discontinuance after adoption of transit. Although the specific barriers to adoption will differ among cities, depending on the structure of the city and of the transit system, the Boulder results illustrate the fact that differences do occur among different user groups within at least one market segment and that different marketing strategies may be needed to obtain increased transit ridership within each group.

A questionnaire discussed by Schwartz in a paper in this Record was used to measure resistances to the adoption of urban transit during off-peak hours in Boulder, Colorado. The findings have implications for transit marketing managers regardless of the cities in which they are located.

The results of this study suggest that, within one market segment, a different marketing strategy must be used to remove the barriers to trial of transit from that which is used to remove the causes of rejection of transit after adoption, or from that which is used to increase the frequency of use by occasional users. A different marketing strategy must also be used to remove the causes of rejection after trial from that which is used to remove the causes of discontinuance after adoption of transit (Figure 1). Although the specific barriers to adoption will differ among cities, the Boulder results illustrate the fact that differences occur between different user groups within at least one market segment, namely, that of middle-class women aged 20 to 65.

RESEARCH PROCEDURE AND RESULTS

A sample of approximately 400 middle-class dwelling units was randomly selected from Boulder, Colorado, neighborhoods having median income levels of $13 000 to $18 000. This income level was selected to obtain a high percentage of responses from families that have two cars but do not have chauffeurs. All of the dwelling units selected were located within three blocks of a bus stop so that the respondents in this study would have the option of going by bus as well as by car. (The option of using transit should exist before the decision not to use it is questioned.)

Data were collected by using $1.00 as the motivation to complete the questionnaire. The usable response rate was 55 percent. The attributes measured are shown in Table 1.

Respondent Characteristics

One hundred and fifty-nine respondents were categorized into bus user and nonuser groups as shown below.

Consumer Category	Sample Size by Category Number in Study	 Percent of Total
Use of bus for shopping		
Adopters	20	12.6
Occasional users	10	6.3
Triers	25	15.7
Rejecters	26	16.4
Discontinuers	5	3.1
Nontriers	73	45.9
Total	159	100.0
Use of bus for any purpose		
Adopters	53	34.9
Occasional users	19	12.5
Triers	18	11.8
Rejecters	22	14.5
Discontinuers	11	7.2
Nontriers	29	19.1
Total	152	100.0

Fifty-nine percent of the respondents (90 of them) had used the bus at least once within the previous 6 months. Nineteen percent of them had never used the bus in their adult lives.

The sample size of the discontinuers of the bus system for shopping (3 percent) was too small for analysis, and so this group was not analyzed separately from the other types of nonusers. However, discontinuers of the bus for any purpose represented 7 percent of the population and were analyzed as a separate category.

Reasons for Using the Urban Bus System

Reasons for using the urban bus system were given by 126 individuals who had used transit within the previous 6 months. The results, shown below, indicate that letting someone else drive is one of the prime advantages of the bus.

Attribute	Number Who Listed This Attribute as Reason for Riding Bus (n = 126)	Percent Who Listed This Attribute as Reason for Riding Bus
Convenience	18	14
Convenient bus routes or bus stops	7	6
Letting someone else drive		
Traffic congestion, relaxation, nice bus drivers, comfort	14	11
Safety in bad weather	17	14
Economy	13	10
Going someplace with others	2	2
Ecology	14	11
To meet someone with a car	1	1
No other transportation	6	5

Twenty-five percent of the respondents rode the bus because somebody else was driving. Of these 25 percent, 11 percent wanted someone else to drive so that they could relax, ride in comfort, or avoid traffic congestion. The remaining 14 percent rode the bus in inclement weather to avoid hazardous road conditions or the discomfort of walking or riding a bicycle in such weather. (The Greyhound Company advertisement "Go Greyhound, and leave the driving to us" is targeted toward this group.)

Fourteen percent of the respondents cited the convenience of the bus system as a reason for riding the bus. However, convenience is an ambiguous term that does not offer any insight into exactly what attributes of the bus system cause the bus to be perceived as convenient. Convenience may mean that a bus stop is located close to the respondent's home—a variable that was controlled within the survey design—or that the respondent does not have to park a car or that it is convenient to have someone else drive.

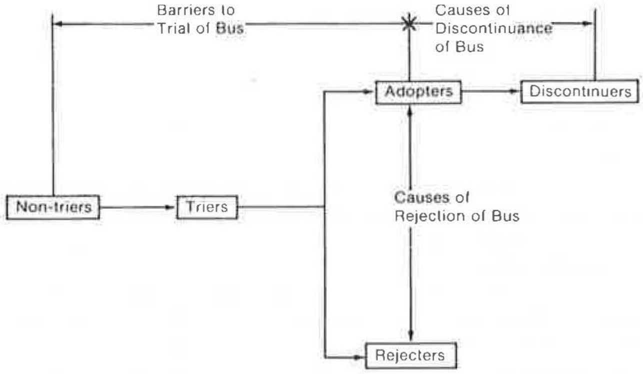
Boulder is an ecology-minded university community that has taken steps to limit its population growth rate. It is therefore not surprising to find that 11 percent of bus riders state that they ride the bus for ecological and societal reasons.

The idea that the bus is economical or saves wear and tear on automobiles was cited by 10 percent of the bus users as their reason for using the bus system. The bus was perceived to be an economical form of travel for a single traveler, but not for a family.

Six percent of the respondents indicated that they used the bus because of convenient bus routes or bus stops, but it is conceivable that many of the respondents who indicated that they rode the bus because of convenience had this type of convenience in mind. In effect, the respondent was stating that a bus stop was close to her home, which was a controlled attribute in this survey, as well as close to where she wanted to go.

Five percent of all bus riders (including individuals with family incomes of less than $10 000/year) indicated that they rode the bus because they had no other form of transportation. It is assumed, however, that for middle-class respondents this restriction is self-imposed. A middle-class individual is assumed to have financing available to purchase an automobile if she finds bus riding to be abhorrent. It is only because bus riding is acceptable that she tolerates not having a car.

Figure 1. Measurements that identify barriers to adoption, causes of rejection, and causes of discontinuance of bus use.



Barriers to Trial of the Urban Bus System

The specific barriers to trial of the bus system were obtained by comparing nontrier perceptions of the bus system (nontriers are individuals who have never, as adults, used the bus system) to adopter perceptions of the bus system for both shopping purposes only and for shopping and nonshopping purposes combined (Fig-

Table 1. Variable list.

Variable Number	Variable
1	Difficulty of using the bus to go shopping with friends
2	Inconvenience of determining what bus to catch and where and when to catch it
3	Inconvenience of being tied to the bus schedule
4	Difficulty of obtaining bus route information and bus schedules
5	Difficulty of remembering bus numbers, bus stops, and bus schedules when shopping
6	Difficulty of determining exactly where to catch the bus when shopping
7	Inconvenience of exact fare requirements
8	Difficulty of understanding bus route maps
9	Inconvenience of waiting for the bus
10	Difficulty of identifying the proper bus to board
11	Attentiveness required to avoid missing destination while on the bus
12	Likelihood of bus breakdown
13	Comfort of the bus interior during very hot or cold weather
14	Odor of bus interior
15	Noisiness of bus interior
16	Likelihood of standing while on the bus
17	Social status of bus passengers
18	Dirtiness of bus interior
19	Dirtiness of bus exterior
20	Closeness of bus seats
21	Bumpiness of bus ride
22	Likelihood of encountering undesirables such as drunks on the bus
23	Ability to relax on the bus
24	Risk of becoming involved in highway accidents while on the bus
25	Likelihood of meeting undesirables such as drunks at bus stops
26	Risk of criminal assault while walking to or waiting for the bus
27	Inconvenience of going home from the bus stop after shopping
28	Discomfort while waiting for the bus in bad weather
29	Hazard of walking to the bus stop with snow on the ground
30	Damage to hairstyle while waiting for the bus in windy weather
31	Punctuality of the buses
32	Frequency of the buses
33	Risk of being pushed or shoved when entering the bus
34	Difficulty of handling babies or packages when boarding the bus and paying fare
35	Inconvenience of stowing packages on the bus
36	Number of times that the bus stops to pick up or discharge passengers
37	Convenience of having someone else drive
38	Helpfulness of bus drivers
39	Convenience of not having to park a car
40	Extent to which the bus routes are circuitous
41	Inconvenience of bus transfers
42	Extent to which bus rides are boring
43	Lack of privacy on the bus
44	Discomfort of bus seats
45	Difficulty of going to more than one shopping area when the bus is used
46	Difficulty of combining shopping with other social activities when the bus is used
47	Friendliness of bus passengers
48	Difficulty of using the bus on a trial basis
49	Reduction in air pollution caused by increased bus use
50	Reduction in traffic congestion caused by increased bus use
51	Reduction in highway accidents caused by increased bus use
52	Energy savings caused by increased bus use
53	Time used by taking the bus
54	Extent to which buses contribute to highway noise pollution
55	Expense of taking the bus (money)
56	Relative advantage of a car as compared to the bus
57	Simplicity of using a car as compared to the bus
58	Inconvenience of going to the bus stop
59	Compatibility of the bus with shopping needs
60	Extent to which a car is a faster form of travel than the bus
61	Concern about catching the bus after dark
62	Education of respondent
63	Education of spouse
64	Family income
65	Percentage of times respondent shops with others in Boulder
66	Percentage of times respondent shops with others in downtown Denver
67	Place that respondent usually meets individuals with whom she is going shopping
68	Percentage of times respondent arrives home from shopping after dark
69	Percentage of times a car is available to respondent
70	Percentage of times respondent comes home from shopping with her hands full of packages
71	Age
72	Percentage of times the bus is taken either to meet someone with a car or after being driven to a shopping center

ure 1). The reasons that the bus was not tried for any purpose, or for shopping only, appear to revolve about the perceived relative advantages, compatibility, and complexity of using the bus system. These items are listed in detail below.

No.	Variable
	Compatibility and relative advantage
45	Difficulty of going to more than one shopping area when the bus is used
41	Inconvenience of bus transfers
46	Difficulty of combining shopping with other social activities when the bus is used
40	Extent to which the bus routes are circuitous
53	Time used by taking the bus
31	Punctuality of buses
3	Inconvenience of being tied to the bus schedule
9	Inconvenience of waiting for the bus
28	Discomfort of waiting for the bus in bad weather
27	Inconvenience of going home from the bus stop after shopping
42	Extent to which bus rides are boring
34	Difficulty of handling babies or packages when boarding the bus and paying fare
35	Inconvenience of stowing packages on the bus
44	Discomfort of bus seats
20	Closeness of bus seats
14	Odor of bus interior
43	Lack of privacy
	Risk
26	Risk of criminal assault
25	Likelihood of meeting undesirables such as drunks at bus stops
	Complexity
4	Difficulty of obtaining bus route information and bus schedules
5	Difficulty of remembering bus numbers, bus stops, and bus schedules when shopping
6	Difficulty of determining exactly where to catch the bus when shopping
38	Lack of helpfulness of bus drivers
8	Difficulty of understanding bus route maps
10	Difficulty of identifying the proper bus to board
2	Inconvenience of determining what bus to catch and where and when to catch it

The list of reasons for not trying the bus for shopping was longer than the list of reasons for not trying the bus for any purpose. This difference helps to explain why obtaining effective use of bus capacity during off-peak hours has been a problem for the Denver Regional Transportation District.

Causes of Rejection and of Discontinuance of Bus System

Rejection occurs if an individual stops using a bus after trying to use it a few times at most. Rejection of the bus system for shopping and nonshopping purposes appears to revolve primarily about compatibility, relative advantages, and complexity as shown below.

No.	Variable
	Compatibility and relative advantage
46	Difficulty of combining shopping with other social activities when the bus is used
41	Inconvenience of bus transfers
53	Time used by taking the bus
3	Inconvenience of being tied to the bus schedule
27	Inconvenience of going home from bus stop after shopping
9	Inconvenience of waiting for the bus
17	Social status of bus passengers
35	Inconvenience of stowing packages on the bus
45	Difficulty of going to more than one shopping area when the bus is used
53	Time used by taking the bus
40	Extent to which bus routes are circuitous
7	Inconvenience of exact fare requirements
54	Extent to which buses contribute to highway noise pollution
	Complexity
2	Inconvenience of determining what bus to catch and where and when to catch it
4	Difficulty in obtaining bus route information and bus schedules
5	Difficulty of remembering bus numbers, bus stops, and bus schedules when shopping
8	Difficulty of understanding bus route maps
10	Difficulty of identifying the proper bus to board

Discontinuance occurs if an individual stops using a bus after using it on a regular basis. Discontinuance of use of the bus system for any purpose revolves primarily about the relative advantages and compatibility as shown below.

No.	Variable
	Compatibility and relative advantage
45	Difficulty of going to more than one shopping area when the bus is used
41	Inconvenience of bus transfers
53	Time used by taking the bus
40	Extent to which bus routes are circuitous
58	Inconvenience of going to the bus stop
34	Difficulty of handling babies and packages when boarding the bus and paying fare
35	Difficulty of stowing packages on the bus
13	Discomfort of the bus during very hot or cold weather
	Complexity
4	Difficulty of obtaining bus route information and bus schedules
5	Difficulty of remembering bus numbers, bus stops, and bus schedules when shopping

Perceived bus system complexity is not as important to discontinuers as it is to nontriers since discontinuers have used the bus on a regular basis and are familiar with how to use it. Nontriers, who have never used the bus, are not familiar with how to use it.

Differences Between Occasional Users and Adopters

Knowledge of the differences between occasional users and adopters (regular users of the bus) should be important to marketing managers. With such knowledge, marketing managers can determine how to increase the frequency with which occasional users ride the bus and thereby increase the adoption rate. The results indicate that occasional users of the bus for shopping are different from adopters of the bus for shopping as shown below.

No.	Variable
	Compatibility and relative advantage
39	More adopters perceive that it is convenient not to have to park a car
18	More occasional users perceive that the inside of the bus is dirty
44	More occasional users perceive that bus seats are not comfortable
47	More occasional users perceive that bus passengers are not friendly
40	More occasional users perceive that bus trips are circuitous
41	More occasional users perceive that bus transfers are inconvenient
	Complexity
2	More occasional users perceive that finding out which bus to catch and where and when to catch it is inconvenient
4	More occasional users perceive that bus route information and bus schedules are difficult to obtain

Table 2. Relative importance of bus attributes.

Variable Number	Roger's Category	Discriminant Coefficient (Standardized)[a]	Relative Importance
4	Complexity	0.689 07	1
37	Relative advantage of bus over car	0.568 18	2
35	Compatibility	0.377 90	3
44	Relative advantage of car over bus	0.297 70	4
60	Relative advantage of car over bus	0.037 70	5

[a] All variables ranged from 1 to 5, where 5 was most probus and 1 was most antibus for this analysis.

Differences Between Triers and Adopters

Knowledge of the differences between triers (individuals who have recently tried the bus for the first time) and adopters should be important to marketing managers. Such knowledge indicates whether individuals who have recently tried the bus are more predisposed to adopt it or to reject it.

The results indicate that triers of the bus for shopping were predisposed to adopt it, while triers of the bus for nonshopping purposes were predisposed to reject it.

All of the triers of the bus for shopping were also adopters of the bus for nonshopping purposes. Both triers and adopters of the bus for shopping were, however, significantly more positive toward the bus than were adopters of the bus for nonshopping purposes.

Contributions of Factors Explaining Bus Use Behavior

The relative importances of bus attributes to adopters of the bus for shopping versus to nontriers and rejectors of the bus for any purpose by Rogers' categories (1) were measured by standardized coefficients obtained from discriminant analysis as shown in Table 2. The results indicated that the perceived complexity of the bus system was the most important reason that the bus had not been tried for the first time or was rejected after trial. These results imply that the primary reasons that individuals do not try the bus or reject it after trial are that they have difficulty in obtaining bus route information and bus schedules; in remembering bus numbers, bus stops, and bus schedules; in determining exactly where to catch the bus when shopping; in identifying the proper bus to board; in understanding bus route maps; and that they do not perceive the bus driver to be helpful.

Real Problems Versus Imaginary Problems

Knowledge of the differences and similarities between adopters, nontriers, rejecters, discontinuers, and occasional users can be used to differentiate between barriers to adoption that are imagined and can therefore be removed by promotion alone and barriers that are real and can therefore be removed only by system redesign.

Barriers to adoption that cannot be removed by promotion alone, but require system redesign, are those perceived to be barriers by rejecters, discontinuers, or occasional users of the bus system. Such barriers have persisted through trial or have been learned while using the bus system.

Barriers to trial and adoption of the bus system are caused primarily by the complexity of the bus system. Both nontriers and rejecters of the bus perceive that the bus is complicated to use and is incompatible with their shopping needs. The complexity problem can be treated by redesigning the bus system, or by improving informational promotion, or by both.

System design changes required to prevent discontinuance of the bus system may be different from those required to prevent rejection of the bus system. A comparison between Tables 2 and 3 indicates that bus transfer problems, child-handling problems, package-stowage problems, the inconvenience of being tied to a bus schedule, the inconvenience of exact fare requirements, and the extent to which buses contribute to highway noise pollution are more often cause for discontinuance than is rejection.

Barriers to adoption that can be removed by promotion alone consist of the bus attributes that are both difficult to observe and are perceived to be barriers by nontriers but not by rejecters, discontinuers, or occasional users. Such barriers are thought to be misconceptions in the minds of nontriers and do not persist after the bus is tried. They are summarized below.

No.	Variable
	Compatibility and complexity
14	Odor of bus interior
38	Lack of helpfulness of bus drivers
26	Risk of criminal assault such as by purse snatchers and rapists
25	Likelihood of meeting undesirables such as drunks at bus stops
45	Difficulty of going to more than one shopping area when the bus is used
40	Extent to which bus routes are circuitous
31	Punctuality of the buses
42	Extent to which bus rides are boring
34	Difficulty of handling babies or packages when boarding the bus and paying the fare
20	Closeness of bus seats
6	Difficulty of determining exactly where to catch the bus when shopping
8	Difficulty of understanding bus route maps
10	Difficulty of identifying the proper bus to board

Structure of Bus User/Nonuser Categories

All of the bus user/nonuser categories discussed in this study were rank ordered based on the extent to which the categories were found to be probus or antibus. Understanding the structural relations between the various user and nonuser groups is important when determining how best to invest limited resources to increase adoption of the bus system.

The extent to which one bus user or nonuser category is more probus or antibus than is another depends on whether or not the bus system is viewed as a multiple-purpose service or as a single-purpose service. A single-purpose service denotes that the bus is perceived only as a means of traveling from point A to point B. A multiple purpose service denotes that the bus is perceived as a different product by those who use it to go shopping than by those who use it to go to a football game.

In the ordering of bus user and nonuser categories, based on the extent to which each category is probus or antibus, adopters and occasional users of the bus system for any purpose are similar to each other and are the most probus of all of the categories in their perceptions of bus system attributes. Nontriers, rejecters, triers, and discontinuers are similar to each other in their perceptions of bus system attributes and are more antibus than are adopters and occasional users.

When one of the transit services, shopping, is viewed separately, the ordering of bus user and nonuser categories is different. The results indicate, as shown below, that adopters and triers are similar to each other and are more probus than are the other categories.

Rank Order Direction	Category	
	User	Nonuser
Most probus	Adopters of bus for shopping	Triers of bus for shopping
↓	Occasional users of bus for shopping	Rejecters of bus for shopping
Most antibus	Nontriers of bus for shopping	

Occasional users and rejecters are similar to each other and are less probus than are adopters and triers. Nontriers are the most antibus of all. These data support the concept that use of the bus for shopping has a different structure from that obtained when the service is evaluated as a single-purpose system.

INCORPORATION OF DATA INTO TRANSIT MARKETING STRATEGIES

The transit marketing manager can use the type of information developed in this study to efficiently direct his limited resources toward a specific goal, such as obtaining a trial, preventing rejection, preventing discontinuance, or increasing the frequency with which occasional users ride a bus.

Situations for which a marketing manager may want to pursue a strategy of targeting specific groups such as nontriers or discontinuers are as follows:

1. The marketing manager may want to allocate his limited resources toward a user or nonuser category that has problems with the bus system that can be solved expeditiously or for the least cost. For instance, occasional users of the bus for purposes other than shopping perceive very few barriers to using the bus more frequently than they are now using it. If the barriers perceived by this group can be inexpensively removed either by advertising or by system redesign, the marketing manager may want to do so. Because triers of the bus system for shopping are also likely to become adopters of the bus system for other purposes, the transit marketing manager may want to allocate his resources toward encouraging adopters of the bus for nonshopping purposes to also try the bus for shopping purposes.
2. The marketing manager may want to allocate his limited resources toward a very large nonuser group. For example, since 46 percent of the population have not tried to use the bus for shopping purposes, removing the barriers to trial of the bus for shopping would, when this strategy is used, become the manager's prime concern; and
3. The marketing manager may want to allocate his limited resources toward the group that has provided the least satisfactory response to current marketing efforts. For example, the marketing manager may find that he or she is satisfied with the number of individuals who are trying to use the bus but dissatisfied with the number of individuals who are rejecting the bus after trying it. Since more than 50 percent of those individuals who try the bus for shopping reject it, the manager would, in this situation, allocate more resources toward preventing rejection than to obtaining trial. The marketing manager who is satisfied with the adoption rate after trial but dissatisfied with the rate of trial would allocate resources toward removing the barriers to trial of the bus. The marketing manager who is dissatisfied with the number of discontinuers would allocate his or her resources toward preventing discontinuance instead of toward obtaining trial or preventing rejection.

CONCLUSIONS

The conclusions reached on the basis of this study should be useful to transit marketing managers for formulating marketing strategies to increase bus ridership. The conclusions having theoretical implications are as follows:

1. Occasional users were different from categories that are currently included in the individual innovation decision process. Occasional users were different from adopters of the bus for shopping purposes, different from rejecters of the bus for nonshopping purposes, and different from triers of the bus for shopping and nonshopping purposes.
2. The causes of rejection were different from the barriers to trial. Removing only the barriers to trial may not cause adoption of the bus to occur, and removing only the causes of rejection may not cause trial of the bus to occur.
3. The causes of discontinuance were different from the barriers to trial. Removing only the barriers to trial may not prevent adopters from discontinuing the use of the bus, and removing only the causes of discontinuance may not cause trial of the bus to occur.
4. The causes of discontinuance were different from the causes of rejection. Removing only the causes of rejection may not prevent adopters from discontinuing the use of the bus, and removing only the causes of discontinuance may not cause new adoptions of the bus.
5. For a multipurpose service such as the bus system, the probus to antibus rank order of various bus user versus nonuser categories may differ for each purpose for which the service is used. Rejecters and discontinuers were more probus than nontriers of the bus for shopping. They were not, however, more probus than were nontriers of the bus for any purpose. Occasional users of the bus were similar to rejecters of the bus for shopping purposes but significantly more probus than were rejecters of the bus for nonshopping purposes.

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Abridgment

Analysis of User Response to the 1975 New York City Transit-Fare Increase

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This paper describes how before and after survey data were used to supplement aggregate ridership counts in describing the effects of a fare increase on patrons of the New York City transit system. While the overall rate-of-ridership decline may be sufficient for a financial analysis, the growing recognition of the role of transit in economic, social, and equity issues requires more in-depth understanding of the kinds of people who ride less or sacrifice mobility when transit-fare increases occur. Two surveys, one before the fare increase was announced and another 3 months after its implementation, allowed the analysis of a before and after pattern of transit use by a given sample of riders. (Except for those derived by inference, data on the effects of fare increases on the various groups of riders and the types of trips abandoned did not previously exist for the New York City transit system.)

SURVEY METHODOLOGY

The Tri-State Regional Planning Commission conducted an opinion survey of area households in June 1975. The questions on trip characteristics and opinions on transportation issues included one on how the respondents would change their transit riding habits if there were a fare increase from 35 to 50 cents.

The specific question asked of household heads who use the New York City transit system to go to work was, "If the bus and subway fares in New York City increased to 50 cents, which of the following would you most likely do? Would you continue to use public transit to go to work, drive to work, walk to work, ride a bicycle, take a taxi, or do something else?" A similar question about off-peak use was asked of household heads who live in New York City and who reported using the transit system during off-peak periods (1).

The reaction to the 50-cent fare was expected to be exaggerated. However, the responses to these hypothetical questions would make it possible to examine the impact of the fare increase on the various transit modes by time of day.

Soon after the survey was completed the Metropolitan Transportation Authority announced an increase in the basic fare from 35 to 50 cents, beginning September 1, 1975. This situation provided the unique opportunity to complete a before and after study of a given sample of users and their behavioral response to the fare increase.

The before portion of this study consisted of telephone interviews with primary wage earners in households in the tristate region. The after portion of the study was a reinterview of all of the New York City residents in the original sample who use subways or buses either for work trips or during the off-peak hours. This provided the posttest half of the one group pretest—posttest design without a control group (2).

Reinterviewing the original respondents, as opposed to selecting an entirely new sample, had several advantages: Accurate preincrease and demographic trip information on this cross section of users was available and their anticipated reaction to the fare increase was known. These conditions provided the opportunity to focus analysis on user groups of particular interest and of known trip and demographic characteristics. Postfare increase interviewing was conducted in December 1976 after 3 months were allowed for ridership to stabilize.

RESULTS

Predicting Ridership Responses to Fare Increases

If small sample surveys could be used to reasonably predict behavior changes, they might be useful adjuncts to observed elasticities in considering price and service changes. However, attempts to predict future behavior by presenting hypothetical questions to respondents are fraught with problems. When the subject is emotionally charged and the respondent's experience and perceptions of the alternatives (other modes) are unclear or incorrect, the problems are magnified.

Nonetheless, the rather simplistic prediction question used in the first survey resulted in only moderate overstatements of expected change. Overstatement was expected for at least two reasons: (a) Respondents may honestly overestimate the ease of changing modes, only to find, when the fare rises, that the alternatives are not as good as were expected and (b) responses may reflect the reaction of near-captive riders to price increases perpetuated by an agency held in bad repute (the spite effect).

The table below shows the respondents' predictions in June 1975 and their actual measured responses in December 1975.

Response	Predicted (%)	Actual (%)
Would change work trip	20	15
Would change to		
Automobile	46	59
Car pool	12	18
Solo driver	34	41
Walk	23	16
Bus (from subway)	14	14
Other	16	11
Would use less transit	47	38
Discontinue use	25	4
Use less often	22	34

The one-third overestimation of work-trip changes represents too many people saying that they would take a taxi or a bicycle or walk to work if the fare rose to 50 cents. For off-peak travel, there was an overestimation by a 47 to 38 percent margin of the number of households whose members would use less transit.

The households grossly overestimated the degree of use reduction, with 25 percent predicting complete discontinuation of transit use but only 4 percent actually doing so.

While the aggregate estimate was not badly in error, the response of an individual in the first survey was of no use in predicting his or her actual behavior, i.e., those who said they would not change (in the first survey) were as likely to change as those who said they would change.

Table 1. Percentage of transit users who changed work-trip mode after fare increase by demographic characteristics.

	Postfare Increase Behavior		
Transit-User Characteristic	Changed Work-Trip Mode	Did Not Change Work-Trip Mode	Number of Interviews
Age, years			
Under 34	11.2	88.8	42
35 to 49	17.4	82.6	43
50 and over	16.5	83.5	32
Income, $			
Under 5000	11.5	88.5	60
5000 to 14 999	11.3	88.7	29
15 000 or more	15.8	84.2	24
Race			
White[a]	13.9	86.1	88
Nonwhite	18.1	81.9	27
Education			
High school or less	11.5	88.5	60
Some or completed college	18.2	87.8	58
Automobile ownership			
None	11.5	88.5	53
One or more	20.9	79.1	63
Total	14.6	85.4	118

[a] Includes Spanish speaking.

Table 2. Percentage decrease in regular passengers in fiscal year 1967 (versus fiscal year 1966).

		Decrease in Regular Passengers			
Mode	Fare Increase (¢)	Weekdays	Saturdays	Sundays	Total
Subway	33.3	1.9	4.1	1.0	2.4
Bus	33.3	9.5	11.1	10.2	9.9

Work Trip Mode Change

There are two types of data available from the transit system operators for use in measuring ridership changes. Counts of the number of subway and bus revenue passengers in each month are available from public accounting reports (3), and there is an hourly count of subway turnstile registrations made on an average weekday in October of each year. The percentage decreases in ridership during the period of analysis (October to December 1975) as compared to the corresponding period of 1974 are shown below.

	Percent Decrease		
Mode	Avg Weekday	Saturday and Sunday	Total
Bus	11.3	9.5	10.7
Subway	4.8	6.1	5.0

The one-day hourly counts showed decreased in ridership of 3.7 percent at the peak hour, 5.6 percent at a midday hour, and 6.9 percent at an evening hour.

There is a pattern of larger declines among bus users. It is surprising, however, that weekday declines were greater than those for weekends and holidays. On the subways, peak-hour ridership showed substantially less decline than ridership during the midday, evening, or weekend off-peak periods.

The two surveys used somewhat different approaches: In the first survey, a hypothetical question regarding possible reaction to a fare increase was asked of household heads. In the second, respondents were asked whether they had actually changed their work and off-peak transit use as a result of the fare increase. (Workers who had changed residences or worksites in the time between the two surveys were excluded from the analysis.) The percentage changes in the work trip after the fare increase are summarized below.

Mode	Number of Interviews	Changed Work Trip
Bus	32	12.5
Subway	86	16.3

These results differ from those obtained by traditional counts shown above. However, while 16 percent of the subway riders claim to have altered their work trip in some manner, they have not necessarily abandoned the subway for work trips. In fact, while 9 percent to 10 percent of the primary mode subway riders ride less, the remaining 6 percent changed other segments of their trip.

There are a number of other explanations for the apparent conflict between the survey results and the operator figures.

1. The survey results represent only New York City household heads, but nonhousehold heads and nonresidents account for about 40 percent of the subway peak-hour trips. Moreover, household heads will have more alternatives to transit (e.g., priority in using the household automobile) than other household members and be able to change more easily.
2. About 16 percent of the work trips represented in the survey results are outside of the 3-h peak period. When there is less highway congestion, workers may be more likely to change modes.
3. By reinterviewing only known transit riders, the survey design precluded measuring new transit riders who would have acted to offset some of the decline among existing riders.
4. With the small sample size (86), the 95 percent confidence interval is approximately ±7.7 percent. There are limitations inherent in the use of small-scale random samples, especially as applied to reinterviews of known respondents.

