TRANSPORTATION
RESEARCH RECORD 857

Bus Operations and Performance

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NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D.C. 1982

Transportation Research Record 857
Price $10.40
Edited for TRB by Naomi Kassabian

mode
2 public transit

subject areas
11 administration
12 planning
13 forecasting
14 finance
15 socioeconomics
16 user needs
53 vehicle characteristics
54 operations and traffic control
55 traffic flow, capacity, and measurements

Library of Congress Cataloging in Publication Data
National Research Council. Transportation Research Board.
Bus operations and performance.

(Transportation research record; 857)
Reports prepared for the Transportation Research Board's 61st annual meeting.
1. Bus lines–United States–Congresses. 2. Bus lines–United States–Fares–Congresses. 3. Bus lines–United States–Finance–Congresses. I. National Research Council (U.S.). Transportation Research Board. II. Series.
TE7.H5 no. 857 [HE5623] 380.5s 82-18893
ISBN 0-309-03360-8 [388.4'1322'0973] ISSN 0361-1981

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Public Transportation in the 1980s: Responding to Pressures of Fiscal Austerity

BRENDON HEMILY AND MICHAEL D. MEYER

Fiscal austerity is a growing reality for an increasing number of public transportation agencies and may become the dominant factor shaping the evolution of the transit industry in the 1980s. The purpose of this paper is to look at how transit agencies are responding to these financial pressures and to examine the likely implications of these trends. An extensive telephone survey was conducted of general managers in 30 transit properties in order to assess the current financial state of the industry, to identify the financial pressures and options as viewed by top management, and to determine future directions that will be followed by local officials. The survey results showed a substantial number of agencies already financially constrained. These agencies have used five basic types of actions to respond to these financial pressures: (a) raising fares, (b) reducing levels of service, (c) reducing costs through labor negotiations or staff reductions, (d) seeking increased public funding, and (e) improving the efficiency of providing service. The survey raised questions as to the extent that fare increases can be used to respond to financial pressures, the role of states in the process, and the criteria used to reduce service. The study concludes that fiscal austerity is most likely a long-term trend for many agencies and would require a reevaluation of agency goals; a reassessment of various tasks, in particular marketing and service planning; and considerable thought to the issues of strategic planning and the improvement of efficiency.

Recent trends in the cost and finance characteristics of public transportation present some ominous signals of the difficulties that transit agencies might face in the 1980s. Capital and operating costs continue to rise at rates greater than inflation. Many local governments, constrained by the poor state of the economy, are having difficulty finding the resources needed to continue transit subsidies. In addition, the Reagan Administration has proposed serious cutbacks in federal assistance. How serious are these trends for transit? How would they affect various tasks involved in providing transit service? How can agencies respond to these fiscal pressures? And how do general managers view the constraints and options that affect possible agency response to these pressures? The purpose of this paper is to focus on these questions, gain insight into the current state of the industry as seen from the perspective of the general manager, and discuss some of the management implications of these trends and the way they are being handled.

RESEARCH METHODOLOGY

Answering the questions posed above required that personal contact be made with high-level management in a cross section of U.S. transit agencies. The most effective means of doing this was to undertake an extensive telephone survey of transit general managers. Such a survey was structured to allow a broad look at the transit industry and to determine its status prior to the possible implementation of cutbacks in Section 5 operating assistance. Clearly, the general manager's perspective on the constraints and options being faced was important, since in most cases the general manager was the key actor in responding to financial pressures. Also, from the view of this research, the manager was probably the best individual from whom to obtain information, given his or her knowledge of both the transit organization and the agency's institutional environment.

Telephone interviews were conducted with the general manager in 30 transit agencies, a sample that represented a broad spectrum of medium-sized agencies (100 to 1000 vehicles). The following transit agencies were surveyed:

1. California: San Francisco Municipal Railway, San Diego Transit Corporation, Santa Clara County Transportation Agency;
2. Colorado: Denver Regional Transportation District;
3. Connecticut: Connecticut Transit, Hartford Division;
4. Florida: Jacksonville Transportation Authority, Metropolitan Dade County Transportation Administration;
5. Georgia: Metropolitan Atlanta Rapid Transit;
6. Indiana: Indianapolis Public Transportation Corporation;
7. Maryland: Mass Transit Administration of Maryland;
8. Michigan: Southeastern Michigan Transportation Authority;
9. Minnesota: Metropolitan Transit Commission;
10. Missouri-Illinois: Bi-State Development Agency;
11. Missouri-Kansas: Kansas City Area Transportation Authority;
12. New York: Niagara Frontier Transportation Authority, Rochester Regional Transportation Authority;
13. Ohio: Cleveland Regional Transportation Authority, Queen City Metro, Central Ohio Transit Authority;
14. Oregon: Tri-County Metro;
15. Pennsylvania: Port Authority of Allegheny County;
16. Tennessee: Memphis Area Transit Authority;
17. Texas: Dallas Transit, Metropolitan Transit Authority (Houston), VIA Metropolitan Transit Authority;
18. Utah: Utah Transit Authority;
19. Virginia: Tidewater Transportation District Commission, Greater Richmond Transit Company;
20. Washington: Metro Seattle Transit; and
21. Wisconsin: Milwaukee County Transit System.

Each general manager was asked questions in three topic areas:

1. Background information: Questions were asked concerning specific tasks, such as planning (size of planning staff, types of service standards used, organization of route evaluation); marketing (marketing tools, public participation process, existence of system map); and operations (last strike, use of part-time labor, management-labor communications). Other questions sought to give a picture of ridership and agency structure (institutional arrangements and organizational structure). All this information was to help supplement information collected from printed sources (1-4).
2. Financial issues: Questions concerning the existing financial condition and its likely evolution were asked. Questions were asked concerning current fares, recent fare increases, formal fare policy, breakdown of revenue sources, existence of dedicated taxes, prospects for new sources of funding, and future constraints.
3. Issues relating to operating under fiscal constraints: Areas examined were recent or future service changes, efforts to improve productivity, and actions taken to otherwise reduce costs.

In the rest of this paper, the survey concerning the sources of financial pressure and the types of responses being pursued by transit agencies will be presented and the issues they raise discussed.

SOURCES OF FINANCIAL PRESSURE

One of the underlying assumptions of this study was that transit agencies were facing significant financial pressures and that specific steps were being taken, or were at least being contemplated, by transit managers in response. In order to put a particular agency's response in perspective, a brief assessment had to be made of the specific financial pressures facing that agency. For this purpose, the assumption was made that costs were fixed in the short run and that the financial condition of an agency could be assessed by determining whether revenues were sufficient to meet the given level of expenditures and then by identifying the pressures on the various revenue sources.

The results of the survey show that the financial situation varies tremendously from agency to agency in terms of whether the system's financial situation is healthy, currently stable, dependent on outside events, or severely constrained. One-third (10) of the managers felt that their situation was currently stable and that they would not have financial problems in the short run. One of the following three reasons was usually given for the belief of stability: (a) large contributions from sales tax revenues (usually in areas experiencing high rates of growth), (b) exceptionally high operating ratios (i.e., that proportion of costs covered out of farebox revenues), and (c) extremely diversified funding sources. However, only 4 of these 10 systems appeared capable of facing Section 5 cutbacks without some response to this funding loss.

Of those systems whose general manager expressed concern about their financial status, the most frequent cause was the shrinking revenues from a major dedicated tax (sales, property, earnings, gasoline). This was affecting 10 properties and ranged from situations in which sales tax revenues grew last year at a pace slower than anticipated, creating minor shortfalls, to one in which the growth rate of the dedicated tax has been consistently under the inflation rate for several years, causing any previously accumulated surplus trust funds to be at the point of exhaustion. Several managers felt that dedicated taxes were no longer a guarantee of financial stability. Sales and earning tax revenues were being affected by the recession, and revenues from gasoline taxes were reduced because of gains in fuel conservation and automobile efficiency.

Other problems cited involved the poor financial condition of major financial contributors to a transit agency, e.g., states (two systems), counties (one system), and municipalities (four systems). Finally, in three cases, the financial condition of the system depended on outside events that would be resolved in the near future, e.g., suburban communities refusing to renew service contracts, current contract negotiations, or the expiration of a dedicated taxing authority.

The information gathered from the survey concerning major sources of revenues is outlined below:

1. Fares: average contribution, 41 percent (range 15-66 percent); less than 25 percent, 3 systems; more than 55 percent, 3 systems;
2. Section 5 funds: average contribution, 18 percent (range 4-30 percent); less than 12 percent, 4 systems;
3. State operating assistance ($\geq$10 percent of agency revenues), 13 systems;
4. Dedicated local taxes: sales tax, 11 systems; property tax, 2 systems; earnings, payroll, license fee, 3 systems;
5. State aid and dedicated taxes, 5 systems; and
6. Only federal and local general revenues, 6 systems.

Fares are still the predominant source of revenue (on average covering 41 percent of costs), although there is a fairly wide variance concerning its exact contribution. Section 5 operating assistance is also an important source of funds, although its contribution is much smaller (18 percent) than that of fare collections. These findings are consistent with numbers available from the Section 15 reporting system for fiscal year 1979, which found an average fare contribution for the classes of systems surveyed of 38 percent and an average federal contribution of 18 percent (5).

As for the other sources of revenue, there is a distinct pattern of income coming more frequently from dedicated taxes or state aid than from local governments. Only four systems received income from county general revenues, and nine received municipal operating assistance. Perhaps this ensures some stability since the six systems that received neither dedicated sources of income nor state aid appeared as a group with the most consistently difficult fiscal pressures on them.

RESPONSE TO FINANCIAL PRESSURES

There are five major types of actions that transit officials have used individually or in combination to respond to financial pressures: increased fares, reduced levels of service, reduced costs, increased public funding, and improved efficiency. Each of these five types of action will be analyzed by using the results of the general managers' survey.

Increased Fares

Increasing transit fares was suggested most often by the general managers as the first step in responding to financial pressures. This reflects a general change in perception about the role of fares that seems to be the result of several phenomena. First, there has been much discussion about fares and their direct influence on the industry's decreasing operating ratios. Several managers expressed interest in the concept of user charges and felt that fares should at least keep pace with inflation, and a few felt that transit patrons should be covering a larger percentage of the costs of using that service.

Second, several managers felt that during the last few years great strides had been made in improving the quality (comfort, reliability, and attractiveness) of the service offered, especially when compared with the condition of many private systems that were taken over publicly in the 1970s. These managers argued that in places where the public transit service compared favorably, not only to the previous state of the system but to competing modes, such as private suburban bus or even to the automobile, patrons must become convinced that a quality ride is worth a higher price.

Third, most managers stated that ridership is more sensitive to service cuts than it is to fare increases. Thus, in times of severe financial pressure it is preferable to increase fares rather than cut significant service.

Fourth, it was felt that the general economic picture has made fare increases easier to implement than previously. The recession has reduced the resistance to fare increases. The representatives of those constituencies who use transit heavily have other issues to defend such as the maintenance of public services, i.e., police, fire, and education or employment. Furthermore, many managers argued that the mood of fiscal conservatism in the country has given more influence to opponents of public service and has created greater pressures for user charges to be increased.

In the first seven months of 1981, 17 of the 30 systems had already increased their fares. Of these 17, 11 had also raised fares in 1980. Eight more systems without fare increases in 1981 had their last fare increase in 1980. Thus, only 5 systems (out of 30) had not raised fares in the last 18 months. The distribution of fares (base fare + transfer) is shown below. The mean fare of the 30 systems was $0.63.

Fare ($)	No. of Systems	Fare ($)	No. of Systems
0.40	4	0.70	4
0.50	5	0.75	0
0.55	2	0.80	2
0.60	6	0.85	2
0.65	3	1.00	2

Some managers suggested that a catching-up process was taking place. This was illustrated by the fact that the mean fare increase over the period January 1980 to July 1981 was 62 percent, implying a 39 percent increase per annum (three times the inflation rate). The average amount that fares increased over that 19-month period was $0.21. More than half the systems have explicit fare policies where a specific amount of costs must be covered through fares. These dictate, in many cases, fare increases every year. Many managers felt that these fare policies would be shifted upward, increasing the operating ratio to be achieved in the years to come and thus shifting the burden increasingly onto transit riders. The distribution of fare increases over the 19-month period is as follows:

Percentage Increase	No. of Systems	Percentage Increase	No. of Systems
20	2	60	3
25	2	65	1
30	2	70	3
35	1	100	2
40	2	140	1
50	5	200	1

Finally, there appears to be a certain movement away from a flat-fare system. Two agencies (Columbus, Ohio, and Salt Lake City, Utah) adopted a peak/off-peak pricing scheme in 1981. Two other agencies (Denver and Cincinnati) already had such a system. In some cases such a pricing system was justified not only through the potential savings in costs by spreading the peak but through increases in ridership that would occur by tapping a latent market, thus producing a net gain in revenue.

Reduced Levels of Service

Although most transit managers felt that cutting service was much more harmful than increasing fares, it becomes the next option because other potential responses require a longer time to be implemented. It is not surprising, then, that a smaller number of systems cut service than increased fares. Nonetheless, 10 systems had to make significant cutbacks in service miles over the last year, and another 5 were involved in minor cutbacks. Only six systems claimed to be expanding their service, and some of these were in the last stages of a planned growth process. Eleven of the 30 systems did not foresee cutbacks next year, but many of the others said that it depended on a series of factors whose outcome was uncertain (e.g., the phasing out of Section 5 funds, labor negotiations, and pending state legislation).

In comparison with fare increases, which were being pursued by the vast majority of agencies, changes in service levels illustrate the major differences between agencies. At one extreme, one agency cut vehicle miles by 25 percent in 1981. At the other extreme, one system was proposing to double service miles at the end of its five-year plan. However, more systems were cutting service than adding it, and most managers saw this trend continuing in the future.

One of the most interesting results of the survey in regard to service cutbacks was the process used to choose which services would be curtailed. Few systems had criteria or procedures for cutting service that would enable them to fully evaluate tradeoffs. This was primarily explained by the fact that route planning had been geared either to expanding service to new areas or generators or to fine-tuning the service provided on a route to match the demand as it varied by month, by day, or by hour. Cutting service is a recent phenomenon and is a dramatic change from the growth that took place in the 1970s. Most systems seem not to have evolved any policy that makes choices clear, and although many agencies had formal service standards, most used them only as guidelines. A few systems were trying to develop indicators to identify costs of providing service by route but were hindered by the complexity of the data-management process involved. In most cases when cutting service, ridership as expressed by X passengers per hour seemed to be the main, and often exclusive, criterion for analysis. This was used to weed out unproductive routes on weekends or evenings and also served, as one manager pointed out, to eliminate "political" routes. Only a few managers explicitly mentioned trying to take into consideration the existence of alternative service so a minimum of passengers were left completely without service.

When more drastic cuts were needed, transit officials took the ridership-criterion approach a step further and evaluated overall ridership by weekly time periods. A similar pattern of service cuts emerged from systems going through massive cuts: first, owl service was eliminated, then Sunday service, and then night service; then major cuts were made in evenings, and then large reductions were made in Saturday service. When massive cuts had to be achieved and preserving ridership was the primary criterion, this cycle of cutting successive time blocks seemed to be the most convenient method, especially when planning-staff resources were limited.

Reduced Costs

A third option often pursued as a response to financial pressures was direct attempts by managers to reduce their operating costs. These actions, however, usually require a larger time to implement and are of two types: cost reductions through labor negotiations and reductions in staff.

The two principal cost-cutting measures sought during contract negotiations included the right to use part-time labor and the limitation of cost-of-living-adjustment (COLA) escalators. There is a significant move toward part-time labor; 15 systems had already negotiated this agreement with five of these in the last year alone (Muni, Santa Clara, Indianapolis, Southeastern Michigan Transit Authority, and Cincinnati). The usual limitation to the use of part-time labor was that it should not exceed

10 percent of the work force. Opinions varied considerably on how useful it was to the system, ranging from enthusiasm and strong results in systems where the ratio of peak to base ridership was very high to systems that rarely used part-time labor because of training and labor issues. However, all agreed that it did increase the manager's flexibility. Many managers also expressed concern about the cost increases and uncertainty caused by COLA payments. Seven systems had actively sought, in the last year, to cap the COLA escalator during negotiations.

Reductions in the level of service usually translated into reductions in the number of drivers. However, several managers also stated that their staff had been severely reduced, with one agency eliminating 170 staff positions. These staff reductions usually fell hardest on the departments of planning, marketing, and general administration in order to, as one manager put it, preserve "the productive service" of the agency, namely, operations and maintenance.

Increased Public Funding

A fourth option in responding to fiscal pressures is to modify the public sources of income to the system, either by increasing income from current sources or by seeking new sources of funding. During the 1970s this appears to have been the preferred method of dealing with fiscal pressures. This practice was based on the public's perception that after public takeover of private systems (usually financed by new sources of income themselves), there was an expectation that not only should service be improved but fares should also become stable.

However, this situation has changed dramatically, and the very pressures that affect transit also affect its ability to seek increased public funding and even the ability to exchange an inadequate taxing authority (such as property tax) for one that is more sensitive to inflation (sales tax). One-third of the agencies surveyed saw no prospects for changing their current mix or levels of revenue from public sources. Even though one system (Columbus) managed to obtain a new sales-taxing authority through a referendum, nine others lost referenda or legislative battles to change their sources of income. Managers suggested various reasons why their attempts at modifying or increasing sources of public funding failed--the recession, Proposition 13-type mood, the strength of rural or suburban constituencies, conflicts between highway and transit lobbies, etc.

Nonetheless, different types of options were being pursued with some prospects of success. Six agencies were hoping for increased state aid; three others were hopeful about changes in state gasoline taxes that would move from a volume base to a price base. Three others were counting on either new state operating assistance or a local option tax. Other prospects included increasing the local sales tax, creating a downtown transit district, or utilizing new federal legislation on charter operations and leasing vehicles.

In terms of the pressures on existing dedicated taxes and their relation to inflation, it would appear that no single tax is truly adequate. By most accounts, the most reliable tax is the sales tax. However, in many cases, managers stated that revenues produced by it have diminished as sales are affected by recession. Its revenue-producing capabilities were greatest in areas of sustained growth (although in one case this was inexplicably not true). As for revenues produced by gasoline taxes, the managers noted that they consistently continue to fall as conservation and fuel economy increased. Basing gasoline taxes on a sales rather than volume base would help and has been sought by two agencies, but the revenues are usually shared by different modes and are thus subject to competition for their use (especially as the needs for highway maintenance soar).

Improved Efficiency in Providing Service

Much recent discussion in the transit field has focused on trying to improve the efficiency of service provision (6-8). Most of this discussion has focused on trying to pay more attention to the real costs of operations and the use of performance criteria, but it is sometimes difficult to see how the concern for efficiency is actually incorporated by operators into the agency's activities. Though not a quick strategy to an immediate problem, some managers did identify actions to increase efficiency as part of their response to financial problems. There seemed to be four levels at which action might be taken to improve efficiency:

1. Organizational efficiency, or the process of improving the efficiency of the overall organization by clarifying responsibilities, improving information, and strengthening control;
2. Network efficiency, or the process of improving the performance of the route structures and network in order to reduce system costs;
3. Operational efficiency, or the process of improving operational performance and ensuring a more efficient use of the various resources (labor, capital, information) needed to provide service; and
4. Individual efficiency, or the process of encouraging better individual performance from each employee.

Organizational Efficiency

One development in recent years that is significant for transit organizational efficiency is the rapidly increasing number of agencies with management-by-objective (MBO) processes. The survey showed that 20 of the 30 properties had formal MBO processes and 13 of these were less than three years old. The process was aimed at specifying goals for the system and objectives for each department, division, or unit, against which related performance could be compared; sometimes it was linked with employee evaluation.

Several managers felt that there was a definite trade-off between the level of detail of the process and the time and effort spent on it. Each agency appeared to be evaluating that trade-off through an adjustment period in the first years of the process' implementation. In two cases, the process had been rejected because the results did not warrant the effort and perceived complexity of the process. Though not directly related to dealing with financial pressures, the MBO process is relevant in that it provides a framework to identify priorities that can help in trading off alternative actions.

Network Efficiency

Actions aimed at network efficiency seek to improve the productivity of operations, thus resulting in reduced costs. Two types of actions that serve this purpose were mentioned by managers as part of the agency's response to financial pressures. The first concerned transportation system management (TSM) actions. Although responses from some managers indicated that TSM as a concept loses some of its priority when immediate financial problems exist, two specific examples were provided where a TSM action was being pursued as a component of the agency's response to financial problems. One involved four bus priority lanes (Pittsburgh) and the other a bus-activated signal priority system (Jacksonville). In both cases, the reduction in travel time meant that fewer buses would be used to maintain the same headways. The priority system cost $80 000 and was estimated to recover its cost in three years.

The second type of network efficiency action changes the overall structure of routes. In one transit agency, corridor planning was adopted to permit a planning process that would be more capable of identifying and eliminating duplicative service. In three other transit systems, the total route structure had been or was being modified from a radial orientation to a grid system. The intent of this change was again to eliminate duplicative service and provide a better market base for crosstown or circumferential routes.

Operational Efficiency

In seeking more efficient use of the various resources needed to provide service, a small number of properties were reevaluating their performance criteria to improve the cost-effectiveness of individual routes. However, most efforts in this area involved actions to improve utilization of labor and capital resources or actions to mechanize certain tasks.

A variety of actions were taken to improve resource utilization: use of transit line coordinator; driver utilization program; reduced number of job bids to avoid job-hopping; use of articulated buses; modernization of maintenance facilities; bus quality control program; and driver suggestion program. Actions to mechanize certain tasks were as follows: improvement of management information system (MIS) (major activity in six systems, ongoing in eight, starting in three); mechanized public information system; mechanical vehicle identification and information systems; computerized recording of inspections, attendance, job descriptions; audiovisual driver and management training classes. Mechanization and computerization to increase the performance of some tedious manual tasks was an on-going process in many agencies, and in a longer-term perspective of improving management performance, MIS were continuously being expended to increase their role for accounting, reporting, inventorying parts, and cutting runs.

Individual Efficiency

Finally, a few properties recently implemented procedures to increase the efficiency of individual employees. This involved three different types of actions: actions to increase employee involvement in the agency's activities in order to improve labor relations, actions to improve employee morale or to create positive incentives for better individual performance, and actions to avoid costly undesirable behavior such as absenteeism or misconduct. Examples of actions used in different agencies are given below:

1. Actions to increase employee involvement:
   a. Driver suggestion program (four systems)
   b. Development production groups (three systems)
   c. Passenger service committee
2. Actions to improve employee morale or to create positive incentives:
   a. Driver-of-the-month program
   b. Employee of the year
   c. Employee newsletter, produced by employees
   d. Comprehensive employee assistance program
   e. Monetary rewards for performance (four systems)
3. Actions to avoid undesirable behavior:
   a. Strengthened performance code or program (seven systems)
   b. Citations for safety violations
   c. Attendance recording
   d. Probationary contracts with code offender

Many agencies expressed particular concern about absenteeism, and eight systems had recently strengthened performance codes and were increasing enforcement through disciplinary actions. Interestingly, there was also an emphasis on increased monetary rewards (four systems), sometimes in the same agencies that had taken tough stands on discipline.

The pursuit of efficiency, whether organizational, network, operational, or individual, as a response strategy to fiscal pressures may not produce significant short-term cost savings. Rather, its importance lies in providing the manager with sufficient flexibility to address longer-term financial issues. Successful management in an era of service cutbacks means maintaining employee morale and discipline as much as possible and especially not losing sight of the agency's goals as the need for cuts becomes more pressing.

CONCLUSIONS

The survey results provide a good picture of the current status of the transit industry as it begins responding to several political and financial challenges. The survey showed the diversity of the various agencies' positions but also indicated some trends that have important policy implications. There are several issues that these results raise, some related to the actions taken and others related to the sustained nature of these financial pressures.

Issues Related to Actions Taken

Diversified Funding Sources

Fare increases have been the first action taken in response to financial problems. All the systems that were financially constrained had increased their fares recently, often by large amounts. This raises the question of how high fares should be and how fast they should increase. Should we anticipate, as one manager did, that fares in three years will be 150 percent of what they are now? There is a limit to the extent such a response can be pursued. It is clear that fares cannot at the same time cover the increases due to inflation, replace public funding sources that are not growing fast enough (property tax, gasoline tax, and even sales taxes in many cases), and substitute for phased-out Section 5 operating assistance.

With respect to public funding, it appears that the existence of dedicated taxes and/or state aid, even if they are not always keeping pace with inflation, still offers the agency some flexibility in dealing with fiscal pressures. This flexibility also seems to increase if the agency is able to diversify its funding sources. In comparison, the single group of agencies with the most consistent pattern of financial problems received neither state aid nor revenues from a dedicated tax. These systems relied on only three revenue sources (fares, Section 5, and municipal or county general revenues). They were particularly threatened by economic forces affecting local finances or by the elimination of Section 5 funding.

However, the existence of a sales tax is not in itself a guarantee of a healthy financial situation, since these sources can be affected by economic recession. An agency should thus resist relying too much on current revenues from the tax and resist using large tax revenues to maintain extremely low fares. Any excess revenues could rather be used to create a trust fund that can permit reliable five-year planning. In the absence of large revenue-creating taxes, diversity of funding sources could be sought. Though it may complicate political interactions, it allows for more flexible responses.

Role of State

The role and attitude of the state will also be an increasingly important factor to consider in analyzing financial options. Eleven of the 22 states covered in the survey provided operating assistance; several others had passed legislation enabling local-option taxes. However, the managers surveyed were generally pessimistic about the prospects of increased aid in states that did not already have aid programs, given the mood of fiscal conservatism. Given the new federal policies of returning funds and program authority to the states, this perceived reluctance for increased state aid could be a serious indication of even more financial difficulty in the future.

Criteria for Service Reduction

The survey showed that the predominant criterion used by managers in reducing service was to minimize total ridership affected, sometimes taking into consideration the existence of alternative service. This often led to a cycle of cutting service from whole successive time periods. The use of this criterion has a hidden implication that should be recognized; it implies that the fundamental purpose of transit is to serve commuters (these are the single group of users who are protected the longest during such a cycle of cuts). This may be in fact what is desirable, but then it should be recognized that alternative social goals may not be served.

Reevaluation of Service Planning

Service planning is usually one of the first staff functions to be severely reduced in times of staff cutbacks. This occurs because increased emphasis is placed on preserving the productive service and because service planning is viewed essentially as a tool for serving growth (i.e., planning for expanded service). Several managers felt that once the system is operating at the necessary level and no service expansions are projected, service planning becomes less essential since minor changes are assumed to be handled by the scheduling and operations staff.

However, it is important to realize that periods of severe cutbacks entail major (if negative) service changes to the system, and if such a trend is to continue, it becomes critical to preserve the agency's means of analysis in order to minimize as much as possible the disruptive nature of these changes on both users and personnel.

Another aspect of this issue is that service planning may have to be reevaluated in light of this new trend. Goals, criteria, and procedures should be rethought in order to take into consideration increased emphasis on costs, explicit analysis of existing alternative services, and the need to trade off different potential options for responding to financial pressures.

Issues Related to Sustained Problems

Curtailment Cycle

Although many managers felt that fiscal pressures were more than just current imbalances in budgets, only in a few cases did an analysis of the implications, or of the actions to be taken, extend beyond the current year. Such a short-term perspective usually leads to a crisis-management attitude when problems occur. To the extent that an agency's financial problems are not simple imbalances in the budget but a signal of a longer-term change in the agency's financial and institutional environment, the response should perhaps be thought of as part of a curtailment cycle with goals and processes different than when service is being expanded during a growth cycle and that might have implications for goals to serve, the organization of various tasks, and network structure.

Importance of Strategic Planning

Given the long-term nature of the financial situation of many transit agencies and its implication on the goals, objectives, and planning procedures the agency uses, strategic planning may become an important tool for agencies trying to deal with this financial uncertainty. Strategic planning provides an analysis framework that helps to define goals and objectives, analyze trends, evaluate options, and merge various actions into a strategy whose outcome a few years hence is understood and desirable.

The identification of goals is a particularly difficult problem during a curtailment cycle. It is easy to serve a variety of goals during growth periods just by expanding service; to serve new geographic areas or new user groups, one can expand the network; and to attract nonusers, one can increase frequency or purchase better vehicles. During a curtailment cycle, one must constantly trade off one goal for another, and there is always the danger of collapsing all goals into one.

Goals have to be specified and the linkages between the transit service provided and the well-being of the community must be made explicit. The manager must know what components of the service are important and why, so that it can be determined how best to protect the achievement of these goals. This is important for top management in its efforts to organize the production of transit service during a curtailment cycle, but it is also important for them in their dealings with outside actors. Defining goals explicitly in a way that links the long-term well-being of the community with that of the agency and that can be translated into clear objectives might help improve transit's image and ease discussions in times of financial problems. The problem is, of course, how to make goals explicit and how to make them operational. In this respect, the trend observed in the survey toward the development of MBO processes in many agencies might provide a good preliminary base since it establishes a coherent procedure for determining priorities.

Improving Efficiency

A longer-term perspective of the financial trend facing transit justified considering improvements to efficiency as another option in responding to financial pressures. However, efficiency improvements are not only difficult to achieve but also difficult to understand and trade off with other managerial options. More analysis should be made of their role within a coherent strategy involving other actions. It was clear for the survey that managers are more prepared to take strikes to achieve gains in efficiency. But it should not be forgotten that unions also have a stake in preserving service for purposes of employment. To the extent that this can be communicated and fair exchanges negotiated, labor relations need not deteriorate.

1980s as Period of Change

The 1980s will bring considerable change and thus strain those transit agencies subject to a curtailment cycle. However, the change, by its very nature, will provide certain opportunities for reorganization. To the extent that this entails reassessment of goals and practices, this might be an occasion for renewal. The challenge to transit management lies not only in preserving a vital service to the public but in seizing the opportunities provided by these changes to rethink and reorganize the provision of a service that will better serve the interests of the public. Thought must be given to how the crisis might be used and not only survived.

ACKNOWLEDGMENT

This research was sponsored by a grant from the Urban Mass Transportation Administration (UMTA) of the U.S. Department of Transportation (DOT). The opinions expressed are ours and do not reflect the policies or procedures of UMTA or DOT.

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Publication of this paper sponsored by Committee on Transit Management and Performance.

Design of Bus Transit Monitoring Programs

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A method is described for the design of a comprehensive, statistically based data-collection program that can support bus route planning and operations. A two-stage approach used in the design of the collection program is advocated. In the baseline phase, a detailed profile of each bus route is developed. This is followed by a monitoring phase in which limited data are collected to verify that the route profile developed in the baseline phase is still accurate. Both the desired accuracy and the inherent variability of the data items are considered in the design of the data-collection program. To reduce the overall cost of the data-collection program, consideration is given to the use of simple linear relationships between data items. The methodology discussed in this paper was developed under contract to the Urban Mass Transportation Administration and has been approved as meeting the Section 15 reporting requirements for passenger-related data.

In recent years, there has been a growing awareness of the need to use public transportation resources more efficiently (1). It has become more important to evaluate carefully all services, both current and planned. In response, many transit agencies, large and small, have developed on-going programs that use performance measures and standards to evaluate their transit services (2,3). Often, however, these evaluation programs have not been supported by adequate data-collection programs. Cost-effective programs are needed to provide the passenger-related performance data that are required for good service evaluation.

This paper describes a methodology for the design of a comprehensive, statistically based data-collection program that can support the service-evaluation process. This methodology was developed under contract to the Urban Mass Transportation Administration (UMTA). By using this methodology, most transit agencies will be able to develop and maintain comprehensive profiles on all their bus routes at a reasonable cost. Although the focus of the approach is route-level data collection, the approach also provides systemwide performance data (such as UMTA-required Section 15 data) through the aggregation of individual route data.

In this paper the overall approach to performance monitoring is described first, followed by a description of the data needed by transit agencies for short-range operations planning. The next two sections describe the available data-collection techniques and how they can be combined into a sampling plan. In the final section the costs of implementing such a program are discussed.

PROPOSED APPROACH TO DATA COLLECTION

The proposed approach consists of two distinct data-collection phases. In the first phase, or the baseline data-collection phase, the base conditions are defined by time of day for each bus route in the system. The base conditions include all the data needed for effective operations planning, including total boardings, loads at key points on the route, running times, revenues, origin-destination (O-D) data, and passenger characteristics. The baseline phase presents a snapshot of route performance at one point in time. Complete route profiles are developed from these data, which facilitate comparisons among routes in specific subareas, function types, or the system as a whole. Since the baseline phase includes the collection of all data items needed for service planning and evaluation, it also provides an excellent opportunity to analyze the potential for route improvements and reallocation of equipment.

In the monitoring phase of data collection, each route is checked periodically to verify that the base conditions (i.e., route profile) for the route are still valid. Only three data items are collected in this phase--bus arrival time, peak-point load, and passenger utilization. It is assumed that if neither peak-point load nor passenger utilization have changed significantly, the other data collected during the baseline phase (e.g., passenger origins and destinations and fare categories) have also not changed significantly.

Although the baseline and monitoring data-collection phases differ in the number of data items collected, the two data-collection phases are designed in the same way. Four important inputs are required:

1. A list of data required by the agency,
2. An estimate of the required accuracy for each data item of interest,
3. Key agency and route characteristics, and
4. Existing data or data obtained in a special pretest from which sample sizes can be determined.

The following sections discuss how each of these inputs is used in the data-collection design process.

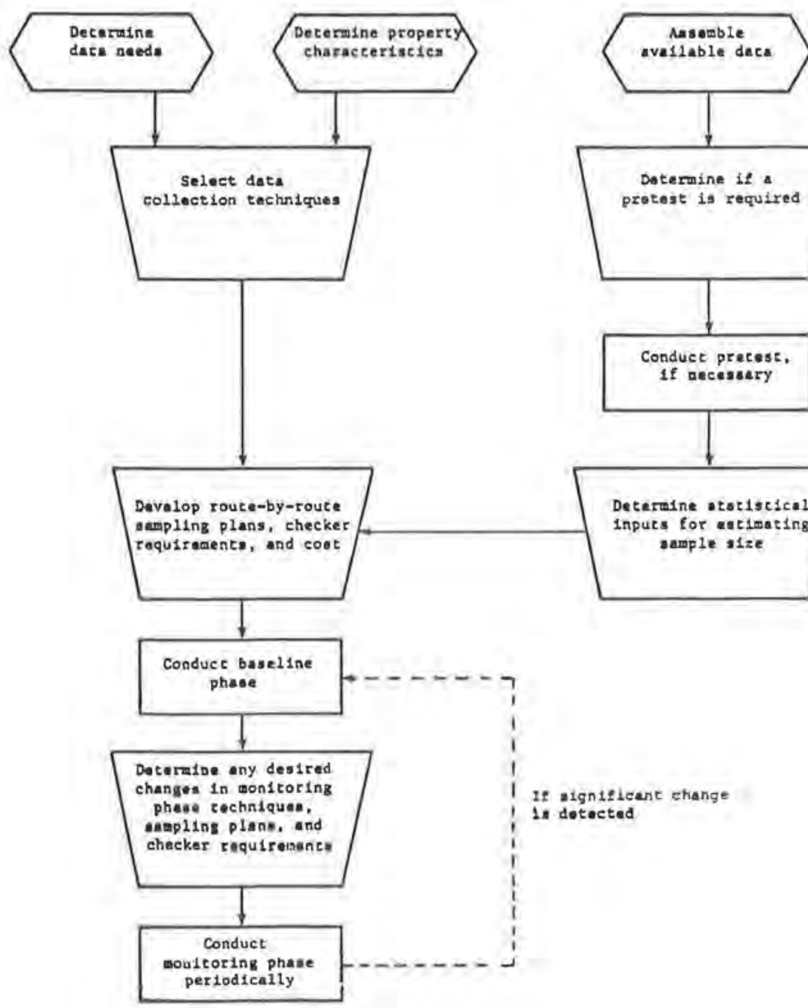
DATA NEEDS

The first step in the design of the data-collection program (Figure 1) is to specify the data required for planning and management activities and for external reporting. These data vary among transit agencies depending on the size and type of system operated, the specific management objectives, and the requirements for the external reporting.

To ascertain typical data needs of North American transit agencies, information from more than 100 bus transit agencies was examined. This included an analysis of the material collected from 71 transit agencies by the Massachusetts Bay Transportation Authority (MBTA) in Boston and the Tidewater Transportation District Commission (TTDC) in Norfolk, Virginia (2). These materials were supplemented by discussions with 41 other agencies that focused directly on the data desired by these agencies and the data-collection techniques currently employed (4).

Based on these efforts, a list of data items was developed that were used by or desired by a large number of transit agencies. Each data item listed

Figure 1. Data-collection program design and implementation.



was reported as being useful in one or more aspects of service management, including route planning, scheduling, marketing, cost reimbursement or deficit allocation, and external reporting.

1. Route- or stop-specific data:
   a. Load (peak or other) at specified points (not averaged throughout trip)
   b. Bus arrival time
   c. Total boardings (i.e., passenger trips)
   d. Revenue
   e. Boardings (or revenue) by fare category
   f. Passengers boarding and alighting by stop
   g. Transfer rates between routes
   h. Passenger characteristics and attitudes (age, handicap, sex, job status, attitudes toward level of service, income, automobile ownership, automobile availability, home location)
   i. Passenger travel patterns [origins and destinations, work and/or school trip location, time of day of work or (school) trip, work (school) trip mode, nonwork (school) travel patterns, trip frequency]
2. Systemwide data:
   a. Unlinked passenger trips
   b. Passenger miles
   c. Average unlinked passenger travel time
   d. Linked passenger trips

Although this list is comprehensive, not all the data items must be collected at the same frequency. The proposed methodology ensures that each data item is collected systematically but not necessarily at the same frequency. The following sections discuss data items requiring frequent monitoring and other data that are only collected during the initial baseline phase.

Data Needs in Baseline Phase

To develop comprehensive information on route performance in the baseline phase, all the items listed above are collected. The collection of these data permits direct comparisons among routes and the analysis of alternative service plans, including schedule modifications, route restructuring, and reallocation of vehicles.

With the data collected in the baseline phase, a comprehensive profile such as that shown below can be developed for each route:

1. General-effectiveness data:
   a. Boardings per trip per day
   b. Revenue per trip per day
   c. Maximum load per trip
   d. Running time by route segment
   e. Difference between scheduled and actual arrival times
2. Data for specialized analyses:
   f. Distribution of boardings and revenue by fare category
   g. Transfer rates per day
   h. Passengers boarding and alighting by stop per trip
   i. Average unlinked trip length per passenger
   j. Average unlinked trip travel time per passenger
   k. Passenger miles per day
   l. Passenger characteristics and attitudes
   m. Passenger travel patterns
3. Data-collection design items:
   n. Relationship between boardings and revenue per trip
   o. Relationship between boardings and maximum load per trip

For items a to e, an operator is generally interested in the mean value and in the variation within each time period and from day to day. These five items are generally used for operations planning and scheduling, which includes the development of performance measures for each route. Items f to m provide more-specialized information, which is used for detailed route, subarea, or system planning (e.g., evaluation of through routing, branching, short turning, and limited or express services) as well as for studies of the agency's fare structure and related policies.

Finally, items n and o provide information on the relationships between specific data items that may be closely linked. These relationships can be thought of as "conversion factors" that may allow an operator to estimate one data item by directly measuring another, thus reducing the cost of monitoring a route. The data collected in the baseline phase allow an agency to test these relationships for each route. If the statistical relationship is shown to be strong enough, the conversion factor can be used during the monitoring phase. For example, a strong relationship may be found between total boardings and peak-load counts. If this is true, then total boardings could be estimated from peak-load counts during the monitoring phase and would not have to be directly collected.

Data Needs in Monitoring Phase

Once a route profile is established during the baseline phase, an operator regularly monitors each route for significant changes. To do this at reasonable cost, a subset of the data listed above has been selected for periodic monitoring. The following three basic data items are used to track individual route performance: bus arrival time, peak-point load, and one of the following--total boardings, boardings by fare category, or revenue.

Bus arrival time must be collected periodically by all agencies to ensure efficient scheduling and reliable service. Usually this information is collected in conjunction with load or boarding counts. Load data are needed to determine appropriate service frequencies. Total boardings, boardings by fare category, and revenue are alternative measures of the utilization of the route. The choice of which utilization data items to monitor depends on the cost and feasibility of different data-collection techniques. Certain data-collection techniques yield two or more of these items at the same time, so that the agency may be able to monitor directly a greater number of route utilization measures.

This approach to monitoring is based on an assumption that if neither peak load nor total route utilization changes significantly from the baseline, neither do any of the other data items collected in the baseline phase. Passenger on/off counts, characteristics, attitudes, O-D patterns, transfers, and some of the systemwide data required for Section 15 reports are all indirectly monitored through the collection of load and utilization data. If significant changes are observed in an individual route during the monitoring phase, another baseline phase must be conducted to revise the route profile.

The accuracy with which the data items should be measured and the extent of change observed in the monitoring phase that triggers a new baseline phase are two important areas in the design of the baseline and monitoring phases. These topics are addressed in a subsequent section of this paper on sampling. First, however, data-collection techniques must be discussed.

DATA-COLLECTION TECHNIQUES

A large number of data-collection techniques are currently used by transit agencies. The seven principal techniques used by most agencies are shown below:

Technique	Description
Ride check	Check taken on board vehicle to record the number of passengers boarding and alighting at each stop and the bus arrival time at selected points;
Point check	Check taken from street to estimate passengers on board vehicle and record vehicle arrival time; peak-load count taken at peak-load point; multiple point checks include several points along route;
Boarding count	On-board count of total number of passengers boarding, most often broken down by fare category;
Farebox reading	Recording of farebox registered reading at selected points; requires registering fareboxes;
Revenue count	Count of revenue in farebox vault by bus;
Transfer count	Count of transfer tickets collected on each bus, which may involve specially issued transfer tickets; and
Survey	Variety of techniques in which passengers are asked to provide information.

Some of these techniques are known by different names. For example, ride checks are also known as on-off checks and characteristic counts; point checks are often called standing checks or load checks. For consistency, the terms used in the above list are used throughout this paper.

The seven principal data-collection techniques provide a range of different data items depending on individual agency and route characteristics (Table 1). Together the seven techniques collect all the data needed for the baseline phase.

Ride checks provide the most complete data, especially if boarding passengers can be recorded by fare category. All the data items except transfer rates, passenger characteristics, travel patterns, and attitudes can be collected through ride checks. Ride checks, like boarding counts and farebox readings, provide reliable and complete data when performed by traffic checkers. If drivers are used to collect the data, experience in the transit industry suggests that the results may be less reliable, since data collection is secondary to the primary responsibility of operating the vehicle.

Point checks provide more-limited data. Multiple point checks (on the same route) increase the usefulness of this technique by providing information at more than just the peak-load point, especially on longer routes that serve more than one activity center. The utility of point checks may decrease somewhat, however, as buses with tinted windows become more common, since estimation of passenger loads is more difficult.

Passenger surveys also provide a wide range of data. Passenger surveys are the only method in which information on passenger characteristics, travel patterns, and attitudes can be collected. Passenger surveys should be used with great care since it is often difficult to ensure that the results will be accurate and unbiased. Because of this potential problem, surveys generally should not be used to obtain data items that can be observed directly by using alternative techniques.

Revenue boarding counts, farebox readings, and transfer counts provide information on a limited number of data items. Their use is very dependent on the operating characteristics of the transit agency.

To collect the required set of data items for the baseline phase, a combination of techniques must be used. The best combination of techniques depends on a number of factors including route structure, individual route characteristics, and operating policies.

The route structure of an agency can influence the relative desirability of using point and ride checks to collect load data. A radial route structure is likely to have routes with a single maximum-load point. Often the maximum-load points coincide (e.g., at points near the downtown area) with others. This enables a single checker to collect data on several routes. This is obviously more efficient than doing ride checks on every bus where one checker per bus is required. Grid systems, on the other hand, are less likely to have routes with single maximum-load points and may require multiple point checks. In this case, it may require fewer checkers to do rechecks than to do point checks.

The relative cost of the different techniques also depends on the number of buses on a route. To collect load data, the point check is usually the best technique when the number of buses on a route is large. The ride check is the best technique when the number of buses is small, since additional information besides load data can be collected.

The level of patronage is also an important factor when selecting techniques. As patronage on a route increases, boarding and ride checks may also become more difficult to perform reliably. This is particularly true for ride checks if they are used to measure ridership by fare category, since boarding passengers must be counted and recorded by fare category. Although this may be possible on a lightly patronized route, it is much more difficult and subject to greater error on a high-ridership route. Nonetheless, it is often better to perform ride checks to obtain detailed boarding and alighting data for heavily used routes, since scheduling and dispatching strategies such as turnbacks and branching can often improve the efficiency of such routes.

The operating policies of an agency directly influence the feasibility of certain data-collection techniques. For example, agencies that do not issue transfer tickets (i.e., have no free or reduced-fare transfers) have no easy mechanism to count route-to-route transfers. These agencies either may have to rely on a passenger survey to determine transfer rates or may conduct a special transfer survey.

There are two operating characteristics that effectively constrain the set of appropriate combinations of techniques to a small number. The first characteristic is the ability of vehicle operators to record reliable data. Where drivers can collect reliable data, the cost of a data-collection program can be dramatically reduced. Even though checker requirements are reduced, the reduced cost must be weighed against the possible reduced accuracy of the data obtained by drivers. Information obtained by drivers may be less accurate than that collected by checkers, since the drivers' primary responsibility is to operate the bus safely.

The second operating characteristic is the availability of registering fareboxes. Registering fareboxes allow a driver, on-board checker, or even a street checker to monitor route revenue and, often indirectly, total ridership. Regular farebox readings can often provide accurate route revenue fig-

Table 1. Data items obtained from principal techniques.

Data Item	Technique Used[a]						
	Point Check	Ride Check	Boarding Count	Farebox Reading	Revenue Count	Transfer Count	Survey[b]
Load (peak or other)	X	X					
Bus arrival time	X	X	X[c]	X[c]			
Passenger trips	X[d]	X	X	X[e]			X[f]
Revenue		X[g]	X[g]	X[h]	X		X
Passenger trips (or revenue) by fare category		X[g]	X[g]	X[e]			X
Passengers on-off by stop		X					X
Transfer rates						X[i]	X
Passenger characteristics, travel patterns, and attitudes							X
Unlinked trips		X	X	X[e]			X[f]
Passenger miles		X					X
Unlinked-trip travel time		X					X
Linked trips		X[i]	X[i]				X

Note: X = applicable, blank = not applicable.

[a] Techniques as defined in text.
[b] For all survey-collected data other than total passengers, the quality of the data depends on the representativeness of the response.
[c] If time can be recorded.
[d] For pure feeder and express routes only.
[e] If electronic multiple fare registering boxes are available.
[f] If surveys are numbered consecutively and distributed to all passengers.
[g] If boarding passengers are recorded by fare category. This typically can only be done with riding checks if boardings are relatively low.
[h] If revenue can be counted by route, this can be substituted for farebox readings although time-of-day data are sacrificed.
[i] If transfer tickets are distributed, collected on terminating route, and identifiable by initial (and intermediate) route(s).

ures that can be used as a check on total ridership figures generated by driver trip sheets.

Several options for combining data-collection techniques were developed for transit systems with specific characteristics. While these recommendations generally provide the necessary baseline data at the lowest cost, specific local characteristics may make other combinations more desirable. Thus, the following recommendations and discussion were developed as guidance to be used by a property to select its own combination of techniques.

For the initial baseline data-collection phase, the following set of techniques is recommended:

1. Ride checks (possibly plus supplementary point checks),
2. Farebox readings or boarding checks, and
3. On-board surveys.

The ride check is included in the baseline phase in order to obtain boardings and alightings by stop, which can be used to estimate average loads on each route segment. Supplementary point checks are needed only when the number of trips to be sampled to assess load accurately exceeds that required to collect total-boarding data. (The calculation of the number of trips to be sampled is discussed in the next section.) Supplementary point checks are recommended in this situation because it is less costly to gather additional peak-load data by using a single point checker than by using on-board checkers.

Farebox readings or boarding checks provide complete route revenue information, although only the latter breaks down ridership and revenue by fare category. For this reason, boarding counts probably should be included by any agency that can reliably use operators to perform such counts. Finally, the on-board survey collects a variety of passenger information that cannot be obtained in any other way.

The recommended techniques for the on-going monitoring phase depend more heavily on agency and route characteristics. If an agency can use drivers to collect total boardings, the following combination of techniques is recommended:

1. Point checks,
2. Boarding counts (by operator), and
3. Farebox readings (if registering fareboxes are available).

Agencies that cannot depend on drivers to collect reliable data have several options. The best combination often includes direct monitoring of peak load, total boardings, and farebox revenue through ride checks (possibly plus supplementary point checks) and farebox readings (if registering fareboxes are available).

However, for routes that exhibit a strong baseline relationship between either peak load or revenue and total boardings, route performance can be monitored simply by using point checks. In this option, a street checker at the maximum-load point records passenger loadings and, if recording fareboxes are available, boards each bus and records the farebox readings. Although using either a load or revenue conversion factor to estimate total boardings requires a larger number of trips to be sampled than does measuring load or revenue alone, often the overall expense of this option is less since on-board checkers are not required in the monitoring phase. The key to using this option is the test of the relationship between the data items, which is described in the following section.

SAMPLING

Once the techniques have been selected, the sampling plan can be designed to incorporate the amount of data to be collected and the timing of the data collection. A sampling plan reflects two factors: the desired accuracy and the inherent variability of the data. As either one or both of these factors increases, so does the amount of data that must be collected.

The data-collection design manual (5) that was the product of this research details the procedures required to determine the desired accuracy and measures of inherent data variability. By using these, step-by-step procedures are presented to determine a sampling plan for any data item and for both observational and survey collection methods. The manual provides procedures for transit operations to apply actual sample-size formulas or to use a set of easy-reference sample-size tables that are included as Volume 2 of the manual (6). Because these procedures and the associated formulas are quite detailed and require substantial explanation, they will not be discussed further here. For further information, readers are referred to the Bus Transit Monitoring Manual (5,6).

USE OF CONVERSION FACTORS

Conversion factors can be used to reduce the total resources required for data collection in the ongoing monitoring phase. Conversion factors are most useful for estimating data items that are important but expensive to measure directly. The primary examples are the estimation of total boardings per trip from either peak-load counts or farebox readings.

To test whether conversion factors are feasible, regression is used to estimate the best linear relationship between x, the independent variable (typically either peak load or revenue), and y, the dependent variable (typically total boardings), for the baseline data, separately for each route and time period. The variance associated with the resulting equation can then be used to define a confidence interval around the mean value of the dependent variable (e.g., total boardings). This confidence interval specifies the range of uncertainty associated with using the equation to estimate the value of y at a given value of x. If this confidence interval is larger than the accuracy desired for y (and thus less accurate), the equation cannot be used. It is then necessary to collect y directly rather than to estimate it. On the other hand, if the confidence interval is small compared with the accuracy desired for y (and thus more accurate), the equation is a satisfactory basis for estimating y.

Detailed formulas for estimating sampling requirements associated with using conversion factors are outlined in the data-collection design manual (5). The resulting sampling plan may or may not be less expensive than that developed for directly monitoring boardings per trip. However, results of field tests by using this approach in Chicago indicate that, for many routes, monitoring by using conversion factors is likely to be less costly than directly counting boardings (7).

SEASONAL CONSIDERATIONS

The timing of the baseline and monitoring data-collection phases raises the general question of how to deal with seasonal variation. Initially the baseline phase could be conducted during any season. For at least one year after the baseline phase, however, the monitoring should be conducted in each period of the year for which scheduling changes are made. If schedule changes are not normally made during the year (as in many small agencies), it is suggested that all routes be monitored during two seasons (one when schools are in session and one when they are not in session) during the first year.

This procedure allows the transit agency to determine the extent of route-level seasonal variation as well as to identify routes that exhibit significant ridership growth or shrinkage. Some simple rules of thumb were developed to determine whether measured ridership changes over the first year of monitoring indicate significant seasonal variation or an overall change in ridership:

1. If total boardings on a route changes by more than 25 percent over that first full year of monitoring (i.e., when comparing the baseline phase figure to a monitoring phase measurement during the same season one year later), an overall trend is assumed and a new baseline is taken on that route; and
2. If total boardings on a route do not change by more than 25 percent over the first full year of monitoring but do change (from the baseline phase) by more than 25 percent during any intervening season during the first year, seasonal variation is assumed.

Significant seasonal variation is important from two perspectives. First, it identifies those seasons during which the monitoring phase should be conducted. Second, for those routes for which an agency wishes to use conversion factors to decrease the cost of ongoing monitoring, it identifies those seasons for which separate conversion factors should be developed.

The selection of 25 percent as the value for a significant change is based on limited data analysis and professional judgment. As more knowledge is gained on the behavior of individual bus routes, a different value may be found more appropriate.

After the first year, the frequency of monitoring depends on the identified variability of the data items. At a minimum, however, the monitoring phases should be conducted during the season of the most recent baseline phase and any season showing a significant variation.

A new baseline phase should be conducted when it is probable that the baseline data are no longer valid. This could occur under two situations. First, when a significant change (e.g., ±25 percent) is observed in ridership or revenue through the monitoring process, a new baseline phase is required. Second, if a significant change is made to the route alignment or to the fare level and structure, there is reason to believe that conditions have changed and a baseline phase is needed.

SECTION 15 DATA REQUIREMENTS

The data-collection approach proposed here has been judged by UMTA to meet the reporting requirements for the Section 15 Transit Service Consumed Schedule (8). This schedule covers unlinked passenger trips, passenger miles, and average unlinked passenger trip time for specified periods of an average week.

If the monitoring phase of the data-collection program is based on ride checks, all data items required for Section 15 are measured directly. The accuracy of the systemwide statistics is based on the adequacy of the sample size and the acceptability of the sampling plan. It has been shown (4) that for systems with 10 or more routes, the suggested route-level 90 percent confidence interval of ±15 percent is consistent generally with the required Section 15 systemwide 95 percent confidence interval of ±10 percent. For smaller systems, it may be necessary to reduce the route-level tolerance to ±10 percent to achieve the desired systemwide accuracy.

The effect of seasonal variation on Section 15 data derived by using route-level data is assumed to be minimal as long as the following conditions are met:

1. The agency follows the suggested procedure of monitoring every route during each schedule period (or at least twice) for one year following the baseline phase to determine whether significant seasonal variation exists; if seasonal variation is indicated, the agency continues to monitor during the baseline season as well as in all seasons that exhibited a 25 percent change in total boardings; and
2. The route-level monitoring activity is spread throughout the year so that routes that are monitored only once a year (i.e., show no significant seasonal variation) are monitored randomly.

As discussed earlier, care is taken to ensure that the set of days to be sampled is selected randomly from all weekdays in the season. Similarly, the trips to be checked on a selected day are selected randomly from all trips operated during the period of interest.

One problem in complying with Section 15 is the estimation of weekend statistics for the annual systemwide reports. Passengers, passenger miles, and passenger trip times generally will be quite different from the weekday figures. They also contribute much less to annual systemwide figures. There is no evidence to suggest that significant seasonal variation occurs for weekend performance compared with normal between-day variation. Routes on weekends are therefore treated as operating over a single year-long season, with Saturdays and Sundays of course treated separately. Either of the following two methods was found by UMTA to be acceptable for estimating Section 15 data for weekends:

1. Sampling 75 percent of all trips on at least one randomly selected Saturday and one randomly selected Sunday for each route in the system; or
2. Random selection of 260 total trips (or 3 trips/day) from all Saturday and Sunday trips operated systemwide during the year (the existing Section 15 sampling requirements for weekends).

Ride checks are required in either method to produce the desired Section 15 data for weekends. Also in both approaches, holidays are classified on the basis of the type of bus schedule operated as a weekday, Saturday, or Sunday and are included in the appropriate population for sampling. The differences in the two methods are cost and information obtained. While the second method is less costly, the first method provides substantially more information to transit planners and managers.

Another issue related to Section 15 reporting is the use of conversion factors. An analysis of numerous bus routes in Chicago and other cities suggests that average passenger trip length and average time per passenger trip on a specific route are quite stable over long periods of time (7). This is true as long as neither the service provided on the route nor the route ridership changes substantially (i.e., by more than 25 percent). This indicates that stable conversion factors can be developed relating total boardings, peak load, or trip revenue to passenger miles, as described earlier in this paper. UMTA has judged that the use of these conversion factors is acceptable for making Section 15 reports (6).

COST OF MONITORING PROGRAM

Cost is likely to be a manager's first concern when considering a data-collection program such as the one proposed in this paper. Although costs may vary widely depending on specific agency characteristics, a simple procedure is used to estimate costs for a given agency.

By far the most costly component of the program is the manpower needed to collect data on board buses or from the street. The translation of route-by-route sampling plans into total checker requirements begins with the sample size required for each data-collection technique selected. The following calculation is used to determine checker requirements based on the sample sizes required for load and total boardings for each route and on the selected techniques for each data-collection phase:

Checkers required for each time period = {[days sampled(load)] x (number of points)} + {[days sampled(boardings)] x [(sampled trips)/(total trips)] x (number of buses)}.

The terms of the calculation vary depending on the data-collection techniques used and the sample sizes required. It is appropriate for (a) sampling plans that require load data only at a number of points on a route, (b) sampling plans based on boarding data obtained by using a ride check, and in many cases (c) a combination of (a) and (b) when both point and ride checks are required.

By using an individual agency's policies and work rules, the individual time period checker requirements estimated by this calculation are transformed into checker assignments. If a point check is included for a number of routes, the total checker assignments are adjusted to account for the possibility that several routes might be counted by one checker.

Based on information from Chicago and other agencies, the range of checker resources required for typical bus system sizes was estimated by using average values for data variability, desired accuracy, and route characteristics. The full-time traffic checker staff requirements shown below are based on monitoring every route in the system four times a year. Generally, the low end of the range represents cases in which reliable operator data are available; the upper end of the range represents cases in which drivers do not collect data. The range also reflects differences in agency and route characteristics that directly affect required sample sizes and therefore total checker requirements.

No. of Peak Buses	No. of Off-Peak Buses	Avg Daily Service Hours	No. of Traffic Checkers Required
25	22	12	0.5-1
50	40	12	1-2
100	70	14	1.5-4
300	215	15	3-7
500	250	16	6-13
750	470	17	8-15
1000	600	18	10-19
2000	1100	19	20-38

Staff requirements for the baseline data-collection phase for most agencies fall near the upper end of the indicated ranges. In addition for the baseline phase, the cost of an on-board passenger survey on all routes must be added to the staff requirements given above.

In addition to the traffic checker cost, there are other costs associated with the program including program planning, data reduction, and data processing. It is very difficult to estimate the ranges of these costs, because of major differences among agencies. To minimize program planning costs, a data-collection program design manual was prepared in the development of this methodology. The manual includes detailed step-by-step procedures and sample-size tables (5,6,9). In Chicago, a draft version of this manual was successfully tested and used to design a data-collection program (7).

Data-processing costs depend on the amount of data collected and the availability of computer support and staffing for the technical analysis. In view of the wide range of possibilities, no attempt was made to present costs for this aspect of the program.

SUMMARY

This paper has presented a systematic, statistically based approach to data collection in the bus transit industry. A two-phase strategy is suggested: a baseline phase to produce detailed profiles of each service operated and a monitoring phase to verify that the baseline conditions are still valid. Basic statistical formulas are used in the design of the data-collection program.

A manual incorporating a step-by-step procedure for program design has been produced. With the existence of this manual, the real test will begin--in a climate of fiscal austerity will the transit industry see the justification for spending enough money to get the reliable information necessary to make better decisions?

ACKNOWLEDGMENT

The research reported here was performed with funding from the Urban Mass Transportation Administration, U.S. Department of Transportation.

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Publication of this paper sponsored by Committee on Transit Management and Performance.

Performance-Based Funding-Allocation Guidelines for Transit Operators in Los Angeles County

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During the last five years, transit performance indicators have been widely used in the transit industry. California and New York have used performance indicators to determine eligibility for funding. In Pennsylvania, transit performance measures have been used to provide incentive payments for superior performance, and in Michigan a detailed analysis of transit operations provides the basis for state managerial assistance. In Los Angeles County, nine transit operators, including Southern California Rapid Transit District, provide fixed-route transit service. Between 1977 and 1980, operating cost per vehicle hour increased from $28.52 to $38.76, a rate higher than the consumer price index for the Los Angeles area. In response to state legislation designed to maximize utilization of public subsidies for transit, the Los Angeles County Transportation Commission undertook the development of performance-based guidelines for allocating transit subsidies. The performance guidelines developed in cooperation with the local transit operators are presented here. In this program, service is classified into local and express categories. Seven indicators were chosen to monitor transit performance on a periodic basis. Three indicators were selected to establish standards to be achieved by all fixed-route service operators in Los Angeles County. Compliance with these standards will determine eligibility for discretionary funds (representing 5 percent of operating assistance) in the future. The methodology for quantifying loss of subsidy funds if an operator falls below the established standards is also described. The performance guidelines merit consideration for two reasons. First, they represent an attempt by a large metropolitan area to control transit costs, and second they initiate performance-based funding allocation rather than funding based on demographic characteristics or operating deficits. Both reasons are substantial advancements in the theory and application of performance-based guidelines to transit-financing issues.

A complex institutional structure supplies transit in Los Angeles (1). Thirteen operators provide transit service. Nine of these are fixed-route providers and the remaining are demand-responsive. Only the Southern California Rapid Transit District (SCRTD) is an independent agency. The others are municipal operators. Programming of state and federal funds is controlled by the Los Angeles County Transportation Commission (LACTC). Short-range transportation planning is sponsored by the Commission and long-range planning by the Southern California Association of Governments (SCAG).

The nine public transit operators providing fixed-route transit service in Los Angeles County operate 2287 vehicles in the peak period and 370 700 miles of service on an average weekday (Table 1). SCRTD, an independent agency created by the State of California, is by far the largest, operating 87 percent of the average weekday miles of service and carrying 88 percent of the total public transit ridership.

The other eight transit systems in Los Angeles County are governed by municipalities in the county. Together they provide the remaining 13 percent of service and carry 12 percent of ridership on an average weekday. None of the operators in the county, including SCRTD, have dedicated local sources of funding except for those state and federal funds that pass through LACTC. However, SCRTD and municipal operators can obtain funding from local sources at the discretion of county and municipal governments.

The total operating cost of average weekday fixed-route transit service in Los Angeles County is $885 960. The passenger revenue recovers about 39 percent of the operating cost on a countywide basis. The shortfall between operating cost and

Table 1. Summary of average weekday operating statistics.

System	Vehicle Hours	Vehicle Miles	Peak Vehicles	Passenger Boardings	Operating Cost ($)	Passenger Revenue ($)
Commerce	56	650	5	2 400	1 890	NA
Culver City	147	1 880	14	5 940	4 340	1 635
Gardena	242	3 140	27	8 930	6 460	2 235
Montebello	269	3 520	19	11 860	7 010	2 510
Norwalk	183	2 760	15	3 635	3 740	610
Torrance	255	3 760	19	8 280	6 920	2 000
Long Beach	1 339	19 880	113	49 170	32 210	8 580
Santa Monica	928	12 090	94	68 190	21 460	11 970
SCRTD	22 870	323 020	1981	1 179 930	801 930	313 200
Total	26 289	370 700	2287	1 338 335	885 960	342 740

revenue is covered largely by state and federal subsidies allocated through the Commission.

Allocation of subsidies is based on a formula that uses both vehicle miles supplied and ridership achieved. After deductions for future rapid transit, paratransit, and the 5 percent discretionary funding, the Commission allocates operating subsidies based on the ratio of an operator's revenue vehicle miles and passengers to the combined total for all operators in the county. This is not a performance-based funding guideline and may result in operators offering more miles of service so as to increase their proportionate share of subsidies.

The formula also made it difficult for the Commission to coordinate duplicating service provided by different operators. A dispute between two operators over boarding restrictions on a major local transit route simmered for nearly two years without resolution and helped to convince the State Legislature of the need to strengthen the Commission's authority over the operators. This coincided with the recurrence of an operating budget crisis for SCRTD, which led to new public and political interest in the problem of cost control.

Assembly Bill 103 (AB103), passed by the California Legislature in 1979, required the Commission to guide the allocation of funds among operators and different types of service and to encourage improvement in performance [Chapter 579, California Statutes, 1979 (Assembly Bill 103)]. The Commission was required to set financial standards and productivity guidelines that would be integrally connected to the ongoing process of allocating operating subsidy funds. Standards and guidelines were to be contained in a policy document called a Transit Coordination and Service Program (TCSP), which the Commission was required to adopt by an extraordinary majority of at least eight affirmative votes (out of 11 voting members).

Thus, while the legislative action mandating the development of the TCSP had its origin in the perceived need to resolve service disputes and improve service coordination, the definition of its specific elements had a distinct emphasis in the areas of performance and operating cost. And although the Commission considered revising its entire subsidy allocation formula, it decided to use the approximately $12 million in the 5 percent discretionary allocation as an incentive for improved performance and to monitor performance more critically and publish the results.

The framework for this program consisted of four components:

1. Development of service classification methodology to determine which services in the county were reasonably similar in operating characteristics so as to make a comparison of their performance characteristics,
2. Selection of performance indicators to provide the Commission with a tool to monitor performance on a periodic basis,
3. Development of performance achievement guidelines to establish level of performance to be achieved by each fixed-route operator in the county, and
4. Development of funding-allocation guidelines to encourage achievement of the desired performance level and to establish a framework for service reallocation in the future.

The objective for the TCSP was to establish a reasonable set of guidelines for separate categories of transit service based on inherent characteristics of transit operations in Los Angeles County and then to use these guidelines, not only to monitor transit performance and recommend management actions to improve performance, but also to reward superior performance through allocation of discretionary funds. It was also a requirement that the TCSP be developed in cooperation with all transit operators in the County of Los Angeles. This both limited the extent of innovation and ensured cooperation. The unanimous adoption of the draft TCSP by the Commission was a reflection of the success in blending new concepts with the practical concerns of operators.

Service classification is an example of this cooperation. There was no established basis for service classification, so the Bus Operators' Subcommittee reviewed the Commission's proposal and collaborated in placing each operator's routes in one of five service categories.