Off-Peak Trips

Survey respondents were asked if any members of their households now use less transit because of the fare increase. But, while information on the age and relationships of the members who had reduced use and their purposes was collected, there was no attempt to estimate the volumes of these trips. The percentage of households who indicated that at least one member was using less transit during off-peak hours because of the fare increase are summarized below.

Mode	Number of Interviews	Used Less Transit
Bus	145	29.7
Subway	123	28.5

Shopping trips and weekday trips are the kinds most often cited by respondents as being reduced. Roughly one-half of these trips were made by other modes.

WORK-TRIP CHANGE BY GROUP

The rate of change in work trips was analyzed by a number of socioeconomic, demographic, and trip characteristics. The work-trip changers were rather evenly spread across all income, racial, educational, and age groups. The trip characteristics such as length, cost, and arrival time at work also showed little correlation with the rate of work-trip change (4). Table 1 shows that the lowest rate of work-trip changes is among household heads with lower incomes, having no more than a high school education, under 34 years of age, and nonwhite.

The workers with automobiles available were nearly twice as likely (21 to 11 percent) to change their work trips as were workers with no automobiles. Automobile availability was also the factor most associated with using less off-peak transit. Approximately 36 percent of the household heads who changed their work trip required more than one fare to complete their journey. The incidence of double fare zones among general transit riders is unknown. In New York the double fare patron usually uses a city bus from home to a subway station where he or she transfers (at full fare) to the subway for the major portion of the trip. Although the number of interviews with users of this type was small, the elimination of the feeder bus by driving or walking to the subway station appeared to be a very popular reaction to the fare increase. This hypothesis is supported by the large response (44 percent) to free transfers between subway and bus as an action that would prompt a change back to the former work-trip mode.

Transit riders who work in Manhattan are less likely to change their trip mode (13.7 percent) than are riders who work in other New York City boroughs (18.1 percent). The mode used by these two groups for their new work trip is even more interesting: Only one-half of the Manhattan-bound workers changed to automobiles (42 percent to solo and 9 percent to car pool), while over 93 percent of the workers in other boroughs changed to automobiles.

ATTITUDES TOWARD THE FARE INCREASE

An interesting adjunct to the data presented above is how citizens react to such governmental activities as increasing transit fares. In this particular study, respondents were asked whether or not they believed that the 15-cent fare increase on New York City subways and buses was necessary. Overall, 62 percent of the households considered that the fare increase was not necessary. But among the households who changed their transit-use behavior, 80 percent said that the fare increase was unnecessary.

The strength of the feelings about the fare increase was however not transmitted into protest actions. When those reporting the fare increase as unnecessary were asked whether they had publicly expressed their opinions on the fare increase, 80 percent said that no action had been taken. Of the actions taken by the remainder, 16 percent had signed petitions, 5 percent had written letters, and a small minority, especially among those who use transit to work, had participated in a demonstration.

CONCLUSIONS

The New York City transit system has had three basic fare increases in the past 10 years. Published data (Table 2) are available on only the 1966 increase from 15 to 20 cents. Lassow (5) has discussed the results of that increase, giving data on changes by time of day, double fare zones, and the economic status of changers. As a proxy for economic status, he selected 13 subway stations in low-income neighborhoods and 10 midtown stations adjacent to train and bus terminals (assuming commuters to be high-income representatives) and showed that morning rush-hour ridership at the midtown stations actually increased. Unfortunately, this comparison can be viewed as one on the differential impact of fare increases on city and suburban residents, as well as one on the users of the subway as either a primary or a secondary mode of travel. This analysis nonetheless showed that low-income ridership declined more significantly than the system average at all times of day. The elasticities implicit in this analysis are approximately those used by the Metropolitan Transit Authority and others in predicting the effects of the September 1975 fare increase.

The 1975 transit-fare increase, however, resulted in ridership reductions in roughly equal proportions from all major socioeconomic and demographic groups, which is, of course, different from the concept of the differential financial burdens of fare increases. The survey results support the theory of automobile availability as a major determinant in mode-choice decisions. The overrepresentation of riders from double fare zones among the changers emphasizes the urgency of a comprehensive transfer policy to mitigate the effects of two fares on this group of riders.

The small-scale surveys employed here do appear to add considerable detail to our knowledge about the effects of a fare increase. While the sample sizes, which were limited by the initial survey, do not permit highly precise estimates, they are sufficient to uncover major variations among groups. Some changes in universe definitions to include all subway riders rather than just household heads (again fixed by the first survey) would allow estimates that are more comparable with the traditional gross ridership measures.

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Cost Increases, Cost Differences, and Productivity of Transit Operations in New York State

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Public transit operations in New York State were analyzed to explore transit costs and operational productivity. Three transit systems were examined over time to determine what cost component are causing the rapid increases in operating costs that have occurred in the past 7 years. Twelve bus operations were analyzed to explore why some transit operations cost more to operate than others, and whether similar transit operations are equally productive. The results showed that employee costs (wages and salaries, pensions, and other employee-related costs) constitute 70 to 90 percent of all operating costs, and that increases in employee costs are almost entirely responsible for past increases in operating costs. Increases in fuel, power, and other non-employee-related costs were found to have little effect on operating cost increases. Differences in operating cost per vehicle-kilometer among operations are accounted for by differences in average vehicle speeds, employee average earnings, and, in some cases, productivity. Cost savings of between 5 and 12 percent could be obtained by increasing the average vehicle speed of a bus operation by 1 km/h (0.6 mph). The difficulties of obtaining an increase in average vehicle speed are also discussed.

This paper extends a previously reported analysis of transit operating costs that was performed during the New York State study of transit operating assistance. The previous analysis (1, 2) showed that transit costs were increasing at a rate that was about 5 percent faster than the consumer price index (CPI), and that there are significant differences in operating costs per vehicle-kilometer among different transit operations in the state. This paper explores several key areas in transit costs.

1. What particular cost component(s) are responsible for past cost increases?
2. Why are some transit operations' operating costs per vehicle-kilometer increasing faster than others?
3. Why do similar transit operations have different operating costs per vehicle-kilometer?
4. What, if anything, can be done to reduce these differences?

The paper also examines transit productivity and investigates whether similar operations have the same productivities and then explores the relations between productivity, total operating costs, and employee compensation.

HISTORY OF TRANSIT COST INCREASES

Three transit operations, which had sufficient data available for the years 1967 through 1973, were chosen for this analysis. They are

1. Regional Transit Service (RTS), the primary transit operator in Rochester, New York;
2. New York City Transit Authority (NYCTA), a subsidiary of Metropolitan Transit Authority (MTA), a bus and subway operation; and
3. Manhattan and Bronx Surface Transit Operating Authority (MABSTOA), a subsidiary of NYCTA, a bus operation.

The data obtained for each operation include

1. Number of employees (including transit police for New York City operations);
2. Revenue vehicle-kilometers;
3. Employee costs: (a) wage and salary costs, (b) pension costs, and (c) other benefit costs (which include health and welfare benefits, Social Security taxes, cost of workmen's compensation, and any other related employee benefits that are paid by the employer);
4. Cost for fuel for buses;
5. Power cost (subway only);
6. Material and supplies cost (except for RTS for which data were not available); and
7. Total operating costs (excluding depreciation and including transit police costs).

Transit police were included in most of the analysis since their employee costs were not separated from transit-worker employee costs. Where possible transit police have been excluded and these places have been indicated.

Component Cost Percentages

Each cost variable as a percent of total operating cost is shown in Figure 1.

Employee Costs (Wages and Salaries, Pensions, and Other Benefits)

This component is 80 to 90 percent of the total operating costs, making it the prime determinant of operating costs. Wages and salary costs as a percentage of operating costs have declined somewhat (although still the largest single component), but pension costs have increased. The percentage costs of other benefits have increased for two operations and decreased only slightly for the other.

Other Costs

Fuel for buses, power, and material and supply costs each represent less than 10 percent of the operating costs for each of these transit operations. Both MABSTOA and NYCTA experienced drastic increases in fuel prices during the energy crisis: During 1973-1974 the cost of fuel for buses increased by about 100 percent and the cost of power increased by about 40 percent. At the same time, however, the percentage of the operating costs represented by the fuel cost increased only 1 percent and that by the power cost less than 1.5 percent. Even drastic increases in the costs of power, fuel, and materials and supplies have little effect on the percentage that other costs represent of the total operating costs.

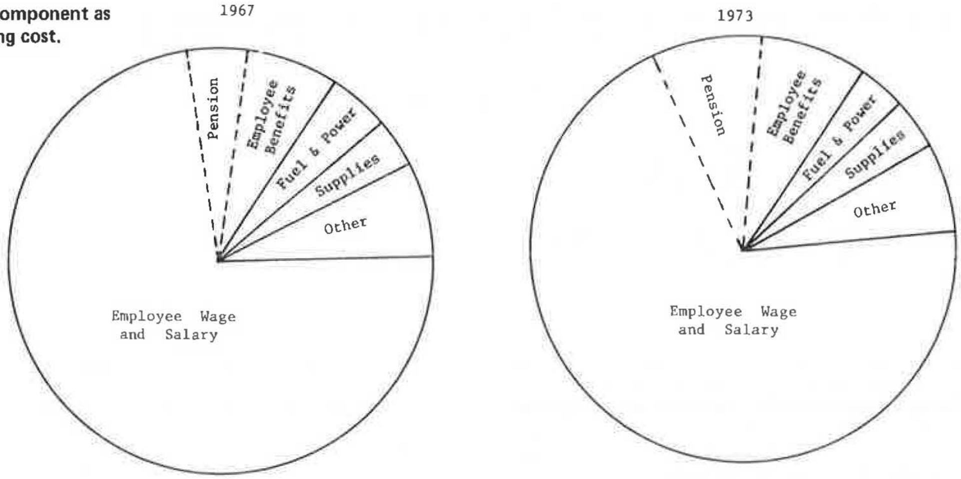


Figure 1. Transit cost component as percent of total operating cost.

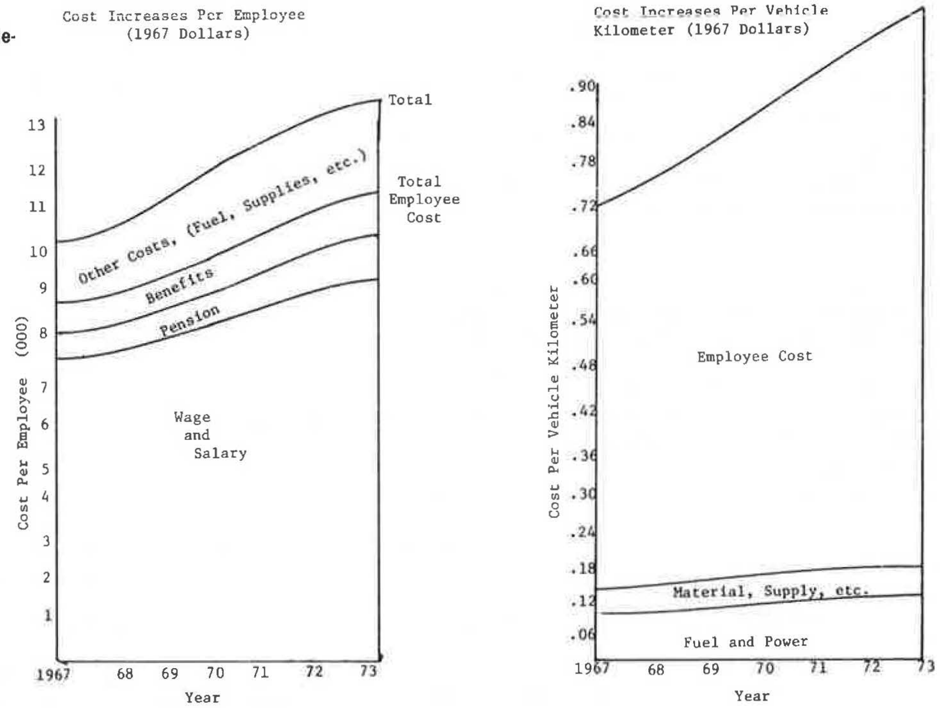


Figure 2. Transit cost component changes per employee and per vehicle-kilometer in 1967 dollars.

Cost Increases

The cost increases occurring from 1967 to 1973 were adjusted in the following ways.

1. The cost per employee and per vehicle-kilometer was calculated for each cost component.
2. An average cost for the three systems was calculated.
3. The costs were converted to 1967 dollars by using the CPI to analyze the real cost increases without regard to inflation.

Figure 2 shows the components of the total operating costs on both a per employee and a per vehicle-kilometer basis. Employee costs, particularly wages and salaries, are responsible for most of the transit cost increase; while wage and salary costs have grown at a lower rate since 1972, pension and benefits have grown more rapidly so that the growth in employee costs has continued at approximately the same rate.

Differing Rates of Cost Increase per Vehicle-Kilometer

Figure 3A shows the operating costs per vehicle-kilometer of each of the systems examined. The operating costs per vehicle-kilometer of MABSTOA are increasing faster than those of NYCTA, whose costs (since mid-1971) have been increasing faster than those of RTS.

Figure 3B shows the index of the operating costs per employee based on the year ending December 31, 1967: All three operations have had similar cost increases per employee. Thus, the differing rates of cost increase per vehicle-kilometer are probably due to changes in the number of vehicle-kilometers of operation without similar changes in the number of employees. Figure 4 shows the changes in vehicle-kilometers and in the number of employees for each of the systems (transit police have been excluded from the number of employees for NYCTA). RTS, since mid-1968, has changed the number of employees and the number of vehicle-kilometers at the same rate. NYCTA did almost the same until 1971,

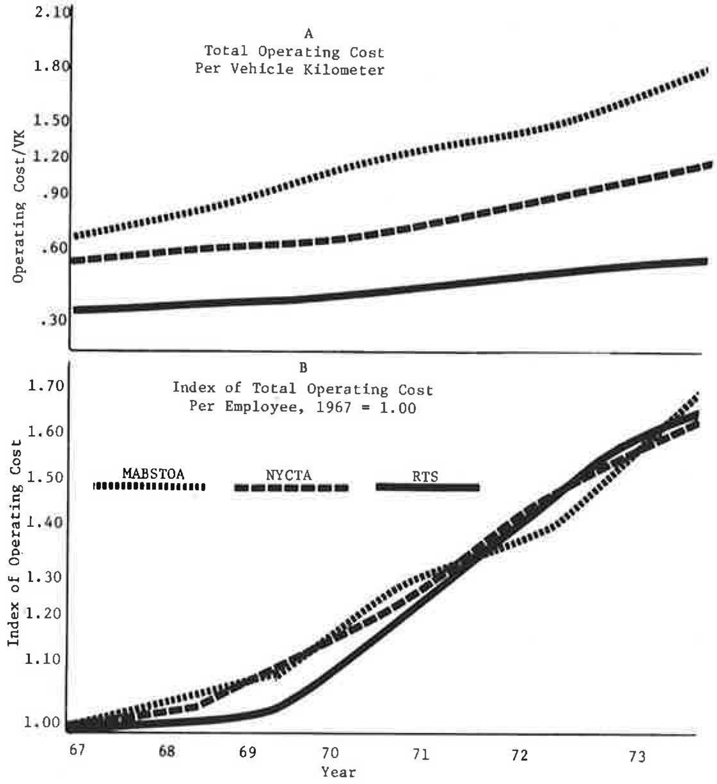


Figure 3. Comparisons of total operating cost per vehicle-kilometer and per employee for three operations.

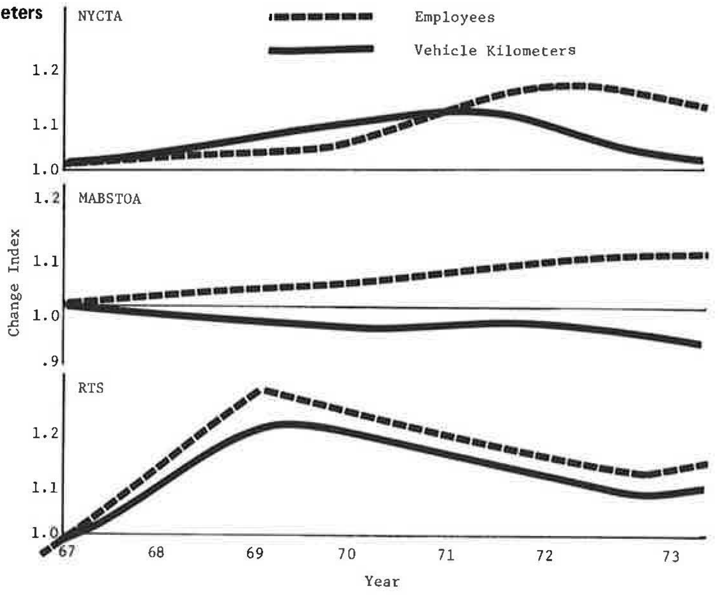


Figure 4. Comparison of changes in employees and vehicle-kilometers for three operations.

after which employment remained about constant while the number of vehicle-kilometers decreased. This explains why the increases in operating costs per vehicle-kilometer for NYCTA and RTS were almost the same from 1967 to 1971, while after that RTS costs increased at a slower rate than those of NYCTA. MABSTOA, which has had the fastest increase in operating costs per vehicle-kilometer, has since 1967 increased its employment but decreased the number of vehicle-kilometers. Thus the different rates of increase in operating costs per vehicle-kilometer have been due to changes in the number of vehicle-kilometers operated without corresponding changes in the number of employees.

Comparison of Cost Component Increases

Wage and salary costs per employee have increased for all three operations at approximately the same rate, to almost 1.6 times higher in 1973 than they were in 1967. Pension costs per employee have increased at approximately the same rate for NYCTA and RTS and were about 2.5 times higher in 1973 than they were in 1967. MABSTOA has had a much higher increase in pension cost per employee (5.7 times as much in 1973 as in 1967). However, its increase in other benefits per employee has been lower than those of NYCTA or RTS (MABSTOA, 1.8 times; RTS, 2.1 times; and NYCTA, 2.5 times higher in 1973 than other benefit costs per employee in 1967).

Costs per vehicle-kilometer for fuel for buses have increased at approximately the same rate for each operation. Power costs per vehicle-kilometer have steadily increased since mid-1969 and were 2.26 times greater in mid-1974 than in 1969. Increases in material and supply costs per vehicle-kilometer have varied. Those of MABSTOA have increased 3.7 times over 1967 levels while those of NYCTA have increased only 1.8 times.

DIFFERENCES IN TRANSIT COSTS (BUS ONLY)

The first section of this report has examined rates of cost increases but has not explained differences in magnitudes of costs. Previous work (3, 4) had shown that the operating cost per vehicle-kilometer between two transit operations varies by as much as $3.20/vehicle-kilometer for the same year. This section and the following one investigate these differences.

Data for the year 1973 were obtained for 12 bus operations in New York State. All of these operations have the following characteristics: (a) a high percentage of fixed-route, multistop service; (b) mainly interurban operations; and (c) little charter service. The companies, the areas they serve, the types of operations, and their average operating speeds are summarized below (1 km/h = 0.6 mph).

Company	Area Served	Type of Operation	Avg Operating Speed (km/h)
NYCTA (bus only)	New York City	Public	12.6
MABSTOA	New York City	Public	9.6
Niagara Frontier Transit	Buffalo	Private	17.3
Regional Transit Service	Rochester	Public	18.7
Queens Transit	New York City	Private	16.3
CDTA	Albany-Schenectady-Troy	Public	17.6
Triboro Coach	New York City	Private	13.6
Steinway Transit	New York City	Private	16.3
Westchester Street	Westchester County	Private	16.5
Club Transportation	Westchester County	Private	19.8
Liberty Coaches	Westchester County	Private	17.9
Avenue B and East Broadway	New York City	Private	10.6

The variations in percent of operating costs for each of the cost components are employee costs = 72 to 91; wages and salaries = 62 to 85; pension costs = 3 to 11; other benefits = 7 to 11; and fuel, oil, and power costs = 2 to 5 percent respectively.

The average speed (obtained by dividing the number of revenue vehicle-kilometers by the number of revenue vehicle-hours) of these operations also varies significantly. The slowest company operates at an average speed of 9.6 km/h (6 mph) while the fastest operates at an average speed of 19.8 km/h (12 mph). There was no correlation between the average vehicle speed and the size of the transit operation.

Total Costs per Vehicle-Kilometer

Figure 5A shows the total operating costs (excluding depreciation) per vehicle-kilometer. The operating costs per vehicle-kilometer varied from $0.65 to $1.81/vehicle-km ($1.04 to $2.90/vehicle-mile). The operations are ranked by order of size, and since the operating cost per vehicle-kilometer still varies, operation size does not explain the differences in operating cost per vehicle-kilometer.

Effect of Vehicle Speeds

Transit operations can have significantly different operating costs per vehicle-kilometer and yet have similar operating costs per vehicle-hour so that the apparent difference in operating costs per vehicle-kilometer may be due to differences in average vehicle speed. To test this, the vehicle-kilometers for each operation were adjusted to reflect a 9.6-km/h (6-mph) average speed by multiplying the number of vehicle-hours by 9.6 km/h (6 mph). (Since the number of vehicle-hours does not change, the number of employee-hours and therefore the employee costs will not change.) Figure 5B shows the effect on the operating cost per vehicle-kilometer due to reducing the average vehicle speed to 9.6 km/h (6 mph). Significant increases in the cost per vehicle-kilometer would occur for most of the faster operations, but the operating cost per vehicle-kilometer, and thus the differences in the system per-kilometer operating costs, are partially, but not entirely, a function of the differences in average speed.

Effect of Employee Costs

The actual employee costs (wages and salaries plus pensions plus other benefits) per employee range from $9774 to $18 744/year. Employee costs constitute 72 to 91 percent of operating costs; hence even a small difference in employee average earning between operations will make a significant difference in the operating costs per vehicle-kilometer. The effects of these different employee costs were determined by adjusting the operating costs so that all employees in each operation received an average wage and salary, pension, and fringe benefits total of $18 744/employee. Figure 5C shows the results of the employee cost adjustment on the operating costs per vehicle-kilometer at a 9.6-km/h (6-mph) speed. Except for three operations, the operating costs per vehicle-kilometer after adjustments for speed and employee costs are all approximately equal.

Employee costs for the three remaining operations represent 72 to 78 percent of their operating costs. Other cost components constitute too small a percentage of operating costs to account for the difference in magnitude of operating costs per vehicle-kilometer among these three operations and the other nine. One possible reason for these three operations having significantly different costs could be that the vehicle-kilometers (after adjustment) per employee are significantly different from those of the other nine operations. This is explored in the next section.

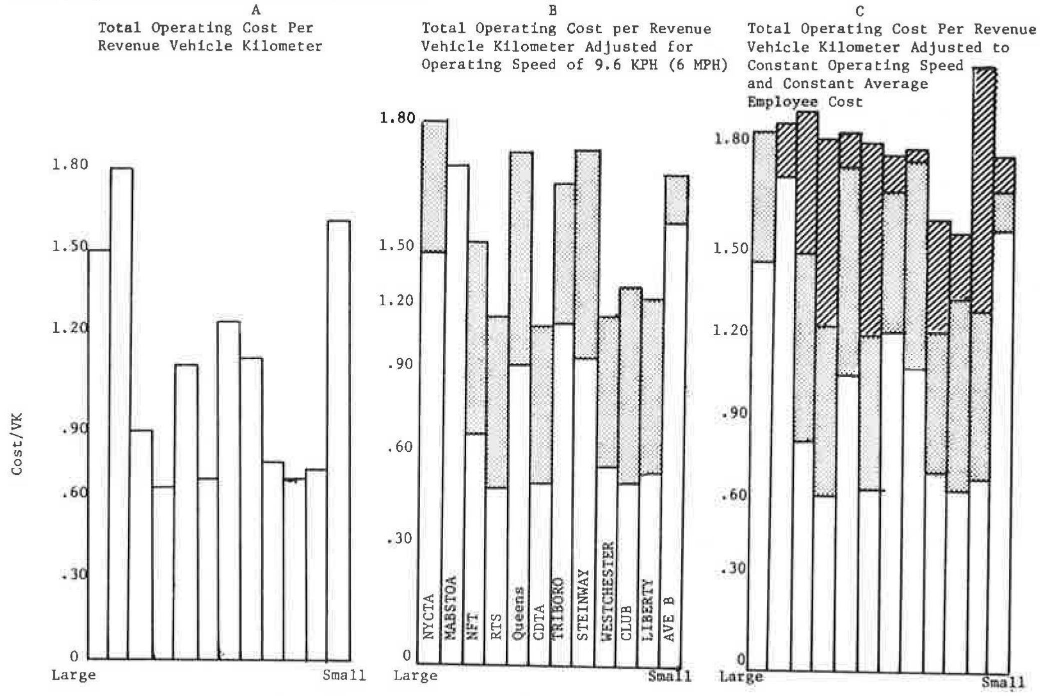
PRODUCTIVITY

Vehicle-Kilometers per Employee

Figure 6 shows the actual productivity in terms of actual vehicle-kilometers and adjusted vehicle-kilometers operated at 9.6 km/h (6 mph). Even after adjustments have been made to average speed, there are significant differences in the productivity of different transit operations. This difference in productivity does not appear to be due to the number of hours an employee works per day. Figure 6 also shows that, with two exceptions, private transit operations are more productive than public transit operations.

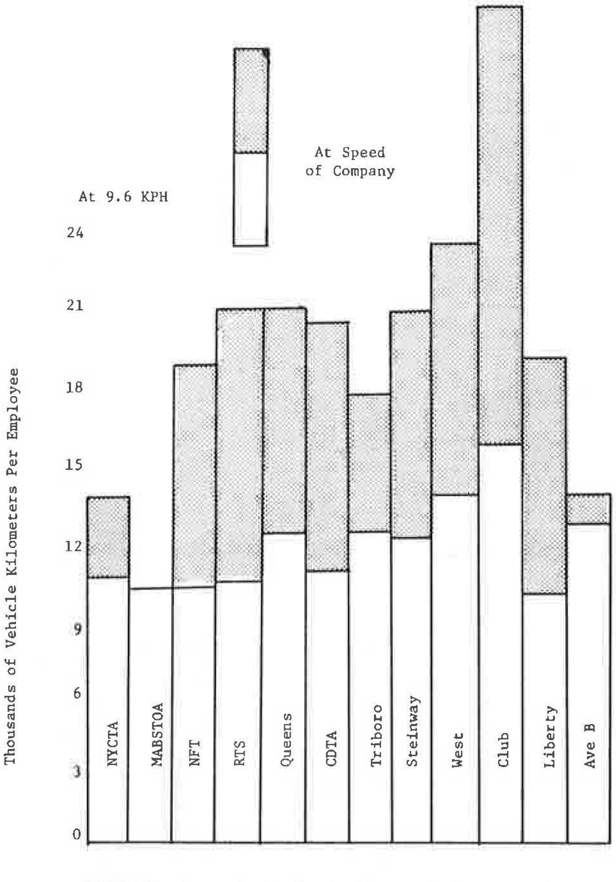
However, Niagara Frontier Transit, one of the two low-productivity private operations, became a public

Figure 5. Effects on total operating cost per vehicle-kilometer if all operations operated at the same vehicle speed and all employees received the same compensation.



Operations are arranged from largest to smallest based on vehicle hours of operation

Figure 6. Productivity of transit bus operations in terms of revenue vehicle-kilometers per employee at operating speed of company and at adjusted operating speed of 9.6 km/h (6 mph).



(Variation in productivity is decreased when operating speed is adjusted)

operation in 1974. Thus, if the analysis had been done a year later, it would show five public operations, all of which are less productive than the private operations with only one exception. This suggests that the lower productivity of public operations may be explained by the fact that the least productive (often the least profitable) private operations tend to become public operations. It is not because operations are public that they are unproductive, but the reverse: Unproductive operations tend to become public.

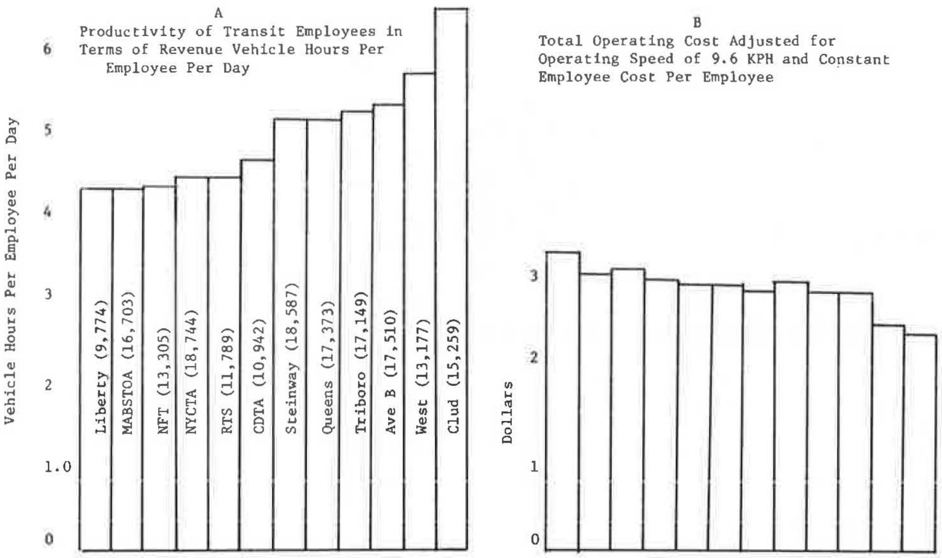
Vehicle-Hours per Day per Employee

Figure 7A shows the productivity of operations in terms of vehicle-hours per day per employee, and Figure 7B shows the adjusted employee costs plus operating costs per vehicle-kilometer at 9.6 km/h (6 mph). As productivity increases, the adjusted costs per adjusted vehicle-kilometer tend to decrease. This is particularly true for the three transit operations that had significantly different costs per kilometer after all adjustments had been made. Westchester Street Transportation Company and Club Transportation Corporation have significantly lower costs per kilometer after adjustments have been made and have the highest productivity. Liberty Coaches, Inc., had the highest cost per kilometer and the lowest productivity. Thus, different average vehicle speeds, different employee costs per employee, and in some cases, different productivities per employee are the reasons why transit operations have different costs per vehicle-kilometer.

Figure 7A shows (in parentheses) the actual employee costs per employee for each of these operations. There seems to be little relation between employee costs per employee and productivity. Employee costs per employee (or employee average earnings) do not seem to be related to productivity.

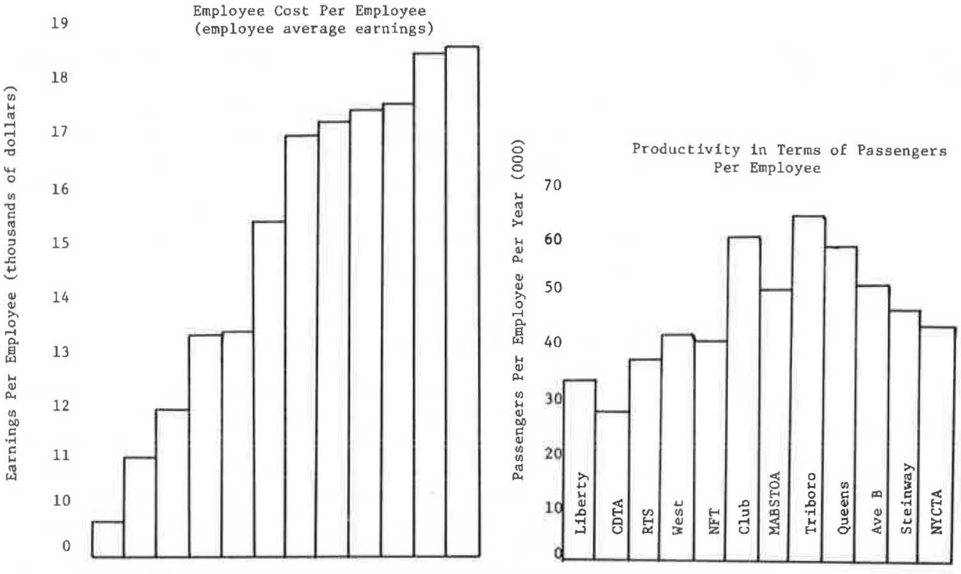
Employee costs may possibly be related to passengers per employee. Figure 8 shows the employee costs per

Figure 7. Comparison of employee productivity in terms of vehicle-hours per employee per day and total adjusted operating costs per adjusted vehicle-kilometer.



( ) $ Average Employee Compensation
Operations Arranged in Order of Increasing Productivity

Figure 8. Comparison of employee costs per employee and employee productivity in terms of passengers per employee.



Operations arranged according to increasing employee cost/employee

employee for each operation in increasing order of costs and the corresponding number of passengers per employee. For six operations, as the number of passengers per employee increases so do the employee costs per employee. However, for the other six operations, this relationship does not hold. Therefore, there seems to be no general relationship that explains why some transit employees earn more than others.

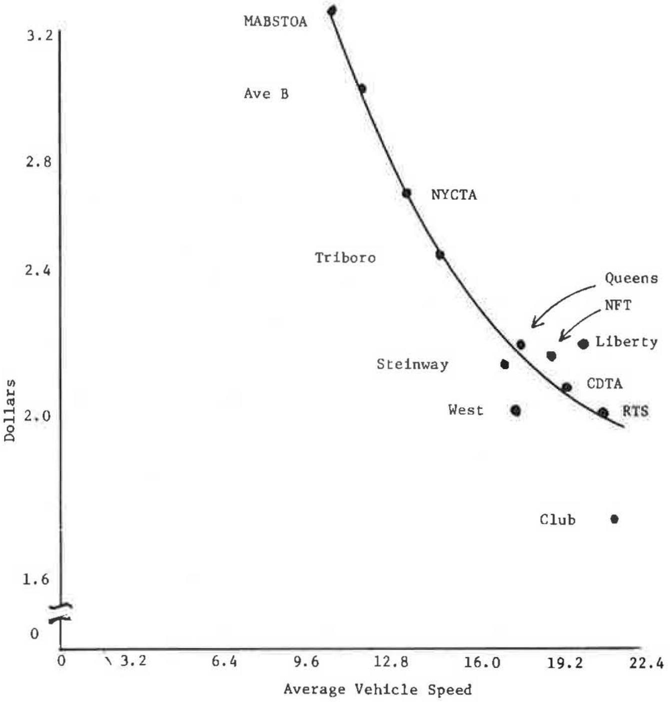
Potential for Reducing per-Employee Costs by Increasing Speeds

To further investigate the effect of average vehicle speed on operating costs, adjustments were made so that, if each of these systems had operated at the same average speed, they would all have had approximately the same operating costs per vehicle-kilometer. This was done as follows:

1. Adjust the total operating costs for each system to account for the different employee costs (wages and salaries, pensions, and benefits) among the systems so that the costs per employee for each of these systems would be the same; and
2. Divide the adjusted operating costs by the number of actual vehicle-kilometers of operation.

The total adjusted operating cost per revenue vehicle-kilometer is plotted against the average operating speed in Figure 9, which shows a dramatic decrease in operat-

Figure 9. Total operating costs plus adjusted employee costs per revenue vehicle-kilometer versus average vehicle speed.



ing costs per vehicle-kilometer as the operating speed increases from 9.6 to 19.2 km/h (6 to 12 mph). The table below shows the approximate percent decrease in operating costs to be expected for each kilometer-per-hour increase in operating speed (1 km/h = 0.6 mph).

Increase (km/h)	Decrease (%)	Increase (km/h)	Decrease (%)
10 to 11	12	14 to 15	6
11 to 12	9	15 to 16	5
12 to 13	8	16 to 17	5
13 to 14	7	17 to 18	5

(As the speed increases toward 19.2 km/h (12 mph) the additional saving from further speed increases becomes less.)

As the average vehicle speed increases, the same number of vehicle-kilometers can be achieved with fewer vehicle-hours. This allows the operator to reduce the number of employee hours, thus decreasing the employee costs, which represent 72 to 91 percent of the operating costs, or, by operating the same number of vehicle-hours with increased vehicle speed, more vehicle-kilometers of service could be provided without greatly increasing the operating costs. Thus, by increasing vehicle speed, the operator has three options:

1. To reduce his operating costs, while maintaining the same amount of service,
2. To maintain the same operating costs and increase the service provided, or
3. A combination of both.

But increases in average vehicle speed will not be easy to attain. Some operations operate at significantly slower speeds because of the on-street traffic environment, particularly during rush hours when congestion on the streets is extremely high and when the large portion of bus service is provided. It may be possible to increase the average vehicle speed by the elimination of on-street parking and better traffic enforcement. Further increases in average vehicle speed would probably be attainable only by restricting automobile traffic or by implementation of exclusive bus lanes or rights-of-way. All of these alternatives are beyond the powers of the transit operator, and would have to be implemented by other government agencies. To produce a cost savings in the short run, if a higher average vehicle speed were achieved, the number of employee hours would have to be reduced, and with a strong transit union that may be difficult.

Even if the free flow of transit vehicles were possible, the average vehicle speed would not be increased by more than a few kilometers per hour because the distance between bus stops, the number of signalized intersections, and the number of people boarding at a bus stop all affect the average speed and set an upper limit on how fast a bus can operate without changes in service.

There are other advantages to increasing the average vehicle speed. If the prime determinants of mode choice (choosing the bus over any other mode for a trip) are frequency of service, travel time, and cost, then increasing the transit vehicle speed will shorten the travel time by bus, which will increase the number of passengers using transit. Shorter headways could also be obtained if service were increased, which should also increase ridership. Either of these options increases the number of passengers carried, thus increasing the operating revenue, which will help to reduce the operating deficit. In summary, the obstacles to obtaining a higher average vehicle speed for a bus operation are numerous, but the benefits are high. Increasing the average vehicle speed by 1 km/h (0.6 mph), particularly for lower speed operations, could reduce the operating costs between 5 and 12 percent without reductions in service. Increasing speed would also help increase revenue because shorter travel time by transit would increase the number of revenue-paying passengers.

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Transit Costs During Peak and Off-Peak Hours

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This paper discusses the relative costs of providing peak-hour and base transit service in Albany, New York, during a 3-month period between January and March 1976. It concludes that the total cost (operating and capital) per passenger was $0.480 during the peak period and $0.746 during the base period. It cautions against the application of these results to other properties because of differences in peak and base service requirements, demand profiles, and union work rules and concludes with a discussion of the implication of the results for transit fares by contrasting an economic viewpoint and a transit-operator viewpoint.

The Capital District Transportation Authority (CDTA), like nearly all other transit properties in the country (1), is subject to far greater passenger demands during the weekday rush hours than during the midday, evening, and weekend hours. To accommodate this demand profile during the morning rush period (the largest of the two at the CDTA) requires 143 vehicles in service. The base requirement for midday weekdays, however, is only 68 vehicles. (The vehicle requirement by time of day is shown in Figure 1.)

Although much of the system revenue is collected during the peak period, a large portion of the costs are borne during these times. While buses tend to be more crowded during the rush hours and are, therefore, at least superficially more productive, in order to produce a high level of capacity during only a portion of the day, a significant amount of human and physical resources must be idle for a large segment of the day. The purposes of this paper are to explore the costs and revenues of peak service in contrast with those of off-peak service and to make some inferences regarding peak and off-peak pricing of urban transit service.

BACKGROUND ON TRANSIT COSTS

There are two adverse effects on the transit industry caused by the time-of-day distribution of service demand. The first effect is that the peak demand requires significant expenses for vehicles and operators that are in use for only a small portion of the day. The second effect is that the peak requirements dictate the number of bus operators and, to some degree, the conditions under which they work. This paper is primarily concerned with the first effect, although additional investigation has shown that unit labor costs increase with the scale of the operation even after correction for cost-of-living differences. This may be due to the greater power held by larger union locals.

The peaked nature of transit demand and, hence, supply also causes extremely complicated contracts with labor bargaining units (2). Hence, proper categorization of costs into peak and off-peak costs is quite difficult, and, on the part of the transit industry, interest in cost assignment has been limited. Although many attempts have been made to ascertain costs of specific routes for the entire day, there has been little work on the aggregate costs of an entire transit system for different time periods within the day.

DRIVER ASSIGNMENT

A brief explanation of industry practice and local union rules regarding driver assignment will be given before the methodology used to assign costs to peak and off-peak service is explained. Since driver wages account for about 55 percent of the transit operating budget, this may explain why the peak-hour service is more costly to provide on a unit basis than is the off-peak service.

Three times each year the drivers select their assignments for a 4-month period. This is done on a seniority basis. There are two types of assignments: regular runs or assignment to the extra board. Regular runs are duty assignments of approximately 8 h for 5 d/week. A driver who has a regular run keeps it for the 4-month period. The extra board is for extra trips during the rush hour, nonscheduled trips, and to cover for sick days and attrition of the regular run drivers. A driver on the extra board may have a different run each day. All drivers work full time, as the labor agreement prohibits the use of part-time operators. Not all regular runs are continuous 8-h tours. Some are split runs consisting of two pieces of work, usually one in the morning and one in the afternoon. During the May 1976 peak at the CDTA there were 37 extra operators out of a total of 208 drivers.

There are three basic rules for determining operator wages.

1. All drivers are guaranteed 40 h/week.
2. Overtime (paid at time and one-half) is paid under the following conditions: (a) more than 8 h work in a single day and (b) work that lasts more than 11 h from the first time the operator reports to work. (This provision affects mainly those drivers with split runs.)
3. Extra operators work 5 d/week and are guaranteed 40 h of work/week. During each day they work, they are guaranteed 6 h of work.

The ability to reduce labor costs lies in skillful manipulation of runs while paying minimal overtime and spread-time penalties. Figure 2 shows the tours of duty on the route that require the largest number of peak-hour buses, the Western Avenue route.

METHODOLOGY OF THE INVESTIGATION

This investigation was carried out by determining the costs and ridership of the peak and base service for the first 3 months of 1976 for the portion of the system that serves Albany and Troy by a study of the CDTA financial records. The major effort of the analysis was the distribution of labor costs to the peak and base periods.

The major problem was that of estimating the additional cost of the peak-hour service above that of the current level of nonpeak service.

Determination of Peak and Base Hours

The peak and base hours are defined by bus assignments on the system throughout the day. The morning peak is defined as the hours between 7:00 and 9:00 a.m., and the afternoon peak is defined as the hours between 2:45 and 5:15 p.m. The longer afternoon peak is due to the fact that school discharge hours do not coincide with normal work discharge hours. On the other hand, the morning school and work starting times are similar. (All hours on Saturdays, Sundays, and holidays are considered to be base hours.)

Determination of Peak Versus Base Service Costs

To assess the performance of each route, the CDTA uses a cost-allocation model, derived by Simpson and Curtin (5), that assigns all authority operating costs to the number of peak vehicles, the service distance, and vehicle (platform) hours of service. The overhead and administrative costs are distributed according to the number of peak vehicles assigned to the route. The hourly costs include driver and field supervision sala-

Figure 1. Vehicle requirement by time of day.

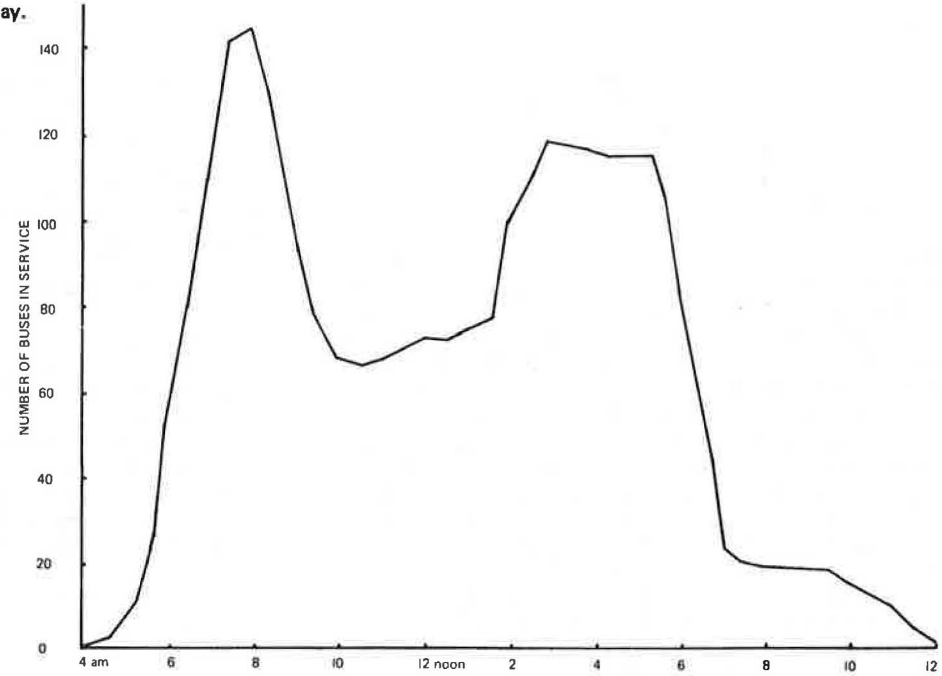
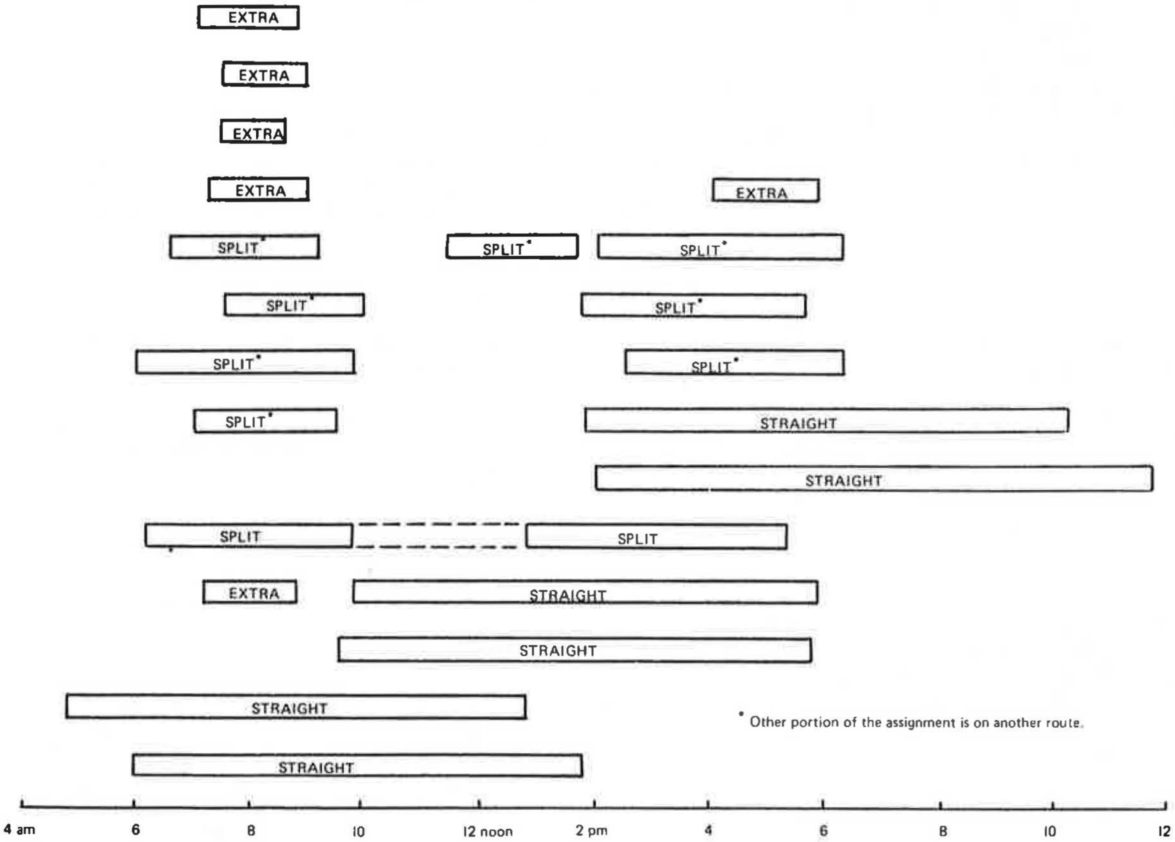


Figure 2. Assignment of runs on route 10 (Western Avenue) on a typical weekday.



ries and insurance and the distance-related costs include maintenance and consumables such as fuel and tires. For the period of the study (January 1, 1976, to March 31, 1976) \$161 805 was assigned to the number of peak vehicles, \$911 553 to the vehicle-hours, and \$344 497 to the service distance. The cost-allocation equation has the form

$$C(x) = K_1V + K_2M + K_2H \qquad (1)$$

where

$C(x)$ = cost of service x,
V = number of peak vehicles assigned to the service,
M = miles of service,
H = bus hours of service, and
K_1, K_2, and K_3 = constants.

(SI units are not given for the variables of this model inasmuch as its operation requires that they be in customary units.) For the period of the study, this was $C(x)$ = \$1131.50V + \$0.31M + \$9.70H. This formula will allocate costs to a certain route correctly if the route requires the system average amount of overtime and the system average amount of peak to base time. However, since the efficiency of labor, measured as a ratio of actual bus hours to paid driver hours, is not uniform for peak and base service, the \$9.70/h cost is higher than the actual cost of labor during the base period but lower than the actual cost during the peak period. The unit cost per mile (\$0.31) is probably independent of peak or base operations since it reflects the cost of maintenance and consumables. Similarly, the peak vehicle charge is used to allocate fixed administrative costs and probably adequately reflects the extra administrative costs caused by the peak fleet size.

The peak hourly cost versus the base hourly cost could be estimated by adjusting the unit cost of labor (\$9.70) upward during the peak and down during the base period and then multiplying each by the number of peak and base hours. This would ensure that the peak service is charged with the inefficient use of labor caused by the peaked demand that dictates that some drivers will be paid for a full day's work but may work only a few hours. This allocation model would be

$$C(x) = K_1V + K_2M + K_3H_p + K_4H_b \qquad (2)$$

where

H_p = peak bus hours,
H_b = base bus hours, and
K_1, K_2, and K_3 = constants.

In this formula, K_3 would be greater than \$9.70 and K_4 would be less than \$9.70, reflecting the more efficient use of labor during the base period. To determine these constants (K_3 and K_4) the hourly costs were divided into operator and nonoperator costs.

Operator Cost

CDTA financial records showed that, for the 3-month study period, the cost for operators was \$622 200 for salaries and \$132 000 for fringe benefits, for a total operator labor cost of \$754 200. The number of pay hours for straight time and overtime for regular and extra operators is shown below.

Drivers	Straight Time	Overtime	Total
Regular	75 468	7 869	83 337
Extra	24 826	4 345	29 171
Total	100 294	12 214	112 508

The operator labor cost (L) is then

$$L = A_1H_s + A_2H_o \qquad (3)$$

where

A_1 and A_2 = constants,
H_s = pay hours for straight time, and
H_o = pay hours for overtime.

A_1 and A_2 represent the unit labor costs of straight and overtime respectively and were \$6.47 and \$6.80. A_2/A_1 is not 1.5 exactly (reflecting the 50 percent bonus for overtime) because the fringe benefits for overtime are less than the benefits for regular time. The labor-cost formula then becomes L = \$6.47H_s + \$8.60H_o. All of the driver pay hours were then assigned to straight time, overtime, peak hours, and base hours. The following time was assigned to the peak hour: all actual driving time during the peak hours, deadhead time between the garage and the route terminal on extra runs during the peak, and the nonproductive time of drivers that is caused by the fact that some are required for only a few hours each day but are paid for a full day's work. Most of the overtime was assigned to the peak periods since overtime is generally a result of using a driver to work both the morning and evening peak hours. The distribution of pay hours is illustrated below.

	Straight Time		Overtime	
Drivers	Peak	Off-Peak	Peak	Off-Peak
Regular	27 923	47 545	5965	1904
Extra	14 505	10 321	3916	429
Total	42 428	57 866	9881	2333

Nonoperator Costs

Not all hourly related costs, however, are due to driver wage and fringe benefits. Some hourly costs are for supervision, training and safety, and other categories. For the study period, these costs were \$157 353.

Assignment of Hourly Costs to Platform Hours

The bus hours, the hours of actual driving time, were assigned in a manner similar to the assignment of the labor hours. As with the labor hours, all platform time on Saturdays, Sundays, and holidays was considered to be off peak. The peak versus off-peak distribution of platform hours is shown below.

Period	Weekdays	Saturdays	Sundays and Holidays	3 Month Total
Peak	659	—	—	42 173
Off-peak	685	525	108	51 788
Total	1344	525	108	93 961

Thus, the operator cost was L_p = \$6.47(27 923 + 14 505) + \$8.60(5965 + 3916) = \$359 486 during the peak and was L_b = \$6.47(47 545 + 10 321) + \$8.60(1904 + 429) = \$394 457 during the base period. The unit operator costs per platform hour during the peak and off-peak hours were \$8.53 and \$7.63 respectively.

The unit cost per platform hour of nonoperator hourly costs (N) was \$1.675 (\$157 353 ÷ 93 962), and the adjusted unit hourly costs were $K_3 = (L_p/H_p) + N = \$10.21$ and $K_4 = (L_b/H_b) + N = \$9.31$. Thus, the adjusted allocation equation for the operating costs is $C(x) = \$1131.50V + \$0.31M + \$10.21H_p + \$9.31H_b$.

Inclusion of Capital Costs

This analysis does not consider the capital costs associated with operating the transit system during the 3-month study period. Essentially, capital costs are in two categories: depreciation or the allocation of a prepaid cost to future time periods, and interest charges. The interest charge, although not an accounting cost, is indeed an economic cost, since the money spent on fixed facilities or vehicles could have been placed in alternative investment. The money that could have been earned by this investment should be allocated to future time periods, but the fact that nearly all CDTA equipment has been purchased largely with capital funds contributed by the federal government obscures this subtlety even further. For the study period, the vehicle and plant depreciation was about \$103 900 while interest charges (at a miminal 6 percent) would be \$91 860. The total capital cost is thus about \$195 760.

The proper assignment of these costs to peak and base operating periods is not readily apparent. Clearly, the interest cost and plant depreciation are peak-vehicle-related. However, it is not so evident whether or not vehicle wear is caused by the passage of time, as the accountant's ledgers view it, or by the accumulated distance driven. The common industry practice of assigning buses to runs so that buses of equal age have been driven similar distances supports either assignment method. In actuality, the reason for bus replacement is probably a combination of the effects of age and use; the allocation used here is on the basis of vehicle requirement. The total cost (operating and capital) then becomes $C(x) = \$2492.60V + \$0.31M + \$10.21H_p + \$9.31H_b$.

Cost Split Between Peak and Base Periods

The cost of service during the peak and base was determined by use of the adjusted allocation formula to be \$774 900 and \$839 200 respectively.

Determination of Peak and Base Patronage

Detailed ridership on a trip-by-trip basis was not easily available during the time of the study. However, based on a consultant's on-board questionnaire (3) administered in 1971 and verified by a more recent staff investigation, a time-of-day profile of ridership was established. The expected distribution of peak and base ridership is shown below.

Period	Weekdays	Saturdays	Sundays and Holidays	3-Month Total
Daily				
Peak	25 640	–	–	–
Off-peak	14 860	11 800	2 400	–
3-month total				
Peak	1 615 320	–	–	1 615 320
Off-peak	936 180	153 400	36 000	1 125 580

Per Passenger Cost During Peak and Base

The cost per passenger during the peak period was therefore \$0.480 while the base cost per passenger was \$0.746, a substantial difference. Since the system average revenue per passenger is \$0.38, it is probable that the added cost of providing peak-hour service is almost balanced by peak-hour revenue. The off-peak service, on the other hand, requires most of the non-fare-box support. The base period was not disaggregated into categories such as midday, evening, Saturday, and Sunday service, and there is no reason to suspect that the per passenger costs for each of these periods would be similar. There is no evidence that the peak-period patron is cross-subsidizing the off-peak patron, or the converse.

APPLICATION OF RESULTS TO OTHER PROPERTIES

The conclusions of this research may not apply to other properties for a variety of reasons. First, the ratio of peak to base units in service will certainly affect relative costs. A property with many long-haul commuter and park-and-ride services will probably have lower labor productivity, which may or may not be offset by higher physical productivity (passengers per unit of service). Second, the CDTA use of certain types of driver assignments reduces the number of extra operators required, which is a key determinant of peak-hour labor efficiency. In addition, work rules such as the hours after which spread-time penalties become effective and the maximum number of percentage of split runs will affect the relative costs of peak and base service.

Finally, a large proportion of the CDTA passengers are school children. Their school hours combined with the work hours of the general labor force provide a profile of demand that has a shorter but sharper peak in the morning but a longer, flatter peak in the afternoon. The absence of substantial school transportation would influence the magnitude, length, and time of occurrence of the two daily peaks so that relative costs might vary significantly from those presented here.

POLICY IMPLICATIONS

This paper provides some insight into transit policy, particularly in the area of urban transit pricing. The issue is whether the current practice of identical peak and off-peak pricing is proper. The transit operator is inclined to apply private business cost-recovery principles to the problem, while an economist is concerned with the proper allocation of resources to activities. The following discussion highlights the two viewpoints.

Economic Perspective

An economic approach to transit-fare policy would be to ensure that the service policy is efficient in that it is related to the marginal cost of the service and equitable in that the income transfers that result from any subsidies are positive. While the analysis above indicates that the average cost per passenger during each period (peak and base) is unequal, there was no inference about the marginal cost of carrying additional patrons. The incremental, not the average, cost is the key to efficient pricing.

During the peak hours, a small increment of passengers would either require additional resources to transport them or cause uncomfortable crowding on the existing vehicles in service. This cost of additional service, including both the out-of-pocket cost of additional resources and the cost imposed by congestion of the vehicle, distributed over the additional passengers, is an efficient price. An efficient price for transit during the peak hour, however, should be considered only if all segments of the urban transportation market during the peak hours are efficiently priced. Since the marginal social cost of driving in cities, particularly during the rush hours, is significantly higher than the price, primarily due to uninternalized costs such as congestion and pollution, attempts to efficiently price the transit sector of urban transportation will be counterproductive. However, this situation will continue until there are realistic attempts to bring automobile prices into line with automobile costs, which will make the entire urban transportation sector efficiently priced and, therefore, properly allocated by mode and time of day.

During the off-peak hours, since there is a substantial excess capacity in the number of vehicles in service, a similar small passenger increment would probably require no additional buses or operators. In fact, since transit fares, even during the off-peak hours, are quite inelastic, a fare reduction would increase passengers without increasing costs. In the capital district, even if the off-peak fare were reduced to zero, the requirement for vehicles and operators would not increase and excessive crowding and congestion in vehicles would not be likely. A truly efficient fare would be one that would just fill the bus. A fare below this amount would result in extra riders and cause additional vehicle requirements while a fare above this amount would be suboptimal in that extra output (ridership) could be produced at no increment in cost.

In effect, transit service in the capital district during the off-peak hours is a public good, in that additional output, within limits, can be produced at no additional cost. The appropriate efficiency-based charge is thus zero or nearly zero. Paying off-peak transit costs from tax revenue would be more efficient than direct user charges since the marginal cost of net revenue due to taxes spent would be less than the marginal cost of net revenue due to transit fares received. That is, the cost to society of transit financing through taxation (measured as the sum of collection, compliance, and excess burden costs) is significantly less than the net cost to society of transit fares priced above the marginal cost (measured as the ratio of the increased consumer cost to the extra revenue created).

As a second-best alternative, if it were considered desirable for users themselves to pay for the cost of service, a system of monthly or annual passes sold to off-peak patrons would be appropriate. The fee for this pass would represent a charge for the option to ride the bus, not unlike the fixed monthly charge to telephone subscribers (4).

These efficiency-based charges could have the effect of shifting some of the transit ridership from peak to nonpeak hours. This could reduce the cost of producing transit service by diminishing the excess off-peak capacity and the need for a large reserve of underused peak-hour resources.

Transit Operator Perspective

An historical perspective is required to fully appreciate the operational viewpoint of transit prices. During the period in which private ownership dominated public transit systems, prices were established on a cost-recovery basis by regulation of various utility and public service commissions. Although most of the urban transit properties in the country are now in public hands, they still tend to be operated with certain vestiges of their former private ownership. Even today, a key performance measure by a transit operator on a specific route is the operating ratio, which is the inverse of the percentage of costs that are covered by passenger revenue. The economist, however, measures efficiency by the cost per passenger trip or per passenger mile, regardless of the source of the revenue.