SERVICE CLASSIFICATION

To minimize differences in operating environment, transit services were classified into relatively homogenous groups. It was decided that the four demand-responsive operators should be eliminated from consideration as well as the demand-responsive services operated by fixed-route operators because they represent a distinct mode. Charter services and special-event services were eliminated for the same reason. The remaining fixed-route services were classified into local and express services. These two primary categories were further subdivided into secondary categories so as to yield classes of similar service between operators:

1. Local service:
   a. Demand: headways and duration of service determined by demand; usually operates additional peak-period service;
   b. Policy: minimum service level set by policy rather than by demand;
   c. Community: circulation within community; operates shuttle or feeder service to other lines.
2. Express service:
   a. Multistop: operates on freeways and/or surface streets and collects passengers at neighborhood stops;
   b. Limited stop: operates predominantly on freeways and includes park-and-ride service.

Not all fixed-route transit companies operate all classes of service. The largest, SCRTD, provides service in each of the five secondary classifications (Table 2). On a countywide basis, 86.8 percent of the average weekday service hours is local service operated at headways based on demand. The majority of the express service is also operated by SCRTD.

In the TCSP the secondary service classifications were used in the development of a performance-monitoring system, and the primary classifications were used to establish performance guidelines.

PERFORMANCE INDICATORS

A wide range of statistics was evaluated as performance indicators. Special consideration was given to avoiding unnecessary data collection. Preference was given to statistics that operators were required to provide for the Urban Mass Transportation Administration (UMTA) Section 15 reports and the performance audits mandated by the California Transportation Development Act. The selection methodology is best described by the relationship among three types of statistics (Figure 1). The three categories of statistics--service input, service output, and service consumption--result in three different and unique categories of indicators:

1. Cost-efficiency indicators measure the resources expended (i.e., service input) to the amount of service produced;
2. Cost-effectiveness indicators measure the level of service use (i.e., consumption) against the resources expended; and
3. Service-effectiveness indicators measure the extent to which transit output is used or consumed.

The selected performance indicators were structured to allow monitoring of both the efficiency and effectiveness of related statistics (2). Though the final selection of indicators was performed cooperatively by the study participants, three criteria weighed heavily in the selection process. These criteria included availability, reliability, and controllability of statistics to change performance in a desired direction (3). The seven indicators selected for inclusion in the Commission's performance-monitoring program are vehicle service hours per peak vehicle, operating cost per vehicle service hour, operating revenue plus local subsidies over operating cost, LACTC subsidy (operating deficit) per unlinked passenger, unlinked passenger per vehicle service hour, passenger revenue over operating cost, and revenue per unlinked passenger.

Transit operators will be required to submit data to the Commission by secondary service classifications as part of their annual reports. The Commission staff will then calculate the indicators for each operator and for each secondary service classification so as to monitor performance as required by legislative mandate.

By using a three-variable cost model (4), the Commission staff will develop operating-cost estimates for each secondary service classification for each operator. All indicators listed above can then be easily computed from the statistics submitted. Comparison can then be made among operators during the reporting period and for the same operator over time on all seven indicators.

Performance indicators for September 1979 showed considerable variation in both costs and revenues for different service classifications provided by the same operator. The magnitude of these differences had not been realized by the Commission since, in the past, data had been reported on a systemwide basis rather than by service classification.

PERFORMANCE ACHIEVEMENT GUIDELINES

Various attempts were made to compute performance guidelines to be achieved by the fixed-route operators in the county. It was agreed that the guidelines should allow some flexibility to transit managers. This was accomplished in two ways: by limiting to three the number of indicators in which operators would be expected to achieve a minimum performance level and by limiting the guidelines to two primary classifications of service, namely, local and express.

Attempts to establish standards quantitatively were unsuccessful due to small sample size and diversity in the current level of performance because of system size and heterogeneous characteristics of the service areas. Therefore, standards were developed against anticipated future changes in transit performance. And in order to obtain agreement by the bus operators, concessions were made for a more rapid escalation in costs for operators who currently provide service more economically. The graduated implementation for operators who already exceed the standards was also a compromise. The three indicators and standards to be achieved are as follows:

1. Operating cost per vehicle service hour: Growth from year to year in operating cost per vehicle service hour should not exceed the actual rate of price inflation, as measured after the fact by the consumer price index (CPI) for the Los Angeles area. However, if an operator's cost per vehicle service hour in a particular year is less than 80 percent of the highest cost per vehicle service hour, then that operator's growth may be as high as a 110 percent increase in the CPI.
2. Operating revenue plus local subsidies over operating cost: The ratio of operating revenue (both fares and auxiliary transportation revenue) and municipal subsidies to total operating costs should not be less than one-third. For operators that did not meet this standard in FY 1980-1981, the standard in the first three years will rise in equal annual increments to 33.3 percent from the operator's actual performance in FY 1980-1981.
3. LACTC subsidy per unlinked passenger: Each operator's subsidy (operating deficit) per unlinked passenger in any fiscal year for local service should not exceed 133 percent of the unweighted mean for that type of service for all operators in the county in that year. For operators who did not meet this standard in FY 1980-1981, the standard in the first three years will fall in equal annual decreases to 133 percent from the operator's actual performance in FY 1980-1981. For express service, a limitation will be placed on the differential between the subsidy per passenger for express service as compared with that for local service. Under this standard, the allowable differential would be the real dollar difference between the unweighted mean subsidy per passenger for local service for all operators in the county and weighted countywide mean subsidy per passenger for express service for all operators in the county, as established in the first year of the program. In subsequent years, each individual operator would be limited to that real dollar differential between the individual operator's subsidy per passenger for express service as compared with the unweighted countywide mean for local service.

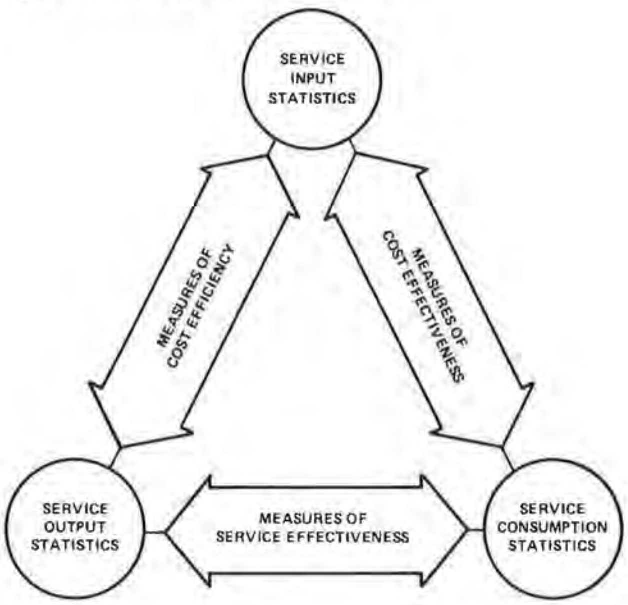
FUNDING-ALLOCATION GUIDELINES

In 1979, also pursuant to AB103, the Commission had

Table 2. Summary of average weekday service hours by service classification.

System	Local				Express			Total
	Demand	Policy	Community	Subtotal	Multistop	Limited Stop	Subtotal	
Commerce	-	-	47	47	-	-	-	47
Culver City	119	-	27	146	-	-	-	146
Gardena	-	112	130	242	-	-	-	242
Montebello	82	129	50	261	-	-	-	261
Norwalk	-	82	95	177	-	-	-	177
Torrance	-	127	-	127	85	-	85	212
Subtotal	201	450	349	1 000	85	-	85	1 085
Percent of total	0.9	1.9	1.5	4.3	0.3		0.3	4.6
Long Beach	1 034	178	15	1 227	56	-	56	1 283
Santa Monica	794	25	10	829	53	-	53	882
Subtotal	1 828	203	25	2 056	109	-	109	2 165
Percent of total	7.7	0.9	0.1	8.7	0.5		0.5	9.2
SCRTD	12 253	4763	373	17 389	2675	250	2925	20 314
Percent of total	52.0	20.2	1.6	73.8	11.4	1.0	12.4	86.2
Total	14 282	5416	747	20 445	2869	250	3119	23 564
Percent of total	60.6	23.0	3.2	86.8	12.2	1.0	13.2	100.0

Figure 1. Relationship of statistics and indicators.



adopted a formula-based procedure for allocating the state and federal funds that were available for operating subsidy and for the local matching share of federal capital grants. The formula was based equally on vehicle miles and on ridership (both linked and unlinked passengers). The application of this formula was limited by a number of conditions. One of the most significant and controversial of these was the stipulation that 5 percent of the funds to be allocated in any year would be allocated on a discretionary basis. For 1980-1981, almost $12 million was available in the discretionary fund, and the bus operators agreed that this fund should be allocated as an incentive for achieving the performance standards.

In addition to the formula-based funding allocation, two additional guidelines were established to be included in the overall program:

1. Impact of noncompliance: If any standard is not met, a funding penalty not to exceed the operator's share of the 5 percent discretionary fund will be applied two fiscal years after the noncompliance occurs. However, if the operator complies with and exceeds the standard in the intervening year (based on unaudited actual data), the excess in that year may wholly or partly offset the shortfall in the preceding year. The shortfall or excess shall be measured in total dollars of variance from the standard. If funds are not allocated as a result of noncompliance with standards, the Commission may reallocate them to other operators who do meet the standards or may invite private operators to bid to operate service that is being curtailed as a result of the funding penalty (first priority) or any other needed service in the county (second priority).

2. Measurement of impact: If an operator fails to comply with more than one of the six standards (three each for local and express service classifications), the total funding penalty shall be the sum of the maximum shortfall (among the three standards) for local service plus the maximum shortfall for express service.

CONCLUSION

The recommended performance-based funding-allocation guidelines were unanimously adopted by LACTC and forwarded for public review and comments. The successful development of this program is further evidence of the recognition by both service providers and decisionmakers of the need to improve overall efficiency and effectiveness of transit services.

However, the program should be regarded as satisfactory rather than optimal. The program was based on sound theoretical and technical concepts: Efficiency and effectiveness constructs from performance theory were used together with the techniques of cost modeling and survey analysis to assign costs and revenue to distinct types of bus service. More rigorous standards could have been based on the subsidy per passenger indicator but there was not sufficient agreement on this indicator to assure approval.

Los Angeles is a complex urban society in which policies that cannot be supported by a broad cross section of participating groups are not helpful in decisionmaking despite their theoretical elegance. The performance-monitoring and allocation program adopted by the Commission provides a satisfactory achievement for an agency responsible for coordinating and funding transportation.

The experience gained from this particular program is generally applicable to a variety of metropolitan and statewide circumstances; the contents, however, may be altered to suit the specific objectives of an agency and the need to achieve cooperation with service providers. The theoretical constructs and analytical techniques used will be more useful than the indicators selected and the intricate method for allocating the 5 percent discretionary fund.

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Publication of this paper sponsored by Committee on Transit Management and Performance.

Transit Performance in New York State

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Over the past two years, the New York State Department of Transportation has developed a program to monitor the performance of transit operations that receive state operating assistance. The initial performance evaluation methodology has been revised to better meet a change in Department emphasis to monitor individual operator performance and encourage improvement. Past efforts are expanded by examining (a) the grouping of transit operators on the basis of mode, service type, and vehicle fleet size; (b) the relative performance of each group of operators over time; (c) the performance levels of public and private bus operators; and (d) the advantages and disadvantages of the proposed change in methodology. The results in this analysis show that grouping operators into peer groups yields more meaningful internal group comparisons and, in most cases, should help identify operators that are performing poorly. The overall change in performance between 1978-1979 and 1979-1980 seems to indicate that operator efficiency is improving while effectiveness is declining. Many of the differences seen in performance measures are found to be attributable to vehicle speed. As expected, private operators report higher levels of operating efficiency than public operators and also seem to be holding the line on rising costs better than the public operators. Future years' efforts will need to include expanded time-series analysis of the state's large operators coupled with a more in-depth review of the use of measures of transit service quality.

The New York State Department of Transportation (NYSDOT) began monitoring and evaluating the performance of the state's transit operators in 1979. This effort was undertaken to comply with a State legislative mandate to certify the economy, efficiency, and effectiveness of transit operations participating in the State operating-assistance program (1). Since 1979, the methodology used in the NYSDOT performance-evaluation program has been modified to reflect a shift in both objective and emphasis by the Department. Initial efforts to monitor and evaluate performance were research oriented in order to provide the Department with a better understanding of the problems faced by transit operators. Current efforts, however, are focused on identifying where specific operators are performing poorly and what steps can be taken to improve performance. The Department has also revised its performance-evaluation program to take advantage of new data sources and a greater understanding by the staff of the performance-evaluation process.

This report reviews the NYSDOT performance-evaluation process, beginning with a brief summary of the program's background. This is followed by a discussion of current performance-evaluation efforts, including the changes in methodology and the reasons for these changes. Trends in transit operator performance are discussed and a brief review of the differences in performance between publicly and privately owned transit operations is presented. The report concludes with a summary of findings and recommendations for future research.

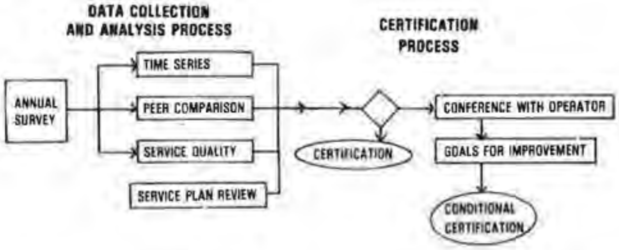
BACKGROUND

NYSDOT began its transit performance-evaluation program in 1979. The operating and financial data necessary to implement the program are collected in an annual survey of transit operators. During the first year of its performance-evaluation program, NYSDOT developed 15 multimodal performance indicators that allowed for the comparison of various modes and service types found among transit operations participating in NYSDOT's operating-assistance program. Because there was little or no theoretical base on which to determine the appropriate level of performance, acceptable and desirable levels were set empirically. Individual operators were then reviewed relative to the acceptable and desirable performance levels established.

During the second year of the performance-evaluation program, NYSDOT's focus shifted from individual operators to major regional or county public transportation systems receiving state operating assistance. A major system was defined as one that annually carried more than 1 000 000 passengers or operated more than 1 000 000 vehicle-miles of service, which could be a regional public transportation authority or a county or municipal sponsor of one or more publicly or privately operated transit operators. Of the state's 62 systems, 17 qualified as major systems in State FY 1979-1980. These 17 systems carried 99 percent of the passengers, operated 98 percent of the vehicle miles, and received about 99 percent of state operating assistance. Evaluating systems rather than individual operators better met the Department's desire to monitor major transit operators serving the same geographic area, particularly where service and financing policies were controlled by a single local agency. However, the disadvantage of this approach was that the poor performance of an individual operator could be hidden within the average system performance.

An additional development during the second year

Figure 1. NYSDOT performance-evaluation methodology.



was the use of service evaluation plans in the performance-evaluation program. The initial year's service plan questionnaire asked for information on the following topics from each major system: transit service objectives, transit system and route performance evaluation, transit service coordination, and transit service problems and needs. By attempting to determine the above information, the service plans provide a basis to begin to relate transit-system performance to local service objectives and also improve the performance monitoring of New York State's major transit systems (2).

CURRENT APPROACH

The results of the first two years' performance evaluations revealed that major transit systems appeared to be operating economically, both when compared with empirical guidelines and with transit systems in other states. However, it was apparent that there was indeed room for improvement in performance. To more precisely identify where improvement might be made, current performance-evaluation efforts concentrate on assessing the performance of individual transit operators instead of the evaluation of county or regional transportation systems. To make the evaluation potentially more equitable, operators have been grouped on the basis of mode, service type, and vehicle fleet size. The resulting groups allow the performance of individual operators within each group to be assessed relative to other, comparable group members.

The Department is also developing a set of transit service-quality measures to complement the traditional economy, efficiency, and effectiveness measures. The use of service-quality, reliability, and safety indicators better measures service performance as viewed by the riding public. Including service-quality measures in performance evaluations will also help explain changes seen in other performance indicators and should result in a more comprehensive analysis of overall operating performance.

Finally, NYSDOT recently completed its third annual survey of transit operators. This information will allow operator performance to be monitored over time, providing insight into trends that might affect the State's transit policy.

The methodology for NYSDOT's performance-evaluation program is illustrated in Figure 1. The performance review is carried out in two steps. The first, data collection and analysis, includes the peer comparison, service-quality, and time-series functions described above along with the review of service plans. The second phase, certification, involves the review and subsequent Department action based on the results from the data-collection and analysis phase.

The remainder of this report will describe the peer-comparison function of the first phase. The service-plan and service-quality functions have been discussed in other NYSDOT reports (2,3).

PEER COMPARISON: GROUPING OF OPERATORS

New York has a wide variety of transit services, ranging from the nation's largest subway, bus, and commuter rail system to small rural bus services. Evaluating the performance of any one operator requires a method of grouping like operations. The method chosen was to group the State's more than 110 transit properties participating in the State operating-assistance program by mode, service type, and vehicle fleet size.

By using these factors, 13 groups of operators were developed, as follows:

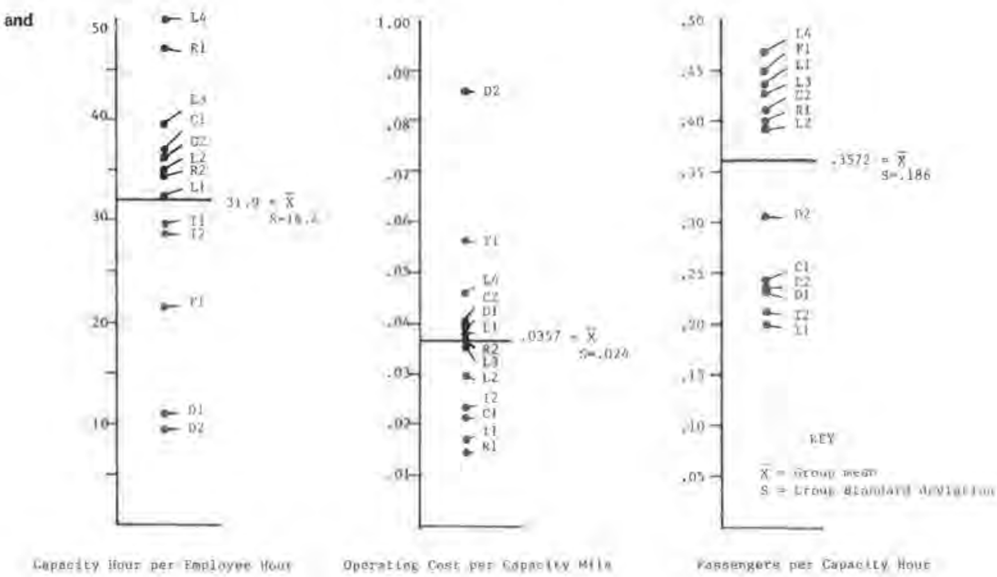
Group	Definition
Local bus	
L1	1-25 vehicles
L2	26-125 vehicles
L3	126-499 vehicles
L4	500+ vehicles
Commuter bus	
C1	1-20 vehicles
C2	21+ vehicles
Intercity Bus	
I1	1-20 vehicles
I2	21+ vehicles
Demand Responsive	
D1	Combined demand-responsive and fixed-route service
D2	Demand-responsive service only
Rail	
R1	Rapid transit
R2	Commuter rail
Ferry	
F1	Commuter ferry

The operator peer groups should ensure that only operators providing similar service will be grouped together. The above groups do not take into account operating conditions such as speed and urban versus rural service. This shortcoming will be studied in the future. Whether a transit system was publicly or privately owned was also not considered in setting up the above groups. It was felt that keeping public and private operators together would more accurately reflect the full range of potential performance. An analysis was performed to determine whether private operators actually performed differently from public operators, and the results of this analysis are discussed later in this report.

The above fleet size groupings were determined by a review of all transit operations. Cutoffs were made where breaks occurred in the frequency distribution of fleet size and where previous knowledge indicated similar types of operation.

To determine whether the groupings on mode, service type, and fleet size were an improvement in describing performance, the means and standard deviations of each group were calculated and compared with the means for all operators combined. The group means are shown graphically for several performance measures in Figure 2. On two of the measures shown (capacity hour per employee hour and cost per capacity mile), the mean values of each group are generally clustered around the overall mean and outlying groups can be easily explained. The groups with low capacity hours per employee hour are demand-responsive systems whose vehicle capacities are much smaller than those of other transit systems, whereas those groups on the high side are the New York City bus and rapid transit systems whose vehicle capacities are much higher than average and whose services operate 24 h/day. The NYC rapid transit system had the lowest operating cost per capacity mile whereas the demand-responsive group had the highest cost per service unit. The

Figure 2. Variation between group means and overall means.



group values on the measure of passengers per capacity hour are clustered at extreme values, though all are within 1 standard deviation of the overall mean. This variation is caused by the low levels of passenger use due to extremely long trip lengths by long-distance service (commuter and intercity) and the high levels by local, fixed-route service in densely developed areas.

These results indicate that the performance levels generally differ between groups. Further analysis of the groups revealed that the standard deviations of each group were considerably lower than those of the service type aggregations. Although the group means vary considerably on some measures (see Figure 2), for the most part, like service types (i.e., local, commuter, intercity, and demand-responsive) appear together on each graph, supporting earlier Department findings regarding performance levels by service type (4).

Changes in Performance Measures

In past years, NYSDOT's performance-evaluation program used a set of 15 multimodal measures. Since the measures used vehicle capacities in a number of the calculations, the performance of different types of transit operations (intercity bus, ferry, commuter rail, etc.) could be more fairly compared and aggregated into county or regional transportation systems (4). A review of the vehicle capacities of operators within each group revealed that capacities were fairly uniform within operator groups and changed by group as expected. For example, the small local bus operator group generally had lower-capacity vehicles than the larger, fleet-size groups. Therefore, the use of vehicle capacities in a number of the ratios was eliminated in favor of calculations on the more traditionally understood vehicle basis (e.g., cost per capacity mile now becomes cost per vehicle mile). The changes in measures used are shown below. This modification results in a more understandable set of measures comparable with those used throughout the transit industry (5). The pairing of measures shown below is done to account for operational differences in transit service related to vehicle speed:

Measures used in system evaluations:
Capacity hours per employee hour
Capacity miles per employee hour

Operating cost per capacity mile
Operating cost per capacity hour

Passengers per capacity hour
Passenger miles per capacity hour
Passenger miles per capacity mile

Measures used in peer-group evaluations:
Vehicle hour per employee hour
Vehicle mile per employee hour

Operating cost per vehicle mile
Operating cost per vehicle hour

Passengers per vehicle hour
Passenger miles per vehicle hour
Passenger miles per vehicle mile

Measures common to both system and peer-group evaluations:
Vehicle hours per vehicle
Vehicle miles per vehicle

Revenue-to-cost ratio
Operating revenue plus excess local aid per passenger mile

Cost per passenger mile
Deficit per passenger mile

Passengers per employee hour
Passenger miles per employee hour

In past years, measures were applied in sets to account for operational differences in transit service related to vehicle speed--a factor over which most transit systems have little control (these sets are also shown in Figure 3). This feature was retained in this year's program. The revised measures have been calculated for the previous year's data (operator fiscal year 1978-1979) to allow an analysis of trends in performance over the last two years. These measures will be used in subsequent years to allow the monitoring of changes in performance over time.

Individual Operator Performance-Evaluation Framework

The framework adopted for reviewing the performance of operators within each group is similar to that proposed for Michigan (6). This framework establishes threshold performance levels that, if not met, serve as a triggering mechanism for additional analysis and potential state management assistance. Any individual operator whose performance is more than 1 standard deviation away from the group means is identified for further analysis. This method is being tested to determine whether it indeed achieves the intended result of identifying operations that should improve performance.

Use of this framework determines the acceptable level of performance on a statistical rather than a subjective basis. This approach has both advantages and disadvantages. The advantage is that the process is easy to document and does not rely on any one person's assessment of the data. The major disadvantage is that when a group has only a few members or when the distribution of group values is skewed, the resulting acceptable level of performance is distorted. In this case, an alternate approach such as monitoring performance over time or comparing performance to similar operations in other states will be applied. Since the setting of appropriate performance levels is the most difficult part of the evaluation, NYSDOT will continue to refine this process as needed to better measure relative performance.

This report will not review the performance of the more than 110 transit operators participating in the State operating-assistance program, since this information will be included in a NYSDOT report on transit performance. Trends in group performance have been reviewed, paying special attention to (a) whether differences exist in average performance from group to group and (b) possible explanations for these variations and changes in performance over time. This review is presented to support the De-

Figure 3. Vehicle hours per employee hour.

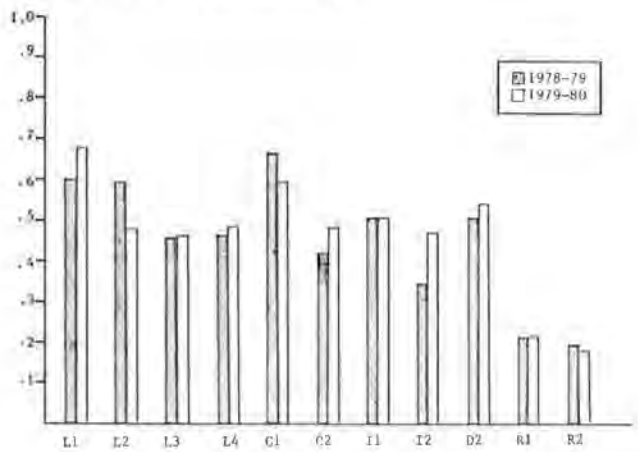


Figure 4. Vehicle miles per employee hour.

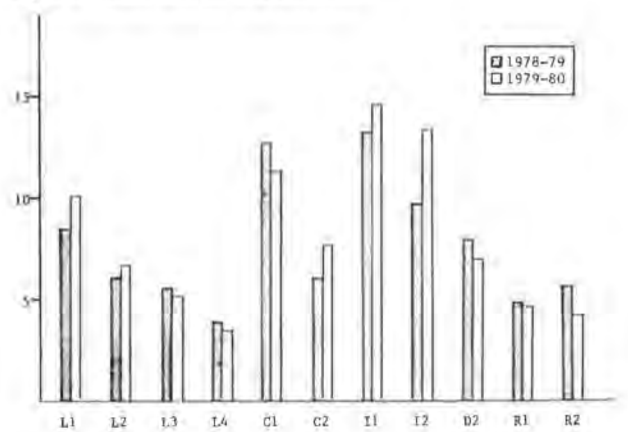


Figure 5. Operating cost per vehicle mile.

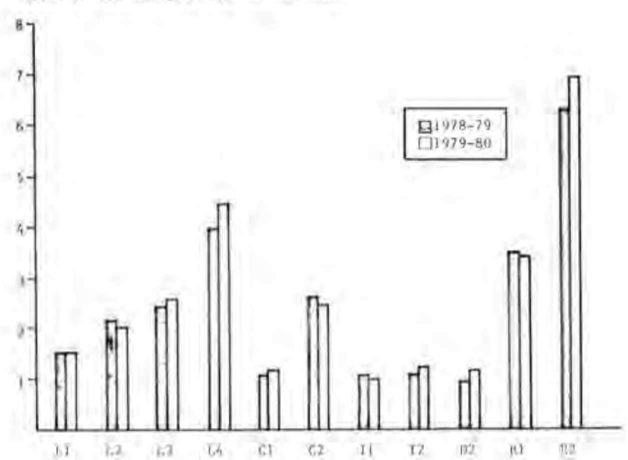


Figure 6. Operating cost per vehicle hour.

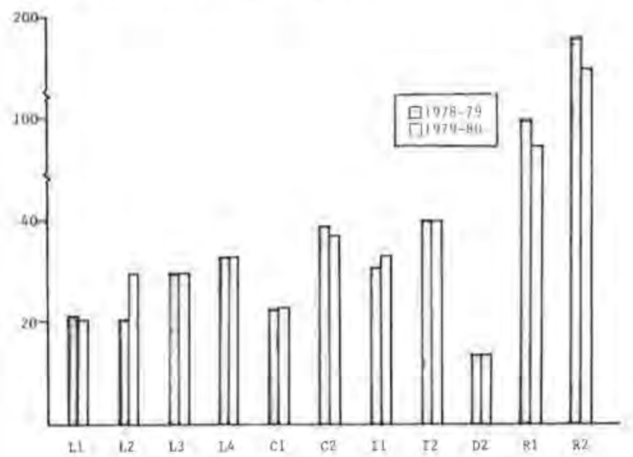
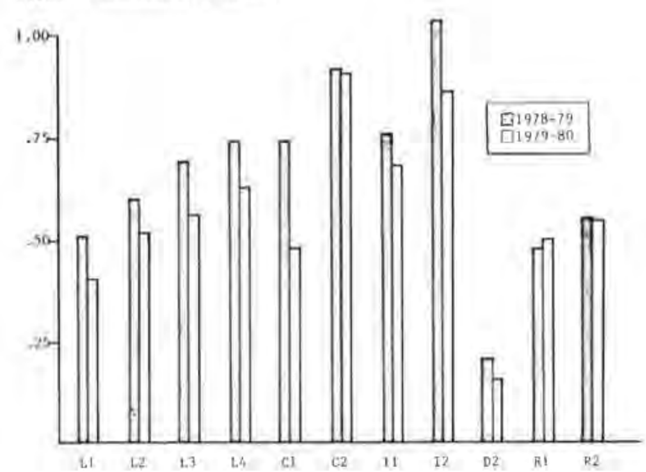


Figure 7. Revenue-to-cost ratio.



partment's approach of grouping operators into peer groups. It should not be construed as an attempt to compare the performance levels of the various groups of operators.

Review of Operator Group Performance

Selected performance measures for a number of groups of operators studied are presented graphically in Figures 3-11. These graphs are useful in that they present the absolute levels of performance for each group and show the change in performance from 1978-1979 to 1979-1980. The percentage of change on each measure by group is shown in Table 1 along with two factors that affect performance measures--speed and passenger trip length. It should be noted that the group levels are operator averages and do not reflect weighting by operator size.

The group levels for two efficiency measures are shown in Figures 3 and 4. Overall, the group levels for vehicle hours per employee hour are fairly uniform except for the rapid rail and commuter rail groups (R1 and R2). The group levels differ considerably for vehicle miles per employee hour; longer-distance commuter and intercity services (C1, C2, I1, I2) perform better than local services. Clearly, accounting for service speed in the measure of vehicle hours per employee hour results in a narrower difference between group levels. Within service types, there are also interesting differences between groups. The small urban bus operators (L1 and L2) have been more successful in improving efficiency than have larger bus operators (L3 and L4). The very opposite is seen among commuter bus operators, where the larger operations (C2) have improved efficiency but smaller operations have experienced declining performance. However, in absolute terms, the smaller operators in the urban, commuter, and intercity groups show higher performance levels on these measures than the larger operators. Figures 3 and 4 show that, overall, bus service efficiency declines as operating speed decreases.

The levels of several economy measures are shown in Figures 5-7. Cost per unit of service generally increases as fleet size increases within each service type, reflecting decreases in operating speed that typically occur as fleet size increases (and urban areas become larger and more dense). However, revenue-to-cost ratios increase as fleet size increases (a favorable change), which is a result of increases in passenger-carrying effectiveness as discussed below. As Table 1 shows, there is no clear trend in performance change. Only the small commuter bus operators (C1) fail to improve their performance on at least one economy measure.

Several effectiveness measures are shown in Figures 8 through 11. The effectiveness levels gener-

Figure 8. Cost per passenger mile.

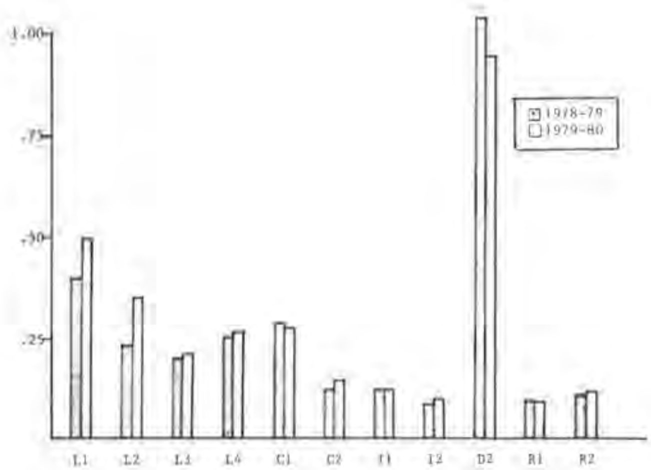


Figure 9. Passenger miles per vehicle hour.

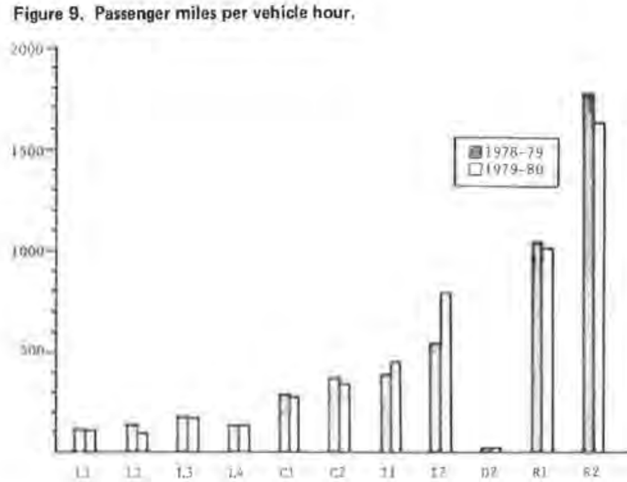


Figure 10. Passenger miles per vehicle mile.