Governed by a fixed budget derived from fare-box revenue and external subsidies, a transit operator wants a fare policy that provides a politically tolerable subsidy and an easy-to-explain and simple-to-administer fare structure. The current practice of identical peak and off-peak pricing with flat-base fares is ideally suited to meeting these two objectives. An efficiency-based fare, on the other hand, is difficult to explain, hard to rationalize in terms of cost recovery, difficult to enforce, and could yield politically intolerable deficits.

Resolution of Conflicting Viewpoints

There is no easy resolution of these viewpoints, particularly because of the price inelasticity of urban public transportation during both the peak and off-peak hours. If off-peak transit demands were elastic, reducing the fare (to price the service efficiently) would result in increasing revenue for a given supply of service. This would satisfy the operator's requirement for revenue recovery and the economist's requirement for efficient pricing.

For the future, transit policy will probably be a compromise between the two positions. For example, the National Mass Transportation Assistance Act of 1974 requires half-fares for the elderly and handicapped during off-peak hours for Section 5 grant recipients. Second, the percentage of transit costs that is recovered by fare-box revenue is decreasing and so it is probably not considered to be as important as it was formerly. Finally, the utility industries are recognizing that the additional costs of peak-hour power generation are in excess of the nonpeak costs, which will soon be reflected in consumer utility bills. Once this procedure is established and accepted, mixed pricing for transit will be easier to explain to the public, which could lead to more efficiency-based prices for services.

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Strategy For Implementing Integrated Regional Transit

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The recent desire for expanded urban public transportation generated by increased environmental and energy awareness and by the negative impact of extensive freeway construction has increased interest in the more efficient use of existing transportation facilities and in finding more cost-effective means of improving and expanding public transit service. A promising solution to these problems is in restructured conventional and paratransit services that are operated as comprehensive regional transit systems integrated operationally, physically, and institutionally. This paper examines the implications of embarking on a 10-year strategy to implement such a system. Three levels of ridership response are assumed, and their effects on system scale and operating policy decisions at biennial intervals are studied. The operating cost and deficit implications of these three response levels are then traced, yielding insight into the feasibility of an evolutionary strategy. It is concluded that, if a high ridership response results, the dual goals of expanded and improved transit service and reduced operation deficits can both be accomplished.

The role of transit in providing travel services in the metropolitan areas of the United States has been dramatically altered in the last quarter century. During the 1950s and early 1960s, extensive highway investments, including urban portions of the Interstate highway program, enabled swift private-mode travel to and within suburban areas, fostering the dispersal of all kinds of development in many urban areas (1). By the late 1960s, the high capital, social, and environmental costs of this policy had generated sufficient opposition to slow or halt many urban freeway developments (2). A dramatic reversal of the steady neglect and decline of public transportation was sought in the early 1970s to achieve broader environmental and planning goals. Transit authorities in several cities became active in planning or constructing heavy rail systems, and in extending conventional bus and paratransit services. However, this expansion in service and coverage, coupled with inflated operating costs, has led to increased operating deficits in most major systems (Figure 1). Faced with a general financial squeeze, many municipalities have reduced service in an attempt to reduce transit subsidies, and turned to state and federal governments for transit operating assistance. At the same time, the regionalization of transit operating agencies has brought pressure from suburban communities to expand their local transit service, which is often a difficult task because of the low residential densities and dispersed travel patterns of suburban development.

Responding to these diverse pressures, the U.S. Department of Transportation has shown increased concern with improving the planning and operation of urban transportation systems. Two visible manifestations are the transportation systems management element (3), now required in the 3-C planning process, and the service and methods demonstration program (4). The department is also continuing its research on improved transit operating strategies. The object of these efforts is to meet the goals of both of the major thrusts of this decade: transit expansion and deficit reduction.

POTENTIAL OF INTEGRATED TRANSIT

One of the most promising strategies is the implementation of integrated regional transit service. This concept, expanding on the tenet that different conditions will require different transit modes and operating policies (5, 6), consists of the coordinated operation of a variety of modes and suppliers. Transit service would be reconfigured to improve service in the cities and expanded to provide effective coverage in the suburbs.

Full integration, however, goes beyond the coordination of spatially diverse transit services. An integrated regional system should be able to respond to temporal changes in travel volumes and patterns, both those occurring during each day (i.e., between peak and off-peak travel) and slower changes caused by urban development and transportation policy. In a number of metropolitan areas, the institutional environment would have to be broadened to allow both the coordination of system components and their operational responsiveness to diverse demands.

The potential of integrated regional transit has been examined under the sponsorship of the U.S. Department of Transportation (7). The thrust of the overall study was the estimation of the impacts of dramatic increases in transit patronage on system structure and performance. Models, including express bus, exclusive lane operation, subscription service, dial-a-ride, and several route-based feeder options, were developed to examine the cost and service attributes of a variety of system components. These models were used to test integrated public transit systems operating in a typical medium-size metropolitan area (population 800 000) over a range of assumed ridership levels. The primary findings of this typical-city analysis were that, as regional modal split increases,

1. Significant but rapidly diminishing economies of scale exist;
2. Significant travel-time improvements are possible, but private-mode service is not matched in many markets;
3. Hybrid modes operating with characteristics of both fixed-route and demand-responsive transit are desirable in many local service areas; and
4. The dedication of certain roadway facilities to transit is appropriate.

The analysis provided insight into system design and operation at different levels of transit patronage, which enabled the study of such questions as, How much of the region should be served? What modes should be operated? and Where? Snapshots of a potential evolution of an integrated transit system derived from this analysis are shown in Figure 2. The analysis suggested that a transition from system A (similar to today's typical fixed-route system) to system C (an integrated transit system carrying a significantly larger share of regional trips) was possible, and could be accomplished in an incremental and orderly manner. Because of uncertainties in system operation and ridership response, however, some questions remained unanswered: How much of the transition is feasible? and What are the consequences of trying? The second phase of the study (7), reported below, addressed these questions.

INCREMENTAL EXPANSION

A strategy for implementing an integrated regional transit system over a 10-year period (Figure 3) was examined. The strategy is incremental, i.e., it is a series of 2-year investments or steps, each designed in the light of the market response to the previous steps.

STRATEGY COMPONENTS

In designing each step, the planner has seven categories of measures at his disposal.

Group 0 measures consist of the measures required prior to the development of an expanded and integrated transit system and were not explicitly included in this investigation. They include an overhaul of the institutions and regulations under which transit service is provided. Management effectiveness is increased, equitable and reasonable labor agreements are negotiated, system maintenance facilities are upgraded, and passenger and system security is ensured.

Group 1 measures revamp routes and schedules so that transfers are coordinated and service is geared to the rhythms of the urban system. Unified user charges to reflect differences in trip distance, time of day, quality of service, and type of user are developed. Prepaid passes are made readily available. Routes, vehicle destinations, and boarding and alighting zones are clearly indicated. Easily read maps and schedules for the system, service areas (neighborhoods), and routes are distributed, and an information center is established.

Group 2 measures expand the system to serve new users. A larger fleet allows new circumferential routes, denser radial routes, more frequent service, and expansion into the suburbs, including the introduction of flexibly routed, demand-responsive local services. Midday and evening services are substantially improved, better using the transit system capital and labor resources.

Group 3 measures increase the efficiency of and accessibility to public transit operation through fixed-facility expansion. They include the dedication of existing roadway to the exclusive use of transit (or high-occupancy vehicles, including van pools and car pools), the construction of new rights-of-way for the sole use of transit, the installation of traffic control devices for priority treatment for transit vehicles on arterials and freeway ramps, and the use of off-vehicle fare collection at high-volume points, all of which improve driver and fleet productivity. Suburban transfer and terminal facilities designed to serve a wide range of transit access modes—park-and-ride, park-and-pool, feeder bus, and walking—are constructed to tap potential network economies.

Group 4 measures are external measures that encourage the efficient use of the metropolitan area transportation infrastructure. Flexible and staggered work hours lessen the ratio of peak to off-peak travel, thereby improving fleet utilization. Car-pool-incentive programs promote the efficient movement of those trip makers who are not diverted to public transportation. Major activity center circulation improvements (such as covered walkways, grade-separated passageways, and moving platforms) reduce the relatively inefficient use of line-haul vehicles for distribution and internal circulation.

Group 5 measures consist of automobile disincentives such as automobile-restricted zones, increased parking fees in major activity centers, and automobile-congestion tolling.

Group 6 measures consist of transit deficit-reduction measures such as fare increases and the conversion of some doorstep local transit services to hybrid and fixed-route operations.

These measures form the building blocks for the incremental steps of the expansion strategy shown conceptually in Figure 3. The measures in categories 0 and 1 would be implemented at the beginning, with the others implemented in varying degrees throughout the strategy according to the insights gained in previous analyses (6, 7, 8) and experiments.

RIDERSHIP RESPONSES

Instead of an approach that predicts the market response to each step of the transit improvement strategy, a parametric approach was taken. Alternative levels of response were assumed (the end points of the linear growth functions are shown below) and were combined with a corresponding series of actions to form three divergent evolutionary paths.

Time and Response	Modal Split (%)		
	Daily	Peak	Off-Peak
Year 0	5	10	3.5
Year 10			
Low response	7.5	15	5
Medium response	15	25	10
High response	25	40	20

At the beginning of the strategy, the daily modal split in the region is 5 percent, which is typical of many medium-size urban areas. The high-response path assumes that a fivefold increase in transit ridership and a complete integrated regional system are achieved by the end of the transit improvement program. In the moderate-response path, a final modal split of only 15 percent precludes the service densities possible in the high-response path, although a regional coverage system can be operated. Finally, the low-response path assumes only a 50 percent increase in transit ridership, reflecting a public that is generally unresponsive to improvements in transit service and extensions in coverage. In this case, the final system would not serve all geographic markets in the region.

STRATEGY RESULTS

The financial consequences of the three expansion paths, including the deficits resulting from a range of fare policies, were traced. As the starting point, the average operating costs (assuming constant base-year prices) at each step in the 10-year strategy are plotted in Figure 4. Economies of scale are generated in all three paths, with the largest economies accompanying high ridership response.

The first fare policy is that of a flat 50-cent door-to-door average fare (regardless of how many transfers may be required) until the eighth year when it is increased to 55 cents. The deficits for this fare policy are also shown in Figure 4. While none of the paths produces a surplus, significant decreases in the per-passenger deficit occur after the fourth year with the medium and high ridership responses, and after the eighth year with the low response.

The total daily (i.e., typical weekday) operating costs and deficits of this fare policy are plotted in Figure 5. The total operating costs clearly rise, but due to economies of scale, the increase is less rapid than is the ridership. More significant are the deficit curves, which indicate that embarking on a major transit improvement strategy does not necessarily result in a runaway operating deficit. The deficits occurring during the 10-year period, while significant, act as seed money.

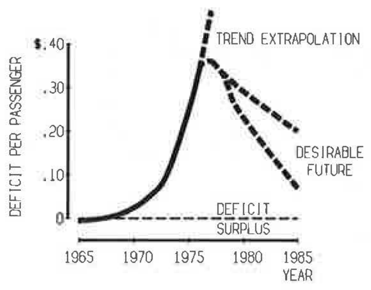


Figure 1. Trends in transit deficits.

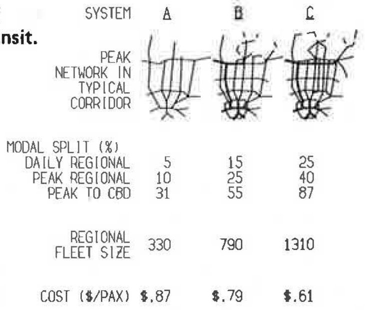


Figure 2. Potential of integrated regional transit.

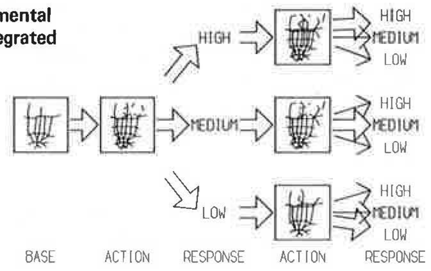


Figure 3. Incremental evolution of integrated transit.

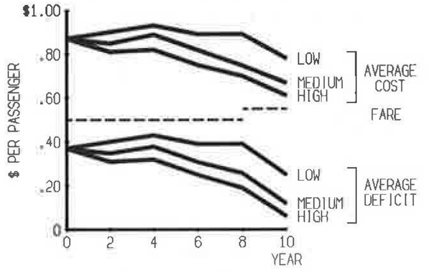


Figure 4. Average costs and deficits of flat fare policy.

By the end of period, the total deficit in all paths has returned to earlier levels, even though more areas are being served by transit.

Alternative fare policies can also reasonably be assumed. For example, the increase in average trip length that accompanies increases in regional modal split, the increased use of flexible and hybrid modes that can offer doorstep service, and the increase in frequency of service and direct routes in the fixed-route system could justify a 50 percent increase in average fare over the 10-year period. The average cost, fare, and resulting deficits of this fare policy are shown in Figure 6. In contrast to the flat-fare case (Figure 4), a per-passenger surplus is achieved by the end of the 10-year strategy under high and moderate ridership responses, and even with a low response, transit operations almost break even.

The total daily deficits that result from the increased fare policy are shown in Figure 7 (distance and service-based fare). The per-passenger surpluses (Figure 6) translate into large total surpluses by the end of the 10-year period if the ridership response is at least moderate, which is an appealing prospect.

Figure 7 also shows the deficit that results from a less stringent fare policy. If average fare increases are due only to increased trip length, and the increases range from 30 to 40 percent of those assumed with the distance and service-based fare policy, this policy will yield a break-even transit operation at the end of 10 years if the response is high and a 60 percent reduction in the daily deficit if the response is moderate.

SUMMARY OF RESULTS

The key financial implications of the 10-year expansion strategy are summarized below.

	10-Year Program Deficit ($)		Tenth-Year Deficit	
Response	Total	Seed Funding	Annual ($)	Per Passenger (¢)
Do nothing	180 000 000	0	18 000 000	39.9
Low	197 000 000	17 000 000	14 000 000	20.8
Medium	217 000 000	37 000 000	9 500 000	7.6
High	252 500 000	72 500 000	3 000 000	1.3

The first row shows the results (in constant 1975 dollars) of not doing anything: 10 years of $18 million deficits. The remainder shows the strategy results for each of the three ridership response levels. The difference between the improvement program and the do-nothing deficits represents the required seed funding, or the cost of the program. What the cost has bought in terms of reduced deficits is shown by the tenth-year annual deficit column. For example, if the high ridership response is achieved, then the annual deficit can be cut from $18 million to $3 million with a 10-year investment of $72.5 million. This saving of $15 million/year allows the investment to pay for itself in less than 5 years. Similarly, the medium and low ridership responses require investments that pay for themselves in 4⅓ years and 4¼ years respectively. Therefore, when a 10-year improvement program can be tailored to the ridership response that it generates, its cost can be recovered in about 15 years (5 years after its conclusion). The other benefits of an expanded, integrated regional transit system—improved service to users, decreased roadway congestion, decreased energy consumption and air pollution, and efficient use of existing roadway capacity—are substantial bonuses of the improvement program (7).

IMPLEMENTING THE STRATEGY

Despite the clear benefits, the implementation of the improvement strategy will not be simple. While some of the components are in operation in some places, such as the Shirley Highway (Washington, D.C.) and Market Street (Philadelphia) bus lanes, or are being demonstrated as part of the service and methods program, such as the Knoxville transportation-brokerage system and the Rochester dial-a-ride system, the complete package has not been assembled anywhere. The Minneapolis-St. Paul region is currently undertaking the group 0 components in anticipation of such an attempt, and in Ann Arbor and Rochester transfers between paratransit and line-haul services have been coordinated.

The improvement strategy uses flexible services for pump priming, i.e., for attracting additional patronage

Figure 5. Daily costs and deficits of flat fare policy.

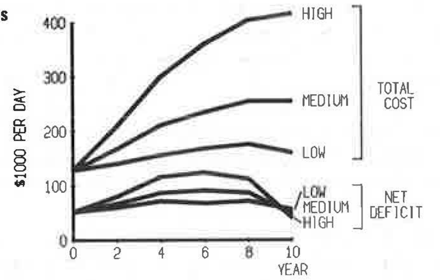


Figure 6. Average costs and deficits of distance and service-based fare policy.

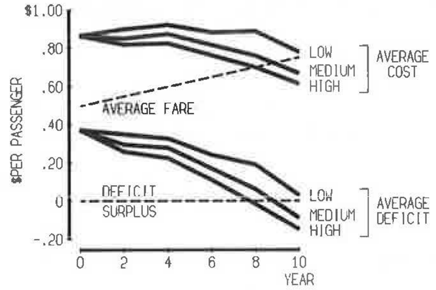


Figure 7. Daily deficits of increasing fare policies.

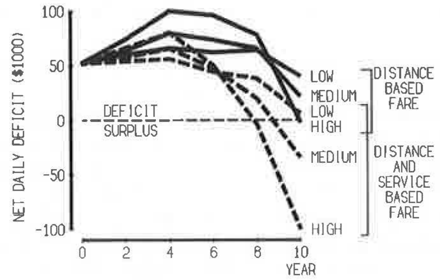
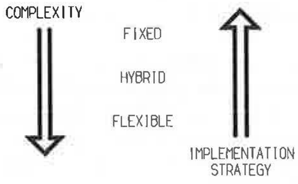


Figure 8. Implementation dilemma.



(9). As ridership grows, the system gradually shifts to more structured operations (e.g., fixed-route and point deviation) in which faster and more frequent service can be offered at lower cost (7). Unfortunately, the flexible services are the most difficult to operate effectively and reliably. This dilemma, posed in Figure 8, indicates that comprehensive transit-improvement strategies should not rely heavily on flexible services until more is learned about their successful operation. Meanwhile, less complex services such as subscription and route deviation might be used as pump primers.

Experience in Ann Arbor, Michigan, suggests that there can be more compelling criteria than mere economic efficiency when making transit operating decisions. Doorstep services, for example, which are very attractive to particular market segments, may have to be retained beyond their theoretically useful life in response to political pressures. But offered as an optional service with a premium fare, they could provide the public with a broader choice of service, which is itself a desirable social goal.

Having described some potential barriers to implementing a major transit improvement strategy, some indication of success is in order. As part of a response to declining ridership, the transit authority in Rochester, New York, implemented a free downtown zone and reduced off-peak fares. Not only did the ridership increase, but the reductions in the peak fleet requirements resulted in a significantly reduced operating deficit.

CONCLUSIONS

This study has shown that goals of expanded and improved transit service and of reduced operating deficits can both be accomplished, and that integrated regional transit is a viable candidate for achieving these goals and the corequisite ridership response. The rich variety of service options provided by this concept helps to create a travel marketplace that should allocate both public and private resources more efficiently than is done in current transportation systems. Together with increased transit coverage, these options could foster the public support needed to undertake necessary institutional changes.

Furthermore, an incremental strategy can be designed for implementing integrated regional transit. The flexibility inherent in this approach is very comforting for, with careful monitoring, large investments in risk capital or seed money (in the form of increased deficits during the 10-year implementation period) are required only when commensurately large payoffs prove feasible. This is the benefit of the incremental approach, which allows goals and actions to be adjusted on the basis of experience. Thus, even with a low ridership response, a slight deficit reduction can be produced, allowing the seed money to be recovered by the fifteenth year following strategy implementation.

ACKNOWLEDGMENTS

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Abridgment

Bus Transit Route Demand Model

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There have been transit-demonstration grants over the past 12 years in almost every city in America. While the general results of these demonstrations are evident in increased ridership and the improved public image of transit, the particular results necessary for further detailed improvements in the system have not been available because there is no accepted model of bus ridership that can be used for data collection to document the findings and results of transit demonstrations.

The need for a detailed model for transit ridership is clearly documented (1). In the day-to-day operation of bus companies there is no way to estimate the ridership effects of changes in headways, route extensions, fare increases, crowding on buses, increased central business district (CBD) parking rates, changes in the cost of gasoline, and so forth. While rules of thumb, such as the 30 percent shrinkage factor for fare increases, can be used, there is no method for correlating and combining the observed effects of other, more recent, fare changes into these rules.

For example, the city of Atlanta (2) purchased the privately owned Atlanta Transit System in March 1972. Over the next year or so they (a) lowered the fare to 15 cents, (b) purchased 490 new buses, (c) improved headways, (d) expanded service periods, (e) extended lines, and (f) created five new lines. The result was an overall 30.2 percent increase in transit ridership by June 1973. A study of systemwide rider characteristics was made to identify new and old riders and their characteristics. However, no individual route information is available, and, without such a breakdown, it is impossible to identify the effect that each of the six separate improvements had on transit ridership (2).

The story is similar for many cities. With new sources of funds and public ownership, there have been new routes, new buses, new hours, and more passengers. Austin, Texas, since 1972, has increased the number of route-kilometers by 77 percent and reduced off-peak fares to 15 cents. Ridership has increased from 300 000 to 500 000/month, but again there is little or no information to identify the effects of each change or of the further changes that should be made to fine tune the system.

THE PROPOSED MODEL

The aim of the model is the prediction of the effects of fare changes, route relocations, headway changes, and such on either an existing or a proposed bus route. The model should be applicable on a single-route basis so that systemwide models would not be required every time a new route extension was being considered. Moreover, the data requirements should be normally available to the operator of the transit property. The model was envisaged as an operations or short-term planning model rather than as a long-term one.

The model is based on the fact that transit ridership is related directly to the existence of both population and employment within good access times of the route. It includes land use variables in a product form (population times employment) similar to the gravity model. Access time is considered for two distances, 150 and 300 m (500 and 1000 ft). The population is divided into two groups: non-automobile-owning and automobile-owning households. The effects of fares, headways, and such are determined by multiplicative factors that modify an average forecast of ridership in a demand-elasticity type of adjustment.

To make the model useful for operations planning, the demand is separated into peak and off-peak time periods, and, to exploit the predominant characteristics of transit ridership, boarding and alighting passengers and the direction of movement (whether inbound or outbound from the CBD) are considered separately.

The general form of the model is then

$$\text{Demand} = (\text{population} \times \text{employment}) \times \text{demand-adjustment factors} \qquad (1)$$

where

demand = (on or off) (inbound or outbound) (by time period),
population = (for automobile or non-automobile-owning household) (for 150 or 300 meters),

employment = (total) (retail) (school), and
demand-adjustment factors = (fare) (headway) (comfort) (automobile cost).

The model currently exists as a set of 16 equations within a computer program. The data requirements are modest, and experience thus far indicates that about 2 person-days per route are required for the data preparation for using the model. However, for calibration, which also requires ridership data, the data preparation time is closer to 3 person-weeks per route.

MODEL CALIBRATION

The model has been calibrated twice, once for Austin, Texas (3), and once for Kitchener-Waterloo, Ontario (4). The calibration results were similar. The model requires more than 60 parameters, which are generally estimated from regression analysis. The R^2 are in the range of 0.55 to 0.95 and the prediction error ($\pm 2\sigma$) is ±25 percent for a route section. There are usually five to nine sections per route.

Tables 1 and 2 contain the regression results for Austin, Texas, and Table 3 those obtained in Kitchener-Waterloo for the attraction, or nonhousehold, variables. Tables

Table 1. Model regression analysis for Austin, Texas, home-based trip ends.

		Regression Coefficients					Input Weights for SMA[a]			
		Target Household		Other Households						
Equation	Dependent Variable	Coeff.	S.D.[b]	Coeff.	S.D.[b]	Transfers	Work	Shop	School	U.T.[c]
A1	a.m. ons inbound	0.0049[d]	0.000 7	0.001 4[d]	0.000 8	5.0	1.0	0.08	0.009	9.3
A2	p.m. offs outbound	0.0059[d]	0.000 9	0.001 8[d]	0.000 1	5.0	1.0	0.44	0.012	4.8
C1	Off-peak ons inbound	0.0049[d]	0.000 53	0.000 98[d]	0.000 51	5.0	1.0	1.0	0.01	0.0
C2	Off-peak offs outbound	0.0049[d]	0.000 6	0.001 8[d]	0.000 77	5.0	1.0	0.5	0.015	0.0

Note: For α = 5%, n = 26, the critical t is 1.72 for the regression coefficients and the critical R^2 is 0.479 for equations A1, A2, C1, and C2.

[a] SMA = summation of land use variables associated with non-home-based trip ends.
[b] S.D. = Standard deviation of regression coefficient.
[c] U.T. = dummy variable for university student population.
[d] Indicates significance at the 5% level.

Table 2. Model regression analysis for Austin, Texas, non-home-based trip ends.

		Regression Coefficients			Input Weights for SMH[a]							
					Work		Shop		School		U.T.[b]	
Equation	Dependent Variable	Target Household	Other Households	Transfers	Coeff.	S.D.[c]	Coeff.	S.D.[c]	Coeff.	S.D.[c]	Coeff.	S.D.[c]
A3	a.m. offs inbound	0.0049	0.001 4	5.0	2.26[d]	0.043	0.199	0.277	0.005[d]	0.0009	2.11	3.01
A4	p.m. ons outbound	0.0059	0.001 8	5.0	0.556[d]	0.027	0.164	0.170	0.0042	0.004	2.66	1.79
C3	Off-peak offs inbound	0.0049	0.000 98	5.0	0.71[d]	0.09	0.50	0.44	0.017	0.015	0.0	–
C4	Off-peak ons outbound	0.0049	0.001 8	5.0	0.62[d]	0.05	0.30	0.24	0.0086	0.0085	0.0	–

Note: For α = 5%, n = 26, the critical t is 1.72 for the regression coefficients and the critical R^2 is 0.592 for equations A3, A4, C3, and C4.

[a] SMH = summation of land use variables associated with home-based trip ends.
[b] U.T. = dummy variable for university student population.
[c] S.D. = standard deviation of regression coefficient.
[d] Indicates significance at the 5% level.

Table 3. Regression analysis for peak-period attractions in Kitchener-Waterloo, Ontario.

	Total Employment			Retail Employment			School			University			Mainline Transfer			CBD		
Variable	Coeff.	R.C.[a]	S.D.[b]	Coeff.	R.C.[a]	S.D.[b]	Coeff.	R.C.[a]	S.D.[b]	Coeff.	R.C.[a]	S.D.[b]	Coeff.	R.C.[a]	S.D.[b]	Coeff.	R.C.[a]	S.D.[b]
a.m. off inbound	1.33	1.0	0.186	–	–	–	1.70	1.27	0.84	0.39[c]	0.29	–	0.55[c]	0.41	–	1.01[c]	0.77	–
p.m. on outbound	1.05	1.0	0.54	2.28	2.17	1.39	1.38	1.31	0.90	0.81	0.77	–	1.80[c]	1.71	–	Negative[c]	–	–
a.m. off outbound	0.80	1.0	0.18	0.31[c]	0.38	–	2.10	2.61	0.34	0.19	0.23	0.05	2.04	2.54	0.67	–	–	–
p.m. on inbound	1.26	1.0	0.13	0.50[c]	0.40	–	2.36	1.88	0.32	0.3[c]	0.25	–	3.74	2.98	0.62	–	–	–

[a] R.C. = regression coefficient relative to total employment.
[b] S.D. = standard deviation of regression coefficient.
[c] Variable did not enter stepwise regression–coefficient value if it would enter at the next step.

Table 4. Degree of fit for Austin, Texas, coefficients.

Equation	$\overline{Y}$	S.D.[a] of $\overline{Y}$	R^2	S.E.E.[b]
Home-based				
A1	26.8	23.9	0.51[c]	16.9
A2	36.1	34.2	0.46	25.4
C1	32.1	23.4	0.55[c]	15.7
C2	29.7	26.5	0.56[c]	17.6
Non-home-based				
A3	17.9	28.1	0.57	18.4
A4	36.3	32.6	0.78	15.3
C3	44.73	58.0	0.55	38.9
C4	36.48	42.5	0.71	22.9

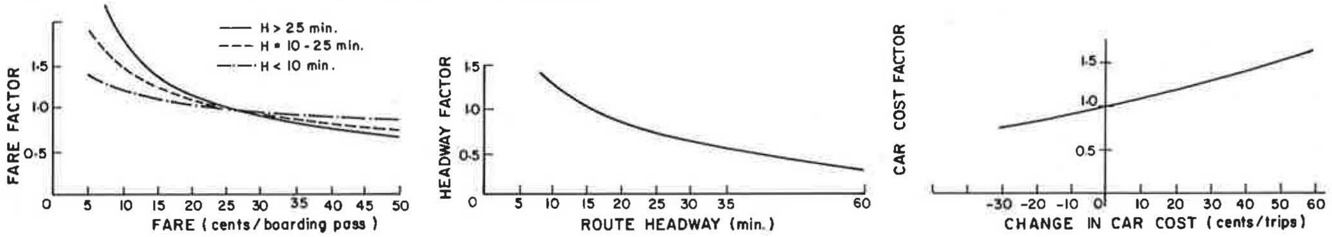
[a] S.D. = standard deviation of observed data.
[b] S.E.E. = standard error of estimate of the regression equation.
[c] Indicates significance at the 5% level.

Table 5. Degree of fit for Kitchener-Waterloo coefficients.

Variable	$\overline{Y}$	S.D.[a] of $\overline{Y}$	S.E.E.[b]
a.m. off inbound	56.72	103.7	33.5
p.m. on outbound	75.65	138.56	37.4
a.m. off outbound	39.79	67.00	37.19
p.m. on inbound	48.38	74.10	36.01

[a] S.D. = standard deviation of observed data.
[b] S.E.E. = standard error of estimate of the regression equation.

Figure 1. Proposals for fare, headway, and automobile cost factors.



4 and 5 indicate the degree of fit for the coefficients listed in Tables 1 and 2 respectively.

Figure 1 illustrates the demand-adjustment factors for fare, headway, and car cost to the CBD (generalized cost) of the model.

SUMMARY

The calibration results thus far have been promising for the two cities studied. The total route ridership is predicted with a standard deviation of about 12 percent, and the data confirm the basic model structure. Because of the large number of parameters to be estimated it has been necessary to do special field studies to validate some of them. These are currently under way.

The transferability of coefficients from one city to another is not directly possible. However, the adjustment factors (1.0, 0.5, and 1.66) required apply to the whole city. Preliminary indications are that these adjustments can be explained by general city character and climate.