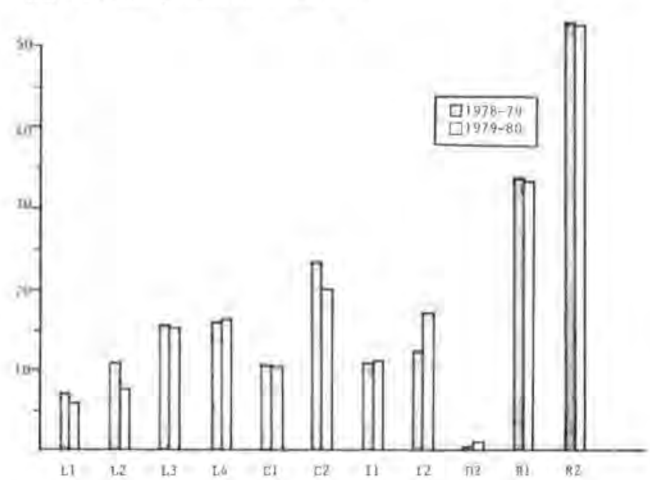


Figure 11. Passengers per vehicle hour.

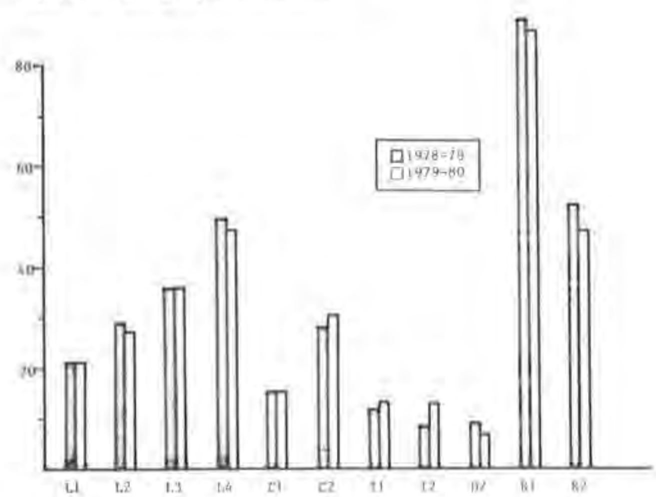


Table 1. Economy, efficiency, and effectiveness indicators: percentage of change, 1978-1979 to 1979-1980.

Performance Measure	Direction of Favorable Change[a]	Percentage of Change											Total Group Performance Change (no. of groups)		
		Local Bus				Commuter Bus		Intercity Bus			Rail				
		L1	L2	L3	L4	C1	C2	I1	I2	D2	R1	R2	Improve	Decline	No Change
Efficiency															
Vehicle hours per employee hour	+	13.68	-18.49	1.19	5.83	-6.47	14.57	0.36	40.50	3.36	1.24	-9.66	8	3	1
Vehicle miles per employee hour	+	19.89	0.96	-3.47	-6.41	-10.35	28.50	8.90	36.59	-11.96	-2.27	-22.80	4	7	1
Vehicle hours per vehicle	+	16.09	6.50	3.57	-1.88	-1.98	23.27	3.34	-26.99	11.54	7.86	14.10	9	3	0
Vehicle miles per vehicle	+	12.73	50.70	-4.10	-12.48	-4.36	31.47	4.10	-36.60	-12.20	7.37	5.37	7	5	0
													28	18	2
Economy															
Operating cost per vehicle mile	-	-0.34	-6.18	4.58	12.37	6.30	-5.07	-5.98	-6.44	24.80	-2.90	8.46	5	6	1
Operating cost per vehicle hour	-	-1.45	48.47	-1.22	-0.44	1.82	-5.48	5.80	-3.07	-1.28	-4.10	-3.41	8	3	1
Revenue-to-cost ratio	+	-18.05	-12.97	-18.37	-10.80	-36.75	-0.49	-9.25	-16.28	-19.70	5.20	0.67	2	8	2
Operating revenue and excess local aid per passenger mile	+	-42.77	103.60	8.09	2.12	-16.64	24.72	20.26	26.20	-17.44	1.24	67.27	9	3	0
													24	20	4
Effectiveness															
Passengers per vehicle hour	+	-2.47	-4.20	-0.44	-4.60	1.74	9.45	5.09	58.96	-24.45	-2.80	-9.25	4	7	1
Passenger miles per vehicle hour	+	-6.33	-26.37	-5.41	-4.57	-6.47	-22.95	16.23	42.34	-25.08	-3.40	-6.22	3	9	0
Passenger miles per vehicle mile	+	-15.91	-36.69	-8.36	8.07	-1.39	-25.75	6.60	31.32	23.65	-1.01	-1.19	5	7	0
Cost per passenger mile	-	25.43	51.05	9.10	5.10	-4.60	17.66	0.80	16.27	-8.30	-1.79	10.76	4	7	1
Deficit per passenger mile	-	56.53	67.55	63.24	38.10	28.99	34.38	19.15	107.70	-8.30	-4.76	0	3	8	1
Passengers per employee hour	+	13.96	-21.30	-1.98	0.10	-0.75	18.76	6.17	105.30	-18.42	-0.40	-20.44	4	5	3
Passenger miles per employee hour	+	-0.18	-38.30	-10.80	0.10	-3.63	-4.20	23.20	52.69	-12.14	-3.11	-25.42	3	7	2
													26	50	8
Total performance change															
Improve		6	3	4	3	2	9	10	9	6	9	4	77		
Decline		7	11	10	9	12	5	3	6	9	5	9		89	
No change (<1 percent)		2	1	1	3	1	1	2	0	0	1	2			14
Factors affecting performance[b]															
Avg vehicle speed (mph)		15.10	15.92	11.42	7.47	21.53	15.95	30.89	30.36	13.28	27.21	28.88			
Avg trip length (miles)		5.45	3.47	4.51	2.70	15.93	12.53	31.50	45.82	5.80	11.50	36.43			

[a](+) = increase; (-) = decrease.

[b]Numbers reported are actual values for 1979-1980, not percentage of change between 1978-1979 and 1979-1980.

ally increase (or improve) within each service type as fleet size increases. It should be noted, however, that effectiveness levels have declined for most groups over 1978-1979 levels. As Figures 8-11 and Table 1 illustrate, all groups have declined in performance on at least two effectiveness measures. Only intercity bus operators (I1 and I2) improved effectiveness on a majority of the measures. As would be expected, the rail systems carry many more passengers per vehicle mile and hour, yet on almost all passenger measures the rail systems declined in effectiveness in 1979-1980.

In summary, this brief analysis has revealed that the efficiency of most transit operators has increased while effectiveness declined in 1979-1980. As has been shown in an earlier report, efficiency measures are not highly correlated to economy or effectiveness measures (4). The graphs have also shown that group comparisons (especially within service types) can yield insight into the factors that contribute to changes in performance. In general, measures calculated on the basis of vehicle hours result in more homogenous group levels than do vehicle-mile measures. A further finding is that differences in vehicle speed can explain much of the difference in group levels for efficiency measures.

PUBLIC VERSUS PRIVATE OPERATOR PERFORMANCE

A significant amount of fixed-route transit service in New York State is provided by private operators, especially in the New York City metropolitan area where the privately owned bus systems serving the 12-county New York Metropolitan Transportation District annually carry more than 150 million passengers. The levels of performance of public and private bus systems often differ due more to inherent characteristics of each rather than the characteristics of the area they service. An understanding of these differing performance levels and their causes can aid in understanding the range of transit performance and the potential for improvement. Table 2 presents the average level of performance for two groups of public and private fixed-route local bus systems serving the metropolitan New York region. The table shows the 1979-1980 average level of performance on each of NYSDOT's 15 performance measures as well as the percentage of change in performance over the previous operating year. Several factors that have been shown to influence the levels of performance measures are also presented.

As Table 2 illustrates, the levels of labor efficiency in terms of vehicle miles and hours per employee hour are slightly higher for small private bus operations (less than 25 buses) than small public operations. Performance levels for large public and private bus systems are identical on the measure of vehicle hours per employee hour, whereas private operators perform better in terms of vehicle miles per employee hour. This result as well as the reason for differing levels of vehicle use between

Table 2. Performance levels at downstate local bus systems.

Performance Measure	Downstate Small Local Bus System				Downstate Medium and Large Local Bus Systems				Direction of Favorable Change
	1979-1980 Level		Percentage of Change, 1978-1979 to 1979-1980		1979-1980 Level		Percentage of Change, 1978-1979 to 1979-1980		
	Public	Private	Public	Private	Public	Private	Public	Private	
Efficiency									
Vehicle hours per employee hour	0.53	0.74	0	19	0.43	0.42	−12	−16	Increase
Vehicle miles per employee hour	6.51	12.88	−22	37	4.18	5.20	−12	−5	Increase
Vehicle hours per vehicle	2 592	2 159	5	18	2 509	2 090	24	−1	Increase
Vehicle miles per vehicle	34 364	37 022	−9	22	23 314	26 574	19	14	Increase
Economy									
Cost per vehicle mile	1.33	1.33	13	3	4.03	2.78	38	−6	Decrease
Cost per vehicle hour	16.72	19.63	−11	0	38.70	33.96	38	8	Decrease
Revenue-to-cost ratio	0.27	0.51	59	−19	0.61	0.64	0	−21	Increase
Revenue and excess local aid per passenger mile	0.16	0.24	160	9	0.18	0.25	6	57	Increase
Effectiveness									
Passengers per vehicle hour	16.19	24.77	54	10	45.86	35.82	16	−4	Increase
Passenger miles per vehicle hour	100.60	98.70	−17	−30	200.10	136.60	46	−29	Increase
Passenger miles per vehicle mile	7.42	6.07	0	−31	18.76	13.63	40	−28	Increase
Cost per passenger mile	0.31	0.45	48	15	0.22	0.35	−8	59	Decrease
Deficit per passenger mile	0.24	0.27	40	58	0.08	0.14	−20	180	Decrease
Passengers per employee hour	9.25	18.24	53	32	19.81	15.46	5	−18	Increase
Passenger miles per employee hour	47.88	70.45	−32	−11	78.63	60.07	39	−41	Increase
Speed (mph)	12.80	16.80	−18	2	10.30	13.80	3	14	
Avg trip length (miles)	7.60	5.00	−30	−39	4.50	3.70	25	−32	
Avg fare ($)	0.28	0.39	−10	−32	0.47	0.62	30	−5	

public and private systems can be attributed to the greater amount of express service provided by the private operators, which results in more vehicle miles of service per hour of operations. Labor efficiency generally declined for both public and private bus systems in the second year (an unfavorable change).

A review of economy measures shows that private operations in the medium-large bus group perform more favorably than public operations. Small private bus systems were reported to have higher operating costs per vehicle mile and hour but nearly twice the revenue-to-cost ratio of small public systems. Both private operator groups reported more favorable changes in cost per mile and hour over the previous year than did the public operators. The decline in revenue-to-cost ratios for the private operators was due to the delay in fare increases for this group until after their operating year covered by these data. The large increase in operating revenue plus voluntary local assistance per passenger mile for both groups was due to increased local government support for transit. It should be noted that the numerical values of the measures of cost per vehicle mile and hour are slightly higher for the downstate bus operators than for upstate New York bus systems (not shown) due to the higher general cost of living in the New York Metropolitan area.

A review of effectiveness levels reveals that large public systems generally perform better than private systems in terms of passengers and passenger miles of use. A factor contributing to this is an unexplained decline in passenger trip length for a number of private operators affecting all measures containing the passenger-mile component. Private operations in the small bus group generally performed as well as or better than public systems for most effectiveness measures. Declines in second-year performance can be attributed to changes in average passenger trip length. Increases in measures containing revenue passengers were due to the general increase in transit ridership in New York State in the late 1970s.

Overall, this analysis indicates that private operators generally provide transit service more efficiently and reported more favorable changes in the second year's performance data for private than for public operators. This reflects the greater ability of these for-profit oriented businesses to enact belt-tightening strategies. However, public bus systems usually achieve greater levels of passenger-carrying effectiveness than private operators. Despite their low passenger-carrying levels, private transit operators in New York continue to report higher revenue-to-cost ratios than public systems. Though comparisons of public and private systems are not always proper, this presentation has shown the areas in which each group performs well and provides a target for possible performance improvement for operators performing at low levels.

CONCLUSION

Grouping transit operators on the basis of mode, service type, and number of vehicles provides insight into the effect of operating conditions on operator performance. In general, measures calculated on the basis of vehicle hours result in more homogenous group levels than did vehicle-mile measures, indicating the importance of vehicle speed on some performance measures.

Analyzing transit operators by peer group has proved to be only a partial solution to the problem of determining which transit operators are performing efficiently and effectively. For groups with a large number of operators (L1, small urban bus, for example), this methodology yields meaningful results. The performance of any one operator has only a minimal impact on the group mean, and the large number of group members assures that groups will include a cross section of operating conditions. For groups with only a few members (R1, rapid transit, for example), in-state peer-group comparisons are not practical. Comparing individual group members to overall group statistics does not make sense when there are few operators in the group. This shortcoming is particularly significant since it occurs most frequently with the state's larger transit operators, those in the New York City area. Improved performance of these operators could have the biggest payoff due to their size and offer the greatest potential for easing the need for public subsidy.

Several alternative approaches are possible as a means of addressing this particular problem. One alternative calls for comparing the larger New York City operators to operators in other large urban areas in the United States and perhaps the world. Although the age of equipment and operating conditions vary drastically from city to city, this comparison should still help describe New York's relative performance on selected indicators. Now that data from Section 15 of the Urban Mass Transportation Act of 1964 have become available, this approach will be studied further. A second alternative is to focus on the time-series analysis of individual operators described earlier. Even if an operator cannot be compared with other similar operators, a review of the operator's performance from year to year should indicate whether performance is improving or declining.

The review of public and private bus operators revealed that there were differences in performance, as suspected. Admittedly, the private operators often operate with fewer bureaucratic constraints, but the usually more cost-effective performance of the private operators provides a target for performance improvement of public operators.

A major drawback of a strictly quantitative performance-evaluation program like the peer comparison described above is that the measures in no way reflect the quality of service being provided as perceived by the rider. This problem is particularly true in the New York City area where traditional efficiency and effectiveness measures do not capture the drastic deterioration in service reliability, quality, and safety seen in the last few years. To address this problem, NYSDOT is developing a set of service-quality measures to monitor for each of the major transit operators in New York State. These service-quality measures, coupled with the traditional efficiency and effectiveness measures, should provide a more comprehensive picture of the level of performance and quality of transit service throughout the state.

FUTURE RESEARCH EFFORTS

Future research in the field of transit-performance evaluation should concentrate on integrating the quantitative performance evaluation presented in this paper with the evaluation of transit service quality. It is clear that only by combining several approaches--time series, group comparison, and service quality--can an accurate and comprehensive picture of transit service be presented.

Additional work should focus on further analysis of performance measures to develop indicators that best identify services that would benefit from in-depth study, determination of the transferability of the performance measures developed in New York State to other areas, more in-depth study of the factors that can be used to group operators for analysis, and more in-depth study of methods to determine acceptable levels of performance.

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Publication of this paper sponsored by Committee on Transit Management and Performance.

Potential Role of Decision Support Systems in Transit Management

HISHAM ELSHERIF, MICHAEL D. MEYER, AND NIGEL H.M. WILSON

The potential of microcomputer-based decision support systems in transit management is explored. Although computers are now used quite widely in the transit industry, their role tends to be predominantly in highly structured activities such as financial management and record keeping. These functions are provided on main frame computers requiring expensive technical support. Microcomputers, however, have the potential to be used directly by the transit manager to assist in decisionmaking. It is suggested that microcomputer-based decision support systems should be the focus of future computer use in the transit industry. Significant potential exists for the development of transferable software to support a wide range of transit management functions. A case study of the Cairo Transport Authority is presented to show how a decision support system can be based on the ideas advanced in this paper.

For many years, computers have been widely used in the management of organizations in many different industries. To date, however, these computers have been used principally in the more structured management tasks where large amounts of data must be processed (e.g., personnel records and payroll). In the last few years, the introduction of microcomputers has revolutionized data processing and is beginning to affect day-to-day management activities. The current political and fiscal environment of the U.S. transit industry suggests that, in future years, transit managers will be under significant pressure to improve the efficiency of their operations (1).

The hypothesis that microcomputers can be valuable in improving transit management is explored. To test this hypothesis, three underlying propositions are investigated in this paper:

Proposition 1: the U.S. industry does not currently make effective use of computers. (This proposition will be tested empirically.)

Proposition 2: decision support systems (DSS) have significant potential for improving transit management. By DSS, we mean the use of computer-based technology to support managers' decisionmaking activities. The potential of DSS in transit agencies will be based on the results of an in-depth case study that illustrates both the process and the approach of DSS.

Proposition 3: microcomputers and end-user languages provide substantial technological capabilities for DSS.

Before these propositions are explored, two major characteristics of DSS merit special attention: (a) such systems provide support for managers in their decisionmaking processes and (b) they should result in more effective and efficient decisionmaking. Thus, one must be concerned not only with the technological capability of DSS, but also with the type of decisionmaking structure that is best suited for DSS application and the needs of the ultimate users of the system, in our case, transit managers. Although management information systems (MIS), as one type of DSS, have been used to some extent in the transit industry, they have played only a special and limited role, as will be seen from the following discussion.

CURRENT USE OF COMPUTERS IN TRANSIT INDUSTRY

The role of computers in transit management is large and growing. A recent survey by the American Public Transit Association (APTA) indicated that a large percentage of transit organizations (79 percent of those responding) now make some use of computers. This survey provides a good basis for exploring current computer applications in the industry and so can be used to address the first proposition.

Table 1 summarizes the current use of computers in the transit industry in the United States as determined by the survey. The table indicates the different applications within each functional area, ordered by decreasing use of computers. In interpreting these survey results, care should be taken with the reported transferability figure. Although the transferability issue is very important, it is often difficult to assess transferability in light of technical compatibility of software and hardware, cost, transfer time, and adaptability to different specifications and needs.

There are several conclusions that can be made about current practice based on the data from Table 1. First, there is little use of computer-based systems in most activities in the transit industry. For example, there are only four activities--payroll, general ledger, accounts payable, and fleet vehicle maintenance--for which computers are used by more than 50 percent of transit agencies. Second, the level of computer use in other activities varies widely, although in several areas (such as planning) in which one might expect significant utilization of computers, there is currently very limited use. Finally, there is a heavier concentration of computer use for activities that do not require managerial judgment. These tend to be structured activities in which the computer system serves strictly the MIS role.

Based on the results of the APTA survey, Proposition 1 seems well founded, i.e., that the current use of computers in the transit industry is limited to a small number of highly structured management functions. Before the next two propositions are addressed, it is necessary to consider transit management at a more general level.

FRAMEWORK FOR TRANSIT MANAGEMENT

One of the first tasks in determining the appropriate role of any computer-aided management tool is to identify the decisionmaking structure in an organization. As noted by Keen and Morton, "a descriptive framework provides the basis for prescriptive design; that is, to 'improve' a decision process, one must first define and analyze it" (2). The analysis of decisionmaking must consider and integrate several dimensions, including the organization's characteristics, management's needs and capacities, specific activities and tasks, and the technology and techniques used to accomplish these activities. This multilevel approach has been lacking in most prior studies of transit management and decisionmaking that have focused on the formal structure found in organizational charts (3,4).

For purposes of this research, transit management activities will be viewed as consisting of a series of tasks that are undertaken in functional areas (see Table 2). The functional areas include service planning and operations, maintenance, finance, and marketing; the key tasks include the following (5):

1. Strategic planning: the process of identifying future directions for the organization, determining the resources needed to achieve specific goals, and establishing policies to assure goal achievement;
2. Management control: the process by which managers assure that resources are used effectively and efficiently in the achievement of organizational objectives; and
3. Operational control: the process of assuring that specific tasks are carried out.

Central to this perspective of management activities is another dimension describing the degree of structure of these problem-solving activities, i.e., whether the activities are structured, semistructured, or unstructured. These characteristics are defined as follows:

1. Structured activities: those that do not involve a manager, situations where the decisions are well enough understood to be given to clerks or to be automated, for example, standard operating procedures;
2. Semistructured decisions: those in which managerial judgment alone will not be adequate, perhaps because of the size of the problem or the computational complexity and precision needed to solve it; on the other hand, the model and data alone are also inadequate because the solution involves some judgment or subjective analysis; and
3. Unstructured decisions: those that either are

Table 1. Current use of computers in U.S. transit industry.

Function	No. Using Computers	Percentage of Operators Using Computers	Percentage of Computer Systems Transferable
Financial management			
Payroll, salaried	59	87	67
General ledger	54	80	64
Accounts payable	47	69	71
Labor distribution/job project costing	31	46	82
Budget and financial responsibility reporting	31	46	57
Fixed assets and property management	25	37	56
Accounts receivable	22	32	76
Fare and revenue collection	16	23	56
Payroll, operating and nonoperating	16	23	78
Financial forecasting and simulation	8	12	67
Maintenance and materials management			
Fleet vehicle maintenance	42	62	67
Materials management and inventory control	32	47	62
Purchasing	17	25	67
Facilities and/or plant management	8	12	62
Operational management			
Schedules	33	48	73
Operator selection/assignment	28	41	75
Productivity/performance measurement	18	26	28
Safety	10	15	50
Claims	9	13	56
Ridership complaints/incident reporting	7	10	71
Marketing and telephone information	7	10	71
Labor relations	1	1	100
Planning			
Ridership statistics	27	40	74
Route statistics and information	17	25	80
Passenger counting and statistics	16	23	78
Revenue planning and statistics	5	7	60
Financial planning	1	1	100
Administration			
Personnel management	8	12	100
Equal Opportunity Office reporting	2	3	50
Benefits and medical	1	1	100
Engineering and construction management			
Capital project control and information	7	10	57
Reliability reporting and quality control	5	7	100
Construction management and contract control	5	7	60
Design and construction estimate and control	5	7	60
Engineering drawings and specifications control	2	3	100

not able to be structured or that have not yet been examined in depth and so appear to the organization as unstructured.

As shown in Table 2, specific activities can fit into both these functional areas and the level of management task. This should be viewed as one classification of these activities, with others also being possible. The relationships shown in the table will be used as the basis for the development of DSS within transit agencies. Later we will incorporate the dimension of the degree of structure of the activity.

DSS PERSPECTIVE

The analysis framework focused on specific managerial activities, whereas the DSS perspective asks how the manager can best be supported in carrying out these activities. The focus of the DSS is on improving management decisionmaking, so care must be taken to understand the existing management process, specifically, the key decisions and tasks, the data on which decisions are based, and the technology and techniques appropriate for mapping the data base into these decisions. Thus, DSS combines two perspectives, description (i.e., how decisions are made) and prescription (i.e., where computers can be introduced to improve decisionmaking).

The important characteristics of the DSS include the following:

1. The impact is on decisions in which there is sufficient structure for computer and analytic aids to be of value but where managers' judgment is essential;
2. The payoff is in extending the range and capability of managers' decision processes to help them improve their effectiveness; and
3. The relevance for managers is the creation of a supportive tool under their own control, which does not attempt to automate the decision process, predefine objectives, or impose solutions.

This should be clearly distinguished from the field of MIS in which the important characteristics are as follows:

1. The main impact is on structured tasks for which standard operating procedures, decision rules, and information flows can be predefined;
2. The main impact has been in improving efficiency by reducing costs and turnaround time and by replacing clerical personnel;
3. The impact on managers' decisionmaking has mainly been indirect, for example, by providing reports and access to data.

Thus, DSS represents a natural evolution in the field of computer-aided management tools from MIS, which concentrated mainly on the product (the package or system provided), to where the emphasis is on both the product and the process used to incorporate the system into the organizational decisionmaking process. The importance of the change process to ensure the diffusion of the product and its adoption (institutionalization) by the user cannot be underestimated (6).

Previous experience with DSS indicates that there are several significant characteristics of the systems (the product), and of the process used in their implementation, that are important in understanding the role they can play in decisionmaking. These include the following:

1. Adaptive design: user learning and participation is an essential component in successful DSS development.
2. Support to improve effectiveness and efficiency of decisionmaking: information support is useful only when the information is directly relevant to the decisionmaker's needs, aims, decisionmaking style, and education.
3. Incremental development based on interaction between user of system, builder of system, and system itself: DSS should be compatible with the way managers approach problems and be flexible enough to evolve to meet changing needs.
4. Most appropriate technology to support decisionmaking activities: the availability of low-cost microcomputers, which can be viewed as on-the-shelf depreciable products with low investment risk, enhances the potential of the DSS approach. In fact, the microcomputer is as much an economic advance as a technical advance; it has brought down

Table 2. Summary of basic transit management activities.

Functional Area	Strategic Planning	Management Control	Operations Control
Service planning and operations	Type of service (local express, paratransit, etc.) Demand analysis Facility planning and network design Surveys R&D	Network-planning improvements Productivity/performance, reporting	Vehicle allocation Dispatching Scheduling Productivity/performance, reporting Operation monitoring and inspection data collection
Finance	Financial planning and capital investment plans	Budget and financial responsibility Reporting Financial and/or bond management Cash management Revenue planning and statistics	General ledger Accounts payable Payroll, salaried Payroll, operating and nonoperating Labor distribution/job-projection costing Fare and revenue collection
Marketing	Market research/information Market segmentation Classes of people Geographical area Economic changes	Customer services Schedules Type of services Special services: ride and handicapped	Contracting
Maintenance	Facility planning Failure cost estimation Life-cycle cost estimation Long-term resource planning Training R&D	Status tracking/reporting Vehicle availability Vehicle fleet inventory Backlog status Management reporting Summary reporting Special reporting Failure monitoring Reliability analysis Inventory management Spare-parts estimation policy Planning Short-term equipment planning Short-term labor planning Short-term policies Availability Repair and maintenance	Preventive maintenance Consumable and mileage monitoring Vehicle-component - labor scheduling Work-order processing Repair history Cost reporting Labor reporting Failure monitoring Road call processing Inventory Inventory transactions Use reporting

the entry cost of using the computer and the cost of computerizing itself.

5. End-user languages that are used with interactive technology: in this way, small-scale models and techniques can be made operational and delivered to managers in days or weeks as opposed to the months or even years that many managers have experienced using traditional computer systems. These end-user systems request from the user what outputs are required or what functions need to be performed and then work out the sequence of instructions involved. Such systems were inefficient or infeasible until the cost of computer power for data manipulation was dramatically reduced by the development of microcomputers. DSS stresses man-to-machine interaction as opposed to reliance on written reports.

Given these characteristics of DSS, there are two potential development levels for such systems:

1. Macro development (industrywide development) focuses on activities that are similar among transit agencies and makes use of software that can be readily used by managers in different agencies; we call these portable systems;
2. Micro development (agency-specific) focuses on those activities that are distinctive to an organization, so that local development of DSS is needed; this can be thought of as a complementary development process.

In the next section a case study of the Cairo Transport Authority (CTA) will be presented to demonstrate the application of DSS at the micro level. The following section will then highlight the issues of development at the industrywide level.

CTA: A CASE STUDY

This section is intended to show the general approach to developing a DSS in a transit organization, the level of technology needed for the development of DSS, and the potential role of microcomputer-based DSS. The DSS approach was applied in CTA, the major provider of public transportation for the approximately 9 million inhabitants of Cairo. The management of such a large organization is of course an extremely difficult problem. Routines and procedures have developed over time as part of a rigid hierarchical structure with overemphasis on information processing, which is often redundant and unproductive. Analysis of such an organization requires a clear differentiation between management's need for information and the means by which this information can be provided, given a limited data base. These means include the techniques, the technology, and the resources that are currently used and those that should be used in the future.

One of the first tasks in this study was to identify which areas were the best candidates for initial DSS development. High-level management identified three principal functional sectors of the organization that should receive attention: the service-planning sector, the maintenance sector, and the financial sector. Applying the approach outlined earlier in this paper, the study was structured in the following stages:

Stage 1: An analysis of the Cairo Transport Authority was conducted examining three different aspects: (a) organization structure, (b) activities and decisions, and (c) information needs, uses, and sources. The first step necessary in developing a DSS was the identification of the decisions made in specific sectors and the type of information collected to support decisionmaking. The results of this analysis are shown in Table 3. Based on this analysis, a more detailed examination of the service-planning sector and its data needs was undertaken to develop the necessary tools that could then be transferred to other sectors. In this regard,

Table 3. Classification of existing and prescribed functional activities at CTA.

Level of Activity	Strategic Planning	Management Control	Operational Control
Existing Activities			
Structured		Counting	Scheduling Payroll
Semi-structured		Bus allocation Network planning System control Statistical analysis/routines	Inventory control
Unstructured		Fare alteration Setting performance standards for vehicles and labor Capital allocation	Preventive maintenance
Prescribed Activities			
Structured	Facility planning	Bus allocation model Budget analysis	Scheduling Counting Preventive maintenance Fuel and oil consumption Inventory control Incentive routines Payroll Revenue reporting cost recording
Semi-structured	Training Capital investment and life-cycle cost analysis	Performance indicators Network planning Fare determination Labor/parts use Labor/parts distribution Vehicle availability Repair and maintenance policy	Auditing Cash management
Unstructured	R&D Sparing policy (due to uncontrollable factors)	Hiring managers or personnel	

from a strategic point of view, it was important to show some improvement in CTA operations to maintain a good working relationship with CTA officials.

Stage 2: The process of describing the existing decisionmaking structure in CTA was useful in immediately suggesting problem areas. Meetings were held with high-level CTA officials to reclassify existing functional activities to improve effectiveness and efficiency. The results of these discussions are also shown in Table 3, which suggests a reasonable set of service-planning activities for the future. This framework was very important in guiding the development of the DSS for CTA, especially in deciding where the initial effort should be made.

Stage 3: A major task was a detailed analysis of the forms and procedures used in the service-planning sector. This analysis resulted in (a) identification of the basic items required to support the sector's activities and (b) work-simplification recommendations that reduced the number of forms used within the sector from 83 (before the study) to 31 (after the study).

Stage 4: A new data-collection program was proposed based on a special characteristic of CTA: the use of two-man crews with conductors issuing tickets. By making minor changes to the ticketing procedure, a solid data base would be available at almost no additional cost. The resulting data base forms a current, reliable, and effective base on which to build most of the decisionmaking activities in this sector. Microcomputers were recommended as the technology for simple processing of the raw data.

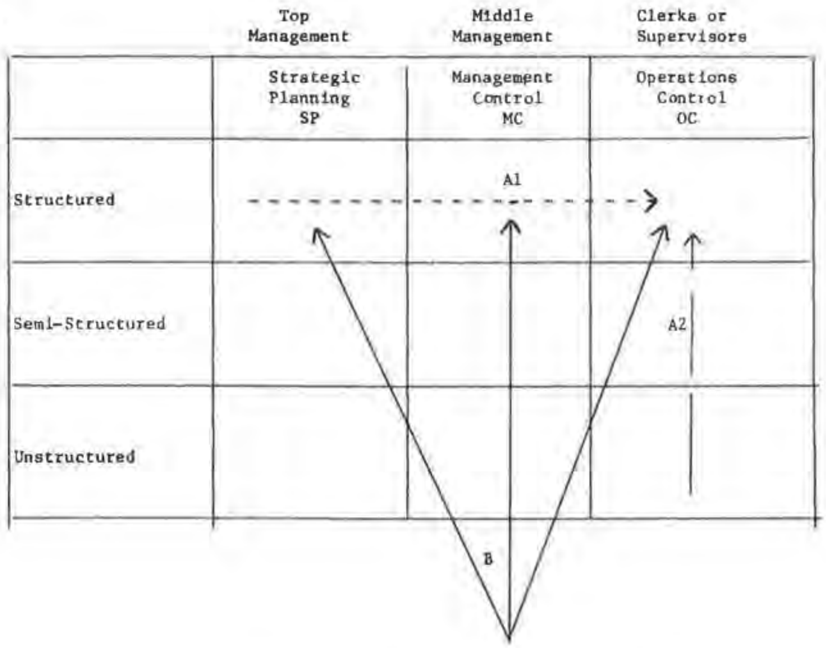
Stage 5: A similar approach is now being used to analyze both the maintenance and financial sectors. The initial analysis of CTA and top management needs showed that the priority activities in the maintenance sector were inventory management, preventive maintenance, and vehicle availability. In the financial sector the focus will be on providing tools for financial planning and control.

Stage 6: A prototype microcomputer-based DSS is currently being developed, which will be the basis for the evolution of the DSS for CTA.

The development of the DSS for CTA, carried out incrementally and interactively, included two phases in the development process: the predesign cycle and the design cycle. The predesign cycle involved the definition of the organizational structure, authority, and power; the degree of commitment; and priorities for development. A clear statement of CTA goals and objectives, resources available, and existing constraints was developed. In addition, each decision process was analyzed to determine type of decision, decisionmaker, the controllable and uncontrollable variables, and the relationship with other decisions. The DSS development process is illustrated in Figure 1, which shows two types of changes occurring. Type A, shifting or reclassifying existing functions, includes A1, transferring existing functions from the management-control level to the operations-control level, thus improving the efficiency of top and middle management through time savings at higher management levels; and A2, making existing unstructured or semistructured functions structured to improve efficiency (for example, preventive maintenance). Type-B changes involve introducing new management functions. Examination of Table 3 shows a lack of strategic-planning functions among the existing activities, as well as other essential management-control and operations-control functions, for example, sampling programs at the latter level. On the strategic-planning level, functional activities including capital investment analysis, life-cycle cost analysis, and facility planning should be introduced. In other words, new functions are introduced at both the semistructured and structured levels and existing functions are reclassified at the strategic-planning, management-control, and operations-control levels.

This process leads to a set of potential changes in CTA management activities (they will be referred to as projects), which can then be evaluated and ranked according to a defined priority scheme.

Figure 1. DSS development map.



After specific projects have been selected, the next step is to make operational the design objectives by defining the data base, the data management software, and the hardware for each area. In the case of CTA, microcomputer technology was selected for implementation of the DSS for the following reasons:

1. Low cost: large computers require a large investment for an organization. In Egypt, this problem is more severe due to the lack of foreign exchange. Microcomputers significantly reduce the cost of using computers.
2. Quick delivery: the lead time to acquire hardware and implement software is usually weeks as opposed to months or even years in the case of the large-computer/MIS approach.
3. Skills: less reliance on the highly technical skills required for large-computer installations, since the microcomputer is designed to be used by managers within each functional area. The ease of use, simplicity, and response to the user needs are the key benefits for use.
4. Learning: Microcomputer-based DSS provide a learning medium in which professionals learn about new techniques and tools that can improve their activities. In addition, they can learn more about their own evolving needs.

The development strategy adopted was based on an initial prototype system, to which the user can react and from which the user can learn to participate effectively in the development of the functional systems. The idea here is to start quickly and to modify the system according to the user's requirements and needs rather than to try to give the user everything at once. With this development strategy, stress must be placed on the user-machine learning process and the facilities of dialogue (in this case in Arabic) between the user and the machine. Here, one should recognize the difference in training required for a DSS compared with that for an MIS; in DSS, the initial user training should be of the order of hours for a high school graduate compared with days or weeks for MIS training.

ASSESSMENT OF DSS IN TRANSIT AGENCIES: INDUSTRY PERSPECTIVE

In previous sections, we have shown (a) the current lack of computer support for transit-management decisionmaking (Proposition 1) and (b) the potential for DSS in transit agencies as illustrated by the CTA case study (Proposition 2). In order to assess the feasibility of DSS for industrywide applications, it now may be useful to consider the technological dimension. This complements the management view of Proposition 1 and expands on the experience gained from the CTA case to the industrywide level.

The current use of computers in transit, as reported in the APTA survey, is shown in Table 4 (7). This summary shows the type of computer used by operators of different size: small, medium, large, and very large. Computers are classified according to whether they belong to a service bureau or are in house. In addition, in-house computers are classified as microcomputers, minicomputers, or large computers.

Table 4 shows the following situations:

1. Only 25 percent of small operators have an in-house computer;
2. About 33 percent of small operators rely on outside services;
3. The dependence on outside computer services is inversely proportional to the size of the operator;
4. The availability of in-house computers is programmed to the size of operator, and large operators often have more than one computer; and
5. Microcomputers are used by only 3 percent of the operators in the industry, and large computers represent 67 percent of all computers used in the industry.

These survey results suggest the following conclusions on current use of computers in the industry:

1. Computers are still used mainly by larger agencies--those that can afford their high cost and risk.
2. Transit officials seem to feel that computer systems require large capital investments, rely on scarce and expensive technical specialists, require long development time for information systems that are mostly "number crunching" (recall that more than 50 percent of the transit operator's use of computers centered around four activities--payroll,

Table 4. Computer use by transit operators.

	Size of Operator									
	Small (N = 24)		Medium (N = 22)		Large (N = 17)		Very Large (N = 19)		Total (N = 82)	
Type of Use	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.
Service bureau	33	8	23	5	18	3	5	1	21	17
In house	25	6	86	19	76	13	100	29	82	67
Microcomputer		-		1		-		1	3	2
Minicomputer		4		13		1		2	30	20
Large computer		2		5		12		26	67	45

Note: Some operators have more than one computer, whereas others make use of service bureaus as well as in-house computers.

accounts payable, ledger, and fleet preventive maintenance).

3. There seems to have been an overemphasis on technical issues, which results in systems that are hard to use, unrealistic, or inflexible.

Examining the recent technological developments, however, we find that technology is changing fast and there is dramatic price-performance improvement in computer technology.

Recent developments now make it possible to solve the problems identified by the APTA survey. Small-scale desk-top computers in the $300-$9000 range (U.S. prices, mid-1981) provide more than enough computer power, speed, and capacity to meet most of the needs of decisionmakers. End-user languages allow flexible systems to be developed very quickly and without relying on technical staff. DSS provide proved methods for developing simple, useful, responsive, and flexible interactive computer aids that meet the needs of decisionmakers, leverage their skills, and mesh with the way they think.

Together, these tools add up to a cost-effective, low-risk strategy at both the transit-agency and industry levels. Thus, the third proposition with which we began, that microcomputers and end-user languages have reached a level of technological development that provides for their economic use in DSS, is shown to hold. The microcomputer technology provided highly suitable application at the CTA and would seem to offer low-cost/low-risk application in DSS in U.S. transit agencies.

SUMMARY AND CONCLUSIONS

The potential development of microcomputer-based DSS in U.S. transit agencies has been examined. A framework for transit management was presented to identify the key activities in the main functional areas in a transit agency (service and operations planning, maintenance, finance, and marketing) and classify each activity as strategic planning, management control, or operational control and also according to its degree of structure.

Based on this framework for transit management, the DSS approach was introduced as distinct from other traditional computer applications. This approach has a high potential in the industry, especially combined with the use of the microbased technology. This statement is supported by the survey of computer use in the U.S. transit industry by APTA in 1980 and a case study of the Metropolitan Transport Authority in Cairo, Egypt. This development is possible at two levels, macrodevelopment (industrywide development) and microdevelopment (agency-specific), which are complementary to each other.

The survey of current use of computers has shown that transit agencies still rely on traditional use of both computer technology, i.e., large computers or minicomputers, and application areas, i.e., structured tasks, such as payroll and general ledger. It shows that there is little use of computers in the semistructured activities where managerial interaction and judgment are key, such as service and operational planning, financial planning, etc. This indicates that there is strong potential in the combination of microcomputers and end-user software on the one hand and DSS on the other hand to provide portable low-cost applications.

In short, we have shown an approach that can be applied to industrywide development or to transit-agency development or to both. The case study also shows that there is a potential use of this approach in developing countries. However, this paper provides only the nucleus on which further research should be conducted to identify the DSS activities that can be easily transferable and to quantify the cost effectiveness of this approach.

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Publication of this paper sponsored by Committee on Transit Management and Performance.

Tri-Met's Self-Service Fare Collection Program

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Self-service fare collection (SSFC) is a concept in which the passenger is responsible for payment of a transit fare and possession of a valid ticket or proof of payment. Checking of fares by transit vehicle operators at the time of boarding can thus be avoided, and transfers between buses or between buses and other modes can be made without delay, barriers, or complex equipment. Such a system is the key to the efficient operation of large surface transit vehicles such as articulated buses and light rail and offers a range of other benefits to both the transit agency and passengers. The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) decided that SSFC would offer substantial financial and operating advantages compared with continuing the traditional farebox system. SSFC is expected to reduce Tri-Met's operating costs by about $2.1 million in the first full year of operations, increasing to about $6 million by 1990. Tri-Met's capital needs for the period 1981-1990 will be reduced by some $7 million, mainly through the more effective use of existing equipment. The Tri-Met SSFC program is designed around policy guidelines intended to minimize operational, legal, and financial risk. Existing fareboxes and monthly passes will continue in use. The program initially involves some 600 buses, which will be equipped with validators and single-ride ticket printers. SSFC is now scheduled to begin on September 5, 1982, at which time Tri-Met will introduce a new five-zone regional fare structure. A proof-of-payment ordinance will go into effect, and passengers will be free to enter or leave buses through all doors.

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) is responsible for providing transit service to a population of about 1 million in the Portland metropolitan area. It operates a fleet of about 580 standard and 87 articulated buses. A 15-mile light-rail line is under construction. Ridership, which has increased almost threefold since 1969, is currently 140 000 passengers per weekday. Fares are collected by the traditional North American method with a farebox on each bus for cash fares. Some 46 percent of fare revenue comes from monthly passes. There are three circumferential fare zones and two zone fares. No zone tickets are used. Fares are 65 cents and 90 cents. Transfers are free.

Although this fare collection system is generally perceived to work adequately at the current time, it nevertheless suffers from continuing minor problems with zone fares, fare evasion, fare disputes, and dollar bills. Much more serious, the traditional system of fare collection will impose major constraints on Tri-Met's plans to improve service and efficiency in the years ahead.

SELF-SERVICE FARE COLLECTION

Self-service fare collection (SSFC) is a concept in which the passenger is responsible for payment of a transit fare and possession of a valid ticket or proof of payment. Checking of fares by transit vehicle drivers at the time of boarding can thus be avoided, and transfers between buses or between buses and other modes can be made without delay, barriers, or complex equipment. To ensure that fares are paid, fare inspectors are assigned to check tickets, and a premium fare is charged to passengers without proof of payment. Such a system is the key to the efficient operation of large surface transit vehicles such as articulated buses and light rail and offers a range of other benefits to both the transit agency and passengers.

First developed in Europe some 15 years ago, SSFC has since become almost universal in western Europe and is now being adopted or considered by several North American transit agencies. Of some significance is the fact that no transit agency anywhere that adopted SSFC has ever subsequently discontinued it.

SSFC is the only type of fare collection universally applicable to all modes of transit, whether bus, commuter rail, or heavy or light rail. Since it is a concept of fare collection rather than a particular hardware configuration, the equipment requirements will vary according to the needs of the particular installation. Extensive experience has built up over the past 15 years concerning the equipment necessary to support SSFC operations.

The following North American agencies are introducing, or plan to introduce, SSFC:

1. Vancouver, British Columbia, has been operating a ferry line (Seabus) on which SSFC is used since 1977. Experience has been highly satisfactory, and SSFC may be extended to other parts of the transit system in the future.
2. Edmonton, Alberta, introduced SSFC on its first light-rail transit (LRT) line in 1980, experiencing major savings in operating costs. Fare evasion is reported to be less than 1 percent, and plans are being developed to expand SSFC to the whole transit system.
3. Calgary and San Diego introduced SSFC on their new LRT lines in the summer of 1981. Initial reports are highly favorable.
4. Many other cities in North America are now considering SSFC as an option to increase transit operating efficiency, particularly cities that also plan to build LRT systems or operate large numbers of articulated buses.

FARE POLICY STUDY

In 1978, the Tri-Met Board of Directors decided to construct an LRT line. The characteristics of this line, including unfenced low-level platform stations, often in the street right-of-way, made the installation of conventional barrier fare collection impossible. Onboard fare collection by using fareboxes would have required fare collection personnel on every car, increased dwell times, and substantially eroded the economic advantage of LRT. The LRT plan carried with it the implication that Tri-Met would switch to SSFC.

In 1979, in the course of developing the Five-Year Transit Development Plan, Tri-Met investigated various possible fare policies, including the continuation of the traditional farebox system and all practical alternatives, including SSFC. These studies examined possible alternative forms of SSFC, how it might be introduced, and alternatively how the existing fare collection system could be modified to meet Tri-Met's future needs.

It was concluded that the choice lay between a succession of palliative measures that at best could minimize the constraints that the traditional system of fare collection places on transit operations, particularly with LRT, or alternatively a bold and probably controversial move to SSFC that would put in place a new system of fare collection able to accommodate any future modes or fare structure that Tri-Met may adopt.

It was also concluded that the early implementation of SSFC would accomplish the following:

1. Improve operation of the bus system, particularly in peak periods and with articulated buses;

2. Ameliorate a variety of fare problems, which would include disputes involving drivers, forged passes, and dollar bills clogging the farebox, and the need to augment the fare zones;

3. Realize the financial benefits expected from SSFC at an earlier date;

4. Provide an opportunity to prove this relatively untried system of fare collection before completing design of the LRT line; and

5. Stand a good chance of attracting funding under the Service and Methods Demonstration Program of the Urban Mass Transportation Administration (UMTA).

At about this time, UMTA had also concluded that SSFC might have considerable benefits in the United States and had made provision for an SSFC demonstration project. But although several transit agencies had expressed interest, none was anxious to be first.

REASONS FOR SSFC

Project Development Studies

The first step toward implementation was a series of project development studies leading to an implementation plan. The purpose of this plan was to provide a focus for all aspects of the project--what are the pieces, how do they fit together, and what areas require further study? The preliminary plan provided a basis for determining what equipment was required, what possible fare structures should be accommodated by the equipment, what legal questions remained to be resolved, the logistics of fare inspection, and public information and marketing. It was discovered that the procurement of equipment had the longest lead time and hence should assume the highest priority.

During the development of this plan, a better understanding developed of the pervasive and generally beneficial effect SSFC would have on the whole Tri-Met system. In general, two kinds of benefit were identified--nonquantifiable benefits, such as increased passenger convenience, reduced driver stress and work load, or improved system security, and quantifiable benefits, such as savings in bus hours or increases in revenue to which a dollar amount can be attached. Realization of many of these benefits requires additional action by Tri-Met beyond the implementation of self-service, such as the procurement in the future of buses with double doors, the rescheduling of lines to capture time savings, and the deployment of high-capacity equipment on lines on which this equipment is warranted.

Advantages of SSFC

Speed-Up of Existing Bus Operations

Part of the SSFC program calls for retrofitting the rear doors of buses to permit passengers to enter through them. This will reduce bus loading time, particularly at busy stops such as transit centers and during the peak period. Retrofitting for rear-door boarding will provide two door streams on standard buses, enabling them to better match the loading speed of the five door streams on articulated buses. Eventually Tri-Met expects to specify buses with double doors on all new procurements.

Effective Operation of Articulated Buses

SSFC enables Tri-Met to derive the fullest benefit from articulated buses. For instance, on the Mall the traffic signals operate on a progression. If a bus can load quickly, it can travel down the Mall and catch each of the traffic signals. However, if the loading time is more than about 15 s, the bus will miss each signal. Thus, a few seconds' increase in loading time is multiplied several times by the delay at each traffic signal. If the articulated buses are operated without self-service, they will not only accelerate more slowly, a characteristic of these vehicles, but will also load more slowly. In doing so, they will also delay all other buses using the Mall, leading to a substantial loss in total system capacity. With self-service, however, the articulated buses will load faster than the standard buses, and Mall capacity will be preserved and probably increased.

In addition, self-service permits the effective deployment of articulated buses on the heaviest inner-city routes. Such routes, generally characterized by large numbers of passengers loading and unloading, are traditionally considered unsuited for articulated buses in the United States, mainly because they are used without SSFC. However, these routes are also those on which the improved productivity and greater schedule reliability that articulated buses offer can be deployed to the greatest economic benefit.

Improved Schedule Adherence and System Productivity

For example, a bus running late will pick up an additional passenger load. This in turn will make the bus later still, thereby destabilizing service. With SSFC and boarding through all doors, late buses will not incur the same proportionate delay, and so there will be less tendency for service to destabilize. In addition, the greatest effect of faster operation of both articulated and standard buses will occur during the peak periods when current loading delays are most noticeable. If buses can be operated faster during peak periods, the capacity of the system is increased. Since the total fleet is sized for the peak hour, an increase in fleet capacity during the peak would permit the same passenger load to be carried by fewer vehicles, a net capital and operating savings.

Effective Operation of LRT

The LRT plan is based on the use of trains of large (88-ft) vehicles, loading from the street. Each two-car train has 16 door streams. Erecting fare barriers at on-street stations would be expensive and in many locations unacceptable. Farebox fare collection would be so slow that each trip would take several minutes longer. More cars would be required to maintain system capacity, and operators would be required on trailing cars for the sole purpose of collecting fares. Not surprisingly, SSFC has been adopted on the new LRT systems in Edmonton, Calgary, and San Diego, as well as on all LRT systems in Europe.

Avoidance of Expense of Farebox Replacement

When Tri-Met's Zone 3 fare reaches $1.00 in June 1982, the ability of fareboxes to accept dollar bills will become a major concern. Not only do Tri-Met's existing farebox vaults have a capacity of about 60 dollar bills, but the bills have a tendency to jam the farebox. Torn bills are sometimes presented, resulting in lost revenue and increased money-room costs. SSFC, by reducing the percentage of fares paid into the farebox to less than one-third of their current volume, will enable the existing fareboxes to continue in service and the drivers to deal with the bill problem by requiring bills to be presented unfolded, if necessary, without significant delay to service. Recent experience by other agencies who have replaced their fareboxes with electronic fareboxes capable of accommodating dollar bills has shown that the capital cost that Tri-Met is incurring in switching to self-service are no greater than the costs other properties are incurring by replacing their fareboxes and vaults.

Increased Fare Equity

As fares increase, Tri-Met, like most agencies operating service over a large geographical area, is finding it desirable to make the fare cost more closely reflect the length of trip. This can only be achieved by use of a zonal fare system. In 1978, Tri-Met switched from a flat fare to a two-fare zone structure. However, under increasing fiscal pressure this is not proving sufficient. Although the fare for the long-distance trips on the system is still less than it was 10 years ago, the fare for short trips is so high as to discourage ridership. This position can be rectified only by adding one or more additional fare zones. But the current fare collection system cannot control more than two zone fares. The alternatives are either a hat-check system, which would delay service and be entirely impractical with articulated buses and LRT, or SSFC.

With SSFC, additional fare zones can be instituted without operational delay and in a fair and enforceable way. Moreover, by selectively increasing fares to what the market will bear, transit revenue can be increased with little loss of ridership.

Fare-Evasion Control

The potential for fare evasion is widely quoted as a reason for not adopting SSFC. However, Tri-Met now experiences passengers who forge passes, refuse to pay, short-change the farebox, and override the zones. Drivers can do little to control these abuses. While opportunities for certain types of fare evasion are increased under SSFC, other types of fare evasion, particularly forged passes, short-changing, and zone overriding, can be effectively controlled by fare inspectors. After a year of SSFC operation, Edmonton reports a fare evasion level of around 1 percent. On Tri-Met, not only is SSFC expected to reduce revenue loss from fare evasion, but some additional revenue will be generated from the premium fares charged to passengers traveling without proof of payment. Moreover, the system is partly self-stabilizing, since the greater the revenue loss from fare evasion, the greater the potential revenue from premium fares.

Improved System Security

The presence of radio-equipped fare inspectors traveling at random on the system will provide a measure of visible and real support to drivers and enhance passengers' perception of transit system security.

More Convenience for Passengers

The new fare structure will open up new and more convenient ways to pay fares. The new multiride ticket, for up to 10 rides, will permit passengers to travel without needing the exact fare for each trip. Moreover, pass holders, who will make up more than 50 percent of Tri-Met's passengers, will no longer have to dig for their pass each time they board a transit vehicle. Except when requested by fare inspectors, pass holders will carry their passes just as automobile drivers now carry their driver's licenses.

Reduced Cash-Handling Costs

The extensive adoption of prepayment of fares (targeted at 85 percent) under SSFC is expected to reduce money-room and cash-transfer costs and related security requirements.

Reduced Driver Tasks

SSFC will provide clearer definition of the driver's role with regard to fare collection and will reduce and define the tasks and responsibilities. The driver will no longer be required to try to extract a fare from a reluctant passenger nor to argue over cash or transfers. Fare disputes are the most common source of passenger/driver friction today and are one of the main sources of stress and driver absenteeism.

Improved Passenger Comfort

Passenger comfort will also be improved because multidoor loading will provide better passenger distribution on the vehicle. Passengers may enter and leave through any door, thereby being exposed to less bunching and jostling on the vehicle. Overall, the passenger's perception of transit service is likely to be enhanced.

Economic Analysis

An economic analysis was developed to estimate the cost and benefits of those aspects of SSFC for which such estimates can be made (1). Estimates were developed for three different years--1983, 1985, and 1990--and for a transit fleet expected to grow as follows:

Type of Vehicle	No. of Vehicles 1983	1985	1990
Standard bus	500	700	800
Articulated bus	87	125	250
LRT	0	26	68

Operating cost and capital cost projections for SSFC were developed separately.

Operating Cost and Revenue Comparisons

The cost of operating SSFC can be determined with considerable accuracy since implementation is well advanced and all major expenditures are budgeted. By far the largest operating cost is fare inspection, for which 50 fare inspectors are budgeted. Other costs include transit police support, administration, marketing, and equipment maintenance. Operating costs are not expected to increase in proportion to system ridership, since as passengers get used to self-service, less inspection effort per passenger is anticipated.

The major dollar benefit attributable to SSFC lies in the reduction in number of vehicles required to provide an equivalent level of service capacity compared with that for operation without SSFC. These benefits will occur primarily on the most heavily used lines and particularly during peak periods. Improvement in system efficiency during peak periods is particularly significant since the transit fleet is sized to provide the necessary peak capacity. Any vehicle savings occurring in the peak period are therefore potential savings in the total fleet size.

Operating cost savings on the LRT system are

Table 1. Net systemwide operating cost savings from SSFC.

Item	1982 Constant Dollars (000s)		
	1983	1985	1990
Costs			
Fare inspection	-1696	-1846	-1846
Administration	-470	-470	-470
Other	-75	-100	-150
Subtotal	-2241	-2416	-2466
Savings			
Bus operation	1000	1405	1789
LRT operation	-	910	2080
Absenteeism	375	400	500
Reduced fare evasion	180	240	290
Zone-fare revenue increase	1800	2400	2900
Premium fares	1000	1100	1200
Net operating-cost savings	2114	4039	6293

Table 2. Net saving in systemwide capital needs from SSFC.

Item	1982 Constant Dollars (000s)		
	1981-1982	1983-1985	1986-1990
Costs			
On-board equipment (validators, etc.)	-2950	-900	-1700
Rear-door modifications	-250	-	-
Vending machines	-	-1030	-800
Subtotal	-3200	-1930	-2500
Reduced capital needs			
Bus fleet reduction	3000	1400	1500
LRT fleet reduction	-	4000	2000
Farebox replacement	2450	460	450
Subtotal	5450	5860	3950
Net reduction in capital needs	2250	3930	1450

particularly dramatic and are expected to exceed the savings in bus operations by the year 1990. The reason for this lies with the nature of LRT operations. Specifically, operation of LRT with the traditional system of fare collection would require a driver on the trailing car of a two-car train solely to collect fares, would increase dwell times at stations, would require two additional train sets to maintain equivalent service capacity, and would require additional maintenance personnel. Along with most transit agencies, Tri-Met experiences considerable lost time and expense due to driver absenteeism. Tri-Met expects SSFC to be one factor in reducing driver job stress and hence absenteeism.

In addition, SSFC is expected to generate some additional revenue. One source of anticipated additional revenue is the reduction of fare evasion due to fare inspectors. In addition, increasing the number of fare zones enables Tri-Met to increase fare revenue without increasing the base fare. Thus, for any given base fare, a fare structure including multiple zones collected by self-service will have a higher level of revenue.

Passengers found riding the transit system without a ticket will be charged a surcharge fare of $20 by fare inspectors. Tri-Met expects to generate significant new revenue from this source, even after allowing for administrative expenses and uncollectable surcharge fares.

The net operating cost savings attributable to SSFC are summarized in Table 1.

Capital Cost Comparisons

The capital costs of introducing SSFC are accurately determinable since procurement of most of the capital equipment is in progress. Equipment requirements include the on-board equipment, such as validators and ticket printers, the retrofitting of rear doors of buses to permit passengers to enter vehicles through either door, and the purchase of a small number of vending machines to sell tickets at key focal points on the transit system.

Just as SSFC will reduce the transit system operating costs by enabling fewer buses to provide the same amount of service capacity, so too will SSFC reduce Tri-Met's fleet requirement, both buses and, later, LRT vehicles. In addition, the adoption of SSFC will enable Tri-Met to avoid replacing its existing fareboxes with new fareboxes able to accept dollar bills and count the large number of coins now required to make up a transit fare.

The balance of capital costs and savings attributable to SSFC is shown in Table 2.

IMPLEMENTATION PLAN

Policy Guidelines

One problem that surfaced early was how to develop a design rationale for aspects of the project for which there was little relevant information, for instance, what the initial level of fare inspection should be or how one should change the system of fare collection on an operating 600-bus system without severe service disruption. To resolve problems of this type, a series of policy guidelines evolved and is used to provide direction when decisions are required.

Among the key policy guidelines are the following:

1. Minimize legal risk through the use of existing powers and a generally low-profile enforcement program;
2. Minimize financial risk through phased implementation to avoid the possibility of substantial fare evasion;
3. Use proved equipment and, where applicable, proved techniques;
4. Be cost-effective; SSFC is not to be a "glorious experiment";
5. Minimize changes required in riders' habits and maintain as much consistency as possible with other U.S. transit systems;
6. Develop the program to provide clear public benefits from the day of start-up; SSFC must be presented as more than a convenience to the transit agency; and
7. Introduce the full program in stages to minimize risk and provide the opportunity for fine tuning and modifications as the program moves forward.

Development of Implementation Plan

The initial implementation plan called for SSFC to be introduced in several phases consistent with the policy of minimizing risk. The first phase would introduce the new ticket and fare structure and the proof-of-payment concept, but fares would continue to be monitored by drivers. With driver monitoring, passengers would, of course, continue to board only through the front door. Legal risk is minimized because the system could still revert to the traditional system of fare collection overnight in the event of a challenge, and financial risk is minimized because during this phase there is no change in the opportunities for fare evasion. Once this system had become established, successive phases would provide a gradual transition away from driver monitoring to full SSFC, starting with the heaviest lines, where the benefits are greatest. This type of phased implementation is often found in Europe, particularly at this time in France. It also can provide a guarantee to the agencies' directors that SSFC will be phased in only as fast as it can be shown to work. Both driver-monitored and full self-service would have the following features:

1. Passengers would be required by ordinance to possess a valid ticket or pass when traveling on district vehicles;
2. Passengers traveling without a pass would complete their fare transaction immediately on boarding, either by paying a cash fare and obtaining a ticket or by validating a multiride ticket purchased before boarding the bus;
3. The farebox would be retained for fare payment since it exists and is fairly efficient, but the percentage of passengers using the farebox would be reduced in order to avoid issuing excessive numbers of tickets; this would be achieved by discounting the new multiride tickets;
4. Fare collection would be enforced by fare inspectors who would check tickets on a random basis; passengers traveling without a valid ticket or pass would pay a surcharge fare.

As project implementation proceeded, an interesting evolution occurred. Phased implementation had the disadvantages of small initial benefits and of giving the impression that the fare system was in a constant state of change. Moreover, as SSFC became better understood and as favorable reports came in from Canada and San Diego, Tri-Met's directors became increasingly comfortable with the concept of SSFC and questioned whether the additional steps inherent in the phased approach were necessary. After extended debate, it was concluded that the increased simplicity of a single one-time switch to systemwide full self-service and the faster realization of operating benefits more than outweighed the benefits of the more cautious multiphase approach. Accordingly, the original plan was revised to provide for full systemwide conversion to self-service without interim phases. This change had no impact on the on-board equipment required for either driver-monitored or full self-service but did require an additional outlay in fare inspection.

Organization

With the partial approval of project funding in September 1980, the project moved into the implementation phase. Because SSFC affects every facet of a transit agency, an organizational structure was required to ensure internal coordination. To achieve this, an interdepartmental committee was established with representatives from each department charged with overseeing all aspects of the work and making recommendations where appropriate on technical details of the project. Subcommittees were assigned to perform the detailed work and prepare technical recommendations. There were nine subcommittees covering the following areas:

1. Fare structure (zones, pricing structure, ticket design);
2. Ticket and schedule outlets (ticket and pass sales, retail outlet policy, vending machines);
3. On-board equipment (procurement of validators and printers, rear-door modifications);
4. Legal aspects (legal review, drafting ordinances);
5. Fare inspection (procedures and selection, training, deployment of fare inspectors);
6. Records, billing, and collection (processing and collection of surcharge fares);
7. Operations (on-street deployment of SSFC);
8. Public information (program and materials for public information and marketing); and
9. Evaluation study (assist independent contractor with evaluation of SSFC).

This organizational structure provides the two most important requirements for a project of this type--assignment of responsibility for performance of all tasks to specific individuals and coordination between departments by direct involvement.

PROJECT DESCRIPTION

This section provides an overview of the key features of the fare collection system that will go into effect on September 5, 1982, together with some of the considerations that led to their adoption.

Proof of Payment

Under SSFC all transit passengers will be required to possess a valid ticket or pass. Under Oregon law, mass transit districts may adopt ordinances having the force of law that cover any matter directly relating to the use of transit district facilities. By using these powers, Tri-Met may require that all passengers possess proof of payment when riding the transit system and may carry out fare inspections and assess surcharge fares to passengers traveling without proof of payment.

Fare-Payment Options

Under SSFC, Tri-Met passengers have three fare-payment options:

1. Cash fare: passengers will pay the fare into the farebox as they do now and receive a single ticket from a machine situated by the farebox and known as the dispenser. The dispenser is activated by the driver and is described more fully below. The single-ride ticket thus issued is similar to today's transfer. Transfers will no longer be necessary. About 15 percent of passengers are expected to continue to use the farebox.
2. Multiride tickets: this new method of fare payment requires passengers to purchase a card ticket valid for up to 10 rides. This ticket can only be purchased off the vehicle. To encourage use of the multiride ticket, a discount of about 10 percent will be offered compared with the cash fare. Passengers using the multiride ticket must validate the ticket at the beginning of each trip, using a validator that will be installed on all buses. Approximately 30 percent of all passengers are expected to choose multiride tickets.

Passes: passes will continue to be used in the same manner as they are now. Pass use will continue to be encouraged by providing an attractive discount to pass users. Pass use is expected to increase from approximately 50 percent to about 55 percent of Tri-Met's ridership.

Each of these three alternative methods of fare payment is targeted on a particular segment of the ridership market. In addition, the payment options are designed to minimize farebox use, since the use of the front door and farebox are factors that limit transit operating speed. Another feature of these payment options is that no passenger will be required to change his or her fare-paying habits at the start of self-service, although many are expected to do so in response to the discounts offered by the new fare structure.

Fare Structure

One issue requiring resolution early in the project was the type of fare structure for which the SSFC program should be designed. Elimination of the constraints associated with multiple fare zones under the traditional system of fare collection automatically raises the question of what zone system is most desirable in the absence of existing constraints. Whether to change the zone system, and if so to what, is influenced by a number of considerations, including the following:

1. Numerous requests by the public at previous fare hearings to increase the number of fare zones rather than the base fare,
2. The desirability of developing a closer relationship between trip length and fare, and
3. The need to adopt the simplest possible zone system.

The fact that the equipment to be installed on the buses would impose a certain measure of constraint on future changes to the zone system gave an added urgency to resolve this issue.

It was found that two possible zone configurations would meet Tri-Met's needs. One was a set of five concentric zones, and the other was a pattern of 25 roughly equal cellular zones covering the entire region. Both types of zone system are widely used on other self-service operations. However, on the Tri-Met system where the majority of ridership is radial, the concentric-zone pattern was sufficient to meet Tri-Met's revenue needs without introducing the complexity of the cellular-zone system. Moreover, the concentric-zone pattern provided an additional incentive for passengers to make increased use of Tri-Met's new crosstown service for crosstown trips, instead of traveling via downtown.

Equipment

The major capital expense of initiating SSFC is the requirement to install equipment on every bus to provide passengers with accurate and readily verified proof of payment. The equipment selected is actually a system made up of three types of units.

To enable multiride ticket users to validate their tickets, every bus will be equipped with a validator attached to the stanchion behind the driver's seat. When a passenger inserts a ticket into the validator, the unit will check that the ticket has the correct dimensions and that it is not used up, and it will then stamp the date, time, and zone on the ticket. At the same moment a small piece of the ticket, corresponding to one ride, will be clipped from the ticket. Validators are a widely used device and are found on almost all European surface transit equipment. Tri-Met's articulated buses will have three validators, one at each door.

To provide a ticket to passengers wishing to pay their fare into the farebox, a ticket dispenser will be installed on all buses adjacent to the farebox. This unit contains most of the same components of the validator and in addition a paper ticket-dispensing unit. When a passenger pays a fare into the farebox, the driver provides a ticket by pressing one of six buttons on the control panel. The dispenser then prints a ticket showing the date, time, zone, and fare paid.

No equipment is, of course, required for pass holders.

The driver is provided with a unit known as a controller to control the operation of the validator and dispenser. The controller contains the electronic logic elements for the validator and dispenser, including a calendar and clock. The controller also enables the driver to code in the zone in which the bus is traveling so that all tickets correctly indicate the zone in which the passenger boarded. In addition, the controller alerts the driver to any equipment malfunction or vandalism and maintains a count of tickets issued or validated.