The model, in controlling for differences in automobile ownership, population, access to route, headways, and such, shows considerable promise in comparing the performance of different routes and systems, and, when sufficient route data have been gathered to allow for a more confident estimate of the parameters, it should be very useful for the planning, design, and operation of urban bus routes.

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Mass Transit Guidelines Versus a Consumer Orientation in Public Transportation Systems

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This paper evaluates present and proposed mass transit guidelines that contain level-of-service criteria for public transportation. The limited scope of public transportation services that is typically contained within such guidelines is emphasized. The rationale presented supports the need for expansion of these guidelines to include the total range of public transportation alternatives and a consumer orientation. A review of the research concerning the attitudes of the ridership of transit systems illustrates the existing gap between the transit desired and that proposed in the guidelines. Areas for further research are also given, and a time frame for change in which public marketing of urban transportation systems is discussed and set in perspective is given.

The relatively recent shift from private to public transit operations and the ensuing local and state support in the form of capital and operating subsidies have caused perplexing problems for local governments. These governmental bodies traditionally have been involved with public support for such entities as police and fire protection and over the years have developed standards and appropriate cost-estimating procedures for those services. Capital and operating subsidies for public transit, however, are relatively new in many urban communities, and there are few standards and little knowledge about what should or should not be provided. Most government officials are seeking to develop standards and guidelines for public transit, the cost of which is consuming an ever-growing portion of their budgets.

The states (particularly those with bureaus of mass transit), rather than the local communities, have taken the lead in the development of guidelines for mass transit to ensure proper allocation of state-level funds for the support of local public transportation. Most notable are Pennsylvania (1), New York (2), and California: For example, Pennsylvania has had operating guidelines and standards for a statewide mass transportation assistance program since January 1973 (1).

Some individual transit authorities have also developed guidelines for service development. The most notable of these are the recent guidelines issued by the Massachusetts Bay Transportation Authority (3), Tri-Met of Portland (4), and the Denver Regional Transportation District (5). Officials in the U.S. Department of Transportation have also developed similar guidelines for public transportation (6).

LEVELS OF SERVICE

A common element of all of the guidelines mentioned above is the part entitled levels of service. This section typically lists the types of services to be offered, the frequency of such service in the form of headways, the availability of seating capacity, and special items (e.g., the density of the route network). It is also standard to include passenger-stop directives, passenger-shelter recommendations, and effective times for the trial of new service. These guidelines usually contain some directives pertaining to the marketing activity desired with respect to the provision of transit services. A few direct that if the minimum ridership levels are not achieved by the recommended level-of-service coverage, then the first alternative should be to analyze the marketing activity to determine whether the service offering is being correctly communicated to the potential markets.

An unfortunate and perhaps devastating aspect of these mass transit guidelines is the limited definition of public transportation-service offerings. That is, the level of service is assumed to be that of the traditional fixed-route, fixed-schedule transit system provided in the traditional manner of public ownership and operation. A few exceptions to this general rule are the provisions for special uses of the transit vehicle, in most cases the bus, for the downtown circulation system or for modification in a specialized program for elderly and handicapped individuals who cannot readily use the traditional system. However, federal law is mandating some form of change in traditional operating systems, and it is the threat of losing their operating subsidies that is making transit systems modify their fixed-route, fixed-schedule service to provide access for the handicapped and the indigent elderly.

A few systems such as the Denver Regional Transportation District are considering the use of paratransit options in the future. The Massachusetts Bay Transportation Authority does provide for the transfer of public transit operations to private operators when private operations appear to be more economical—of course with the provision of a protective labor clause that guarantees that no individual employee will be disadvantaged by such an operation. While it is encouraging to see such plans in a few operating systems, this should be set in the perspective that these are merely operational plans and are not yet implemented. Throughout the industry, the general rule is that many operational guidelines are aimed at maintaining a single service—the fixed-route, fixed-schedule transit system that has historically been unacceptable to the American consumer if the alternative of the private automobile was available.

The unfortunate aspect of these operational guidelines is that they may become the justification for the expenditure of funds for traditional transit systems in an environment of declining resources, and it is possible that urban areas that presently have funds to improve public transportation will find themselves building extensive fixed-route, fixed-schedule grid systems that are used only by captive riders who lack other alternatives. Another ironic note is that such guidelines can and are being used by larger urban areas in financial difficulty as the justification for cutting services that are not patronized by a sufficient number of individuals. In essence, plans for improvement and development in public transit are being used in many urban areas as a rationale for cutbacks in service. At the same time, the cost of this service is becoming continually greater to urban and rural taxpayers alike.

There is obvious need for a rethinking and subsequent revising of mass transit guidelines. Before public sentiment is completely eroded, there should be a reconsideration of the types of public transit services that truly meet consumer needs and an attempt to achieve the energy and pollution goals now being sought by federal, state, and local governments. The Mass Transportation Act of 1974 provided $12.9 billion for the improvement of public transportation over the ensuing 6 years. As the midpoint of this period approaches, those involved should recognize that in actuality little has been accomplished by the massive inputs of federal, state, and local moneys aimed at improving public transportation in urban areas. Major improvements have been made in rolling stock, physical facilities, and the wages of those involved in the provision of public transportation services; however, the output figures are dismally poor. There have been few increases in ridership, and this indicates a failure to decrease the emphasis on automobile traffic and to obtain the ensuing reduction in energy use and pollution. The time for action and change in direction is now.

REDEFINITION

The major point to be emphasized in this discussion of mass transit guidelines is the need for redefinition and expansion of the term level of service. The level of service provided should not be restricted to traditional transit and its variations in the form of express routes, route deviations, and such. Rather, the term should encompass all service offerings and combinations presently known to exist in the urban environment. This would include variations in the size of the bus, vans, taxis, and pools (either automobile, van, or bus operation). A complete range of service offerings would even include the jitney service.

The concept of levels of service should include all of the following:

1. Private automobile,
2. Rental automobile,
3. Car pool,
4. Van pool,
5. Taxi,
6. Jitney,
7. Subscription automobile or bus pool,
8. Charter,
9. Traditional tailored service (trippers)
10. Traditional route deviation,
11. Traditional express service,
12. Traditional transit,

13. Bicycle, and
14. Walking.

Fixed-route, fixed-schedule traditional transit service is only one of the services in this continuum. It is only by the recognition of this spectrum of service that there can be more understanding of the interaction of the levels of service provided by various alternatives and of the markets attracted by those levels of service. Only through an understanding of the attributes of ridership and of why individuals choose a particular mode will it be possible to develop standards for the appropriate level of service to be provided by a given service alternative and to communicate its availability and attractiveness to the potential user.

URBAN TRANSPORTATION MODE-CHOICE RESEARCH

Historically, transportation modal-choice research has been conducted by engineers. The typical origin-destination study counts the present traffic and determines the anticipated demand by using projection techniques. These techniques have worked well in planning for peak highway capacity, but they are inadequate for forecasting the expected demands of ridership choice by users of public transportation.

Many of these often simplistic mathematical models assume that individuals base modal decisions on strictly economic criteria. Typically, in this procedure, a mode-split analysis, based on specified performance characteristics of the transit system and selected socioeconomic characteristics of the trip mode, is used to forecast the aggregate demand for transit services. Unfortunately, the construction of such a theoretical model often uses a black box or unknown understanding of the specific mode choices made by consumers of public transportation alternatives.

More recently, consumer-attitude research developed from marketing research has been used to gain a deeper understanding of transportation mode choice in urban transportation. Analysis of this research by Mundy (7), Soloman, Soloman, and Sellien (8), Hille and Martin (9), and Lovelock (10) indicates that the significant variables in modal-choice behavior of urban consumers are safety, reliability, time savings, cost, convenience, and comfort. While the order of importance among these variables varies from study to study, they are consistently the ones that influence consumer behavior.

Although research in this area is recent, it is beginning to impact the planning for future transportation systems. For example, a recent article by Stein (11) concluded that "attitude surveys can be used to assess reactions to existing transportation facilities and improvements or to predict future travel behavior." An interesting review by Wachs (12) demonstrates the types of conclusions that can be reached through an analysis of consumer-attitude research. For example, consumers are extremely sensitive to urban transportation travel time. Travelers on the Shirley Highway Express Bus-on-Freeway System in Washington, D.C., have switched from their private automobiles in order to save time. Other amenities such as cost, lack of congestion, and comfort are secondary in importance. However, consistency and reliability of arrival time are more significant than total travel time.

More surprisingly, attitudinal research has shown that cost does not play the significant role in the choice of transportation mode that some have thought. The interpretation of such studies suggests that, in the relative range, cost is more dependent on the perceived level of service received. A poor service, no matter how inexpensive, will be perceived as being too expensive, and on the other hand, a transit service that meets the perceived expectations of the consumer can charge a premium without detracting from ridership interest. This concept is becoming well-known and understood by researchers in the area of urban transit, but appears to be incomprehensible to many transit operators and politicians.

In the comparison of attitudes toward public transit versus the private automobile, many of the alternatives among public transportation services have been completely neglected. But, in considering public transportation levels of service and alternatives, a complete range of the alternatives must be considered to gain a total appreciation of those options that may or may not be made available to urban consumers.

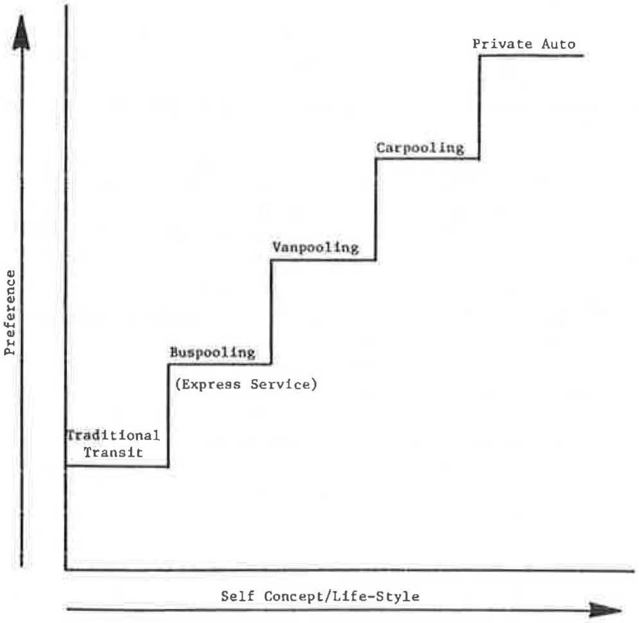
Consumer-related research indicates much about the urban traveler; however, there are many blank areas. For example, much is known about the user who is a transit captive. (This individual is readily accessible for answering opinion surveys while a captive on a public transit system.) The focus has only recently shifted to the noncaptive rider, the nonuser of public transit. Then, all too often, attempts are made to compare the attributes of the private automobile with the attributes of the public transit system and their respective levels of satisfaction. Such research is less than intelligently thought through and its results are, at best, inconclusive (13).

There is a broad spectrum of alternatives between the traditional fixed-route, fixed-schedule system and the private automobile. These alternatives should be considered, even though satisfaction data may or may not be appropriate in assessing true motives for modal-choice behavior. The conceptual differences of mode-choice behavior between these two alternatives are immense. For example, for many potential urban consumers of public transportation, choice of travel mode is not a simple continuum but a series of step functions. Figure 1 depicts the service alternatives and corresponding levels of service thought to be desired by most urban commuters. As one moves down from the private automobile, both consumer preferences and life-styles are threatened. It should be understood that requesting a change in personal travel mode is requesting a change in life-style, and perhaps in the personal perception of one's station in life.

Consumer researchers have a clear picture of the transit captive and what he or she desires from the public transit system: This is, of course, more direct service, shorter headways, more seating, and greater comfort. Also needed, however, are ridership profiles of the occasional rider. For example, what is the difficulty experienced by the occasional rider in attempting to use the traditional system? Is it readily accessible to that individual? What threshold levels of information are necessary to enable the casual rider to participate in the system? Through some very hard and expensive lessons, transit systems and authorities, bureaus of mass transit, and the federal government are beginning to realize that the nonpublic transit riders (those who have a true choice) cannot be persuaded to use a system that does not meet their personal needs by any amount of advertising. Many well-planned federal programs have failed to meet the consumer needs and to accomplish even the minimal goals and objectives set forth by Congress in appropriating vast sums of money for their purposes.

Demonstration projects and the appropriate testing of consumer attitudes toward them lead to a better understanding of the relationship between a service alternative, its level of service, and the markets attracted

Figure 1. Step function approach to urban transportation commuter mode-choice behavior.



by such service. As the attitudinal survey on the Shirley Highway Express Bus-on-Freeway System showed, time sensitivity is one of the most, if not the most, important variable in mode selection. This time concern reaches across all of the socioeconomic and demographic variables and affects a wide range of market potential. Much more experimentation, however, is needed with smaller vehicles, van pools, shared-ride taxis, and other similar systems. Only consumer attitudinal research on these demonstration systems will lead to a better understanding of the dynamics of the choice, which will make it possible to develop a comprehensive planning approach to public transportation offerings.

For example, in Knoxville, Tennessee, the current van-pool demonstration program is carrying as many riders as is the extensive express bus service. After legal, regulatory, and insurance problems were reduced as obstacles to private van operators, this new alternative to the automobile captured 1 percent of the consumer work-trip market in the first 6 months of its operation. (From a marketing or product penetration concept, 1 percent of the market in the initial 6-month period is an amazing success story.)

TIME FRAME FOR CHANGE

Life-styles, especially perceptions of one's own life-style, change very slowly. Individual mode choice for personal transportation will change gradually. To those who are seeking answers to problems of national energy shortages and urban pollution, the experience with revitalization improvements for traditional transit systems has been very disheartening. The one bright spot in accomplishing national goals has been the relatively enthusiastic acceptance of vans and van pools as acceptable alternatives to the private automobile.

As knowledge about urban transportation-service alternatives and the various levels of service within these alternatives increases, it is becoming apparent that new institutions or structures for providing public transportation services in urban areas are needed. The integration of traditional and paratransit services in a regulatory and organizational framework has been discussed elsewhere (14). However, merely diminishing regulatory and financial barriers and creating new organizations for providing public transportation will not by themselves bring about changes in consumer life-style with respect to mode-choice behavior.

At a minimum, a 5-year trial time will be needed to test many of the suggestions made as a result of consumer attitudinal research, and it will be the smaller and medium-sized communities that initially implement such changes and service offerings. Major changes in large metropolitan areas will come later, after comprehensive knowledge of the relationship between levels of service and the various markets attracted is developed.

However, certain kinds of cost-cutting measures can be very useful in large urban areas. The growth of contracted peak-hour commuter services such as Colonial Transit in the Washington, D.C., metropolitan area indicates a large potential commuter market willing to participate in express commuter services when they are offered. Colonial Transit began with a single vehicle a few years ago and is now a profitable multimillion dollar operation. In other urban areas this demand has become so strong that consumer groups have themselves formed bus pools to provide their own service.

It is significant that the specific problems of today are operational or management-oriented—they are not technological problems. These institutional and regulatory management problems can be solved with existing, well-understood techniques. Funds for and appreciation of consumer attitude research must be provided if these techniques are to be helpful in bringing about changes in urban public transportation. For the interim period at least, technology alone will not solve urban transportation problems, and funds currently directed toward research and development might better be spent in resolving regulatory and management problems. Technology and the development of transportation systems should not be forgotten in the long run, but in the very short run, more concern should be directed toward operationalizing what is becoming known and understood about urban transportation.

SUMMARY

This paper has reviewed existing mass transit guidelines and their emphasis on levels of service. It has attempted to show that a much broader definition of transit service alternatives (and the levels of service within these alternatives) is necessary to develop urban public transportation systems that meet consumer needs and desires. While there have been significant advances toward understanding urban transportation modal choice through consumer-attitude research, much yet needs to be done. Only by filling in the blanks about various transportation service alternatives and the reasons for their attractiveness to various target markets can one fully appreciate and comprehend the dynamics of the urban transportation mode-choice decision-making process. But such an understanding and a restructuring of the regulatory, financial, and institutional structures responsible for the development, implementation, and management of public transportation systems are required before the national goals of energy conservation, pollution control, and increased mobility for all citizens set forth by the federal government can be met. Much can be achieved through efficient, effective public transportation; however, it must also be recognized that in a free society mode-choice decisions are a right of the consumer. This freedom of choice is a constant challenge that requires continued change in service offerings, and it should be the concern of responsible planners and developers of public transportation that the systems developed are those that are desired and acceptable.

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Bus Passenger Service-Time Distributions

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The characteristics of bus passenger service-time distributions are a necessary input for the transportation simulation models that are used to evaluate the operations of street transit systems. In this paper, distributions of passenger service times through bus doors (the rates at which passengers entered, passed through, and departed from the bus) are analyzed by photographic studies and simulated by an Erlang function. These mathematical expressions simulating the passenger rates of flow entering and departing from a bus are compared with the observed times; the differences are not significant at the 95 percent level. The results of this research can be used to analyze a series of bus transit-flow situations and may serve as guidelines in assisting the designer and operator in evaluating existing or proposed bus systems. Specific models could be developed to evaluate the effects of the method of fare collection on passenger queue lengths and average waiting time under different rates of passenger arrivals. The overall design of bus transit vehicles has been shown to affect passenger flows in relation to such items as fare collection and in the use of door(s) for boarding and alighting.

The characteristics of bus passenger service-time distributions are necessary for the evaluation of street transit systems by the use of simulation models. This paper analyzes photographic studies of passenger movements through bus doors and shows that an Erlang function can represent the service-time distributions in the simulation process.

The door of a street transit vehicle can be viewed as a single-server queueing model. Passengers arrive at a certain rate, pass through a service area, and depart at another rate. The rate of departure depends on how fast they pass through the service area. A simulation model that uses generalized arrival and departure rates for transit stations has been developed by Fausch (1).

Simulation models of the type developed by Fausch are tools that can be used to evaluate the operations of street transit systems. The information necessary for such a simulation includes data on the capacity of bus doors and on the arrival and service-time distributions of passengers. Under maximum capacity conditions, the alighting or boarding of passengers invariably occurs in a group. In other words, when a bus arrives at a stop, the passengers to board are already waiting and alighting passengers are waiting in the vehicle. The service-time distribution, however, is not the same for boarding and alighting passengers as it depends on factors that affect the interaction between passengers and vehicles. Those factors include human characteristics, modal characteristics, operating policies, mobility, climate and weather, and other system elements (2).

Photographic studies were taken to aid in analyzing the service-time distributions of passengers. These involved filming individual passengers alighting and boarding from the front doors of buses in San Diego; Montreal; and New Brunswick, New Jersey, in 1974. This information is summarized below.

Item	Montreal	San Diego	New Brunswick
Service	Local	Local	Suburban
Day of week	Wednesday or Thursday	Wednesday or Friday	Monday or Tuesday
Date	July 17 or 18	December 4 or 6	April 29 and June 18
Method of fare collection	Pay-enter (cash and change)	Pay-enter (exact fare)	Pay-enter (cash and change)
Type of fare	Flat, mixed	Flat, mixed	Multiple zone, cash
Number of buses observed	30	25	23
Number of passengers observed	412	233	411
Men	125	127	326
Women	286	105	83
Children	1	1	2

All photographs were taken at a nominal speed of 18 frames/s, with an 8-mm movie camera equipped with an f/1.8 zoom lens that could vary focal lengths from 7 to 70 mm. The number of frames required for each person to pass through the portal of the bus was recorded, the passengers were classified as to men, women, and children, and the type and number of items that they carried were noted. The information was keypunched and tabulated by computer.

ANALYSIS OF DATA

There were two areas of analysis. One was the study of the time sequence of the passengers in the order that they boarded the bus, and the other was the determination of service-time distribution characteristics for boarding and alighting passengers.

Time Sequence of Passengers

The average service times of the first 18 passengers in boarding sequence in San Diego and Montreal were studied by using the analysis of variance (ANOVA) technique. As might be expected with counting data, the cell variances were not equal but were proportional to the cell means. Homogeneity of variance was obtained by using a logarithmic transformation and a two-factor ANOVA. A plot of the cell means is shown in Figure 1 and indicates that the time for the first passenger is generally less than that for succeeding passengers. This is due to the availability of storage area on the steps between the bus door and the driver.

By using the results of ANOVA and analyzing Tukey's limits for multiple comparisons at the 5 percent level, the time differences between the first and third through the nth passenger were shown to be statistically significant at the 95 percent level. The time differences between the second and all other passengers were not statistically significant at the 95 percent level.

Service-Time Distribution

The means and variances of the service-time distributions for each successive person to pass through the vehicle door were calculated to assist in determining the mathematical function that could be used to represent the distributions in the simulation model.

Several forms of service-time distributions including the Gamma function, the Erlang function, and the uniform distribution function have been used in the development of queueing models. The most commonly used is the negative exponential function, a special case of the Erlang function (1, 3, 4).

The probability density functions for each of the distribution forms were plotted to view their general shape, and from these observations, it was hypothesized that the distributions could be described by the following Erlang function (3):

$$P(g \geqslant t) = \left\{ \sum_{i=0}^{K-1} [K(t-\tau)/(\bar{t}-\tau)]^i \, e/i! \right\}^{-K(t-\tau)/(\bar{t}-\tau)} \qquad (1)$$

where

$P(g \geq t)$ = probability that time g is greater than or equal to time t,
K = positive integer,
t = any service time,
$\bar{t}$ = average service time, and
τ = minimum service time.

The individual means and variances were then used to calculate an Erlang function for each distribution. Integer values of K were estimated from the mean (t) variance (s^2) and the minimum service time (τ) by the following:

$$K \approx (\bar{t}-\tau)^2/s^2 \qquad (2)$$

These initial K-values were adjusted as necessary to improve the goodness of fit between the observed and calculated distributions. Table 1 lists the parameters of the observed passenger service-time distributions and the derived Erlang functions.

The K-value of 1 indicates that the two distributions for the one-door buses are represented by the negative exponential function, a special case of the Erlang function. Figure 2 shows the observed values and the calculated functions for alighting passengers in New Brunswick and boarding passengers in San Diego.

To check the mathematical validity of these results, the distributions of the observed and calculated functions were compared by a chi-square test. In all cases, the test results did not reject the hypothesis that the distributions were the same at the 95 percent level. Hence, it can be concluded that passenger service-time distributions can be represented by an Erlang function. It can also be inferred that K is equal to the number of doors on the vehicle and that the minimum service time (τ) is approximately half the average service time ($\bar{t}$). These results can be used to estimate any particular passenger service-time distribution if the minimum and average service times are known and K can be estimated.

ANALYSIS OF RESULTS

Two approaches were used to analyze the results of this research. One was a comparison between the data obtained by manual surveys of the time required for an entire queue to board the vehicle and the data obtained by the photographic studies of individual passenger service time. The other was a comparison between service-time distributions and stairway-service standards.

Figure 1. Average service times of passengers in the sequence in which they boarded.

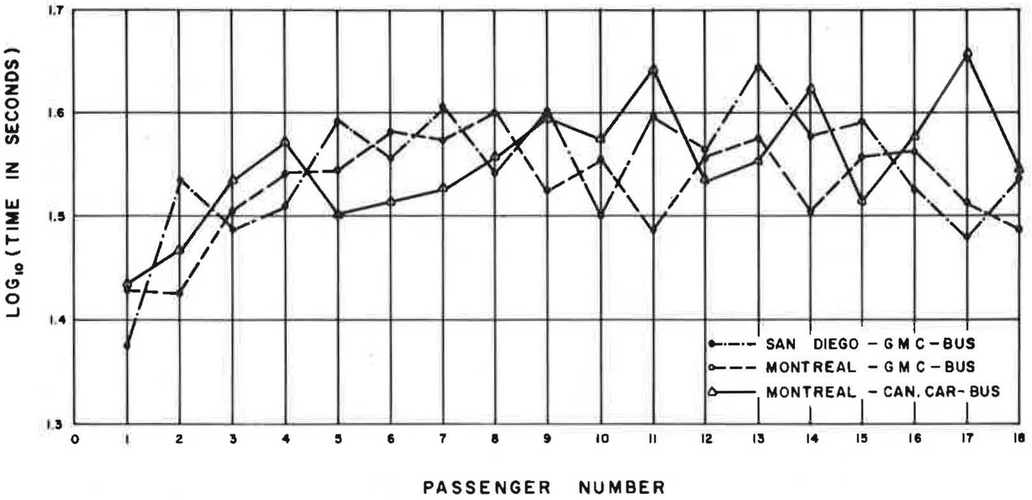


Table 1. Parameters of observed passenger service-time distributions and derived Erlang functions.

Location	Direction of Flow	Number of Doors on Bus	Observed Time (s)		Erlang Parameters		
			Mean	Variance	K	$\bar{t}$ (s)	τ (s)
Montreal	Boarding	2	2.097	0.727	2	2.097	0.90
Montreal	Boarding	2	2.034	0.834	2	2.034	1.25
New Brunswick	Alighting	1	1.972	1.045	1	1.972	0.95
New Brunswick	Boarding	1	3.471	3.499	1	3.471	1.75
San Diego	Alighting	2	1.472	0.403	2	1.472	0.75
San Diego	Boarding	2	2.180	0.868	2	2.180	0.75

Since the individual service times can be represented by an Erlang distribution, it should be possible to derive regression equations for the time required for varying sizes of queues to enter a bus. The validity of such derived equations could then be checked by comparing them with the equations developed from the observed data. This process was followed to develop a simulation model for use in determining the amount of time that it would take a specified number of passengers to board a bus.

Development of Simulation Model

The model to simulate the boarding of passengers at a loading area was constructed as a single sequence of blocks, as shown in Figure 3. Basically, the model generates any specified number of passengers to arrive at the bus instantaneously. The first passenger in line captures the door, leaves the line, and passes through the door on the basis of a randomly selected value from the Erlang service-time functions previously derived. He or she then frees the door and enters the bus. At that time, the next passenger captures the door and the process continues.

The second segment of the model is a timer that puts a limit on the amount of time the model can simulate. The longest limit is usually set at the amount that could be expected if all maximum service times were used.

The simulation model was run twice for each integer in the range of values of the observed regression equations; i.e., if the original observed regression equation had values between 6 and 25, then the derived regression equations were run twice for each of the values between 6 and 25. Actually, only five of the six Erlang functions were simulated because the observations of the boarding passengers in New Brunswick were too few in number and clustered in too narrow a range to develop a meaningful observed regression equation.

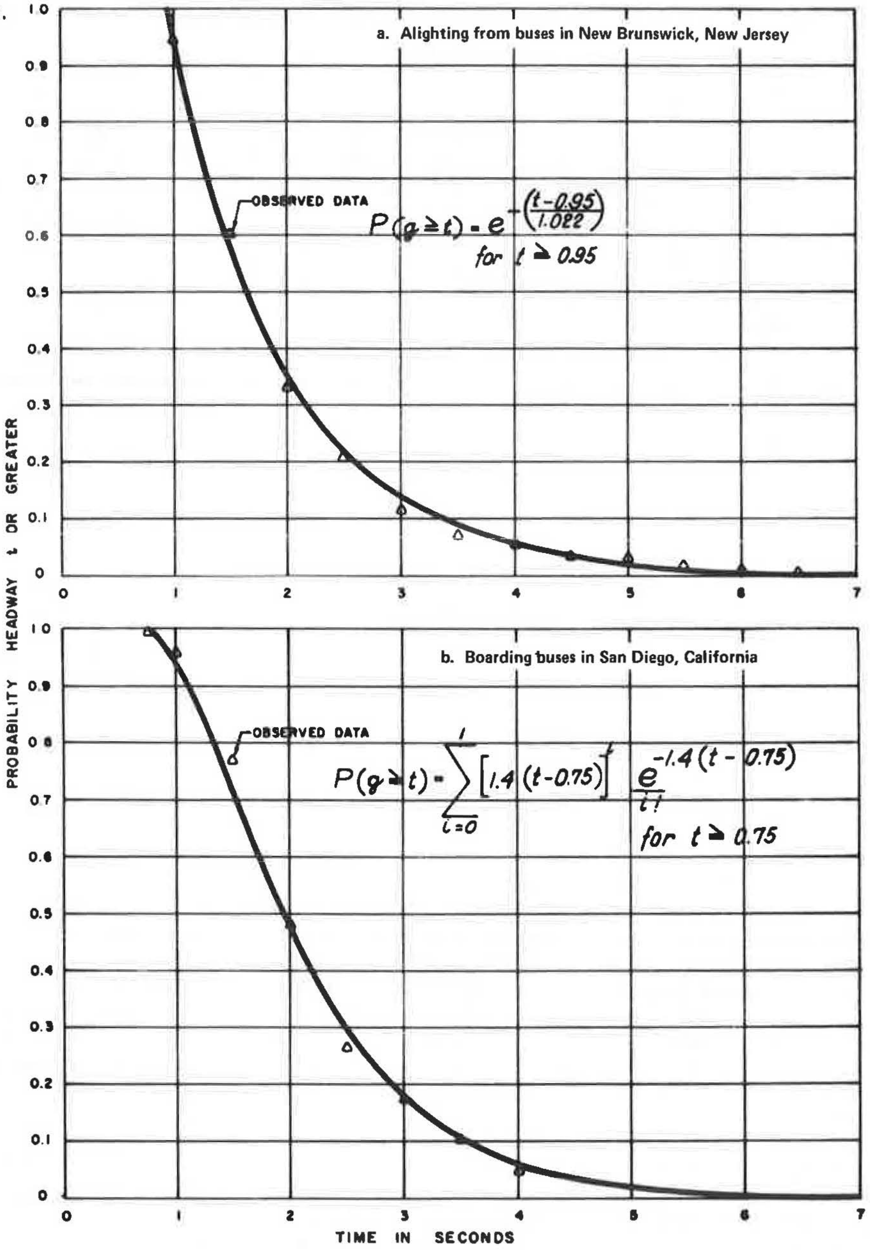
The simulated equations were compared with the observed equations by using an F-test for the variances of estimate and a t-test for the slopes. This comparison is shown in Table 2. All of the F-tests and four of the five t-tests indicated that the differences were not statistically significant at the 95 percent level. The fifth t-test indicated that the difference was not statistically significant at the 98 percent level. Thus, the simulation results were consistent with the observed data.