Tri-Met has awarded a contract to supply this equipment to a joint venture of CAMP of Paris, France, and Vultron of Waterford, Michigan, who are in the process of supplying and installing 874 controllers, 1198 validators, and 904 dispensers.

A second equipment program is the modification or retrofitting of the rear doors of all buses to enable passengers to board through both front and rear doors.

Ticket and Pass Sales

Prepayment of fares through the use of multiride tickets and passes is a vital element of the SSFC program. Over a number of years, Tri-Met has developed a distribution system for tickets and passes by using retail outlets. Under SSFC, this existing system will be streamlined and expanded. In addition, Tri-Met expects to introduce a limited number of vending machines at key focal points of the transit system. These vending machines would initially sell only multiride tickets. The possibility of multiride ticket-vending machines that accept only credit cards is being investigated for this purpose. If successful, these machines would significantly reduce the cost and problems of servicing, since no cash would be handled.

Fare Inspection

Fare inspection is a vital and integral part of self-service. It is also the most controversial element. In establishing a plan for fare inspection, Tri-Met was guided by a number of policy considerations. The Tri-Met fare inspection program is intended to be as reasonable and unprovocative as possible, using transit employees in transit uniforms rather than police uniforms. Simple rules and modest penalties are designed to avoid antagonizing inadvertant offenders. Although easy on inadvertant offenders, the enforcement program must have credible disincentives for anyone who would challenge or ignore the fare ordinances. Enforcement should require no more powers than are now thought necessary. Should experience demonstrate a need for additional enforcement powers, they can be more readily justified in the light of experience. The enforcement program should also incorporate sufficient flexibility to be able to adjust enforcement practices in the light of experience.

Tri-Met's initial fare inspection program is targeted at a 6 percent inspection level systemwide. Inspectors will normally work in teams of two and will be deployed according to a carefully developed schedule, working on one or more quadrants of the system on specific days. The inspection schedule will be developed in order to provide an equal but apparently random level of inspection throughout the system. Passengers found traveling without proof of payment may be charged a surcharge fare by a fare inspector. The fare inspector will record all instances of passengers traveling without proof of payment and may collect the surcharge fare on the spot, issue a written notice to pay the surcharge fare, or in exceptional circumstances give a written warning. In every case the fare inspectors will attempt to get identification from the passenger.

Initially, some 30 full-time fare inspectors will be used, supported by an additional 30 extra fare inspectors. These extra fare inspectors may work either as fare inspectors or bus drivers, as required, thereby building some flexibility into the fare inspection process.

Surcharge fares that are not paid at the time of inspection may be paid by mail or in person to Tri-Met within seven days. Persons who ignore a notice to pay a surcharge fare will incur a late charge after a certain time period. Persons who continue to ignore the surcharge fare will eventually have their account turned over to a collection agency. All record keeping, billing, and collection of surcharge fares will be handled by an outside contractor. Passengers who persistently travel without proof of payment will also be liable to increased civil penalties up to $500.

Tri-Met will institute an internal appeals procedure in order to provide recourse for persons who feel they have been charged a surcharge fare unfairly.

Public Information Program

An effective public information program is a vital component of the SSFC project. With approximately 140 000 trips on Tri-Met a day, a major communications effort is called for. Elements of the public information program include the preparation of decals and signage for use on Tri-Met vehicles and facilities, the preparation of exhibition buses to tour the region, and the development of brochures, advertising, and on-street customer assistance personnel. Closely related to the public information program is the training of all Tri-Met employees to have a basic understanding of the self-service system, as well as the detailed training of drivers, fare inspectors, and maintenance personnel. Perhaps the biggest challenge for the public information program is this: Although the full SSFC project consists of a complex of interrelated elements, the individual passenger is concerned only with an individual fare. Knowing and paying that fare must be made as simple as possible.

Schedule

Implementation of SSFC began in September 1980 on the award of project funding and will be complete at the start-up of self-service on September 5, 1982. The main task controlling the schedule has been the procurement time for the on-board equipment, which will have required 18 months from contract date to start-up.

Evaluation Program

A small but highly significant element of the SSFC program is an evaluation study sponsored by UMTA through the Transportation Systems Center to determine how well SSFC has worked and how other transit properties may benefit from Tri-Met's experience. This study will address seven areas of interest: fare compliance, operating impact, equipment performance, fare-payment characteristics, enforcement, and passenger attitudes and awareness. For each of these work elements comparisons will be made before and after start-up of SSFC and wherever possible numerical analysis will be performed.

The major aim of the evaluation study will be to help other transit properties decide whether it makes sense for them to follow a similar program and, for any who do make that decision, to provide data and perhaps recommendations on how to do so with the greatest benefit.

ACKNOWLEDGMENT

The program described in this paper has been financed in part through grants from the U.S. Department of Transportation under the Urban Mass Transportation Act of 1964, as amended.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

Atlanta Transit Pricing Study: Moderating Impact of Fare Increases on Poor

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Alternative methods for moderating the impact of fare increases on low-income groups in Atlanta are described and evaluated. The study, sponsored by the Transportation Systems Center under the Service and Methods Demonstration Program, considers five alternatives to a flat fare increase: direct user subsidies, quality-based fares, reduced fares on designated routes, peak/off-peak fare differentials, and distance-based fares. We evaluate these fare strategies according to a set of standardized criteria that considers the target efficiency, coverage of the target group, administrative cost, total cost, and degree of relief offered by each option. The study finds that a direct user subsidy provides the highest degree of relief to low-income patrons with the lowest revenue loss. This is because user subsidies are more efficient in reaching the target population and offer a higher level of coverage of the poor than do other alternatives. The results of the analysis also suggest that fare strategies that increase pricing efficiency by relating fares to cost, such as peak/off-peak fare differentials and distance-based fares, may not aid low-income riders. The analysis indicates that the equity implications of such pricing strategies must be assessed on a city-by-city basis. The desirability of direct user subsidies as a means of offering fare assistance appears to be more universal, however, primarily because it is distributed directly to the poor. With many transit properties facing court challenges to flat fare increases, these results may be of interest to operators throughout the United States.

This case study describes and evaluates alternative methods for moderating the impact of fare increases on low-income groups in Atlanta. Although the study primarily concerns the Metropolitan Atlanta Rapid Transit Authority (MARTA), which recently raised its fare from $0.25 to $0.50, the results of the study may be of interest to transit agencies throughout the United States. Faced with financial pressures similar to those confronting MARTA, many authorities seek information on fare strategies that are capable of generating significant farebox revenue while maintaining low fares for those who can least afford fare increases.

The trend toward higher passenger fares in the public transit industry is well documented. Over the past few years, rapidly rising operating costs and slowly growing operating subsidies have forced transit operators in almost every major American city to increase farebox revenue. In January 1979, most major cities had base transit fares ranging from $0.25 to $0.50. Now most base fares are approximately $0.75, and some operators have planned for continuing fare increases to maintain farebox revenue cost-coverage targets. Cutbacks in Section 5 operating assistance from the Urban Mass Transportation Act of 1964 soon will make these financial pressures even more severe.

Several recent fare increases have provoked opposition. Both the Southeastern Pennsylvania Transportation Authority (SEPTA), which imposed a $0.15 increase in Philadelphia's base transit fare, and MARTA, which doubled its base fare to $0.50, faced court challenges when they announced fare changes in the summer of 1980. In both cities, coalitions of citizens' groups opposed the fare hikes because of the potential impact of higher fares on low-income transit patrons. Although initially raised on technical grounds concerning the transit boards' voting procedure or organization, these protests focused public attention on the necessity of higher passenger fares on the one hand and the needs of the poor on the other. Although court challenges have not yet been successful in preventing fare increases, they have forced transit authorities to consider the equity implications and political acceptability of fare changes.

One result of court hearings in Atlanta concerning MARTA's proposed fare change was the general realization that alternatives to the flat-fare increase should be found. The court recommended the formation of a committee of state and local officials and concerned citizens to study the problem.

The U.S. Department of Transportation aided the committee's quest for solutions by sponsoring a study of alternative pricing options through the Transportation Systems Center (1). Because the committee wanted to use the report in its planning efforts, the study had to be completed in a short period of time.

This paper presents the resulting analysis of alternatives to MARTA's flat-fare increase for moderating the impact of fare changes on low-income patrons. The pricing strategies that appeared to be the most promising, and which we discuss here, are direct user subsidies, quality-based fares, reduced fares on designated routes, peak/off-peak fare differentials, and distance-based fares.

First we present the five evaluation criteria that we used in assessing each pricing option. Next, we describe each pricing option and provide a quantitative analysis of each option with respect to the evaluation criteria. Finally, we summarize the results of the analysis and consider the implications of these findings for fare policy.

EVALUATION CRITERIA

To aid in the assessment of pricing strategies designed to aid the poor, we use five criteria that reflect concern about the efficiency and distribution of the subsidy. Using standardized criteria to evaluate each strategy facilitated comparison across alternatives and ensured that we explored each strategy fully. The five criteria are target efficiency, coverage, administrative cost and efficiency, total cost/financial responsibility, and degree of relief.

Target Efficiency

A major concern in the evaluation of transit pricing is the degree to which the fare adjustment reaches only the target population. Some pricing strategies can be directed to low-income riders. Other strategies may aid these groups but provide fare reductions for high-income riders as well. With limited resources, it is crucial that the price relief be targeted to those who need it most. In this study, we measured how efficiently the suggested pricing strategy performs this targeting function by estimating the percentage of the price relief that the intended target group would receive.

Coverage

Besides targeting aid to specific groups, it is desirable that the pricing strategy chosen for Atlanta maximize its coverage of the target group and provide the same degree of relief for all eligible riders. In this analysis, we measured this coverage as the percentage of all aid-eligible riders who would actually receive it.

Administrative Cost

Although it is desirable to choose a pricing strategy that targets aid efficiently, administrative costs should not outweigh the advantages of this efficiency. Moreover, the administrative cost of the program must not exceed the cost of passing the subsidy through to all riders (e.g., a user-side subsidy should cost less to provide than the cost of providing a general fare decrease to all MARTA riders). Therefore, we considered the relative difficulty of administering each pricing alternative.

Total Cost/Financial Responsibility

MARTA operates under legislative constraints that limit the range of adjustments the authority can make in its fare policy. MARTA operations are partly funded by a 1 percent local-option sales tax. Not more than 50 percent of the revenue from this earmarked sales tax can be used for operating assistance. Since MARTA is mandated to maintain a balanced budget, operating expenses not covered by sales-tax revenues must be obtained from passenger fares or other subsidy sources.

If MARTA institutes fare reductions for lowincome riders, it must obtain additional external funding or increase the amount of revenue it receives from other riders. The total cost of aiding low-income riders is therefore a very important evaluation criterion because it indicates the amount of funding that must be obtained through these sources. We estimated the total revenue loss from each option so that public officials could measure the adequacy of various sources of external funding. We also estimated the fare level necessary to sustain internal subsidization and compared these estimated figures across options.

Changes in patronage resulting from fare increases or decreases complicate the estimation of revenue loss from any given subsidy program. If fares for unsubsidized riders increase, some riders will restrict their patronage or switch to different time periods or different routes (depending on the type of fare increase implemented). In this study, we did not estimate these secondary impacts of fare changes. However, we have noted where such secondary effects are likely to be significant.

Degree of Relief

Because this study's objective is to assess the capability of various pricing options to decrease transit fares paid by low-income riders, it is crucial that the degree of relief afforded by each option be carefully evaluated. To measure the degree of relief offered by each option, we estimated the average fare that would be paid by all eligible low-income riders and compared this with the current base fare of $0.50. We also compared the average fare paid by low-income patrons across options to determine which pricing strategy offers the largest reduction.

PRICING OPTIONS: OBJECTIVES, OPERATION, AND ASSESSMENT

In this study, we analyzed five pricing options that appear to hold promise for aiding low-income riders. They are direct user subsidy, quality-based fares, reduced fares on designated routes, peak/off-peak fare differentials, and distance-based fares. We present the objectives and an assessment of each pricing option below. In our analysis, we defined low-income persons as those having a total 1980 household income less than $5000 and those larger families with total income less than $10 000. We obtained data for this analysis from the May 1980 MARTA Transcard Integrated Fare Study (2). MARTA provided information on systemwide ridership in May 1980 and on the total number of individual patrons in each income group. For each alternative, we analyzed two subsidy levels: $0.10 and $0.20 reductions from the current $0.50 fare. Table 1 presents a summary of these analyses.

For the direct-user subsidy alternative, it was necessary to define the number of monthly trips that would be subsidized. To ensure that all high-value trips (e.g., work, educational, religious, and medical trips) are covered, the direct subsidy could apply to an unlimited number of trips each month. With no limit on the number of trips subsidized, however, the potential for resale of subsidized tokens or tickets is very great. A photographic identification mechanism for all those eligible can prevent some of this activity, but with MARTA's fully automated rail stations the potential for fraud under a program of unlimited subsidy would still exist.

Before one can arrive at a reasonable maximum number of subsidy-eligible trips, it is important to note that at the present time, through the purchase of a Transcard pass, frequent MARTA users can pay less than $0.50 per trip. On average, monthly Transcard patrons pay only $0.33 per trip (2). The average fare for an individual decreases as a pass patron's trip frequency increases. After a given trip frequency, a low-income patron would be better off purchasing a weekly or monthly Transcard rather than paying even a subsidized cash fare. The point at which a low-income patron would pay a lower average fare with a $4.00 weekly Transcard than with a subsidized fare depends on the level of the subsidy. With a $0.10 subsidy, one who makes more than 10 one-way trips per week would be better off by using a Transcard pass than by paying the subsidized fare. With a $0.20 subsidy, one would be better off with a Transcard if he or she makes more than 13 one-way trips. Note that a low-income rider faces this trade-off regardless of the fare alternative chosen to distribute the subsidy (e.g., user subsidies, peak/off-peak differentials). Thus, a limit of 10-13 trips per week can be set on the number of trips subsidized through a direct subsidy program, thereby significantly reducing the potential for fraud yet still ensuring that all trips by low-income patrons are covered by some type of subsidy mechanism.

Direct User Subsidy

Direct user subsidies give transit subsidies directly to low-income riders. Such subsidies avoid the problems of indirectly targeting subsidies to low-income riders through the services of the urban transit system. Many studies have shown that transit is a blunt instrument of social welfare in that subsidies to transit providers (as opposed to those offered directly to users) usually do not redistribute income to the poor. A direct user subsidy program could provide relief for low-income MARTA riders while alleviating pressure to keep transit fares low. Transportation subsidies for those with a low income are now offered by county welfare departments in Sacramento, California, and Arlington, Virginia.

The design of a direct user subsidy program should permit maximum use of existing institutions and programs. Because the administrative costs of screening and certifying individuals are quite high, user subsidies must be channeled through an existing administrative mechanism. In this study, we assumed that the Food Stamp certification procedure would be used to certify individuals for transit subsidy eligibility.

The target efficiency of user subsidies for MARTA riders would be very high (see Table 1). Only those properly certified would be permitted subsidized fares. Of course, fraud is possible but is likely to be limited, given the certification procedures already used in the Food Stamp Program. However, as mentioned, fraud can also be perpetrated by those eligible who resell subsidized tickets or tokens to those ineligible. Such behavior could be minimized by limiting the number of subsidized tokens given to those eligible each month and through the use of photographic identification.

A direct user subsidy program would provide excellent coverage for the poor. The State of Georgia Department of Family and Children Services estimates the participation rate of eligible households in the Food Stamp Program to be roughly 80 percent for Fulton County and 70 percent for De Kalb County. With an outreach advertising campaign on MARTA buses and trains, those eligible who wish to participate in the subsidy could take steps to enroll themselves at an agency providing certification for the program. Thus, coverage of the poor with direct user subsidies could be as high as 100 percent.

In estimating the revenue loss from a direct user subsidy, we considered the revenue effect of both existing and potential riders paying the discounted fare. As of September 1980, Fulton and DeKalb Counties had enrolled 139 991 individuals in their Food Stamp Programs. However, not all these are transit riders.

Therefore, we estimated the number of those who are subsidy-eligible and who are current riders. Household income eligibility limits for receiving food stamps indicate that most households with total earnings of less than $5000 are eligible for food stamps and would therefore be eligible for the transit subsidy. For those with household incomes between $5000 and $10 000, eligibility depends on the number in the household. In this analysis, we assumed that all MARTA riders with household incomes

Table 1. Comparisons of five alternatives designed to aid low-income riders.

Criterion	Fare Alternative: Direct User Subsidy	Quality-Based Fare	Reduced Fare on Designated Route: Plan 1	Reduced Fare on Designated Route: Plan 2	Peak/Off-Peak Fare Differential	Distance-Based Fare
Target efficiency	Close to 100 percent; identification program to minimize fraud	53 percent of subsidy goes to low-income riders	58 percent to low-income riders	77 percent to low-income riders	55 percent to low-income riders	Low, probably around 50 percent to low-income riders
Coverage	70-80 percent; all those who are eligible could receive aid	73 percent of low-income patrons subsidized	78 percent of low-income subsidized	29 percent of low-income subsidized	52 percent of low-income subsidized	Could be close to 40 percent subsidized
Administrative costs	High, reduced through extensive use of existing social service mechanisms	Low	Low	Low	Low	High implementation costs; costs to patrons in time lost due to fare procedures
Monthly revenue loss ($)						
$0.10 subsidy	151 788	728 964	495 696	160 372	560 992	N/A
$0.20 subsidy	394 649	1 147 928	991 392	320 744	1 121 984	N/A
Fare required to cover loss ($)						
$0.10 subsidy	0.55	1.08 (rail)	0.64	0.52	0.69	N/A
$0.20 subsidy	0.60	1.56 (rail)	0.78	0.55	0.88	N/A
Degree of relief[a] ($)						
$0.10 subsidy	0.40	0.46	0.48	0.51	0.54	N/A
$0.20 subsidy	0.30	0.41	0.45	0.48	0.59	N/A

Note: N/A = quantification not possible due to data limitations.

[a]Average fare for low-income riders, assuming subsidy funded by fare box.

below $5000 and half of all riders with household incomes between $5000 and $10 000 would be eligible for the transit subsidy. Under these assumptions, the number of current cash-paying riders that may be eligible for the transit subsidy is 67 462. (This figure does not include those currently purchasing Transcard passes since, as stated above, a monthly Transcard user pays an average fare of $0.33.)

Of course, not everyone who is eligible for food stamps registers for them nor will all those who register take advantage of the transit subsidy. Therefore, the maximum number of estimated subsidized trips must be scaled downward to reflect nonparticipation. At present, Food Stamp participation averages about 75 percent of the eligible population. If we also assume that 75 percent of those eligible for food stamps would engage in the "transaction costs" of participating in the transit subsidy, the number of current riders that would use the subsidy becomes 37 947.

Another factor to consider in estimating the number of trips subsidized is the number of tokens that would actually be purchased by those who are subsidy-eligible. Based on the May 1980 on-board survey, we estimated that 2 850 100 boardings were made by the subsidy-eligible. Dividing this number by the estimated number of the subsidy-eligible, we obtained an average weekly trip rate of 10 one-way trips per person. From this data, therefore, we assumed that all current MARTA riders who register for the transit subsidy would purchase their full allotment.

Under a $0.10 subsidy plan, we estimated that 1 517 880 boardings per month by current MARTA riders would be subsidized (37 947 persons making 40 subsidized trips per month). Monthly revenue forfeited by subsidizing this number of trips would be $151 788. Dividing the cost of subsidizing trips that would be made by current low-income cash fare patrons into the number of unsubsidized boardings indicates an increase in unsubsidized fares of $0.02.

We did not include the cost of subsidizing trips by new riders in these calculations. In fact, trips by new riders may actually serve as a source of net revenue if the marginal cost of serving these riders is less than the discounted fare. Unless additional capacity must be provided to meet demand from these new riders, furnishing discounted tickets or tokens for new trips by the subsidy-eligible is unlikely to have an adverse effect on transit deficits.

Under a subsidy plan of a $0.20 discount per trip, monthly revenue forfeited by this subsidy program would be $394 649. Apportioning the cost of the $0.20 subsidy among unsubsidized boardings indicates an increase in fares to unsubsidized riders of $0.06. Note that under the subsidy plans discussed here, moving from a $0.10 to a $0.20 subsidy more than doubles the subsidy cost. This is due to the larger number of trips per week that qualify for subsidization under the $0.20 subsidy plan.

The total cost of a direct subsidy plan would include costs other than the forfeited revenue. Even if certification is provided through the Food Stamp Program, some administrative costs would be incurred. Furthermore, if the marginal cost of serving new riders is higher than $0.30 or $0.40, the subsidy cost would be greater than that computed above.

With user subsidies, the average fare to low-income riders is set by the subsidy level. With a $0.10 subsidy, average fare for low-income riders would be $0.40; with a $0.20 subsidy, it would be $0.30. By taking frequent trips and using Transcard passes, low-income riders can reduce their average fare even further.

Quality-Based Fares

Quality-based fares are an attempt to relate fare to the quality of service provided. Authorities may charge higher fares, for example, on rail transit service operated on its own right-of-way and on express bus service. Quality-based fares would aid low-income riders to the extent that high-income riders use high-quality services and to the extent that a transit authority uses the additional revenue collected to reduce or hold constant fares on routes serving primarily low-income riders. Whether or not this type of arrangement could be achieved in Atlanta depends on the trip patterns of all income groups and the types of services offered by MARTA.

MARTA could implement quality-based fares by raising fares on special or high-cost service. Existing examples of quality-based fares nationally include higher fares on rail service, express bus services, subscription bus services, airport services, special transit services for sports events, and vanpools. Resulting increased revenue could be used to aid low-income riders by reducing fares on regular surface bus services.

Because this fare strategy relates fare to service quality rather than directly to income, it is not surprising that quality-based fares would be inefficient in targeting aid to low-income riders. If bus fares are lowered, only 53 percent of those cash patrons aided and 50 percent of bus Transcard patrons aided would be riders with household incomes less than $10 000. Thus, under a quality-based fare scheme, 47 percent of total subsidy expenditures would be funneled to middle- and high-income riders.

Quality-based fares would perform slightly better against the criterion of coverage. Of all trips made by low-income patrons, 73 percent are cash-fare bus trips. Thus, reducing bus cash fares by $0.10 or $0.20 would aid 73 percent of all low-income riders.

Conversely, the impact of higher rail fares on low-income riders clearly indicates that quality-based fares are not a good method of aiding poor transit patrons. Raising rail fares would affect all riders, but it would particularly hurt low-income rail riders, who make up 30 percent of all cash rail patrons. Higher rail fares could also affect poor Transcard patrons, perhaps through a rail surcharge. Forty-four percent of all rail Transcard patrons are in the low-income category. The MARTA bus system carries many more people than its rail system and therefore it must be noted that only 12 percent of all low-income transit patrons use the rail system.

With a $0.10 reduction in bus fares, a quality-based subsidy would result in a revenue loss of $728 964 per month; a $0.20 reduction in bus fares would result in a loss of $1 457 928. At the higher level of subsidy, some Transcard users would be likely to switch to cash fares. For each user who does so, the average revenue loss would be $0.03 ($0.33 average Transcard fare minus $0.30 subsidized fare).

If rail patrons were to bear the subsidy cost to low-income bus riders, the impact on rail would be quite severe since bus riders outnumber rail riders by more than 5 to 1. The $0.10 reduction in bus fares, apportioned among all rail riders, would increase rail fares by $0.58 (to $1.08). A $0.20 reduction in bus fares would increase rail fares by $1.16 (to $1.56). Clearly, a large surcharge would also have to be added to Transcard passes when used on rail service lest everyone switch from cash fares to Transcard. This surcharge might decrease the amount by which rail fares would have to be raised. Substantial changes in rail ridership could also occur.

With a $0.10 subsidy, the average fare paid by low-income cash patrons would be $0.46. With a $0.20 subsidy, the average fare paid would be $0.41. These average fare calculations show that, due to its poor coverage of low-income patrons, reducing bus fares by $0.10 would drop the average fare for the poor by only $0.04. Reducing bus fares by a $0.20 discount would result in an average fare for those in the low-income category only $0.09 lower than the existing fare. With either subsidy level, 8-12 percent of the poor would pay very high rail fares. In addition, due to its poor target efficiency, many middle- and high-income bus patrons would be subsidized under this fare alternative.

REDUCED FARES ON DESIGNATED ROUTES

Reduced fares on designated routes might be an attractive alternative in that the transit authority could target lower fares to specific user groups. It could offer reduced fares on specific bus routes serving low-income residential areas or charge lower fares to patrons boarding at designated stops. This option would enable discounts to be distributed most selectively when income groups are concentrated in identifiable residential areas.

Data from the May 1980 on-board survey indicate that low-income patrons ride all segments of the MARTA system. Furthermore, low-income patrons made up no more than 80 percent of the riders on any route among this representative sample of bus routes. Therefore, to assess this fare option, it was necessary to assume some cutoff percentage of low-income riders in designating routes eligible for fare reductions. We analyze two cutoff plans here. These identify the set of routes where (a) 50 percent or more of the total cash fare route ridership are low-income patrons and (b) 70 percent or more of the total cash fare or Transcard riders are low-income patrons. Plan (a) defines the more inclusive set, accounting for 80 percent of all routes served. Plan (b) includes 26 percent of routes surveyed. These percentages reflect the wide dispersal of low-income patrons along the bus routes surveyed. We used these and other findings from the May 1980 on-board survey as the basis for generalizations about the distribution of low-income patrons throughout the MARTA bus system.

Looking at the target efficiency of both plans (a) and (b), it is clear that as the transit authority designated more routes for fare reductions, more of the subsidy would go to the middle- and high-income patrons. If buses with ridership composed of at least 50 percent low-income patrons charge reduced fares, 58 percent of all subsidized riders would be low-income. If buses with ridership composed of at least 70 percent low-income patrons charge reduced fares, 77 percent of all subsidized riders would be low-income. Thus, with this option, the transit authority would achieve higher target efficiency with fewer designated routes.

Not suprisingly, if the transit authority designated fewer routes for reduced fares, the subsidy program would cover a smaller percentage of all low-income patrons. With plan (a), which reduces fares on more buses, 78 percent of all low-income cash patrons would receive the subsidy. With plan (b), which reduces fares on fewer buses, only 29 percent of all low-income patrons would be covered by the subsidy. These figures dramatically illustrate the trade-off between target efficiency and coverage that would occur with this option.

The revenue that the authority would forfeit from each of these plans also reflects the trade-off between target efficiency and coverage. Under plan (a), granting fare reductions on buses with 50 percent low-income riders, an estimated 4 956 955 subsidized boardings would occur. With a $0.10 subsidy, forfeited passenger revenue will total

$495 696 and a cash-fare increase of $0.14 (to $0.64) would be necessary on other segments of the MARTA system. This increase would in turn lead to higher Transcard patronage or, perhaps, Transcard fare increases. With a $0.20 subsidy, revenue forfeited would be $991 392, and a $0.28 cash-fare increase (to $0.78) on bus and rail would be necessary.

Under plan (b), granting reductions on buses with 70 percent low-income riders, an estimated 1 603 720 subsidized boardings would occur, since 22 percent of all cash-fare bus boardings would be on designated routes. With a $0.10 subsidy, forfeited revenue would total $160 372 and a cash fare increase on bus and rail of $0.02 (to $0.52) would be necessary for internal subsidization. With a $0.20 subsidy, a $0.05 cash-fare increase (to $0.55) would be necessary. As with plan (a), this increase in the cash fare might induce some cash patrons to switch to Transcard or necessitate increased Transcard fares.

The estimated average fare for low-income cash-fare patrons under plan (a) with a $0.10 subsidy would be $0.48. With a $0.20 subsidy, the average fare for low-income patrons who pay cash would be $0.45. The average fare for low-income cash-fare patrons under plan (b) with a $0.10 subsidy would be $0.51. With a $0.20 subsidy, the average fare for low-income patrons who pay cash would be $0.48.

Peak/Off-Peak Fare Differentials

Peak/off-peak fare differentials are an option that may allow MARTA to bring its fare structure more in line with the cost of service as well as aid low-income riders. Metro, in Washington, D.C., for instance, charges higher fares for peak-period riders. It has long been believed that peak service costs more to provide than off-peak service. Thus, increasing peak fares could equalize existing variations in revenue collected as a percentage of cost at different times during the day. If, as has been suggested, a large number of off-peak riders are also from low-income groups, peak/off-peak pricing would help moderate the impact of fare increases on low-income riders.

The target efficiency of offering aid to low-income riders through peak/off-peak fare differentials on both bus and rail lines would be very poor. Only 55 percent of all off-peak riders are low-income individuals. Reducing off-peak fares, therefore, would aid both low-income and high-income individuals almost equally. Moreover, 45 percent of all individuals riding during peak hours are in the low-income category. Thus, almost half of those paying higher fares under this fare alternative would be low-income individuals.

Coverage of the poor with peak/off-peak fare differentials would also be inadequate. If lower off-peak fares were offered, only 52 percent of all low-income riders would be aided. Conversely, if higher peak fares were necessitated by off-peak hour decreases, 48 percent of all low-income riders would pay higher fares than they currently pay.

A $0.10 reduction in off-peak period fares would result in $560 992 in forfeited passenger revenue. If internal subsidization is required, a peak period fare increase of $0.19 to $0.69 would be necessary. A $0.20 reduction in off-peak period fares would result in forfeited revenue of $1 121 984. Absorbing this loss across peak period boardings would necessitate a $0.38 increase in peak fares to $0.88. The administrative costs of collecting different fares at various times of the day might further increase these fares.

With peak/off-peak differentials, the average fare paid by low-income patrons who pay cash fares depends on the number of boardings made by this group during the peak and off-peak periods and on the level of subsidy. With a $0.10 reduction in off-peak fares, the average fare for low-income patrons who pay cash would be $0.54, $0.04 higher than the current flat fare. With a $0.20 reduction in off-peak fares, the average fare for low-income patrons who pay cash would be $0.59.

Distance-Based Fares

Distance-based fares may offer MARTA the opportunity to capture a higher percentage of costs on long-distance trips as well as to reduce the impact of fare increases on low-income riders. The total cost of providing a longer-than-average trip is higher than the cost of providing shorter-than-average trips. Yet, with a flat fare, the poor, who typically (but not always) make shorter trips, may be paying a higher portion of the cost of their trips than more affluent riders who travel longer distances. Graduating fares by distance may also increase efficiency by matching fares more closely to the cost of providing service. Furthermore, depending on the response of riders to price changes, revenue intake may increase with a distance-based fare schedule.

Whether or not a distance-based fare schedule would aid low-income riders in Atlanta depends on their trip patterns. Many transportation researchers have observed that due to the distribution of various income groups within metropolitan areas, higher-income patrons typically ride longer distances than lower-income patrons. If Atlanta conforms to this pattern, moving from a flat fare to a distance-based fare collection method might aid low-income riders. A variation on this alternative is to charge distance-based fares only in the peak direction, assuming that low-income riders primarily travel long distances as reverse commuters.

Distance-based fares can be implemented in a variety of ways. While finely graduated fare structures may result in higher revenue intake, the costs to both the transit authority and passengers can be greater than the additional revenue collected. Distance-based fares are sometimes graduated by miles traveled, with a separate fare for each pair of stations. Fares may also be structured according to a network of zones, with a surcharge added to the base fare each time an additional zone is crossed. Zonal fares typically do not capture as much passenger revenue as either finely graduated or station-to-station pricing schemes. They may, however, be far easier to implement.

Detailed information on trip distance traveled by each income group was not available from the MARTA survey at the time of this study. As an alternative, we used information on journey-to-work patterns from the 1970 U.S. Census to provide a rough indication of distance traveled to work by each income group. The 1970 census data include place-of-residence and place-of-work statistics by income class but not by mode. Thus, the data indicate only work trip patterns in general, not trips on MARTA. We used these census data to assess distance-based fares by assuming that an individual who lives and works in the same geographic area makes short-distance work trips, whereas a person who lives in one county and works in another makes long-distance work trips.

Census data show that the income distribution of Atlanta city residents commuting to each of four destinations does not vary significantly between each origin-destination pair. Reducing short-distance fares, therefore, would be likely to aid persons from all income groups. If combined with peak-directional pricing, the target efficiency of distance-based fares would be perhaps somewhat improved. From existing information, however, no firm conclusions can be drawn concerning target efficiency.

While distance-based fares would provide aid to persons from all income groups, the data suggest that they would assist a large percentage of low-income travelers. Low-income workers are more likely to work in their county of residence than outside it. Of employed low-income Atlanta residents, 84 percent work inside Atlanta. Of Fulton County's employed low-income residents, 44 percent work in Atlanta and another 51 percent work within the remainder of the county. Of low-income residents of DeKalb County, 60 percent work within the county, whereas 28 percent work in Atlanta. Although no data are available, trips made by the unemployed and nonwork trips made by low-income persons are likely to cover shorter distances than work trips.

The most serious problem with these data is that they indicate work locations for all persons, not just transit users. For example, transit, with its fixed routes generally radiating into and out from the central business district (CBD), does not serve short-distance neighborhood or crosstown trips well. In fact, transit is most competitive with automobile for trips to the CBD, which it serves directly. Therefore, the work locations and hence trip lengths of MARTA riders may be quite different from those suggested by aggregate census data. Furthermore, the data do not indicate whether intracounty trips are truly shorter than intercounty trips. Consequently, without additional information, little can be stated conclusively regarding distance-based fares.