Comparison of Service-Time Distributions With Stairway-Service Standards

Fruin has shown that the maximum flow volumes for persons ascending and descending stairs are 62 to 66 persons/min/m (18.9 and 20.0 persons/min/ft) of stair width respectively (5). These results are similar to the values of 62 and 69 recommended by Hankin and Wright as design criteria for the London Subways (6). The average service times previously discussed were transformed into similar flow rates, as shown in Table 3.

For both directions of flow, the maximum observed values are less than those observed by Fruin and recommended by Hankin. These results are logical for a number of reasons. The riser height on bus stairs is normally higher than that on building stairs [23 to 25 cm versus 15 to 20 cm (9 to 10 in versus 6 to 8 in)] and would be expected to result in slower climbing speeds. Since the fare or method of fare collection should have no effect on alighting, the different flows shown in Table 3 for alighting are probably due to the effects of baggage. The boarding flows are different because they are affected by baggage, fare, and method of fare collection.

Figure 2. Service-time distribution of passengers.



APPLICATIONS

The results of this research can be used by the transit operator, the terminal designer, and the transit-vehicle manufacturer to evaluate certain aspects of existing or proposed systems. Specific models can be developed to evaluate the effects of different methods (such as pay-enter versus pay-leave) of fare collection. Other models can be developed to evaluate the effects of using single-flow doors versus double-flow doors and of using various combinations of front and rear doors for boarding and alighting. As an example, the following model was developed to evaluate the effects of method of fare collection on queue length and average waiting times under varying rates of passenger arrivals.

Example Simulation of Terminal Loading Platform

At a typical terminal loading platform, empty buses arrive at the platform every 5 min. Each bus begins to receive passengers as soon as it has stopped and its front door has been opened. Passengers continue to board for 4.5 min. Then the last passenger is permitted to finish boarding, the door closes, and the bus departs. The next bus arrives 5 min after the first had arrived.

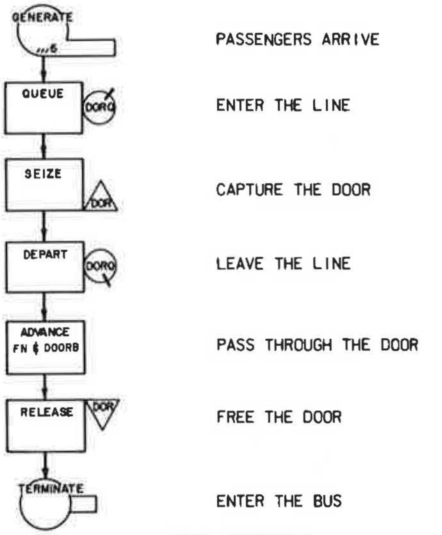
Passengers arrive at the platform in a Poisson stream at a rate of 300 to 1100 passengers/h. They board the empty bus until all 50 seats are filled and then continue to board at a slower rate due to the effect of the standees (it is assumed that boarding times are 20 percent greater when standees are present). Both boarding service-time distributions are represented by the following negative exponential function:

$$P(g \geq t) = \exp[-(t - \tau)/(\bar{t} - \tau)] \tag{3}$$

The parameters used for each function in the simulation model are shown below.

Method of Fare Collection	Presence of Standees	Parameters	
		$\bar{t}$	τ
Pay-enter	No	7.06	3.53
	Yes	8.50	4.25
Pay-leave	No	3.70	1.85
	Yes	4.44	2.22

Figure 3. Block diagram of simulation model for validation tests.



a. MODEL SEGMENT 1

b MODEL SEGMENT 2

Table 2. Comparison of test statistics with tabular values for validation tests.

Location	Direction of Flow	F-test		t-test	
		Value	Statistic at 95% Level	Value	Statistic at 95% Level
Montreal	Boarding	1.00	2.91	1.72	2.02
Montreal	Boarding	1.46	2.15	2.33	2.39[a]
New Brunswick	Alighting	1.56	1.75	1.26	2.00
San Diego	Alighting	1.19	2.25	0.60	2.03
San Diego	Boarding	1.71	1.73	0.10	1.99

[a] At 98% level.

Table 3. Maximum observed flow rates through front door of bus.

Direction of Flow	Fare	Passengers Carrying One or More Items (%)	Maximum Observed Flow (persons/min/m)
Alighting (down)	Flat, exact fare[a]	55	53.5
	Multiple zone, cash and change[a]	82	39.6
Boarding (up)	Flat, exact fare	52	36.1
	Flat, cash and change	81	38.7
	Multiple zone, cash and change	78	22.6

Note: 1m = 3.3 ft.

[a] No fare was collected from alighting passengers.

The minimum service times were assumed to be one-half the average service time, which is consistent with the above information. The sequence for boarding is on a first-come, first-served basis. Persons who arrive at the stop while a bus is loading will be able to board during the 4.5-min period that the bus accepts

Figure 4. Example–block diagram for passenger model.

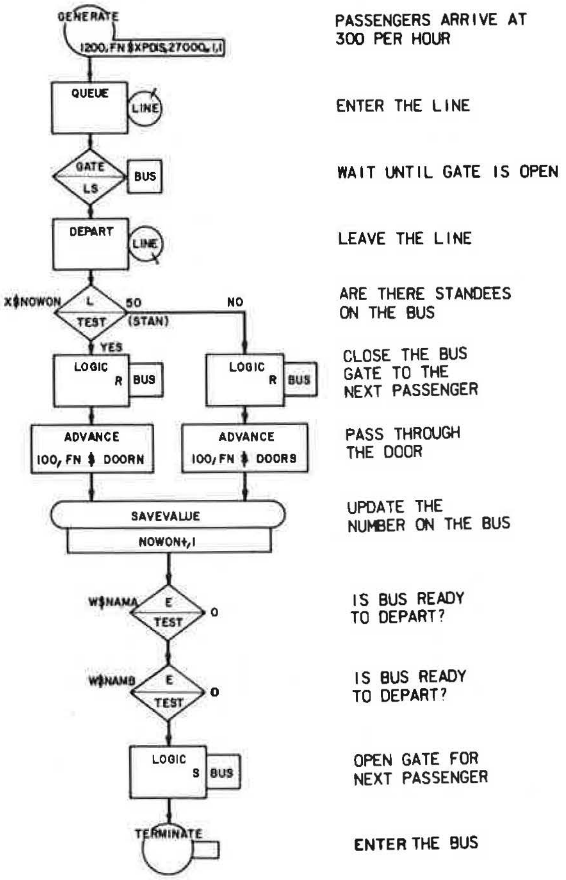


Figure 5. Example–block diagram for bus model.

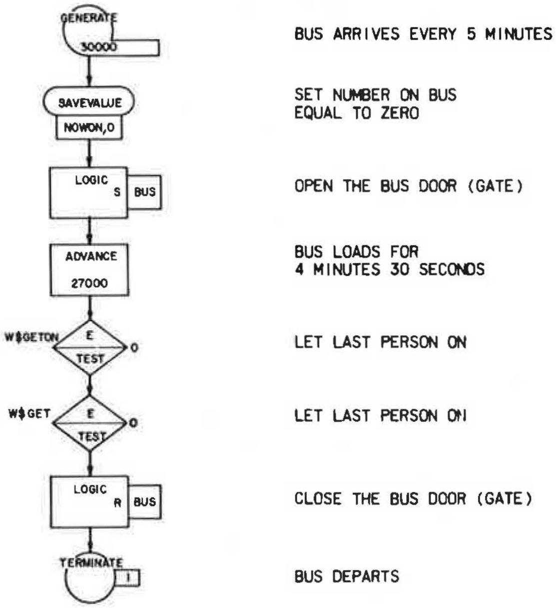


Table 4. Example—program output for pay-enter method of fare collection.

	Passengers per Hour						
Output	300	400	500	600	700	800	900
Total passengers arriving	318	407	495	582	682	778	884
Total passengers on bus	318	391	478	563	574	574	574
Number of standees	0	2	2	10	13	13	13
Number of zero entries	61	7	1	0	0	0	0
Percentage of zero entries	19.1	1.7	0.2	0	0	0	0
Maximum queue	30	43	33	55	117	204	310
Average queue	5.08	15.67	15.10	26.15	61.08	104.90	149.51
Average time per passenger in queue, s	62.76	149.04	118.10	173.88	346.57	521.81	654.54

Table 5. Example—program output for pay-leave method of fare collection.

	Passengers per Hour								
Output	300	400	500	600	700	800	900	1000	1100
Total passengers arriving	313	407	498	582	683	778	884	987	1095
Total passengers on bus	313	407	498	582	682	778	842	845	845
Number of standees	0	0	2	32	89	178	242	245	245
Number of zero entries	170	200	214	189	142	63	2	0	0
Percentage of zero entries	54.3	49.1	42.9	32.4	20.7	8.0	0.2	0	0
Maximum queue	6	8	7	10	13	30	49	143	255
Average queue	0.29	0.52	0.51	1.15	2.41	6.50	25.83	68.15	114.95
Average time per passenger in queue, s	3.62	4.93	4.00	7.62	13.69	32.36	113.20	267.30	406.41

passengers. Those not able to board that bus must wait in the queue until the next bus arrives and opens its door. (The model does not limit the number of passengers that can board due to the capacity of the bus. If bus capacity is a critical factor, then appropriate changes to the model should be made. Bus capacity was not a critical factor in this example because of the passenger flows used.) The simulation model is built in two segments. Model segment 1 simulates the passengers who arrive at the bus stop, wait for the bus, and board. Model segment 2 simulates the bus. The generalized programming service standards (GPSS) entities are defined below.

GPSS Entity	Interpretation
Transactions	
Model segment 1	Passenger
Model segment 2	Bus
Functions	
XPDIS	Exponential distribution function
DOORN	Distribution of boarding service times—no standees
DOORS	Distribution of boarding service times—standees
Logic switches	
BUS	When set indicates that the bus is at the stop and ready to load passengers
LINE	Queue in which people wait until the bus comes and they can board
Savevalues	
NOWON	Counter to keep track of the number of people on the bus
Tables	
INQUE	Table used to estimate the in-queue residence time distribution

Model Segment 1

Passengers are generated at a rate of 300 to 1100/h by 100-passenger increments. The first passenger arrives 4.5 min from the start of the simulation. This permits queueing for 0.5 min until the bus arrives; thereby a steady state condition is reached almost immediately. Passengers are given a priority level of 1 so that, if a passenger arrives at the time that the bus is ready to close its door, the passenger has priority and is permitted to board. The number of parameters for each transaction (boarding passenger) has been reduced to one to minimize the core storage that is used.

After the passenger is generated, he or she enters the queue and waits until the bus gate is opened. After the gate is opened, the passenger leaves the line and a test is made to determine whether more than 50 passengers are on the bus. If there are fewer than 50, the passenger boards according to the DOORN distribution. If there are more than 50 (indicating standees), the passenger boards according to the DOORS distribution. After the passenger has boarded, the number of persons on the bus is updated by one and the passenger gate is opened for the next passenger if the bus is not ready to depart. A block diagram of model segment 1 is shown in Figure 4.

Model Segment 2

A bus arrives every 5 min, opens its door, and loads for a period of 4.5 min. A test is then made to see whether the last person is still boarding. The bus waits until the last person has boarded and then the bus gate is closed. The bus then leaves the model. A block diagram for the bus model is shown in Figure 5.

Program Output

The simulation model was run for both the pay-enter and pay-leave methods of fare collection. In each case, 12 buses were loaded with passenger arrivals ranging from 300 to 1100/h at 100-passenger increments.

The output of each of the model runs includes the total number of passengers in the queue, the total number of passengers on the bus, the number of standees, the number of zero entries (i.e., the number of passengers that could board without waiting in the queue), the percentage of zero entries, the maximum queue, the average queue, the average in-queue residence time in seconds, and a frequency distribution of in-queue residence time. This information, except for the distribution of in-queue residence time, is given in Tables

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:

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

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.

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

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

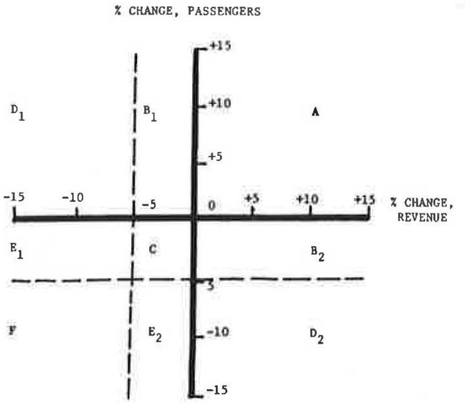
Because ridership and revenue levels are influenced by transit-demand elasticity, and because that elasticity varies from city to city (Table 1), the effect of differential fares will also vary among cities. Generally, elasticities are lower in larger cities; that is, there is a lower percentage change 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.

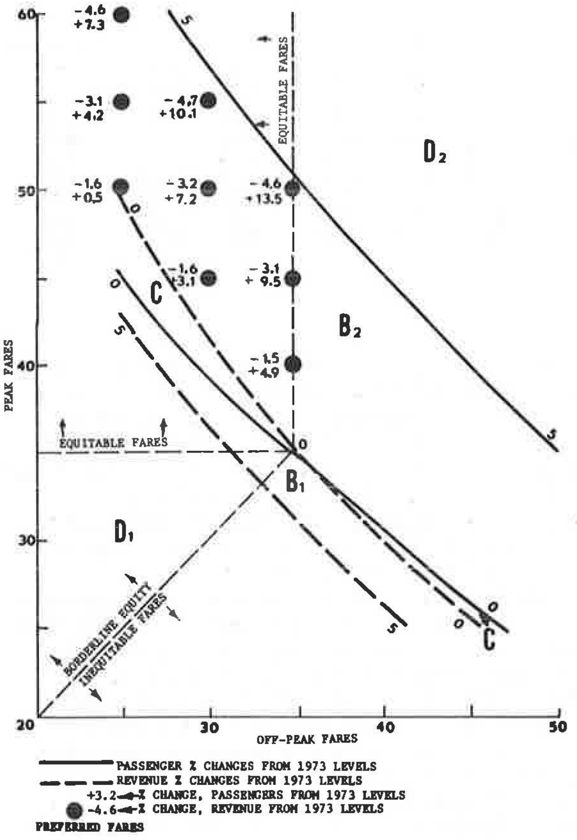


Figure 4. Passenger and revenue effects of combination fares: Buffalo.

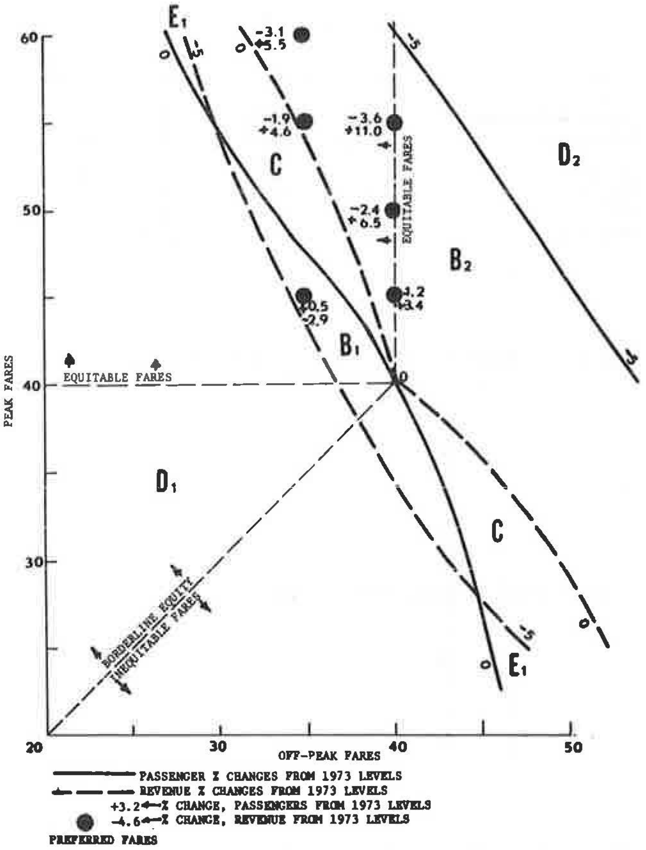


Figure 3. Passenger and revenue effects of combination fares: New York City public bus.

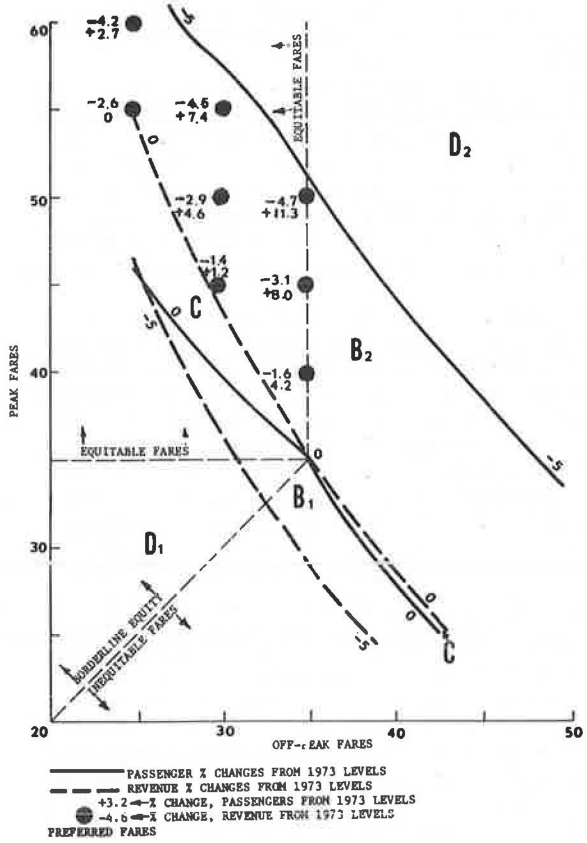


Figure 5. Passenger and revenue effects of combination fares: Capital District (Albany-Schenectady-Troy).

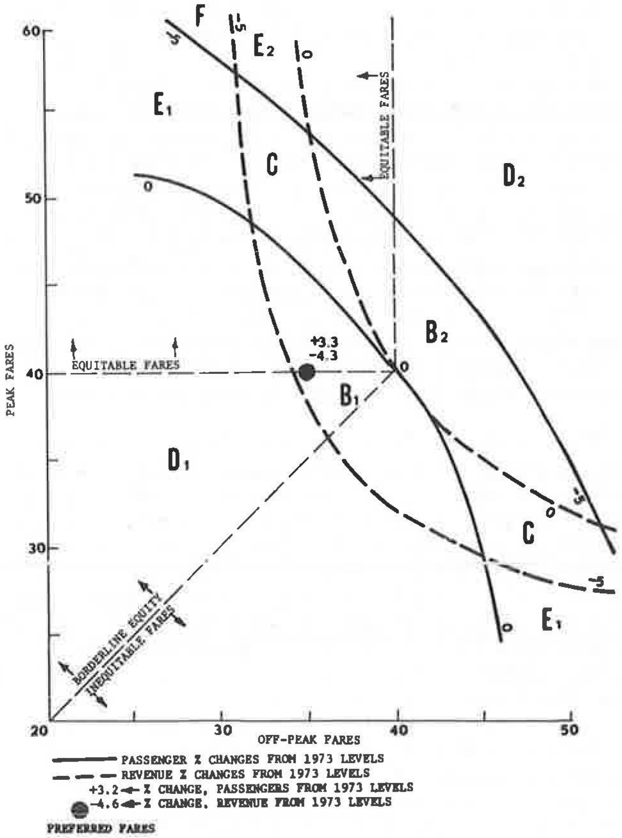


Figure 6. Passenger and revenue effects of combination fares: Rochester.

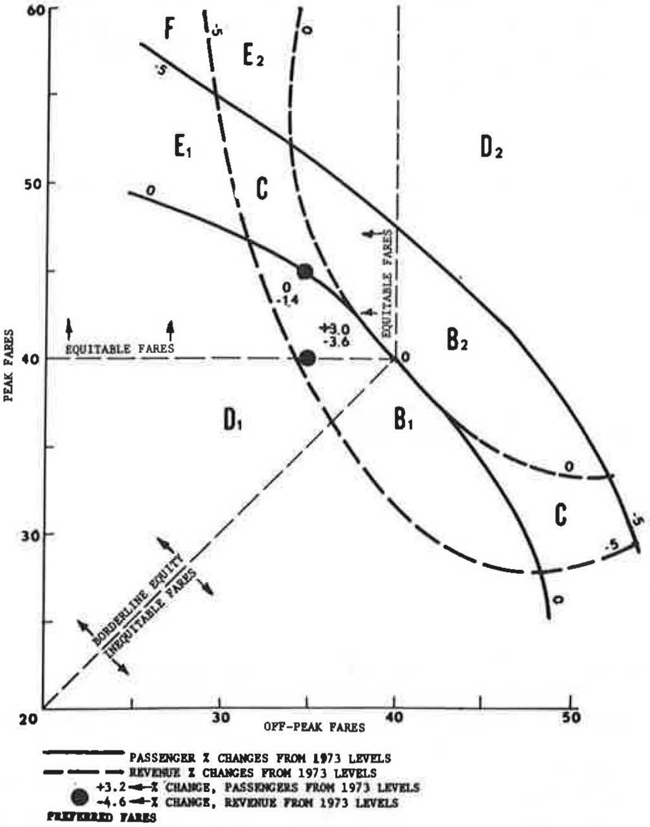


Figure 7. Passenger and revenue effects of combination fares: Syracuse.

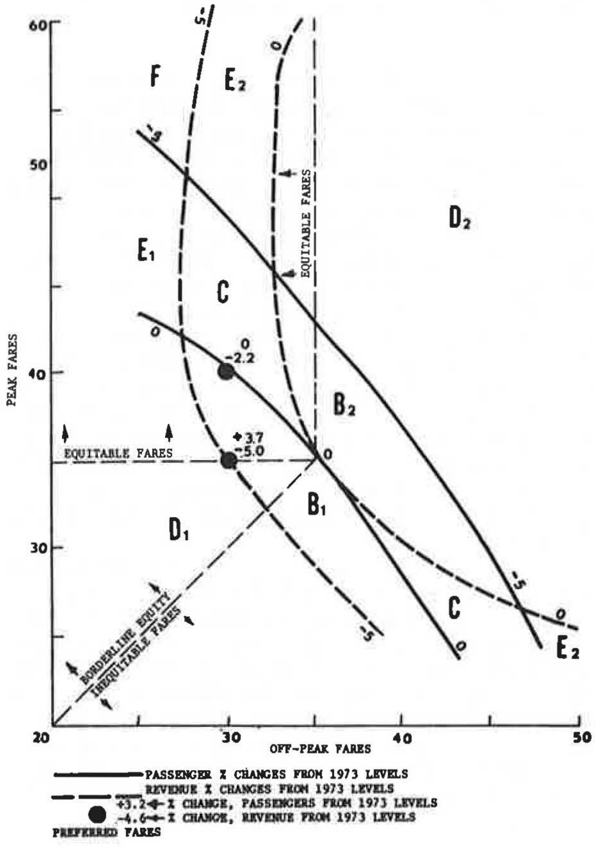
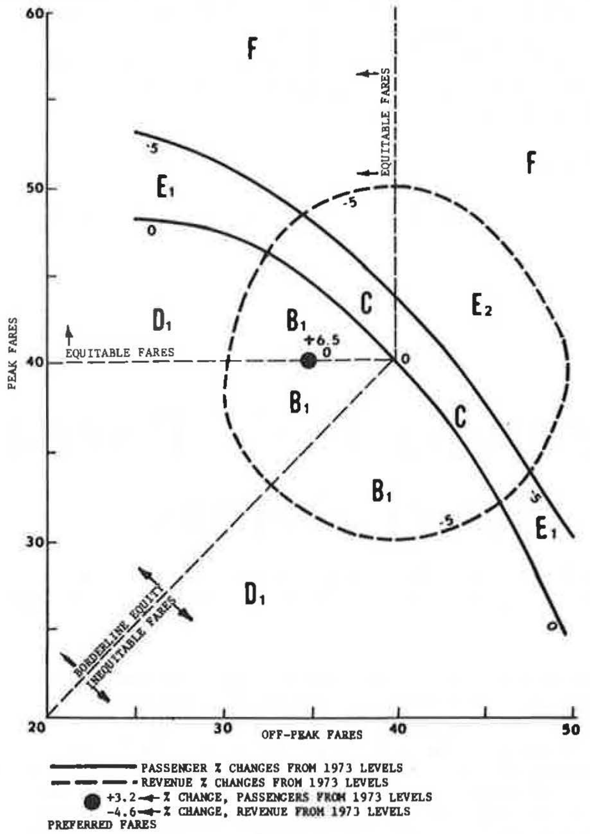


Figure 8. Passenger and revenue effects of combination fares: Binghamton.



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.

Vision-impaired individuals cannot rely on standard signs and signs in braille should be provided. Sharp corners and edges should be avoided and differences in textures can be used to provide information such as the direction in which to proceed. If transit routes are color coded, the spelling of the name of the color is essential for people who have difficulty in distinguishing colors.

4. Shelters protect against the weather. A shelter is helpful in all seasons, for it can protect people from sun, wind, and precipitation. Analysis of the prevailing

Figure 1. Bus-shelter design process.

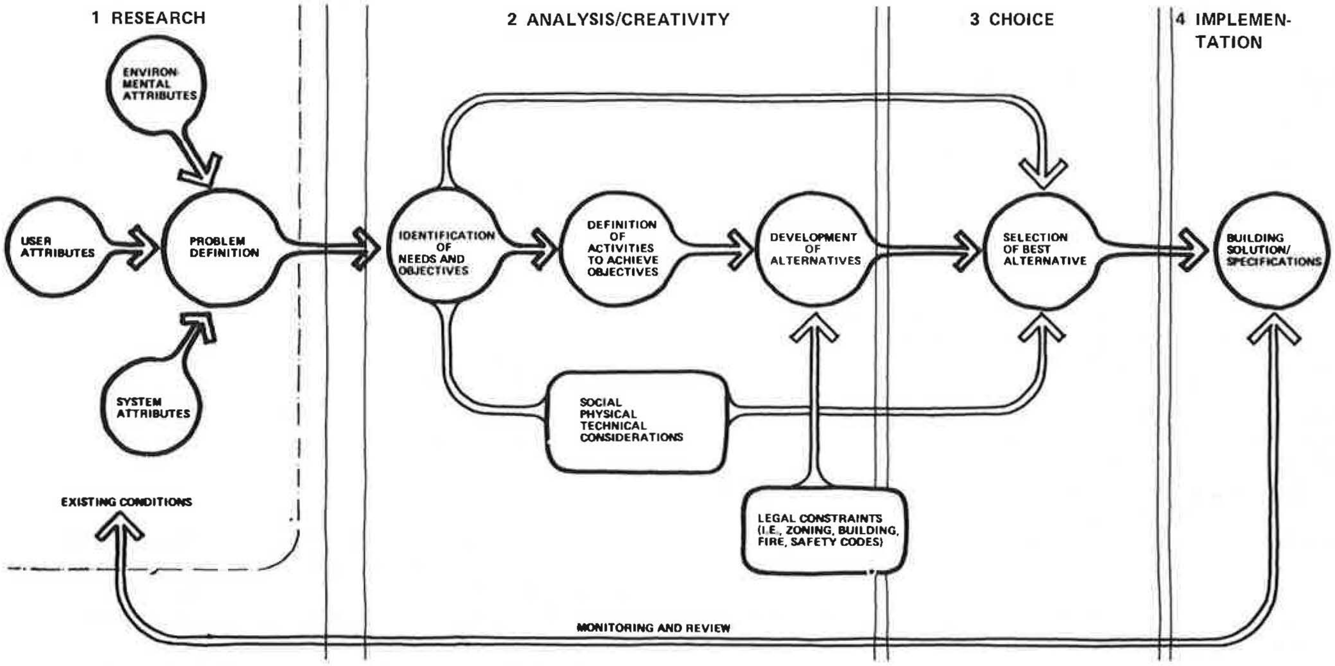
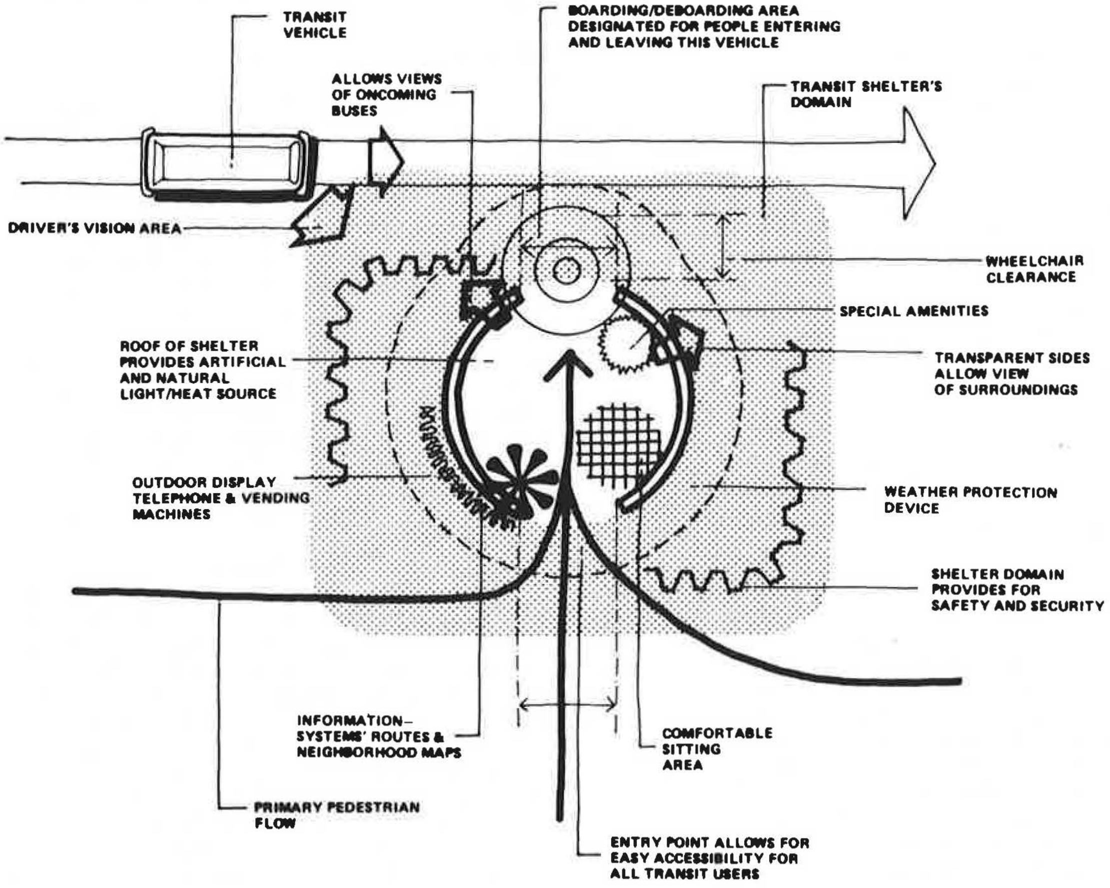


Figure 2. Functional arrangement of transit shelter.



wind direction at specific shelter locations will permit construction of shelters that shield the patron from the weather while he or she awaits the arrival of the bus and then boards it. The access to shelters should not result in the shelter acting as a sail and collecting wind, rain, snow, and rubbish.