CONCLUSION

Table 1 summarizes the quantitative analyses of the fare alternatives presented in this report. The table provides some important findings and a clear recommendation for direct user subsidies.

User subsidies have the highest target efficiency of any alternative analyzed. By limiting misuse through an identification program, close to 100 percent of subsidy aid would be funneled to low-income riders. Coverage of the poor would also be very high with user subsidies. With such a program, all low-income people eligible for transit aid could obtain it regardless of their travel patterns or residential location.

A disadvantage of user subsidies is that they can entail high administrative costs. Certifying and identifying the eligible and providing a subsidy mechanism (tickets or tokens) can be expensive. The subsidy program described here, however, would minimize these costs through extensive use of an existing social service, the Food Stamp Program. More importantly (as is shown in Table 1), due to their target efficiency and strong coverage potential, direct user subsidies would provide the highest degree of relief for the lowest revenue loss. Only one other fare alternative--reduced fares on routes serving at least 70 percent low-income riders--would have a similar or lower monthly subsidy cost. This option, however, would offer little relief for low-income riders.

Because of low target efficiency and/or inadequate coverage of the poor, the four other fare alternatives analyzed are inferior mechanisms for aiding low-income riders when compared with direct user subsidies. Quality-based fares would reduce the average fare paid by low-income riders but, because of poor target efficiency, would result in unacceptable fare increases on the rail system. Reduced fares on designated routes would either provide little relief or result in large fare increases for unsubsidized riders. Peak/off-peak fare differentials would offer both inadequate target efficiency and coverage and would actually result in higher average fares for the poor. Little information on distance-based fares is available, but their poor target efficiency and high administrative costs indicate that they would represent a very expensive mechanism for offering a minimum amount of aid to the poor.

These findings suggest that pricing options that may increase pricing efficiency by relating fares to cost, such as peak/off-peak fare differentials, quality-based fares, and distance-based fares, may not aid low-income riders. In fact, this analysis indicates that such pricing strategies may actually increase the average fare of poor transit patrons. Thus, we must assess the equity implications of pricing changes that offer greater efficiency by relating fares to cost on a city-by-city basis.

In conclusion, this analysis of five fare alternatives designed to reduce the impact of the MARTA fare increase on low-income riders clearly identifies direct user subsidies as the best method of offering relief. Direct user subsidies would be target efficient, provide good coverage of the poor, require only 10-20 percent fare increases for unsubsidized riders, and reduce the average fare for low-income riders. The high administrative costs of a direct subsidy program can be more than offset by these advantages.

ACKNOWLEDGMENT

This paper summarizes the findings of a study sponsored by the Transportation Systems Center under the Service and Methods Demonstration Program. We wish to express appreciation for the support and guidance of Lawrence Doxsey of the Transportation Systems Center and Vince Milione of the Urban Mass Transportation Administration.

John Bates of MARTA also contributed significantly to the study by providing essential information on MARTA ridership characteristics. We also acknowledge the work of Thomas Parody and Kim Honetschlager of Charles River Associates, who performed primary data analysis and provided helpful insights.

The opinions and conclusions expressed in the paper are ours and do not necessarily reflect the views or policy of the Transportation Systems Center or the Urban Mass Transportation Administration.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

Socioeconomic and Travel-Behavior Characteristics of Transit Pass Users

THOMAS E. PARODY

A large number of transit systems have begun selling monthly transit passes during the last decade without the benefit of data on who buys transit passes, what effect buying a pass has on transit travel behavior, and how many bus trips per month are taken with a pass. This paper documents these characteristics of transit pass purchasers by using a large-scale data base collected after the introduction of a monthly transit pass in Atlanta, Georgia. The quantitative information presented can provide useful input to transit officials who are planning to start a transit pass program or who may want to evaluate and possibly modify an existing one. In general, the findings show that pass purchasers tend to reflect the characteristics of frequent transit users. Thus, those purchasing passes include relatively more women and minorities and those with lower incomes and fewer automobiles available. There exists, however, a large number of frequent transit users who have not bought a monthly transit pass. On average, the monthly transit pass was used to make about 52 one-way transit trips per month compared with the breakeven-price level of 40 one-way trips. Thus, significant savings can be realized by using passes compared with paying cash fares. Although two-thirds of the bus trips are made for commutation purposes, about two-thirds of the new trips taken after buying a pass were for nonwork purposes. Basically, this was because pass buyers were already frequent users of the system for traveling to and from work.

The changes in travel behavior that occurred after a monthly transit pass was introduced in Atlanta are evaluated and the socioeconomic characteristics of the pass users (prior to the start of the rail transit system) are described. Given the contrasting actions taken in different areas with respect to selling transit passes, information on who buys passes and why along with how frequently passes are used and for what purposes can be used as a yardstick by transit officials who may be planning to start a pass program or who are considering modifying an existing one.

The number of transit agencies selling monthly transit passes has grown significantly since the early 1970s. A survey of 241 transit agencies across the United States conducted in February 1981 by the American Public Transit Association (APTA) revealed that slightly more than 50 percent of the properties contacted sell a monthly transit pass (1,2). This is in sharp contrast to the very few properties that were selling passes in 1970 or the 36 major transit systems that had monthly passes available in 1975 (3).

This growing trend in the number of transit agencies selling passes has occurred in spite of recent actions in a few cities to suspend the sale of unlimited-use passes. For example, the Regional Transit Service of Rochester, New York, suspended (and eventually discontinued) the sale of its $6.00 weekly pass in September 1980 because the rapid growth in the number of these passes sold was leading to an overall decline in revenue. The monthly unlimited-use $24.00 pass continued to be sold, however (4).

On May 26, 1981, a judge of the Pennsylvania Common Pleas Court ordered the Port Authority of Allegheny County to eliminate all weekly, monthly, school, and annual pass discount programs (5). This action was allegedly taken in order to reduce revenue "losses" that result from selling reduced-price passes, thereby keeping to a minimum the then-proposed increase in regular cash fares. However, an injunction was obtained staying this order. Subsequently, a higher court ruled that the case be reconsidered and the matter is still before the courts.

Notwithstanding these actions, other areas continue to introduce new transit pass programs (especially those marketed through employers) or have even reduced the breakeven price of their monthly passes, as shown by Parody in a paper in this Record. For example, in Atlanta, the Metropolitan Atlanta Rapid Transit Authority (MARTA) reduced the breakeven price of its monthly TransCard from 20 to 17 round trips in July 1980, while in Boston, the Massachusetts Bay Transportation Authority (MBTA) reduced the breakeven level of its three most expensive monthly passes from 18 to 16 round trips in October 1981.

MARTA TRANSIT PASS PROGRAM

On March 1, 1979, MARTA introduced a monthly pass called TransCard that was valid for unlimited rides during a given month by a single individual (i.e., the pass is not transferable). The pass program was introduced at the same time that the regular transit fare was increased from $0.15 to $0.25. One of the objectives of the pass program was to help lessen the impact of the 67 percent fare increase on frequent users of the system as well as to act as a fare and transit integration instrument for intramodal (i.e., bus to bus) and later intermodal (i.e., bus to rail) transit transfer users (6).

The TransCard was priced at $10.00, reflecting a breakeven use rate of 20 round trips per month. (Subsequent to this evaluation the pass price was increased to $17.00 in July 1980 when transit fares were increased from $0.25 to $0.50 and again to $21.00 in July 1981 when fares were increased to $0.60.) As further background information, it is important to note that MARTA has a single, flat fare (except for limited-service areas outside of DeKalb and Fulton Counties) and operates with a universal system of free transfers. Thus, unlike other transit systems that have reduced-fare or no transfer privileges, individuals who must transfer on the MARTA system do not save money on the cost of transferring by buying a TransCard. Convenience of transferring is increased, however, since a passholder does not have to obtain a transfer slip from the bus driver. In this sense, the pass acts as an integrated fare collection instrument.

The majority of TransCards are sold at MARTA's Ridestore, which is located in the central business district. Passes are also available to the general public at about 20 other participating outlets and through the mail. At the time of the data collection and analysis reported in this paper, very few passes were sold through employers.

The locations at which transit passes are sold can have an important influence on the type of individuals buying a pass and thus on how often the pass is used. In this instance, virtually the entire transit-riding community--and in particular, those who are transit dependent--had access to a pass outlet. This is not always true, however. For example, transit passes that are sold only through employers (7) usually cannot be purchased by students or by lower-income transit dependents who work alone or for small firms (e.g., domestics and service personnel). While these other programs minimize potential losses in revenue to the system, since frequent transit users may not be able to buy the pass, issues such as equity should be a consideration in their development.

DATA-COLLECTION PROCEDURES

To undertake this analysis, data on the characteristics of cash-paying and TransCard users were obtained through the use of a personally administered on-board bus survey. This approach avoids the problem of relatively low response rates associated with self-administered postcard surveys and the uncertainty associated with biased or disproportionate response rates from either pass or cash users or along any other market segment dimension (e.g., income). The questionnaire and accompanying evaluation plan were developed by Charles River Associates with input provided by the Transportation Systems Center (TSC) and MARTA (6). The survey was administered by MARTA personnel on a representative sample of bus routes equally divided by corridor of the city and over six time periods: morning peak, midday, afternoon peak, evening, and all day Saturday and Sunday.

The determination of the number of bus routes to be surveyed was based on the number of surveys that can be completed over a given time period and the total sample size required. The total sample size is a function of the accuracy desired and the eventual use of the data. To evaluate small changes in behavior by fare payment type (i.e., pass and cash users) and by different socioeconomic categories, a relatively large sample size was required. To achieve these objectives, a minimum total sample size of 4000 usable surveys consisting of 2000 TransCard and 2000 cash-fare users was determined (8).

The survey was conducted and supervised by MARTA staff over the period May 10 to May 31, 1979. Interviewers were instructed to administer the survey to every fifth boarder but to alternate between cash and TransCard users. Thus, the survey was stratified by fare payment type but was random for those within a fare category. By using these procedures, a usable sample of about 2400 cash and transfer boarders and about 2200 TransCard boarders was obtained.

Because it is desired to examine the characteristics of pass-purchasing and non-pass-purchasing individuals rather than those of transit boarders, it is necessary to weight the sample by the inverse of a respondent's transit-trip frequency. This is a procedure that is often neglected. By not carrying out this weighting procedure, the information obtained is biased toward the characteristics of frequent transit boarders rather than representing the characteristics of transit-riding individuals. This is true for any characteristic that is correlated with transit-trip frequency.

As an example of the bias introduced by not using this weighting procedure, mean transit-trip frequency without weighting for TransCard and cash boarders was determined to be 14.9 and 11.6 trips per week, respectively. However, after weighting, the mean transit-trip frequencies were reduced to 13.3 and 8.8, respectively. Note that the largest change was for those who paid cash since this group has a relatively wider and more skewed variation in transit-trip frequency (i.e., from 1 to 30 trips per week) compared with that of TransCard purchasers (i.e., from 10 to 30 trips per week).

SOCIOECONOMIC CHARACTERISTICS OF USERS OF TRANSCARD AND CASH

Various socioeconomic characteristics of those who paid fares by cash or by using a TransCard are presented in the top half of Table 1. (Cash users include those who boarded and paid a cash fare as well as those who boarded with a transfer slip obtained by paying a cash fare on a previous bus.) The table lists the mean, standard deviation, sample size, and t-statistic that can be used to test the hypothesis that there is no difference between the means (i.e., Ho: $U_1 - U_2 = 0$).

The second column in Table 1 indicates whether the null hypothesis is accepted or rejected at a 95 percent level of confidence. As is readily apparent, the null hypothesis was rejected in almost all instances, implying that a statistical difference does exist between the characteristics of those who use TransCard and those who pay cash. In some instances, however, the difference is relatively small and yet is significant; this is due to the appropriate but relatively large sample size.

The numerical findings of Table 1 are presented as concise summary statements below. In broad terms, the results indicate that those socioeconomic characteristics traditionally associated with frequent transit users are also associated with TransCard purchasers.

1. Age: no difference between those who paid cash and those who used TransCard;
2. Income: TransCard users have lower incomes than cash users;
3. Automobile availability: TransCard users are less likely to have an automobile available;
4. Sex: women are slightly more likely to be TransCard purchasers than are men;
5. Race: minorities are slightly more likely to be TransCard users;
6. Transfers: TransCard users make more transfers than cash users;
7. Bus work trips: those who use TransCard make about three more (one-way) bus work trips per week than those who pay cash;
8. Bus nonwork trips: TransCard users make about 1.3 more (one-way) bus nonwork trips per week than cash users;
9. Additional bus work trips: TransCard users made an average of 0.6 additional work bus trips per week, while cash users made no additional bus work trips; and
10. Additional bus nonwork trips: Transcard users made an average of 1.1 additional nonwork bus trips per week, while cash users made no additional trips.

Figure 1 presents a frequency distribution showing the percentage of those who paid cash and those who used TransCard in each income category. The distribution reveals that although those with the lowest incomes are only slightly more likely to purchase a TransCard, those with higher incomes are much less likely to buy a TransCard. On a relative basis, the highest percentage of TransCard purchases comes from those in the income group \$5000-\$10 000, which could be referred to as "the working poor." However, if other factors such as transit trip frequency are controlled for, income is not a significant variable in terms of describing a pass purchaser (9).

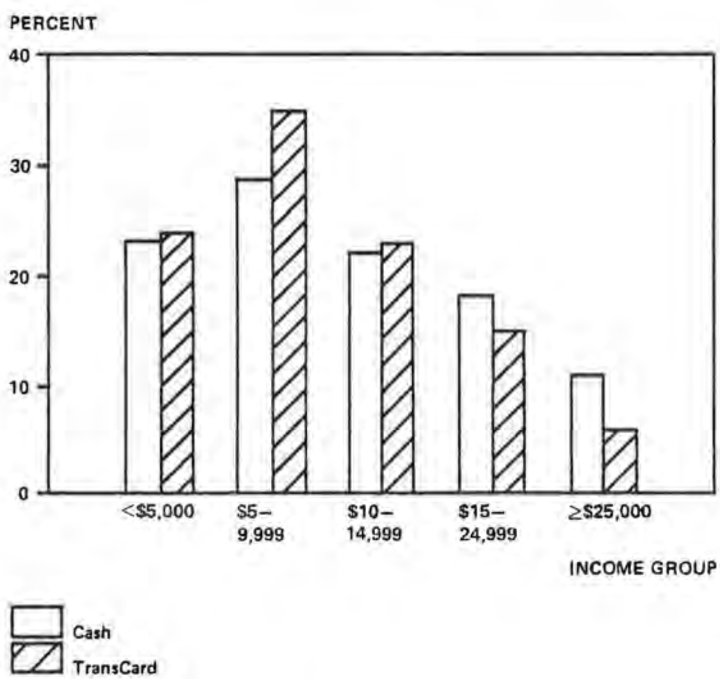
Because of the disproportionate sampling approach that was used, care must be taken in interpreting Figure 1. That is, although the survey sample contains roughly 50 percent cash boarders and 50 percent TransCard boarders, the population share of boarders is estimated at 83.1 percent cash and only 16.9 percent TransCard. (This estimate was determined by performing an independent count of fare payment type by boarders on a random sample of 385

Table 1. Socioeconomic and travel-behavior characteristics of those who paid cash and those who used TransCard.

Characteristic	Paid Cash Mean	Paid Cash SD	Used TransCard Mean	Used TransCard SD	t-Statistic[a]	Null Hypothesis
Age (years) (N = 2372, 2132)[b]	34.30	15.55	34.33	14.01	-0.07	Accept
Income ($) (N = 1980, 1820)	12 007	8425	10 521	7284	5.8	Reject
Automobile available (N = 2431, 2191)	0.48	0.50	0.34	0.47	9.8	Reject
Sex (%)						
Male (N = 1015, 860)	41.6		39.2		1.7	Borderline
Female (N = 1423, 1337)	58.4		60.8		1.7	Borderline
Race (%)						
Minority (N = 1717, 1645)	70.4		74.9		3.4	Reject
Nonminority (N = 721, 552)	29.6		25.1		3.4	Reject
Total no. transfers (N = 2441, 2200)	0.740	0.782	0.897	0.816	-6.7	Reject
Bus trips per week						
Total (N = 1892, 2034)	8.86	5.59	13.26	4.69	-26.6	Reject
Work (one-way) (N = 2134, 2122)	5.85	4.50	8.77	3.60	-23.4	Reject
Nonwork (N = 2131, 2068)	3.22	3.67	4.46	4.66	-9.6	Reject
Additional work (one-way) (N = 2134, 2122)	-0.005	1.04	0.58	1.81	-12.9	Reject
Additional other (one-way) (N = 2131, 2068)	-0.013	1.18	1.06	2.54	-17.0	Reject
Total additional (one-way) (N = 1892, 2034)	-0.01	1.80	1.63	3.40	-19.1	Reject
Prior work (N = 2134, 2122)	5.85	4.52	8.19	3.79	-18.3	Reject
Prior other (N = 2131, 2068)	3.23	3.73	3.41	4.18	-1.47	Accept
Total prior (N = 1892, 2034	8.87	5.64	11.63	4.67	-16.6	Reject

Note: Data from MARTA on-board bus survey (May 1979), calculations by Charles River Associates.
[a] Between groups.
[b] The first sample size is for the group that paid cash; the second is for the TransCard group.

Figure 1. Income characteristics of those who paid cash and those who used TransCard.



bus vehicle trips.) Therefore, it would be incorrect to infer from Figure 1 that there are more TransCard users than cash users (on an absolute basis) in the income range of $5000-$9999. Rather, the results presented are such that the sum of the five cash columns equals 100 percent as does the sum of the five TransCard columns.

Examining the age characteristics of those who pay fares by using cash or a TransCard reveals that relatively few TransCards are purchased by those who are either less than 16 or older than 65. Generally, we would expect these groups to contain fewer full-time workers. On a relative basis, passes are most popular with those in the groups aged 40-59. As one might expect, the data indicate that those without an automobile available are much more likely to buy a TransCard.

TRAVEL-BEHAVIOR CHARACTERISTICS FOR TRANSCARD AND CASH USERS

The travel-behavior questions of most interest consist of the number of transit trips made by cash users and TransCard users both before and after the introduction of the pass and the extent to which monthly transit pass purchasers increased the number of trips taken by transit. To this end, Table 1 lists the mean number of work and nonwork bus trips taken per week by cash users and TransCard users. For TransCard users, Table 1 also provides the mean number of additional or new one-way work and nonwork bus trips taken per week since the pass was purchased. For cash users, the change in the mean number of one-way work and nonwork bus trips per week since the time before the fare increase is also listed. With this information it is possible to compute the number of work and nonwork bus trips per week that were made prior to the systemwide fare increase and introduction of TransCard that occurred on March 1, 1979.

As summarized in the statements presented above, those who purchased a TransCard increased their use of transit by 1.1 trips per week, whereas those who paid cash did not change their transit trip frequency. About two-thirds of the increased number of trips by TransCard users were made for nonwork trip purposes. This may be explained by the fact that since TransCard purchasers were already frequent users of transit for commuter work trips, they had less opportunity to make even more work transit trips once they bought a TransCard. However, without a similar upper limit on the number of nonwork trips that can be made, those who bought a pass increased in both absolute and relative terms the number of transit trips made for discretionary or nonwork purposes.

Figure 2 shows that there is a strong relationship between the number of transit trips taken per week to or from work and whether an individual purchases a TransCard. Figure 3 shows a similar but less-pronounced relationship for nonwork bus trips per week.

Figure 4 depicts the total number of transit

Figure 2. Transit work-trip frequency characteristics of those who paid cash and those who used TransCard.

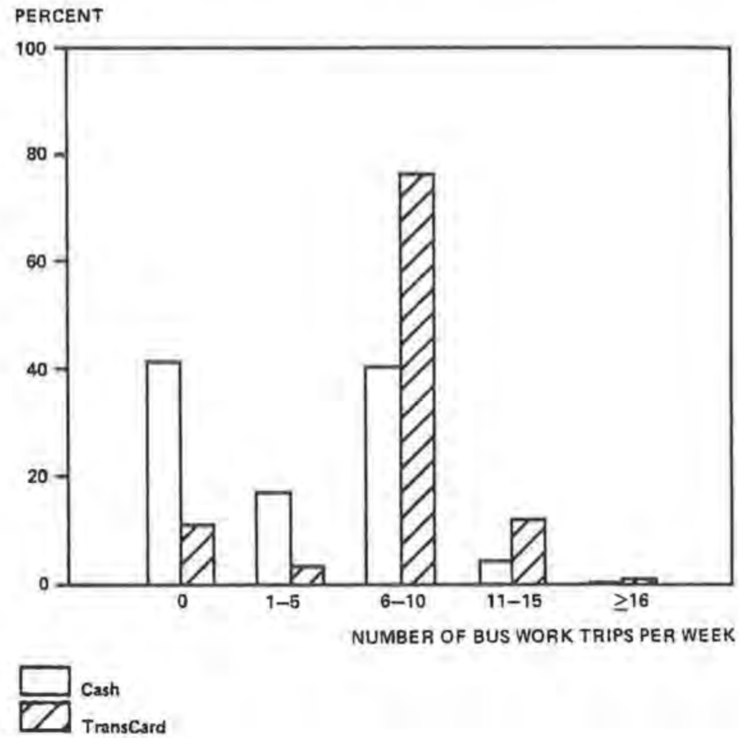
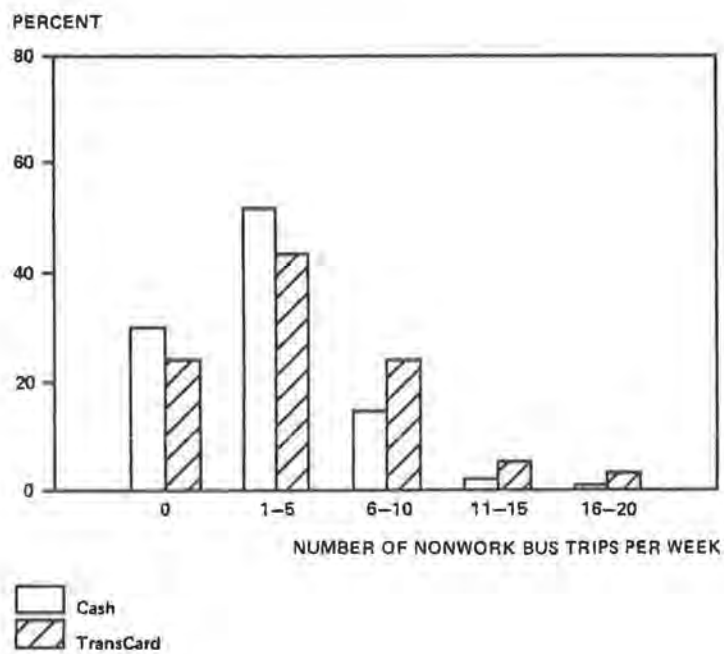


Figure 3. Transit nonwork-trip frequency characteristics of those who paid cash and those who used TransCard.



trips made per week for those who paid cash and those who used TransCard. It is readily apparent from Figure 4 that TransCard use becomes significant only when the number of transit trips taken per week equals or exceeds 10. (Note that 85 percent of those in the 6-10-trip/week group make exactly 10 transit trips per week.) By comparing Figures 2 and 3, it is obvious that a transit pass has its greatest appeal to regular work-trip commuters.

In addition to showing that the vast majority of those who used TransCard make the same or more than the breakeven number (i.e., 10) of transit trips per week (mean equals 13.3 trips per week), it is also apparent from Figure 4 that a large number of them make many more than the breakeven number of trips per week (and presumably per month) but continue to pay cash fares. Although these individuals appear to be heavy users of the system, they are clearly not taking advantage of the TransCard to save money or to offset the impact of the fare increase. This same finding is illustrated in Figure 5, which presents the percentage of transit users who purchased a pass according to the number of total transit trips taken per week before the pass went on sale.

Figure 4. Total transit trip-frequency characteristics of those who paid cash and those who used TransCard.

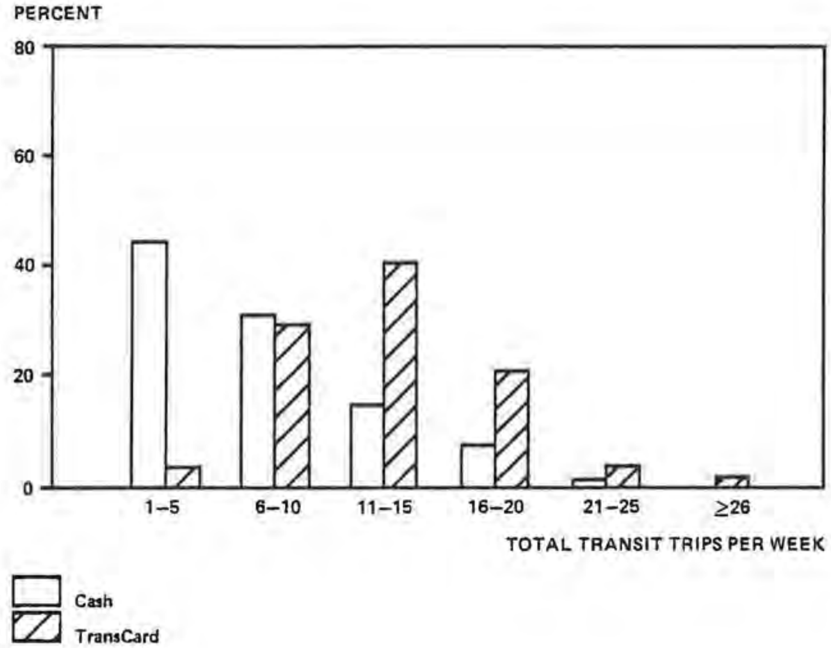
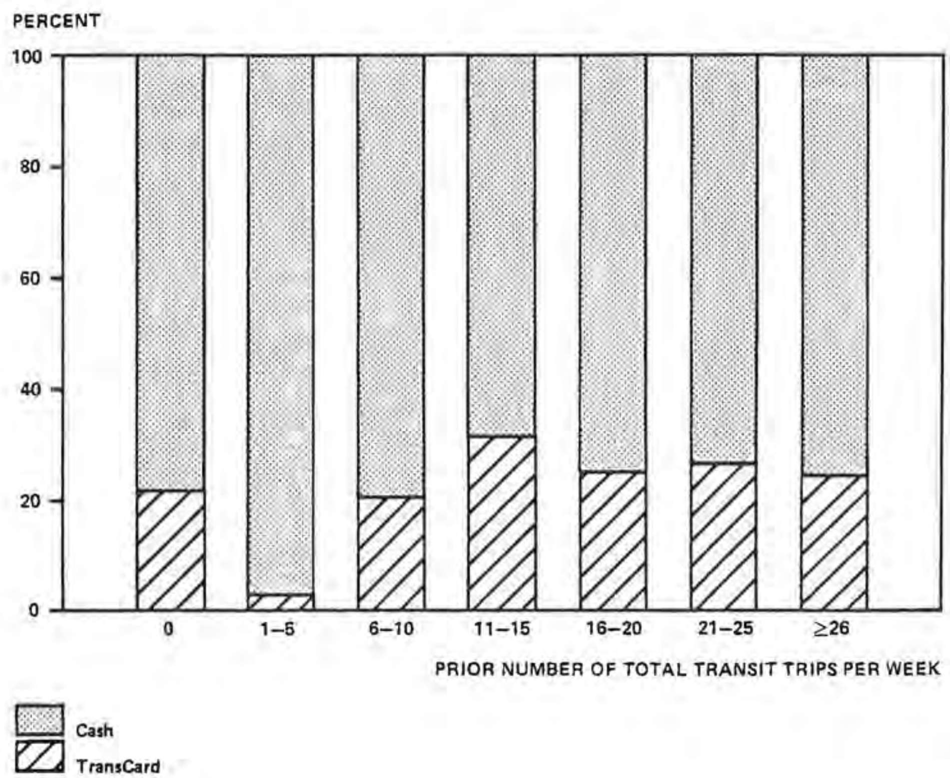


Figure 5. Percentage of transit users who buy TransCard by prior number of transit trips per week.



Typically one would have expected, a priori, that pass penetration rates would increase as prior transit trip frequency increases.

TransCard purchasers who are less than 40 years old were much more likely to increase, on an absolute basis, the number of work trips per week taken by transit compared with TransCard users who are 40 and older. For the age group less than 16 years old, this is in part because these individuals tended to make fewer work trips per week compared with other age groups before purchasing a pass. Changes in work trip transit trip rates by TransCard purchasers were not found to be significantly different by income categories.

There was no difference between white women and black women in the mean number of additional trips made and only a very small, insignificant difference between white men and black men (t-test = -0.385). Thus, race is not a significant factor in the change in work transit trip rate for those who used TransCard.

With respect to sex, the results are mixed. The difference in the mean number of additional work transit trips between white women and white men who used TransCard is not significant (t = -1.23), while the difference in means is significant (t = 2.62) between black men and black women who used TransCard. Although the absolute difference is slightly larger between black men and women, the statistical significance is due primarily to the larger number of blacks in the sample. For those who paid cash, only white women exhibited a net decrease in the number of work bus trips per week. The three other groups all increased by about similar amounts the number of new bus work trips taken per week.

Those who purchased a TransCard and who had an automobile available made more new transit trips per week for work than those who did not have an automobile available (t = 2.0). Basically, those who used TransCard without an automobile available tended to take transit more often to begin with and consequently were less likely to make more work trips by transit even given an opportunity to do so (i.e., by buying a pass). However, as TransCard users without an automobile available were not similarly constrained when it came to nonwork bus trips, they made more additional trips per week for nonwork purposes compared with those who did have an automobile available.

WHY PURCHASE TRANSCARD

A number of studies have indicated that individuals purchase a monthly transit pass either for convenience or to save money (7,10). More than likely, the combination of both factors is important and the relative importance between the two factors is probably a function of the number of transit trips an individual typically makes and the breakeven price of the pass. However, the data indicate that relatively few individuals purchase a pass and make fewer than the breakeven number of trips strictly for the convenience of using a pass.

The first and second reasons that were given by those who used TransCard for purchasing a pass are listed below:

Reason	First Reason (% responding)	Second Reason (% responding)
Save money	56.2	16.9
Convenience, no need for cash	28.4	43.8
Allows stopovers	4.8	4.7
Easier, faster to board bus	4.5	9.8
Pay once a month	2.3	7.5
Easier to transfer	1.9	9.8
Other	1.7	2.1
Offset fare increase	0.2	2.5

The most frequent response given was to save money (i.e., compared with the alternative of paying separate cash fares). This is a logical reason, since, as determined from Figure 4, about 70 percent of those who have a TransCard make more than the breakeven number of bus trips per week. (About 95 percent of the TransCard users report making the same or more than the breakeven number of bus trips per week.)

Although the singular response "convenience, no need for cash" was stated by 28.4 percent of the respondents, many of the remaining reasons could be encompassed under a broad definition of convenience (i.e., easier to board bus, pay once a month, easier to transfer). Thus, convenience is certainly a popular (second) reason for buying a pass.

Purchasing a pass to offset the impact of the fare increase was given as a reason by very few of the respondents. Although this reason might be considered a subset of saving money, it apparently has little salience in its own right.

For those with an annual household income less than $15 000, the responses given are fairly uniform, to save money being the predominant reason, followed by convenience. However, as income increases, convenience becomes a more frequent response and correspondingly, saving money declines in importance. In fact, of all the socioeconomic variables examined, the only instance in which convenience was given as the most frequent response for buying a TransCard was for those with household incomes in excess of $25 000.

WHY NOT PURCHASE TRANSCARD

Just as it is useful from a marketing perspective to understand why individuals purchase a pass, it is also useful to examine why cash users do not purchase a pass. The reasons that cash users gave for not purchasing a TransCard are listed below:

Reason	Percent Responding
Do not ride MARTA enough	61.64
No opinion	12.13
Other	7.06
High initial cost	7.05
Have not taken time	4.00
Outlets are not convenient	3.36
Do not know where to buy it	2.53
Would lose it	2.24

More than 60 percent of those who pay cash responded that they do not ride MARTA enough. This is by far the predominant response; "no opinion" and "other" rank second and third. The distribution of responses by income categories reveals a modest positive relationship between income and the response "Do not ride MARTA enough." Conversely, high initial cost is a relatively more frequent response for those with low incomes and declines in importance as income increases. This may be one reason why some who are very frequent transit users continue to pay cash fares. The barrier of high initial cost is borne out by MARTA's observation that a fair number of passes are purchased well into the middle of the sale month, presumably because only at that time has the individual accumulated the up-front funds for the price of the pass. If the purchaser is a frequent transit user, he or she will still save money, even though the pass will not be used for the entire month (9). [As a further means of lessening the impact of a fare increase on low-income transit users, MARTA introduced a weekly pass in July 1980 when fares doubled from $0.25 to $0.50 (11). Other methods of mitigating the impacts of a fare increase on the poor were evaluated in a separate study by Charles River Associates (12).]