5. Shelters increase transit service areas. Transit shelters have consistently been an important consideration for system patrons. In surveys designed to determine whether improved services would increase the use of a system, patrons have always responded in the affirmative. When employees in one smaller midwestern city were asked how far they would walk to a bus stop without a shelter as opposed to how far they would walk to one with a shelter, on the average sheltered stops attracted people from a half-block farther away.

LOCATION OF TRANSIT SHELTERS

To this time the primary emphasis in the development of analytical tools has been on (a) the definition of transportation networks, (b) the identification of levels of service, (c) the identification of vehicle requirements, and (d) the analysis of transit-system options. There are only limited quantitative tools available (2, 3, 4) for locating and designing transit shelters, which have generally been placed on the streets according to rules of thumb and subjective professional judgment, a practice that has resulted in the use of the following type of criteria (5, 6):

1. One shelter per block in central business district (CBD) or high-density residential areas;
2. One shelter every two or three blocks in medium-density residential areas; and
3. One shelter every six or more blocks in low-density residential areas.

Similar guidelines for the placement of shelters with respect to traffic flows have also been promulgated (7). These include midblock, near-block, and far side of intersection placements.

1. Midblock placements are primarily used at locations where bus routes require left turns at the next corner or where traffic volumes are low.
2. Near-block (near side of intersection) placements are primarily used at signalized intersections to facilitate passenger crosswalk movements. It is also used where on-street parking is not permitted, where there are heavy left-turn movements, and where through traffic is heavy.
3. Far side of intersection placements are primarily used at intersections with heavy right-turn movements or on streets with limited curb lengths due to on-street parking facilities.

SPATIAL REQUIREMENTS FOR TRANSIT SHELTERS

Two types of areas are currently used to determine the total spatial requirements for bus stops (8). These are the bus curb loading zone and the pedestrian-and-patron waiting area. The former is usually given in distance and may vary according to the location and the number of bus loadings required. The pedestrian-and-patron waiting area is that space wherein a shelter would be located and has been narrowly defined as that area occupied by the shelter structure. The most commonly recommended pedestrian shelter varies between 4.5 and 7.6 m^2 (50 and 84 ft^2) (9, 10). Given the weak and piecemeal character of the techniques that are presently used for the planning of bus-stop shelters and the need to improve bus and transit interface facilities, appropriate procedures and guidelines that will encourage new alternatives in the location and design of transit shelters should be developed.

Guidelines that will aid in the location and design of the appropriate shelter(s) that best meets community needs must consider a series of evaluation criteria. These include

1. Users of the facility,
2. Types of transit systems that the shelter will support,
3. Types of pedestrian and vehicular systems that it will reinforce,
4. Design objectives and constraints,
5. Space availability,
6. Incorporation of activities and amenities,
7. Materials,
8. Flexibility,
9. Maintenance,
10. Resistance to vandalism,
11. Accessibility for the mobility-limited,
12. Weather protection, and
13. Aesthetics.

FINANCIAL IMPLICATIONS

The 1976 prices for relatively simple shelter facilities range from approximately \$1000 to \$2400. These shelters are 1.8 and 6.75 m^2 (20 and 75 ft^2) respectively and contain few amenities. A minimal graphics installation costs between \$750 and \$1000. The average cost of installation of these structures is about \$200 and requires 7 to 10 person-h. Shelters with benches and panels for information dissemination or advertisements are double or triple these prices, depending on site conditions and location.

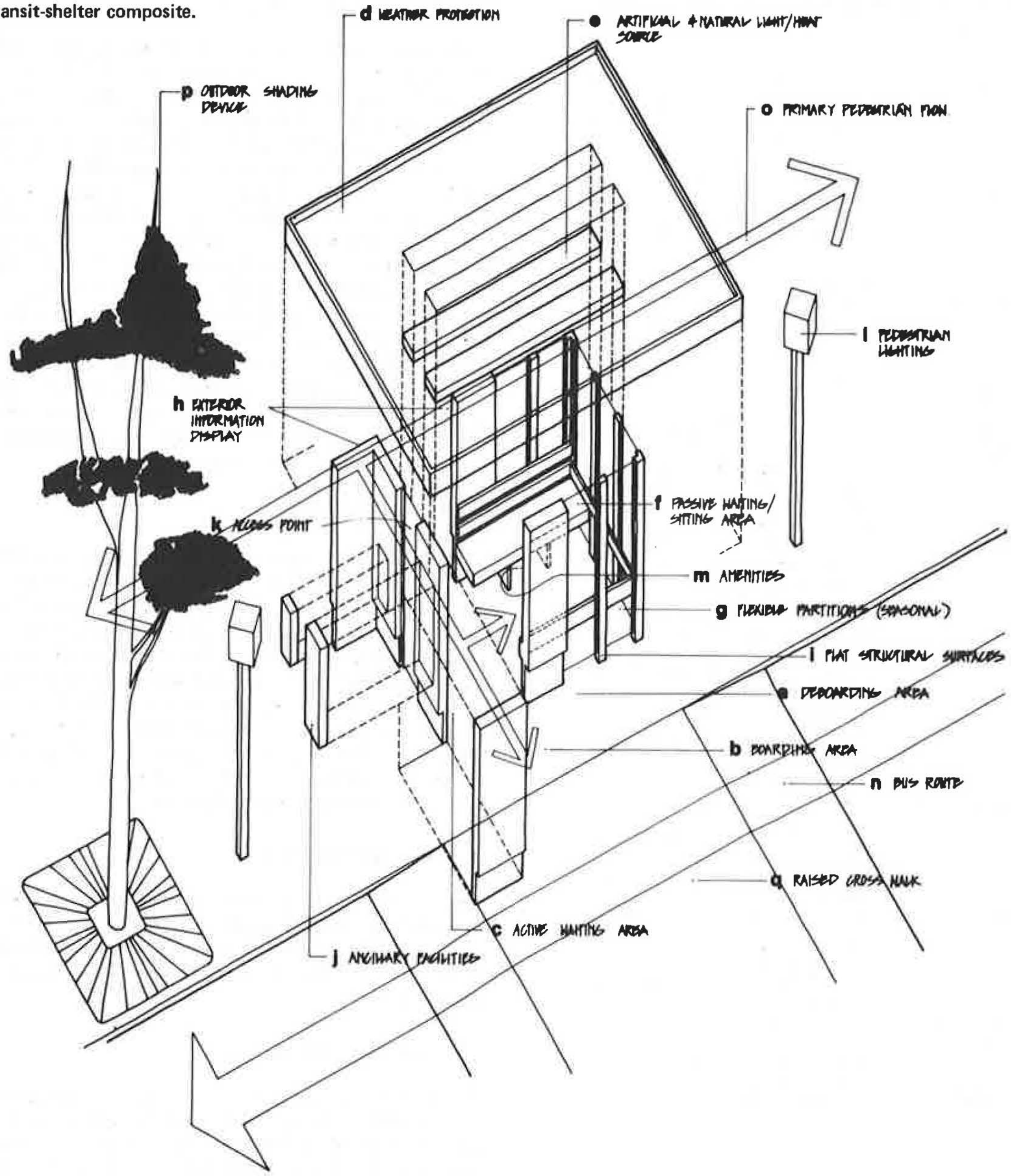
Perhaps the most ambitious shelter project undertaken is in Austin, Texas. There, as part of a bicentennial downtown redevelopment project, two shelters were erected at a cost of \$30 000 each and site preparation costs of \$90 000. Only the best materials were used, the needs of people and transit vehicles were taken into full consideration, and there are many amenities.

Who takes responsibility for shelter placement and programs? In Austin it was a combined public and private effort; in the Chicago region there is a combined federal, state, and local effort; and in New York City the effort is largely a private enterprise. This case is the most interesting. A commercial firm that erects 4.3-m^2 (48-ft^2) lighted shelters with large advertising panels has been established. The revenue from the advertisements is sufficient to pay for the installation of the shelters by the city as well as a fee of five percent of the revenue from the advertising to the city. There are 254 shelters in Manhattan and the Bronx and 600 new ones are planned for 1977. A similar enterprise will soon be under way in the Chicago area.

When public money is used for shelter projects, the usual source has been 80 percent from section 3 of the Urban Mass Transportation Administration and 20 percent from local matching. This approach has been used by the northeastern Illinois Regional Transportation Authority (RTA) to build several hundred shelters: Funds for shelters have come from local community money, directly from the RTA, and from the Illinois Department of Transportation (IDOT). IDOT has also used the shelter concept to provide facilities at railroad stations rather than construct new depots.

Another source of funds for the construction of shel-

Figure 3. Transit-shelter composite.



ters is from commercial property owners. As a joint development effort, both the retailers and commercial interests and the transit operators can be served.

Beyond the capital and construction costs are the maintenance outlays. These can be large in cities and communities with large programs. Vandal-resistant materials are often essential, and lights, heater elements, information inserts, cleaning, and resupplying vending machines will require attention. Annual maintenance costs per shelter vary greatly, reaching $1000 for weekly inspection and service, with labor costs being the largest part of the expense. More detailed maintenance experience will become available as more units are installed in more cities.

PROCESS FOR IMPLEMENTATION

The usual approach to the implementation of a bus-shelter program involves jumping from the recognition of the problem to a hardware solution. The recognition that a process-oriented effort is needed is an improvement on this because a planner is then involved with the complex design problem. This paper proposes a creative effort that consists of a number of phases and activities that overlap and are aimed at identifying, describing, and analyzing the problem prior to the attempt to synthesize the solution.

Figure 1 provides a summary of a creative yet pragmatic approach to the planning and design of transit shelters. Briefly, the following questions must be considered.

1. Environmental attributes: What are the physical surroundings at the specific site?
2. User attributes: Who is most likely to come to the transit system at the specific site? Is it the elderly or the mobility-limited? How many people will there be?
3. Problem definition: What, based on environmental, user, and system attributes, is hoped to be accomplished at the site?
4. Identification of needs and objectives: What types of shelters meet the specific sociogeographic requirements?

Table 1. Identification key for transit-shelter placement and design.

Key	Element	Identification
A	Deboarding area	Area into which people leaving buses walk, preferably when exiting through vehicle rear door; so located that these patrons do not interfere with those boarding the bus or waiting to board that or any other bus
B	Boarding area	Area between shelter and bus itself where people queue for access to vehicle; pavement treatment in areas with sidewalks, paved area in areas without sidewalks to designate path between shelter and vehicle
C	Active waiting area	Area reserved for standing while waiting for bus and incorporating features that facilitate passage of time; includes informational displays, art work, or any other acceptable exhibit
D	Weather protection	Overhead protection from sun and rain; shelter from wind
E	Artificial and natural light and heat source	Roof of shelter designed to permit natural daylight to enter and also provide shade; should hold light fixtures for nighttime illumination and heat lamps for cold weather
F	Passive waiting and sitting area	Area in which people rest while waiting for buses; light enough for reading; comfortable seating; open view to arriving vehicles
G	Flexible partition (seasonal)	Protection in winter; freer air flows in summer
H	Interior and exterior information display	Panel of shelter wall to contain route and system information (maps, telephone number, schedules) for boarding passengers and neighborhood information for arriving passengers; use of both sides of panel minimizes loss of transparency and increases number of people who can refer to the information at any given moment
I	Flat structural surface	Flat surfaces to facilitate maintenance and cleaning
J	Ancillary facilities	Vending machines, telephone, trash receptacles placed on outside of shelter so as to not interfere with transit function
K	Access point	Entry point to shelter; placed to be immediately recognizable to patrons approaching from either major pedestrian flow or buses; essential if transfers are possible or patrons desire to meet others at shelter
L	Pedestrian lighting	Outside light
M	Primary pedestrian flow	Major direction of approach to shelter
N	Curb cut	Ramps cut into curbs at corners
O	Wheelchair clearance	Minimum horizontal clearance of 90 cm

Note: 1 cm = 0.4 in.

5. Social, physical, and technical considerations: Are shelters accessible to all potential users? Do proposed shelters conflict with the immediate surroundings? How does the proposed hardware enhance personal comfort and safety?

6. Definition of activities to achieve objectives: Which activities (waiting, reading, or resting) are compatible with the shelter and the site?

7. Development of alternatives: What is the range of design concepts?

8. Selection of the best alternative: Which alternative best meets the social, physical, technical, legal, and financial concerns of the community?

9. Building solutions and specifications: How shall the shelter program be implemented? What are the architectural guidelines for shelter construction and monitoring?

DESIGN CONSIDERATIONS

The desired attributes of the transit shelters must be translated into design considerations.

Functional Considerations

A transit shelter should not create conflict within its own surroundings by becoming a barrier and obstructing circulation or access. It should support the series of activities that will take place there. It should be a key element in the planning and development of pedestrian and street networks and their immediate land uses. Tailored to the existing natural and man-made features and local climatic conditions, the facility should contribute to the overall appearance of its surroundings and become an integral part of the streetscape. The transit stop should be the portal or entryway to the transit system and should support the functioning of that system through its physical, social, and technological attributes. The shelter and the transit system can help reinforce the community's social, physical, and economic goals. Finally, any shelter must meet vehicle and system operational requirements as to capacity, geometrics, and facilities.

User Considerations

Any transit shelter should be easily accessible to all potential users, regardless of age or mobility restrictions. The internal arrangement of such a facility and its pedestrian-circulation pattern should be easy for the user to understand. The design should accommodate optimal passenger densities and help to increase the patron's safety through proper site location and lighting, elimination of visual and physical barriers and of blind ends, coordination of entry and exit points with external pedestrian and vehicular traffic flows, and appropriate external surveillance.

Social Considerations

The bus stop and the transit shelter should help increase the passenger's perception of system reliability, which will be accomplished if the facility is a dynamic environment in which the user is comfortably active while awaiting the bus.

Physical Considerations

The structural system of any shelter should be flexible in size and arrangement of partitions to facilitate maintenance and allow for potential change in patronage and spatial or climatic conditions. The walls should allow for maximum transparency to facilitate visibility through and from the shelter. This is important for the patron's sense of security, especially if he or she is alone or with one other person. Insulating devices are desirable to decrease noise discomfort, vibration, and the effects of inclement weather. A heat source to provide warmth and eliminate the formation of ice on the floor during the winter is essential in certain geographic areas. At night, there should be a level of artificial lighting adequate to permit reading of personal material and posted information. The inclusion of any ancillary activities (e.g., telephones, advertising, vending machines, and trash receptacles) should, to the extent possible, serve the transit user exclusively and not conflict with the waiting area by inviting nontransit users into the facility.

Signs should be visible, and the information system should be concise and sufficiently flexible to allow changes. Signs should be properly scaled and should direct passenger boarding and alighting activities. The needs of the visually handicapped must be considered.

Flat structural surfaces will allow easier assembly and maintenance, and the avoidance of totally enclosing surfaces will reduce the accumulation of trash and dust in corners. Construction materials should be durable and economical without sacrificing the needs of the user or attractiveness. Figure 3 illustrates a typical prototype shelter. The critical elements of this shelter are identified in Table 1. The mass-produced shelters currently available are not apt to meet the criteria and considerations discussed above, although modifications to them can lead to a successful program.

In addition to the space available for the shelter, the availability of pavement is also important. While there are sidewalks and pavements in the CBD and other high-activity locations, they are sometimes absent in residential neighborhoods. This should not preclude shelter placement in low-density residential areas without paved walkways. The placement of a shelter should encourage its use and not inhibit pedestrian flows. Therefore, the ideal location is at curbside when wide sidewalks are available, set back across narrow sidewalks, and close to curbside (with a pavement added) when there is no sidewalk. In all cases, there should be provisions for people with mobility limitations so that wheelchairs or walking aids are not hampered.

CONCLUSION

The viability of our transit systems is going to depend not so much on their own technology as on those elements of the system that represent them to the community. A key element that symbolizes transit systems in our cities and communities is the transit shelter, the place where the components of transit service interact. The patron meets the operators and equipment, pays fares, gains information about the system, and forms opinions about the level of service. The operator should intend that such a facility be more than simply wind and weather protection. The role of the transit shelter should be carefully identified through a close analysis of the community and its perceived needs, the patrons themselves, and the system as a whole.

The present approaches to the planning and design of transit shelters have been piecemeal at best and limited in scope. This paper suggests a more systematic, yet flexible, approach, and a methodology that will allow better definition and analysis of the problem and encourage more creative thinking toward the planning and design of transit shelters. By examining transit shelters in the context proposed here, they will have the potential to transcend their identity as simple waiting areas. Shelters could function as indoor-to-outdoor rooms for the transit user in which he or she would not only wait but might also socialize, read, rest, listen, or watch in a safe environment; i.e., transit shelters could become social places oriented to the needs of all the system's patrons, including the elderly, the mobility-limited, the young, the commuter, and the choice rider.

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Role of Simulation Models in the Transit-Station Design Process

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This paper summarizes the ways in which a transit-station simulation model could be developed to function as a more integral part of the design process. It examines in detail the interface of the user with the model. Specific problems dealing with network and spatial representation are discussed, and the model output is matched with the information needs of the designer at the appropriate stages in the design process. The paper concludes with a discussion of the cost-effectiveness of station-simulation models.

Over the past several years, the Urban Mass Transportation Administration (UMTA) has been developing an analytical tool to assist transportation planners and engineers in the design of public transportation facilities. Recently, a pilot version of a computer program to evaluate transit-station designs was tested and evaluated (1). The role of simulation models in the design process was examined in detail, and a number of ideas about the expanded range of analysis possible when computer models are used to supplement more conventional techniques of facility design were developed. This paper summarizes the ways in which a future version of the simulation model could function as a more integral part of the design process. Basically, the paper focuses on the interface between the user and the model, rather than on the adequacy of the underlying theory and mathematics.

Design is a synthetic process, which places it at the periphery of scientific activity. The acts of designing, manipulating and arranging components, and developing principles of organization cannot be decomposed into a series of easily defined sequential steps, for the process itself requires creativity and imagination. Consequently, tools to aid the process must be flexible and easy to use. They must not present barriers to the process, but should be shortcuts that release the designer from drudge work and give him or her more freedom to exercise imagination and test alternatives.

A conservative approach was used in developing the transit-station simulation model (USS). The model does not attempt to optimize the station or treat the problem deterministically. It uses a Monte Carlo discrete-event simulation procedure with a Markov-type path-choice model (2). The simulation approach presents the designer with a representation of the station, which he or she is free to use as a physical model. Because of the large number of unknown values and the lack of a deterministic theory that would permit the application of mathematical formulas to predict station performance, the computer is used to generate a simulated history of station performance in time. The designer can then study this performance record, modify the design where necessary, and test the design again.

To use the model, it is necessary to translate the physical design for the station into a prescribed mathematical notation that the computer can understand. At present, it is not possible to enter a drawing of the station into the computer memory, although future modifications may permit this. As in any computer model, the assumptions and mathematical rules used by the programmer largely determine the results.

NETWORK CODING AND SPATIAL DESCRIPTION

In abstracting a station design to provide input data for the model, a coding protocol that is based on a network or graphical representation in terms of links and nodes must be used. However, designers, particularly architects, find this notation foreign to their thinking, since they have been trained to think in terms of spaces and sequences of spaces, which are best described by areas and their boundaries. Networks are difficult for architects to conceptualize because of their spatial ambiguity.

The network-coding protocol often requires many subjective judgments by the analyst. The layout of paths is fairly straightforward, but locating nodes requires more intuition. The most difficult to determine are the link and node characteristics, such as allowable areas for movement and queueing. Consequently, what may be evaluated is not the actual physical dimensions of the station, but an interpretation of the area available.

Often, repeated runs are necessary to debug a station. Nearly all coded stations abort in the initial runs because of link and queue-area overloads, and to eliminate these errors, movement and queue areas must be changed on the input data cards. Since the cases studied have dealt with existing stations that are accommodating flows equal to or greater than those specified in the simulation, it was assumed that the coded areas had been underestimated. However, in dealing with designs for proposed stations, the designer may not be sufficiently confident in his or her knowledge of the operation of the model to determine whether the source of an error is faulty design, faulty coding, or faulty interpretation of the area available.

To remedy the problem of correctly interpreting and coding the stations, several alternative coding schemes were investigated. Of these, the most promising retains the basic link-node network representation and subdivides the station plan into a series of sectors or areas of homogeneous use and simple geometry. Links are drawn across each sector to represent major straight-line movement paths. Nodes occur at sector boundaries and devices. Performance statistics for all links crossing each sector are aggregated to give a level-of-service measure for the sector. Consequently, most of the subjective judgments required by the translation of spaces into the network format are removed, and the designer can evaluate the individual spaces in the station.

ROLE OF SIMULATION MODELS IN THE DESIGN PROCESS

The design of transit stations has been a major concern of transit planners and operators for many years. However, for architects and engineers, transit stations are simply another among many specialized facility types that they design. They are not usually specialists in one facility type, but are trained to deal with specific facilities in a generalized design process.

As a part of their training, designers are taught methods of assembling factual information about their problem. Where this information is not available, they rely on experience and intuition to supply the basic data needed. They rely on synthesis rather than on analysis, and most prefer to spend most of their time on actual design preparation rather than on research and data acquisition. Data collection and analysis are viewed as peripheral activities to the commencement of the design. Consequently, an analytical tool that deals with the evaluation of a fully developed design is of limited usefulness. Once a design has reached a level of detail sufficient for a formal analytical evaluation, all of the important decisions have been made, and revisions cause a considerable loss of time.

Although design processes vary, there are usually four phases into which they can be divided: (a) programming, (b) site analysis, (c) schematic design, and (d) detailed design. For most architectural projects, the design requires less than 15 percent of the total person-hours expended.

Programming and Site Analysis

Programming and site analysis are analytical stages. Programming involves the development of user and client requirements. What functions must be accommodated? What spaces must be provided? How much space is needed? Site analysis involves the inventory of conditions found at the proposed location and includes such items as subsoil conditions, adjacent land uses, traffic, circulation, building regulations, and visual characteristics.

Schematic Design

In the schematic-design phase, the designer begins to assimilate the information that he has acquired and to function as a black box in synthesizing alternative schematics for the facility. These schematics are quite crude, graphically, often no more than scribbled sketches. The designer cycles through a number of ideas, constantly testing and refining the images, working quickly, dealing with the major spaces and design elements, and ignoring unimportant elements entirely.

The resulting drawings are quite diagrammatic and seldom have spaces accurately measured and dimensioned. In this stage the design takes shape as an organizing principle rather than as a set of functional elements.

Detailed Design

Once the organization of the design has been established, it must be reconciled with the site and the program. In the schematic phase, the designer has usually dealt with these aspects internally and impressionistically. In the detailed-design phase, measured drawings are made and individual sections can be worked on and developed separately. This is the point at which the simulation model can currently be used.

USE OF SIMULATION MODELS IN PRACTICE

A simulation model will be used by transit-station designers if it can respond to their needs by (a) saving design time, (b) answering hard questions, or (c) reducing construction costs. Each of these areas is examined below.

Saving Design Time

It does not appear that the use of a simulation model can reduce the time needed to design a new transit station. As an evaluation tool, the model is a means to verify the adequacy of a design, but because of its information requirements, it cannot substitute for intermediate evaluations during the schematic-design phase. Currently, it would be most effective as a tool with which to review completed designs submitted by consultants. Architectural and engineering firms who attempt to use such programs without prior experience will have heavy initial costs in time and computer resources. Consequently, the use of simulation models will be limited to those that are already heavy computer users (perhaps only 10 to 15 percent of all architectural and engineering firms). Coding requirements and machine-processing time will also increase the amount of time needed for station design.

However, the use of a simulation model can save significant time in the redesign or retrofitting of existing stations where the designer begins with a completed plan. The coding becomes much simpler and the simulation results can be verified in the field. In such applications, the model can provide the designer with a means to recreate conditions in the existing station without lengthy field observations. Flows can be sampled and used to calibrate the simulation, for which conditions can then be varied to recreate a variety of operating modes. The use of a simulation model also permits a reduction in data collection for the existing station. Finally, the program itself can be used as a manipulable sketch-planning model.

Answering Hard Questions

Because the job requires a complete facility plan, regardless of information gaps, the designer is frequently forced to make assumptions and resort to intuition. In many cases, however, assumptions and intuition fail to provide the correct answers, and facilities may later be deficient. In certain critical areas, such mistakes can be costly or even tragic. The model should be used in those critical areas for which there are no ready solutions or standards. Three areas of station-design uncertainty in which USS could provide answers to hard questions are (a) safety, (b) area requirements, and (c) trade-offs between devices and space.

Safety

Designers need better information on how stations function during emergencies. For example, subway fires occur with sufficient frequency to require designs that explicitly consider evacuation. Other mishaps, such as stalled trains, collisions, and flooding, may also require simultaneous evacuation of all of the trains or vehicles in a station. The station designer usually has no firsthand knowledge of the physical design requirements for evacuations and may have to use existing space and exit standards that may or may not be adequate.

In some systems there are design-performance specifications that specify the maximum time in which to evacuate a fully loaded train. Those for the Southeastern Pennsylvania Transportation Authority, for example, specify that "The circulation system should permit the total capacity of a loaded train to exit from the station in 4 min" (3). These standards also contain capacity guidelines and minimum dimensions, but give no guidance in determining the compliance of a station design with the 4-min evacuation standard.

A simulation model could be used to evaluate station performance in an evacuation, with some modifications from normal operating requirements. The station-evacuation mode would permit the user to start the simulation with fully loaded transit vehicles in the station, alter gates and inbound links from pedestrian entrances to permit passengers to flow out of the station, and introduce a higher than normal desired mean walking speed and the ability of individuals to backtrack on one-way links as needed. Rather than specifying a period to be simulated, the user would specify a maximum simulation period and terminate the program as soon as all individuals had exited from the station or when the maximum period had elapsed. The outputs would specify how many individuals remained in the station at each time interval and where they were located.

Area Requirements

The determination of space requirements for a facility is accomplished during the programming phase. Architects and designers generally begin schematic designs with the required areas known. Currently, the simulation model tests the adequacy of spaces under passenger flows, but not until the detailed design is under way. The most important spatial element in transit-station design is the platform size, but since link-node coding protocol requires the disaggregation of platforms into subareas for analysis, platforms cannot be easily modeled by simulations that rely on network representation.

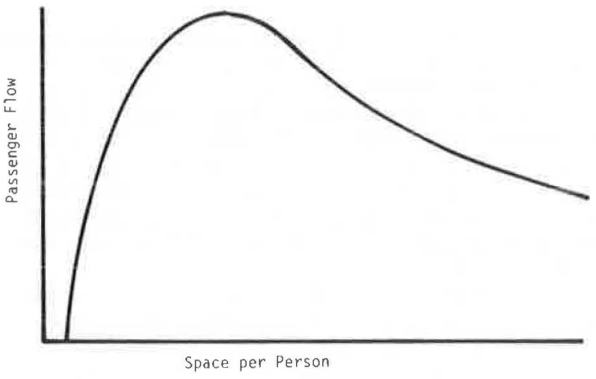
Essentially, the designer needs an initial estimation of the station areas required prior to the schematic-design preparation. A simulation model could be solved for these areas for given passenger flows and service-level requirements. From the passenger flows, the model could be used to calculate the required movement and queue areas. This mode of operation would permit the designer to code and simulate the transit station early in the schematic-design phase while using only a minimum of information (primarily link and node locations). A set of default-device characteristics would also simplify the initial coding.

By helping the designer to determine the areas at the beginning of the schematic-design phase with minimum information inputs, the model could provide data for the station design before major decisions have been made.

Device Versus Space Trade-Offs

In most instances, devices such as turnstiles and esca-

Figure 1. Relation between passenger flow and space per person.



lators produce queues during periods of maximum use, and additional areas must be constructed to accommodate these queues. Alternatively, the addition of more turnstiles or such devices could reduce the queue-area requirements. Simulation models could permit the designer to make this kind of analysis, and, to make this analysis even more useful, the model could include a comparison capability between configurations. This could be achieved in two ways: First, the program could produce aggregate reports of the movement and queue areas required for the entire station. This would provide a simple means for comparing alternative station designs. Alternatively, the program could accept several station plans as input, compare them internally, and produce comparison statistics. The second alternative reduces work for the user but would probably be neither sufficiently flexible nor cost-effective.

Reducing Construction Costs

The single most important use of any design tool, particularly with regard to transportation facilities, is in reducing construction costs. Because of the high costs of these facilities, it is desirable to minimize both the total area required and the number of devices such as escalators, turnstiles, and elevators. In general, the area requirements for a station are determined during the programming stage, prior to the development of schematic designs. Station designers usually begin with an estimate of passenger flows. Most often, they also need to know the hourly variations and the peak expected volumes and use these volumes to apply space standards, such as those developed by Fruin (4), to determine the required areas and widths for generic space types (hallways, platforms, stairways, and such), which serve as a program for schematic-design development.

There is some uncertainty in using these space standards. These standards are generally mean rates or averages derived from observed data, but often there is a large associated variance. Area standards can also be associated with levels of service, as by Fruin (4) and Pushkarev and Zupan (5). The designer must assume that the areal standard is applicable, and determine the appropriate level of service. Because of the uncertainties in determining spacial requirements for a transit-station facility, the designer may tend to overdesign it and provide too much space to compensate for possible errors in space estimates. Most designers are comfortable with designs that have an overabundance of space, since, once a completed facility is found to be undersized, there is seldom a possibility to add additional space economically. Indeed, because of the serious problems caused by inadequate space in transit stations, the current emphasis in simulation modeling of stations is in locating undersized areas.

The overdesign of stations could be reduced with more accurate estimates of spatial requirements. A simulation model could provide this information: This is one of its most useful applications. It is relatively easy to run several simulations, reducing the areas each time, to determine the minimum area required. However, this requires an iterative approach, and many runs may be needed to optimize the station. In addition, the program currently requires a fairly specific initial estimate of space requirements, which is time-consuming. For stations coded with a large number of links and nodes, the process of comparing results and incrementally reducing areas may also be time-consuming.

The present simulation model is better suited to detecting portions of stations that are underdesigned. The program operation draws attention to areas that have movement blockages and overflowing queue areas. Consequently, optimization of the station design is not an explicit program function although, in a crude sense, it is possible. Figure 1 shows the relation between pedestrian flow and space per person for walkways. If one assumes that there is a similar relation between passenger throughput and area per person, there will be a theoretical maximum station size for any given passenger volume. It is improbable, however, that station design can be specified and modeled as an optimization problem, although several previously mentioned program capabilities could increase the usefulness of a simulation model in minimizing transit-station cost. The most important of these are (a) program-generated area requirements and (b) the incorporation of level-of-service indicators.

POTENTIAL COST-EFFECTIVENESS

The UMTA station-simulation program is still in a developmental state and is not yet ready for release to the planning community. However, the program is a unique tool with considerable potential for station designers. Although only a few new fixed-guideway transit systems are under construction or planned for the near future, tremendous cost savings are possible. Currently, for example, escalators cost about $60 000 so that the elimination of one escalator per station in a 10-station system could save more than the cost of developing the program. Rapid-transit stations cost from $3 000 000 for surface stations to $12 000 000 or more for underground stations with construction costs alone ranging from about $650/m^2 ($60/ft^2) for the surface stations to several thousand dollars per square meter (several hundred dollars per square foot) for the underground ones. Thus, even small reductions in station area have a major impact on system costs.

Although few large transit stations will be constructed in the foreseeable future, hundreds of existing stations need modernization and rehabilitation. Major portions of the rapid-transit systems in Boston, New York, and Chicago were constructed more than 50 years ago (some are nearly 75 years old) and are still in use. A station-simulation model could be a widely used and vital tool for planners rehabilitating existing transit stations, if it were flexible and responsive to user needs.

ACKNOWLEDGMENT

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Rehabilitation of Suburban Rail Stations

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This paper reports the results of a study of the feasibility of rehabilitating underused suburban railroad stations. Seventy-seven stations on eight commuter lines in New Jersey were surveyed. Each station was inspected, photographed, and evaluated for its restoration potential by criteria that were developed for the study. The Red Bank station was selected as a case study. The study included the development of community and local government participation, the renovation of the 100-year old depot, the redesign of the passenger facility as an intermodal terminal for bus, rail, and taxi, the redesign of the pedestrian facilities, and an economic analysis. The municipality has now taken possession of the station, which is used by 1500 daily commuters. Preliminary architectural plans have been drawn up, the station has been designated as an historic site, and the building restoration and sitework are nearly completed. This study is intended to be a prototype for other restoration projects that could modernize urban transportation facilities while preserving historically valuable structures. The emphasis is on maximizing the economic benefits of the project.

Each day, approximately 500 000 Americans travel to work on commuter railroads. In the Northeast, seven of these private carriers are bankrupt, are unable to make a profit even on freight traffic, and have been federally reorganized into a single entity, the Consolidated Rail Corporation (Conrail). Passenger service exists only because of heavy federal and state subsidies and is often run entirely by public authorities. Although intercity rail service is being steadily improved by the National Railroad Passenger Corporation (Amtrak), intraregional commuter service is barely adequate, and only on those routes where high concentrations of commuters bound for the central business district (CBD) create intolerable highway congestion. Off-peak, weekend, and non-CBD-bound travelers have little rail service. Over the past 40 years, service quality has steadily declined, breakdowns have become more frequent, cars have grown dirtier, and track and equipment have deteriorated. As conditions have worsened, more commuters have sought alternative means of going to work, primarily by automobile. As rail commuters have switched to automobiles, rail revenues have declined, which has caused even more cutbacks in service and less maintenance. Thus, today commuter railroads are in a continual downward spiral.

Because of decentralizing trends in metropolitan growth and the convenience of the automobile, it is unlikely that railroads will ever again have the major role in intraregional passenger transportation. But recent petroleum shortages and price increases have emphasized the need to conserve energy resources and, specifically, to reduce automobile travel. Railroads can be from 5 to 10 times more energy-efficient than can automobiles, depending on the number of seats occupied per vehicle. In addition, one railroad track has an hourly capacity approximately equal to that of 10 expressway lanes carrying automobiles. In certain applications, notably the journey to work, railroads can still provide an important service.

IMPROVEMENTS IN RAIL SERVICE

Where there are competing facilities, the commuter has a choice of travel modes. In selecting the preferred travel mode, he or she attempts to minimize travel time and cost and the discomfort of the trip. Trade-offs are made, since individuals value time differently, and since time spent in uncomfortable or unpleasant surroundings is more onerous than time spent in a pleasant environment. Travelers value time spent waiting for transit more highly than time spent riding in a vehicle (1). Transfers between modes also impose penalties beyond time and cost.

The relation between factors such as transfers, discomfort, inconvenience, and unpleasant surroundings and the decision to use rail transit is known to exist, although it is not easily quantified. Time and cost are not the only factors that influence modal choice.

Through subsidies from federal and state governments over the past decade, efforts have been made to improve service for rail commuters. Priority has been given to purchases of new cars and locomotives. In most metropolitan areas, electrified commuter service was established in the early 1900s, and cars built then can still be found in active service. These ancient vehicles have caused frequent breakdowns and delays, and their poor riding quality and environmental conditions have been major irritants to passengers. Newer equipment with a smoother, quieter ride, more dependable and faster service, and better environmental-control systems helped to slow the massive defection of commuters from rail to highways.

With fleet replacement under way in many areas, attention is now being given to other types of service improvements. In New Jersey, in addition to subsidies for capital improvements, operating subsidies totaled more than $50 million in 1976. Other states are providing similar levels of support. Improvements to commuter rail stations are planned in many areas. In the New York metropolitan area, the adoption of a new fleet of cars required the construction of new high-level platforms at stations on the electrified portions of the Long Island Rail Road and Penn Central Transportation companies. Other improvements to stations have usually involved the addition or expansion of park-and-ride lots. Some stations have been relocated to better serve commuters, particularly in areas where newly constructed urban beltways provide high-speed access from the suburbs to rail corridors.

These station improvements have been directed primarily toward increasing capacity and reducing delays. Other factors, such as comfort, station appearance, and impacts on the surrounding urban environment, have largely been ignored. Frequently, to increase capacity and speed, the most expeditious course has been to close or demolish existing stations, some of them of important cultural and historical value. Their replacements are generally uninspiring. This paper reports a study in which historical and environmental concerns were given high priority in the rehabilitation of a commuter rail station to increase its cultural value to the community as well as to improve its transportation efficiency.

HISTORIC PRESERVATION

Although the importance of railroads has diminished, there is a growing awareness of their historical role in the development of the nation. Some of the more important rail facilities are worthy of preservation as a part of our national heritage, regardless of their future role in transportation. In other instances, it is possible to preserve and restore historically valuable railroad facilities and improve conditions for rail travelers at the same time.

Of the many types of buildings and engineering works erected by the railroads in their 150 years of operation, none has been more visible or symbolically expressive than the passenger terminal. As John Maas (2) writes:

> Today the railroad station is often a backwater on the wrong side of town. In the nineteenth century it was the hub of the community, the link to the Great World—the wretched roads were blocked by snow and mud for months, good highways came only after the automobile. Railroading was the nineteenth century's premier industry, it offered the finest careers to ambitious men, the most jobs to skilled workers. The Victorian railroad depot was a place of glamour and excitement and designed to look the part.

As the importance of railroad technology increased during the nineteenth century, the passenger station developed into a unique architectural type. In large cities, terminals were created to handle unprecedented volumes of passengers and were designed as civic monuments by some of the most famous architects of the day. Probably the most significant of all American stations was Pennsylvania Station in New York, designed by the distinguished firm of McKim, Meade, and White and completed in 1910. Patterned after the Baths of Caracalla, its main waiting room had a vaulted ceiling 46 m (150 ft) high, and the main concourse was roofed with iron and glass vaulting (Figure 1). When this great landmark was demolished in 1963, architects and preservationists fought in vain to save it. Its irrevocable loss is a tragic sacrifice of an important part of our history for short-run economic gains. Elsewhere, in Chicago; Memphis; Portland, Maine; and Spokane, landmark stations have been razed because they were no longer needed as transportation centers and the urban land that they occupied was valued highly by real estate developers.

In the past decade, however, the public has recognized that the continual destruction of landmarks in the name of progress and urban renewal is robbing our heritage. In many cities, terminals have been rehabilitated and converted to new uses. In Washington, D.C., Union Station has become a national visitor center. The elegant Mt. Royal station in Baltimore has become part of the Maryland Institute College of Art. In Chattanooga, Tennessee, the 70-year-old terminal station has been renovated into a restaurant and hotel complex. Smaller stations, such as those in Lincoln, Nebraska; Fargo, North Dakota; and Oberlin, Ohio, have also been reused. But much work remains to be done. At present three monumental landmark stations are threatened with destruction: Reading Terminal in Philadelphia, one of the largest remaining glass and steel trainsheds in the nation; Union Terminal in Cincinnati, with its huge rotunda and murals; and the incomparable Grand Central Station in New York. In cities and towns all over the country, other stations are in danger.

Many stations have been lost through fire, deterioration, vandalism, or demolition. Others, some still in use, are badly deteriorated because of lack of maintenance. Not all stations were noteworthy examples of design or endowed with historical significance, and their continued existence would serve no useful or worthy purpose. In some areas, however, passenger stations are valuable community resources. The preservation and restoration of selected stations could have a beneficial effect on rail ridership and on the cultural and economic lives of the communities they serve.

The preservation of railroad stations has received attention at the national level (3). Title 49 of the Code of Federal Regulations was amended in 1975 to include Part 256—Financial Assistance for Railroad Passenger Terminals. This action provides 60 percent federal funding for planning, preservation, and restoration of passenger railroad terminals. Other federal funds are also available for historic preservation from the National Endowment for the Arts and the Department of the Interior.

Unfortunately, Title 49 funds are available only for stations served by Amtrak, and other programs emphasize the reuse of railroad stations as cultural facilities. There is little support available for restoring active rail commuter stations at the local level. Further, many of the stations that best typify nineteenth-century Victorian station architecture are located in smaller communities. They are often modest wooden structures rather than the large masonry terminals found in major cities. These small stations are not monumental architectural landmarks, but they are often fine examples of vernacular architecture, built from indigenous materials and displaying unique examples of detail produced by local craftsmen. It is the rehabilitation of these small and medium-sized stations to which this study is addressed.

In a time of limited availability of resources, the restoration of public, non-revenue-producing facilities has a low priority. If resources are to be expended on rail station-rehabilitation projects, they must be carefully allocated to the areas in which the impact on community welfare will be maximized.

REHABILITATION CRITERIA

To ensure the relevance and viability of this project, the rehabilitation potential of each station was evaluated by the following criteria.

1. The station must be located on a rail line currently in use for passenger service. Preference is given to stations with a high volume of passenger traffic.
2. The station must be in an area that has the potential to support commercial activity. In some highly urbanized areas, land use changes have shifted commercial activity and residences far away from the rail transportation corridors, and the areas adjacent to the stations have been converted to industrial uses or highway corridors or have been abandoned. The revitalization of stations in such areas would be successful only if it were related to a major urban-renewal effort. At the other extreme, some stations are located in rural areas where the population is insufficient to support commercial activity.
3. The station building must be structurally sound and in reasonable condition, so that the restoration costs do not exceed those of demolition and the construction of a new facility.
4. The station should have historic and aesthetic value. Although these qualities are difficult to define and measure objectively, a reasonable test would be the ability to qualify for historic-site status under the guidelines established by the New Jersey Department of Environmental Protection. The designation of the station on the Historic Register ensures its preservation in any project requiring state or federal funds and is a prerequisite for several categories of restoration grants.
5. The community served by the station should be heterogeneous with respect to income and race. Traditionally, railroad commuters are upper-income professional people. Often, the communities served by the commuter lines are among the wealthiest in the state. In effect, renovation of stations in these communities with public funds would be an unwarranted subsidy to the rich. Preference should be given to stations in middle-to-lower-income communities with predominantly middle-income transit ridership.
6. The local government and business community should have demonstrated some interest in and commitment to the restoration project. Without local support and active involvement, it is unlikely that the restoration project will have a significant impact on the community. Local officials must be willing to participate.
7. The possibility of functionally retrofitting the station should exist. The project should not be simply a restoration of an active station. Most of the railroad stations in the late nineteenth century were designed for travel conditions that are different from those that exist today. Large waiting rooms and baggage facilities are no longer needed. The primary emphasis should be on accommodating high peak-hour volumes, park-and-ride facilities, and fast and convenient transfers between modes.

PROJECT DESCRIPTION

Because of the uncertain future of the bankrupt commuter railroads, the outcome of the study was expected to be the development of planning and design concepts, rather than a physical restoration. However, the circumstances that were found, particularly the strong community support and local recognition of the historic and economic value of railroad stations, permitted the project to shift from conceptual planning to an actual station restoration.

The first task was a survey of 77 suburban railroad stations on eight commuter lines. Many of these had deteriorated beyond hope of restoration. A few were maintained in excellent condition, most often by private nonrailroad owners or local governments. The majority, however, are still used and in varying states of disrepair. Each station was inspected, photographed, and evaluated, and Red Bank, New Jersey, was selected for rehabilitation.

RED BANK STATION

The Red Bank railroad station is on the fringe of the CBD and is surrounded by deteriorated parking lots and a number of small business establishments. It has a daily flow of 34 trains and 1500 rail commuters, and serves as the terminus for five local bus lines and as a scheduled stop for four intercity bus lines. Consequently, it is the hub of public transportation in the community although continued physical deterioration in the area could destroy its economic vitality. Improvement of the rail station, however, could provide the impetus to preserve and increase the economic viability of the area (4).

Meetings with local officials started in May 1975. A preliminary site plan was prepared for discussion with local transit operators, and a preliminary cost estimate of $400 000 was developed. This estimate was used as the basis for a grant application for improvement funds submitted to the Federal Railroad Administration. Other improvement grant applications were prepared for submission to various federal agencies. A commitment of $50 000 was obtained from the Department of Housing and Urban Development community block grant program.

A study of potential revenue generation from the improved commuter parking areas around the station and concession rentals showed that annual gross revenues of $20 000 to $40 000 could be expected, which is more than enough to cover the operating costs to the community. The Borough of Red Bank then leased the railroad station from the Central Railroad of New Jersey on October 14, 1975, for a period of 5 years with an option to buy, and plans are now under way to purchase the station from the new owner, Conrail.

The project included historical research on the station. It was built in 1876 and was a handsome Victorian design with a great deal of ornamental woodwork. Since there were no plans of the station available, measured drawings were made of the existing building, and the design of the ornamental woodwork was taken from old photographs and picture postcards (Figure 2). An application for historic site designation was then filed with the New Jersey Department of Environmental Protection. The building was placed on the state historic register December 24, 1975, and designation as a national historic site was announced in July 1976.

A final site plan was completed, and the borough appropriated $25 000 to begin site improvements. A certified restoration architect was retained to complete working drawings of the ornamental woodwork from the measured drawings of the station. By using these as patterns, the regional high-school industrial arts department fabricated the ornamental woodwork. The original Victorian paint scheme and colors were investigated, and several local industries contributed paint and materials. The restoration of the station exterior is now complete, and underground utilities, curbing, and new sidewalks have been installed. The parking-area paving and the sitework are not yet completed.

Figure 1. Pennsylvania Station, New York (1908).

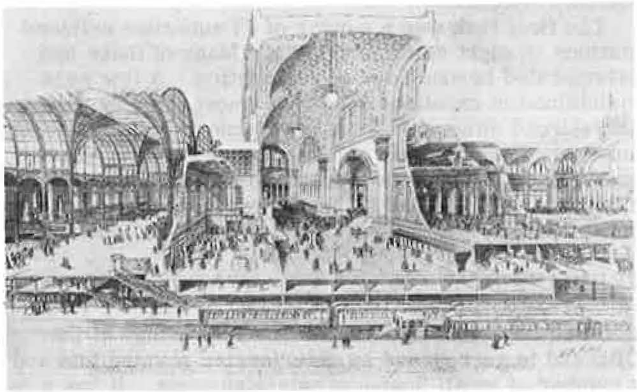

Figure 2. Original appearance of Red Bank Station (1876).

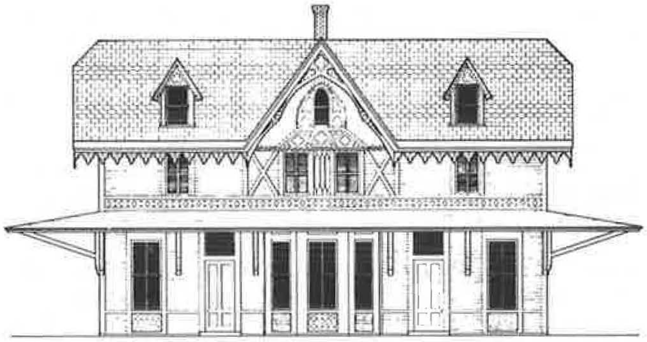

Figure 3. Existing station in May 1975.

Station Environment Prior to Rehabilitation

In general, the station was in disrepair. In 1945, the ornamental Victorian woodwork that had distinguished it had been removed. Unsightly wooden vestibules had been placed around the east doors, and it was characterized by peeling paint, dirt, and accumulated trash (Figure 3). A lack of trash receptacles on the platform resulted in refuse strewn along the track.

Traffic congestion was a significant problem in the area. In addition to the traffic generated by the station, the railroad cuts diagonally at-grade through a major intersection adjacent to the station. The pavement in the 120-automobile parking lot was deteriorated, with large broken-up areas and many potholes. At times of inclement weather or train delays or both, a backup of kiss-and-ride pickup cars clogged the parking area during the evening rush hour. The pedestrian conditions were also poor. Bus passengers were required to cross a busy street to board the buses after purchasing their tickets at the bus terminal. The sidewalks were broken and in general disrepair and pedestrian crosswalks were unmarked. A pedestrian underpass under the tracks was poorly lighted, foul-smelling, and often flooded because of clogged drains, and passengers often chose to cross the tracks by walking around standing trains.

Goals and Objectives

The project was initiated to fulfill three basic goals. These were

1. To encourage more people to ride mass transit,
2. To enhance the economic viability and amenity of the community adjacent to the railroad station, and
3. To instill civic pride and increase community awareness of the history of the borough through the preservation and restoration of one of the oldest public buildings in town.

The specific objectives of the rehabilitation project were

1. To restore the station to its original exterior appearance;
2. To provide new high-quality facilities for intermodal operations, specifically bus, taxi, park-and-ride, and kiss-and-ride;
3. To provide new platform shelters and related passenger-convenience facilities;
4. To improve and repave parking facilities;
5. To improve pedestrian access to the station;
6. To provide information displays about transit routes and schedules;
7. To reduce traffic congestion;
8. To coordinate public transportation and improve service; and
9. To provide additional landscaping and visual interest.

Site Improvements for the Red Bank Station

Figure 4 shows the site plan for the first-stage improvements to the station. The design attempts to respond to the visual elements in the site context, as well as to the transportation requirements. Because the railroad runs diagonally through the site, pedestrians and drivers lose a sense of orientation to the street system. This is especially true at the Bridge Avenue and Monmouth Street intersection. Thus, the design of the parking lots and platform shelters tries to visually relate the geometry of the railroad tracks to that of the street system. To do this, another diagonal element, the east-side parking adjacent to the station, is used to counter the effect of the track and station orientations. This creates the effect of the station front being on Monmouth Street although it is actually in the middle of the site. The design also attempts to focus attention on the restored station by creating a small plaza in front. All of the public transportation activity is concentrated in one area, to increase ease of transfer and to permit shared use of facilities. A well-defined pedestrian system is developed to link bus and rail platforms directly to the sidewalk system. The long diagonal

Figure 4. Proposed site plan for Red Bank Station.

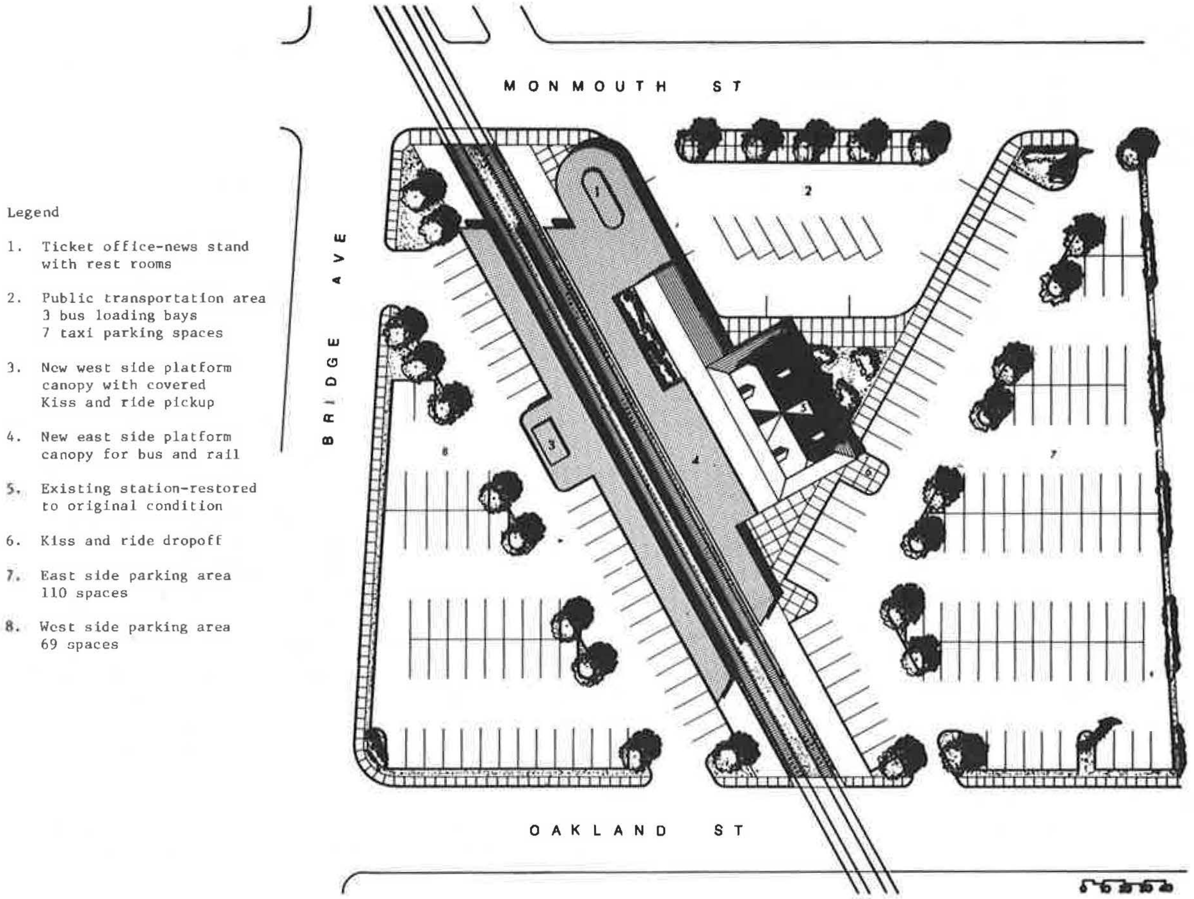

Figure 5. Red Bank Station after restoration (1976).

walk on the east side follows the path of the original flagstone walk and is intended to strengthen pedestrian links to the main business district east on Monmouth Street. The trees are placed in distinct rows to help focus attention on the station and to provide a softening and delineating element between the access roads and the parking areas.

The site plan has the following features.

1. The oval area is a new combination ticket office and newsstand. This facility, approximately 3 by 6 m (10 by 20 ft), would contain ticket counters and information for bus and rail passengers. A concession would be included to sell newspapers, magazines, and coffee to morning commuters. New public rest rooms would be provided. If desired, other transportation activities such as a taxi dispatcher and parking permit sales could also be accommodated. This facility is located at the most heavily used area of the station, where it can serve all modes equally well. Being outdoors, it can serve passengers much more quickly and easily than can the existing ticket office. It is highly visible and provides a convenient point for obtaining schedule information.

2. This area of the site is reserved for public transportation. Space is provided for seven taxi parking spaces in the center, and cabs can pull up to the curb to load and unload passengers. The area can accommodate up to five buses loading simultaneously. There is sufficient space for each of three buses to parallel-park, unload, and pull out without blocking the others. All traffic enters the area counterclockwise to provide maximum visibility for the bus drivers.

3. The existing west-side waiting room and shelter will be demolished and a new 61-m (200-ft) long canopy will be constructed in its place. The new shelter will be closer to the track, to provide weather protection for passengers boarding the train. The platforms will be 4.6 m (15 ft) wide. A 6 by 14-m (20 by 45-ft) extension of this canopy will shelter the entrance to the pedestrian tunnel running under the tracks, and will create a covered pickup area for kiss-and-ride commuters.

4. The east-side platform will have a similar 61-m (200-ft) long canopy. This canopy will connect with the existing station and the kiosk containing the new ticket office. At its widest point, it will cover the 14-m (45-

ft) distance between the bus loading area and the northbound platform.

5. The existing station has been restored to its original condition and color scheme, as shown in Figure 5. The slate roof has been repaired, and the chimney will be rebuilt to its original height. All of the original ornamental woodwork has been replaced. Once the ticket facilities have been moved to a more convenient location outside, a suitable commercial tenant will be found to occupy the station and produce rental income for the property. Four possible types of commercial activity that seem suitable for the interior are restaurants, banks, municipal offices, and antique shops or boutiques. The interior restoration will be deferred until the tenant has been found.

6. This small extension of the sidewalk will provide a convenient drop-off for kiss-and-ride commuters.

7. The east-side parking area contains 110 parking spaces. Thirty-two of these are adjacent to the station. If desired, they could be designated for use by the station tenant or used as metered parking. The remainder could be used for monthly permit-holding commuters.

8. The west-side parking area contains 69 parking spaces for commuters. Both lots contain 90-deg-angle parking to use the space most efficiently. The lots will be asphalt-paved and surrounded by concrete curbing. All of the parking spaces are 5.8 m long by 2.7 m wide (19 ft long by 9 ft wide) with concrete wheel stops where necessary. Those portions of the lots adjacent to the public streets have a parallel 0.9-m (3-ft) wide grass strip and a 1.5-m (5-ft) wide sidewalk along the street. There are concrete curbed islands at the end of each row of parking spaces. Each island has two shade trees and an organic ground cover or a decorative paving surface.

Design of New Shelters

The proposed canopies should be of simple contemporary design, using lightweight steel construction with transparent panels for wind protection and visibility. They should contain ample space for advertising posters in standard 1.52 by 1.23-m (60 by 48-in) double-bill panels. These panels should be carefully designed into the structure so that the advertising becomes a harmonious and visually interesting element. As a potential source of revenue, outdoor advertising should be encouraged, but within the limits set by the designer. No advertising will be permitted on the restored portion of the station. In the design of the new canopies and the ticket office, the signs and transportation-information displays should be included as an integral part. Other elements, such as telephone booths, benches, bicycle racks, and trash receptacles should also be included in the design. The overall effect should be that of a well-thought-out modern system of passenger facilities, but the new facilities should not outshine the restored station structure.

Economic Potential

The initial construction-cost estimate of $400 000 is conservative and may be significantly reduced. It is expected that federal funding will be available for 50 percent of this, and that in-kind services provided by the borough can be used for much of the local share. The potential revenues are shown below.

Source	Amount ($)
Parking	
On site (179 spaces at $0.50/d)	19 690
Other lots (147 spaces at $0.50/d)	16 170
Services to taxi and bus companies	1 200
Concessions, including advertising and vending machines	500
Newsstand rental ($300/month)	3 600
Station rental ($200/month)	2 400
Total	43 560

Parking provides the bulk of the income. The maximum likely parking charge is $0.50/day. If operating expenses are reduced, parking charges should be lowered to encourage more people to use the facility. A daily average charge of $0.25/day would still yield annual revenues of $17 930 at 100 percent occupancy.

CONCLUSIONS

Many of America's aging railroad stations are a unique part of our architectural heritage. The preservation of these stations, however, in the face of declining rail traffic and industrywide bankruptcy, is quite uncertain. If we are to succeed in preserving some of the more important landmark railroad stations, appeals to sentiment and decency may be insufficient motivations. It will be necessary to establish that these stations are valuable resources to the community and yield perceivable direct or indirect economic benefits.

This study tested the hypothesis that railroad stations could be recycled as better railroad stations. It was posited that communities with rail passenger service had a better opportunity to preserve their stations because the historic significance of the station is interwoven with its traditional economic and transportation roles. The following criteria for the selection of candidate stations for rehabilitation were established:

1. Is there sufficient rail-passenger volume to warrant continuation of rail service?
2. Does the potential exist for increased commercial activity?
3. Is the station structurally sound?
4. Does it have historic and aesthetic merit?
5. Is the local community sufficiently heterogeneous to permit an equitable expenditure of public funds on the project?
6. Is there interest and support from local government and the business community?
7. Does the potential exist for functional transportation improvements and intermodal transfers?

This pragmatic approach to the question of restoration offers the best chances for success.

The professionals in transportation planning and engineering have all too frequently ignored cultural and historical considerations in creating new facilities to replace the old. The grime and dilapidation that characterize many rail stations invite scorn and arouse the instinct to tear them down and build something modern and clean. We fail to look beneath the dirt for the hidden beauty and importance of these structures.

The tragedy of the situation is that of all of the groups in our society we, the transportation professionals, have the most to lose. For the structures that we have torn down are the symbols of our profession, monuments to the past achievements of transportation planners and engineers. If future generations are to admire and respect the achievements of today's transportation-system designers and builders, the tradition of preserving historic transportation facilities must be strongly established within the professional community itself.

ACKNOWLEDGMENT

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