CONCLUSIONS

This paper has examined the socioeconomic and travel-behavior characteristics of both pass-buying and non-pass-buying transit users. While the findings indicate that those who purchase a monthly transit pass come from all socioeconomic groups, they also show that passes tend to be purchased more often by those who have characteristics typically associated with frequent transit users. Consequently, pass purchasers include relatively more women and minorities and those with lower incomes and fewer automobiles available.

Pass purchasers are very astute in determining the costs and benefits of buying a pass. Of those who bought a pass, 95 percent made the same or more than the required number of trips to break even. The average number of trips taken per month by pass users was about 52 compared with the breakeven-price level of 40 one-way bus trips. Thus, few individuals buy a pass and pay more to travel than if they had used cash fares. Two-thirds of the trips taken with the pass were made for commuting to and from work.

Somewhat ironically, those who were very frequent users of the transit system before the pass was introduced made fewer new trips by transit compared with the marginal transit users who also purchased a pass. Equally surprising was the fact that pass penetration rates increased very little as transit-trip frequency increased beyond the breakeven point. Some evidence exists to indicate that the lump-sum, up-front cost of the pass prohibits certain low-income transit riders from buying it.

On average, those purchasing a pass increased the number of bus trips taken per week for work by 0.6 and by 1.1 for nonwork trip purposes. If the concurrent increase in the price of gasoline is factored out, transit tripmaking by non-pass-buying individuals declined by about 2.5 percent following the 10-cent fare increase.

Consistent with the findings above on how often a transit pass is used each month, the majority said that they purchased a pass to save money. Given that 30 percent of the pass purchasers make the same or less than the breakeven number of transit trips per week (and thus do not save money compared to paying cash fares), convenience was the second most frequent response given for purchasing a pass. Only those with incomes exceeding $25 000 cited convenience factors more often than saving money as reasons they purchased a monthly transit pass. These latter results can be useful in devising promotional material aimed at different market segments. Other information presented in the paper can be used as a yardstick by transit agencies who may be reevaluating their own pass programs or considering implementing one.

ACKNOWLEDGMENT

The work described in this paper was performed under contract to TSC as part of the Service and Methods Demonstration Program of the Urban Mass Transportation Administration (UMTA). The support of those agencies is hereby acknowledged. Particular recognition goes to Larry Doxsey of TSC, who served as technical advisor and monitor for this evaluation, and UMTA project monitors Marvin Futrell and, more recently, Vince Milione. In addition, John Bates and Norris Anderson of MARTA were helpful in providing much of the data from the site. Daniel Brand of Charles River Associates provided important insight and comments during the course of the work, and Kim Honetschlager performed the computer tabulation work. The opinions and conclusions expressed in the paper are mine and do not necessarily reflect the views or policy of TSC, UMTA, or MARTA.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

Economics of Transit Fare Prepayment: Passes

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Transit fare prepayment has become widely used by transit operators in an attempt to increase ridership and reduce costs. However, most fare prepayment plans, especially pass plans, are improperly priced, resulting in unnecessary revenue losses. The current knowledge on the economics of fare prepayment is reviewed and summarized. Specifically, start-up and operating costs are presented, as well as the potential returns from dwell-time reductions, savings in coin-handling costs, interest accruals on cash flow, peak to off-peak trip diversions, generated travel, and price discrimination. In addition, the price elasticities of demand for fare prepayment are summarized, a simple model for predicting market penetration rates is presented, and the economics of pass pricing is discussed. Criteria for pass-pricing plans are also presented. It is emphasized that when properly designed and priced, transit fare prepayment can improve a system's performance and operating ratio.

Few transit operators with fare prepayment plans can give explicit reasons why their plans were established. Among the principal reasons (1) given for implementing fare prepayment plans are (a) to increase ridership by making transit service more convenient; (b) to increase revenues, an objective not easily accomplished given the high diversion rates from cash patrons; (c) to reduce operating costs by lowering cash-handling costs, reducing theft, and reducing dwell-time costs; (d) to help meet the Section 5(m) requirements of the Urban Mass Transportation Act of 1964 with regard to off-peak reduced fares for the elderly and the handicapped; (e) to improve the image of the transit company; and (f) a variety of miscellaneous reasons such as providing promotional offers to new residents.

The economic aspects of designing and implementing fare prepayment plans are analyzed with special reference to passes. The focus of this paper is on passes because pass-pricing strategies are the most misunderstood aspect, with the consequence that most operators are facing serious revenue losses through improper pricing.

COSTS AND BENEFITS OF FARE PREPAYMENT PLANS

The evidence presented below shows that fare prepayment plans are cost-effective in the sense of providing benefits in excess of costs if cash revenue losses from improper pricing can be avoided. The costs and benefits of a hypothetical monthly pass summarized below show potential benefit-cost ratios of 1.17-1.57 for typical medium-sized programs with large start-up costs. Note, however, that the potential benefits are three to five times larger than the recurrent costs.

Costs and Benefits	$1980
Costs	
Start-up	0.439
Recurrent operating	0.233
Total	0.672
Potential benefits	
Dwell-time cost savings	0.270
Coin-handling cost savings	0.450-0.720
Interest accruals on cash flow (10 percent borrowing rate)	0.064
Total	0.784-1.054

Needless to say, fare prepayment plans are effective only if improper pricing decisions are avoided. Some evidence on the costs and benefits of fare prepayment plans is presented next.

Costs

The cost figures presented above correspond to those of the Ottawa-Carleton Transpo (OC Transpo) monthly pass program (2). Our analysis of the costs of fare prepayment programs reported elsewhere (3) shows the recurrent operating costs to be as low as $0.14 per instrument sold in the smaller systems to $0.94 in some of the larger, more expensive systems. It is our contention that most transit operators can attain unit costs of between $0.15 and $0.20 if efficient administrative distribution methods are employed.

Benefits from Dwell-Time Savings

Boarding times are significantly reduced as the proportion of prepaid fares increases. Boarding times in the OC Transpo system diminished as much as 25 percent as a consequence of the monthly pass program. The benefit figures given above are based on Wilbur Smith and Associates (4) estimates of savings of 2 s in boarding times between passes, permits, and tickets versus conventional cash fares and a smaller saving of 0.5 s for tokens. The benefits shown correspond to reduced demand for driver hours if bus schedules are revised accordingly. Driver hourly wages and fringe benefits were estimated as $11.37 with potential boarding-time savings estimated as $0.006 per passenger boarding. Forty-five boardings per month were assumed for the monthly pass example given above.

Benefits from Savings in Coin-Handling Costs

Fare prepayment can reduce coin-handling costs, particularly the costs of sorting and counting coins and dollar bills, repairing fareboxes, and reducing theft. According to several studies (5,6), these savings vary from $0.010 to $0.016 per prepaid passenger trip and are reflected in the data given above.

Benefits from Interest on Advanced Cash Flow

One feature of prepaid plans is that fares are collected in advance of services being delivered. This positive cash flow from prepayment reduces the financial requirements of the transit agency, requirements met by a combination of funds from municipal taxes and debt obligations. Assuming a uniform daily trip rate per prepaid user and purchase of prepayment instruments the day before their use, the interest cash accrual may be estimated as follows:

$$I = (1/2) \times (\text{prepayment plan price}) \times [(\text{days covered in plan}) - 1.0] \times (i/365) \quad (1)$$

where i/365 corresponds to the daily interest rate. The estimated benefits shown above assume 10 percent borrowing rates.

EVIDENCE ON RIDERSHIP AND REVENUE IMPACTS

As stated earlier, the attractiveness of fare prepayment plans depends to a great extent on their ability to stem cash revenue losses due to diversion of cash riders to discounted prepayment plans. This section analyzes the evidence on ridership impacts.

Lack of Significant Generation of New Riders

Most of the discussion on ridership impacts fails to

Table 1. Average monthly trip rates for pass holders in selected cities.

City	Pass Type	Avg Monthly Trip Rate (linked trips)
Milwaukee	Weekly	62.4
Chicago		
Chicago Transit Authority	Monthly	59.5
Commuter rail[a]	Monthly	39.0
Honolulu[b]	Monthly	56.5
Ottawa-Carleton[c]	Monthly	55.8
St. Louis[d]	Monthly	53.6
San Francisco	Monthly	51.2
Sacramento (employee)	Monthly	46.4
Oakland		
Alameda-Contra Costa Transit Authority (AC) local	Monthly	45.2
AC Transbay	Monthly	44.0
Duluth (employee)	Monthly	46.9
Tucson		
Adult	Monthly	41.6
College student	Semester/monthly	43.5
High school student	Monthly	37.0
Elderly and handicapped reduced fare	Monthly	52.9

Note: Data on the remaining sites were obtained through conversations with agencies in each city and from unpublished documents.

[a]D. Jhaveri (7).
[b]A. Fujita, T. Hamayasu, P. Ho, and J. Magapdi (8).
[c]Bureau of Management Consulting (2, p. 29).
[d]W.C. Gilman and Co. (13, p. II).

distinguish between new riders and new transit trips by previous transit riders. The generation of new transit riders is rare and hardly ever does it exceed 5 percent of the previous adult cash riders. However, in contrast to the lack of generation of new riders, fare prepayment does significantly increase the number of off-peak transit trips taken by previous cash riders. For example, in the OC Transpo experience (2), only 2 percent of the trips by pass purchasers were trips diverted from other modes and another 2 percent were trips generated by new riders. On the other hand, although peak-period travel by pass purchasers was unaffected, off-peak travel of previous cash riders increased 24 percent. Thus the main effect of fare prepayment is to divert cash riders.

High Trip Rates of Pass Purchasers

A major problem in designing proper pricing policies for time-limited fare prepayment plans such as passes is presented by the high trip rates experienced by pass riders in American cities. In small transit systems such as those operating in Duluth, Tucson, and Sacramento, the average monthly trip rate of pass holders ranges from 42 to 46. In larger systems operating in such cities as San Francisco, St. Louis, Honolulu, and Ottawa-Carleton, the average monthly trip rates of pass purchasers ranges from 51 to 56. Thus, in larger systems in which the opportunities for off-peak and weekend transit travel are the greatest, the average monthly trip rates are more than 50. In Milwaukee and Chicago, the average number of unlinked monthly trips is 91 and 107, corresponding to linked monthly trip rates of 59 and 62, respectively. This means that current practices of offering large discounts to monthly pass riders by pricing passes at under 40 trips per month are self-defeating since they will not encourage a significant amount of new riders and will lead to a diversion of cash riders and therefore to significant revenue losses. A compilation of the trip rates of pass holders in selected American cities is presented in Table 1.

Demand Elasticities of Prepaid Fares

The knowledge of fare elasticities of demand for transit fare prepayment is limited. The scant information available shows that pass riders are more inelastic than cash fare or ticket riders, reflecting the fact that pass users are frequent riders who, like commuters, exhibit low fare elasticities. Examples of pass elasticities that have been estimated include values of -0.36 for Jacksonville (9) and -0.18 to -0.38 for the Sacramento employer-promoted monthly pass program (10). Although these elasticity estimates are reasonable, the econometric demand work conducted on pass programs has failed to analyze passes as rate structures. The result of this improper reflection of the econometrics of rate structures is to confuse the price and income effects of passes on demand.

As an aid in the design of fare prepayment demonstrations, we developed a simple sketch-planning model, presented below. The sketch-planning model is based on information from 62 independent fare prepayment programs. The model was estimated by using regression analysis and predicts the market penetration of a given fare prepayment plan as a function of its effective discount over cash fare, its length or period of validity, and the number of competing plans. Two versions of the sketch model are available and are shown below:

$$\begin{aligned}\text{PEN RATE} = {} & 23.6229 + \underset{(0.1437)}{0.4323}\,(\text{DISC}) - \underset{(0.1172)}{0.2509}\,(\text{TRIPS}) \\ & - \underset{(1.3238)}{2.8006}\,(\text{COMP}) + \underset{(0.1388)}{0.3341}\,[(\text{TRIPS})(\text{DISC})/100] \\ & R^2 = 0.5899 \end{aligned} \tag{2a}$$

$$\begin{aligned}\text{PEN RATE} = {} & 22.6930 + \underset{(0.1363)}{0.5169}\,(\text{DISC}) - \underset{(0.1204)}{0.2217}\,(\text{TRIPS}) \\ & + \underset{(0.000\,25)}{0.000\,52}\,(\text{TRIPS})^2 - \underset{(1.3390)}{2.8572}\,(\text{COMP}) \quad R^2 = 0.5805 \end{aligned} \tag{2b}$$

where the figures in parentheses are the standard errors of the respective regression coefficients and

PEN RATE = market penetration rate expressed in percentage terms (e.g., 20 percent penetration), which denotes the percentage of prepayment plan riders to total transit riders;

DISC = percent discount over base fare (e.g., 5 percent discount); in case of implicit discount plan (e.g., monthly or semester pass), the discount rate is computed based on the average trip rate noted below;

TRIPS = quantity of trips associated with plan; time-limited pass plans have been interpreted as follows for the purpose of quantifying this important variable: semester pass = 140 trips, monthly pass = 40 trips, weekly pass = 10 trips, day pass = 2 trips; and

COMP = number of competing fare prepayment plans offered by the transit agency.

These equations have successfully predicted the penetration rates in several transit agencies not in the original data base. However, they should not be used to test either extremely long-term plans (e.g., annual passes) or very large discounts (i.e., more than 50 percent).

ECONOMIC PRINCIPLES IN DESIGN OF PASS PLANS

Part of the reason why so many fare prepayment plans fail to contribute significantly to revenues is their failure to incorporate economic principles of rate structure design. Weekly and monthly passes, for example, are analogous to two-part tariffs with a fixed charge equivalent to the pass price and a quantity or marginal charge of zero. This section concentrates on the design of pass plans, the most misunderstood of all plans. The pricing of tickets and punch cards is not different from that of regular cash fares and therefore is not discussed here.

Price Discrimination Through Pass Programs

In the context of transit pricing, price discrimination refers to the fact that an identical service may be priced differently to reflect differences in demand characteristics, such as trip rate, trip purpose, and income. This deviation from single-fare pricing requires two main conditions to be effective, namely, the preclusion of resale, since otherwise riders in the low-fare market could resell to those in the high-fare market, and the ability to divide transit riders by their elasticities of demand. Thus, there must be some easily identifiable method by which the transit agency can separate those riders that belong in the high-fare market. Of course, some monopolistic elements must also be present.

The design of price-discriminating pass programs may be approached by applying the principles of rate structure design. The price structure of fare prepayment instruments can be considered similar to a two-part tariff where the consumer pays a certain fixed price (E) as entry into the system, after which as many rides as desired may be purchased at a constant per-unit price (π). The cost (p) of the prepayment instrument to the user may be represented by the following equation:

$$p = E + \pi(q) \quad (3)$$

where q is the number of transit rides.

In the case of weekly and monthly passes, the above expression reverts to the following one:

$$p = E, \text{since } \pi = 0 \quad (4)$$

whereas for tickets and punch cards the cost to the user becomes as follows:

$$p = \pi(q), \text{since } E = 0 \quad (5)$$

It is worth noticing the difference in demand impacts between E (the pass price) and π (the quantity or marginal charge). The demand effects of changes in E are analogous to the effects of lump-sum taxes and or income transfers. That is, the effect of changes in E is analogous to income effects. Thus, the demand elasticity of changes in the fixed charges of pass plans is similar to the income elasticity of demand. On the other hand, changes in π are analogous to the price elasticity of demand. This distinction is important because most of the demand work on pass programs conducted to date has confused these two very distinct effects, which, as shown by Taylor (11), should be separated and properly identified in the demand-estimation procedure.

Graphical Exposition

The design principles of pass programs are discussed in a graphical exposition presented in Figure 1a and 1b. The graphical exposition makes extensive use of the concept of consumer surplus. However, as shown by Willig (12), no significant biases occur because of the use of consumer-surplus concepts at the low ratios (i.e., less than 2 percent) of pass expenditures to disposable personal incomes that characterize pass programs. Let Figure 1a portray constant-utility demand curves for transit by two prototypes of transit riders: the demand D_1 of a frequent rider and D_2 of an infrequent rider. If the price per ride for a ticket, punch card, or even cash fare is set at $\pi = p_1$, then the frequent rider takes p_1a_1 rides (i.e., 34 trips), whereas the infrequent rider takes p_1b_1 rides (i.e., 8 trips). The frequent rider's consumer surplus is given by ap_1a_1 and bp_1b_1 is the consumer surplus of the infrequent rider.

Suppose a monthly pass program is introduced at a fixed charge of E = x. The effect of the fixed price is to shift downward the demand curve of the frequent rider to D_1' (this shift being analogous to the income effect of a lump-sum tax, assuming that transit is a normal good). If the frequent rider purchases the pass, a_1' rides will be consumed (i.e., 45 trips) since the quantity charge is $\pi = 0$. That is, once the frequent rider buys the pass, transit use will be expanded until saturation is reached, given the opportunities for making use of transit, especially during off-peak hours. The maximum fixed charge that the transit agency can ask for the monthly pass and still get the frequent rider to purchase it is $E \leq a_1'oa' - a_1p_1a$. Thus, the frequent rider will purchase the pass if the willingness to pay for the 45 trips--denoted in function D_1' by the area $a_1'oa'$--exceeds the previous consumer surplus a_1p_1a by more than the pass price E = x.

However, this maximum pass price that can be extracted from the frequent rider is larger than the one that can be extracted from the infrequent rider reflected by D_2. The infrequent rider will not purchase the pass if the price of the pass is set at the maximum the frequent rider is willing to pay.

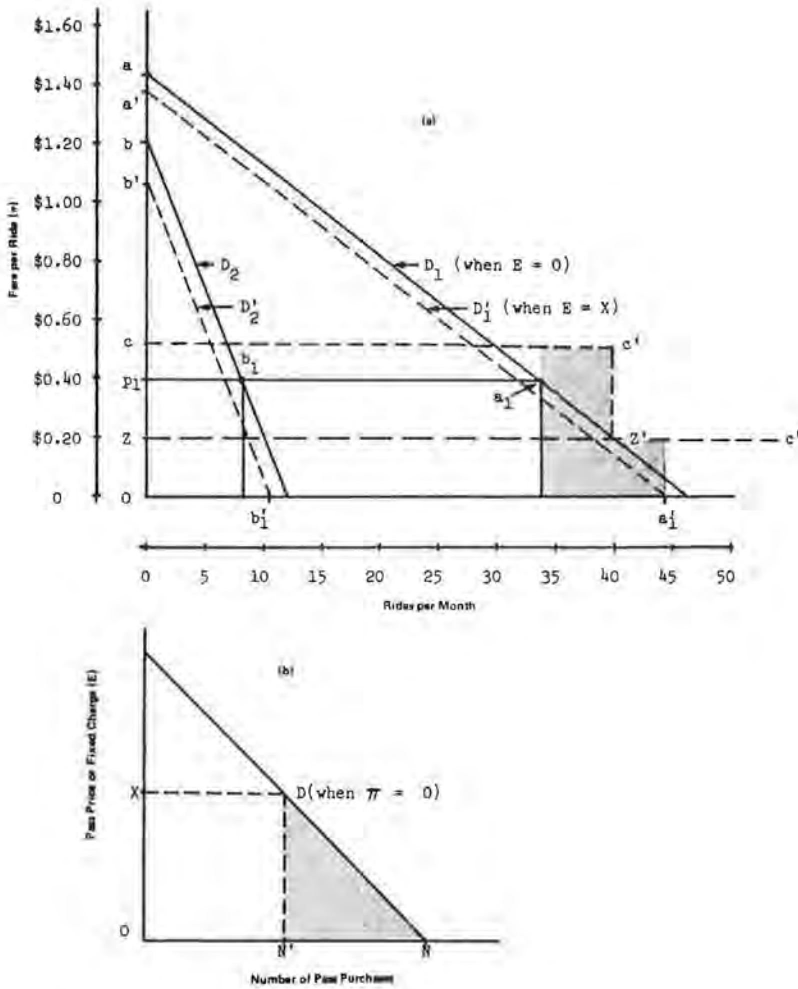
In Figure 1a, the maximum price the infrequent rider is willing to pay is given by $b_1'ob' - bp_1b_1$, which is much less than the amount the frequent rider is willing to pay. Therefore, given the choice of purchasing the pass at a price of E = x or paying cash at p_1, the infrequent rider will opt for the cash fare. This is an important difference between the public utility case and the transit case, since in the case of transit the rider has the choice of self-selection among several possible rate structures. Because of the difficulty in designing one pass program common to both frequent and infrequent riders, the preferred solution is to design a pass program for the frequent rider and a ticket program or cash fares for the infrequent rider.

The design of optimal pass prices or fixed charges also requires consideration of the cost impacts of increased travel by pass purchasers. At cash fares of p_1, the marginal cost function represented by cc'c" in Figure 1a exceeds the fare line p_1. After the frequent rider purchases the pass, monthly rides are increased to a_1', thereby adding extra costs represented by the shaded area in Figure 1a. These extra costs have to be financed by the revenues from pass sales.

Figure 1b shows the demand curve that can be derived by varying the pass price E (for a given level of π). When the pass price is E = 0 (i.e., the free pass), ON consumers will purchase the pass. As the price increases to E = x, fewer passes are purchased, with the infrequent riders (represented by N'N) shifting to cash fares.

As shown in Figure 1a, the lower the initial fare the greater the level of consumer surplus that can be extracted from the pass price or fixed charge.

Figure 1. (a) Demand for transit rides under alternative rate structures. (b) Demand for pass purchases.



The transit rider benefits from the pass in that the quantity or marginal charge is now zero, or below the cash fare. This encourages additional transit rides by the pass purchaser. Through the proper choice of pass prices, losses occurring due to the low variable or quantity charges can be removed. Customers who cannot financially afford the fixed charge of the monthly pass continue to purchase transit rides through the uniform cash fare structure and are therefore not affected.

Numerical Example

A frequent problem encountered in the design of pass plans is underpricing. This underpricing fails to account for the loss of cash fares and the extra costs of new rides. The result is a high revenue loss due to a faulty pricing strategy. Design of optimal pass programs requires information on the trip rate distribution of riders, estimates of demand functions for groups of riders, and estimates of marginal costs. Tables 2 and 3 present a numerical example for a hypothetical transit system with trip rate distribution data from the St. Louis monthly pass study (13).

Table 3 represents the demand functions calibrated for each ridership group. A fare elasticity of -0.30 was assumed in accordance with our previous work (14), while an income elasticity of +0.10 was assumed following Grey (15). Also presented in this table is the trip rate for the pass purchasers and the amount that would make each consumer group indifferent between the pass price and cash fare. Suppose now that the transit agency prices the pass at 40 rides (40 rides x 0.40 = $16.00), which is the general convention in the industry. In this case all riders taking 36 trips or more would benefit by shifting from cash fares to monthly pass use, with the transit agency losing a significant amount of cash revenue. For example, the riders taking 60 monthly trips are indifferent between paying a monthly pass price of $28.90 or paying cash. Setting the pass price at 40 rides provides them with windfall gains.

As shown in Table 3, as the price of the pass increases, pass penetration decreases and the average trip rate by pass holders increases. The decision on the level of optimal pass price in the example depends on the marginal costs per off-peak ride generated by the monthly pass plan. If off-peak riders can be transported at zero or negligible extra cost, the optimal pass price would be $18.65 or 46 rides, which would generate the most net revenue of the pass price alternatives. However, if the marginal cost of off-peak travel is half the cash fare, only the highest pass price (i.e., $32.65) can be accepted. Thus, the optimal pass price depends on several factors, including the distribution of riders and the marginal costs of off-peak service. However, it is self-defeating to offer the monthly pass at a price level comparable with that of 40 monthly rides or less. The result will be a net revenue loss.

It is important to remember that transit-pass purchasers exhibit diminishing marginal utility or benefit of pass use, especially after 40-45 trips

Table 2. Trip-rate demand functions and willingness to pay for monthly pass on hypothetical transit system.

No. of Monthly Trips	Proportion of Cash Riders (%)	Trip Demand Functions[a] ln T = A_0 − b(P) + c ln (Y − E)	Trip Rate for Pass Purchasers[b]	Pass Price That Makes Rider Indifferent with Cash Fares[c] ($)
70	0.5	ln T = 3.8395 − 0.75(P) + 0.10 ln (Y − E)	94	32.65
56	2.0	ln T = 3.6164 − 0.75(P) + 0.10 ln (Y − E)	75	26.10
50	3.0	ln T = 3.5030 − 0.75(P) + 0.10 ln (Y − E)	67	22.30
44	4.0	ln T = 3.3752 − 0.75(P) + 0.10 ln (Y − E)	59	20.50
40	25.0	ln T = 3.2799 − 0.75(P) + 0.10 ln (Y − E)	54	18.65
36	11.5	ln T = 3.1745 − 0.75(P) + 0.10 ln (Y − E)	48	16.77
32	12.0	ln T = 3.0567 − 0.75(P) + 0.10 ln (Y − E)	43	14.92
28	1.0	ln T = 2.9232 − 0.75(P) + 0.10 ln (Y − E)	38	13.05
24	8.0	ln T = 2.7691 − 0.75(P) + 0.10 ln (Y − E)	32	11.19
20	7.0	ln T = 2.5867 − 0.75(P) + 0.10 ln (Y − E)	27	9.32
16	8.0	ln T = 2.3636 − 0.75(P) + 0.10 ln (Y − E)	22	7.45
12	2.0	ln T = 2.0759 − 0.75(P) + 0.10 ln (Y − E)	16	5.59
8	10.0	ln T = 1.6704 − 0.75(P) + 0.10 ln (Y − E)	11	3.72
4	2.0	ln T = 0.9773 − 0.75(P) + 0.10 ln (Y − E)	5	1.84
2	4.0	ln T = 0.2841 − 0.75(P) + 0.10 ln (Y − E)	3	0.50

[a]The trip demand function was calibrated at a fare elasticity of −0.30 and an income elasticity of +0.10. Fare levels of $0.40 and monthly incomes of $1200 were assumed. In this equation, T represents the monthly transit rides, P represents the cash fare, E represents the pass price or fixed charge, and Y represents the monthly household disposable income. The functional form was selected to represent elasticities that increase as functions of the price level, properly reflecting derived demand considerations.
[b]Calculated at the pass price of $16.00 (E = 16 in the above demand equation).
[c]Calculated by integrating each respective demand curve between the trip rate for regular fares and that of pass riders.

Table 3. Net revenue effects or alternative monthly pass-pricing policies in hypothetical transit system.

Pass Price (or fixed charge) ($)	Percentage of Pass Purchasers[a]	Average Monthly Rides per Pass Purchaser	Pass Penetration Rate (%)	New Monthly Rides Generated	Monthly Revenues from Pass Sales ($)	Monthly Revenue Losses from Cash Fare Diversions ($)	Net Revenue from Pass Sales and Cash Fare Losses ($)
16.77	40.25	56	65.0	580	675.0	672.00	3.00
18.65	22.0	59	20.7	336	410.30	389.20	21.10
20.50	7.5	69	17.1	131	153.75	154.00	(0.25)
23.30	4.0	74	10.1	75	93.20	88.8	4.4
26.10	1.5	81	4.2	31	39.10	36.4	2.7
32.65	0.25	94	0.8	6	8.20	7.0	1.2

[a]The pass purchasers are those whose willingness to pay for the monthly pass (or indifference level in Table 2) exceeds the actual pass price. In trip-frequency groupings where willingness to pay (or indifference level) and the pass price are equal, these riders are shared equally between cash fares and monthly passes.

per month have been taken. The fact that more trips are taken with passes than without them reflects the fact that the marginal charge to the pass holder is zero and the user will ride transit until satiated. In most cases, however, the marginal cost of providing transit service is not zero.

The actual benefit or utility of frequent transit travel depends on the quality of service provided. In very small systems and on commuter services where the opportunities for off-peak and weekend transit travel are small, the monthly average trip rate will be in the low 40s and monthly passes can then be priced at 42-52 times the base fare. In larger systems where more off-peak travel opportunities exist, monthly passes should be priced between 52 and 60 times the base fare. For very large transit properties where the number of monthly unlinked trips can be greater than 100 (as in Chicago), monthly passes should be priced at more than 60 base-fare trips.

PRICE DISCRIMINATION THROUGH TWO-PART PERMIT PLANS

The monthly-pass example illustrates the fact that pass programs are seldom self-financing. This occurs because the quantity or marginal charge is zero, which in turn encourages pass users to ride until satiated. The extra travel increases the off-peak costs of the transit system.

Analysts of the economic welfare aspects of two-part tariffs, such as Gabor (16,17), argue that optimal two-part tariffs require the quantity or marginal charge--in an economic welfare sense--to be set equal to the marginal costs that each user imposes on the system. In terms of transit planning this argues for a two-part tariff where the marginal charge is set equal to the marginal off-peak transit costs, whereas the fixed charge is set at the maximum willingness to pay or consumer surplus. Since the concept of a nonzero quantity or marginal charge cannot be accommodated with a pass program (whose marginal charge is zero), it is necessary to look elsewhere for the design of fare prepayment plans that meet the economic welfare criteria (also called the Pareto optimum criteria) of economics.

Fortunately, the often-ignored permit plans provide an ideal implementation procedure for the economic welfare underpinnings of optimal two-part tariffs. In the first place, permit plans provide a relatively easy method of discriminating among user groups with different transit-fare elasticities, such as commuters, students, the elderly, the handicapped, and the poor. Moreover, the permit plan could be redesigned into a two-part permit plan charging a fixed charge for a permit to travel at a quantity charge equal to the marginal off-peak cost. The quantity or marginal charge could be paid with tickets in order to preserve the economic advantages of fare prepayment plans.

In terms of the demand functions presented in Figure 1, the implementation of the proposed permit plan would mean charging a marginal or quantity charge of 0Z equal to the off-peak marginal cost for each rider purchasing the permit at the maximum-willingness-to-pay level represented by the area $P_1a_1Z'Z$. To capture the cash-avoidance benefits of fare prepayment, the marginal charge could be paid through tickets. The infrequent rider would still be left to pay in cash fares or be served through another short-term ticket plan. The impact of the two-part permit plans would be to reduce the number of generated rides below that of pass programs while still capturing a significant consumer surplus. In this fashion, fare prepayment revenues are increased with a modest increase in off-peak travel. An on-going UMTA demonstration of permit plans in Bridgeport, Connecticut, may throw more light on the promise of this concept.

Two-part permit plans offer another advantage over pass programs in that they provide an excellent adjunct or supplement to distance-based fare systems, enabling distance-based fares to reflect the demand elasticities unique to each user group. More experimentation with their use is in order.

CONCLUSIONS

This analysis of the costs and returns of transit fare prepayment reveals that when properly priced, fare prepayment plans can improve a transit system's performance and operating ratio. If care and attention are taken to convert dwell-time savings into operating-cost savings through proper schedule changes and to capture all cash-flow benefits, transit fare prepayment plans can be cost-effective alternatives to cash fares.

Today, however, most fare prepayment plans are improperly priced. As a general rule--depending on the mix of frequent and infrequent riders--two types of prepayment plans should be made available to the general public: (a) a short-term ticket plan (punch cards should be avoided) to serve infrequent riders and (b) a long-term plan, such as a monthly pass, for more frequent transit users. The short-term, trip-limited plan should be priced identically to the cash fare (i.e., no discounts). The price of monthly passes should depend on the trip frequency distribution of transit riders and the opportunities for extra travel during the off-peak period at low marginal costs. There may also be opportunities for implementing fare prepayment plans for specific user groups.

Although each transit agency is unique in terms of its ridership distribution and off-peak travel possibilities, some guidelines on the proper pricing of monthly passes can be advanced. In large transit systems where off-peak service levels are relatively high, monthly passes should be priced between 52 and 60 rides. In some cases, passes can be priced at levels more than 60 times the base fare. In smaller systems where the potential for greater off-peak travel is limited, monthly passes could be priced at lower levels of 42-52 rides. Nevertheless, transit operators must be sure that there is enough off-peak capacity to serve the extra off-peak ridership generated by the program. If monthly passes are priced at or below 40 rides, revenue losses will occur, thereby exacerbating the difficult financial position of transit agencies. Monthly and weekly passes are valuable products in which transit riders have shown immense interest. There is no cost-effective reason for transit operators to have to offer permanent discounts over the equivalent cash fares in order to sell transit passes. It should be evident that the full opportunities for adopting fare prepayment plans in a cost-effective fashion have barely been explored in American transit systems.

ACKNOWLEDGMENT

This research was funded by UMTA. The study was prepared for the Pricing Division of the Office of Service and Methods Demonstrations within UMTA's Office of Transportation Management and Demonstrations. Opinions expressed in the article are ours.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

Abridgment

Evaluation of Employer-Based Transit Pass Programs

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Programs encouraging the distribution of monthly transit passes by employers have been implemented by many U.S. transit agencies over the past three years. In many cities, employers are contributing to the cost of the pass. Despite the increasing participation of both employers and employees, concern over the impact of these programs on revenue is causing many transit agencies to reexamine them. There is a need for more rigorous evaluation procedures to examine the cost and benefits to all parties involved. Included is a discussion of program costs and benefits to employers, employees, transit agencies, and the general public.

Programs encouraging distribution of transit passes by employers have become increasingly popular among U.S. transit agencies in the past three to four years. A natural outgrowth of these programs is an employer contribution to the price of the pass. The growth in transit pass contributions as an employee benefit can be attributed to several factors involving economic conditions and energy problems:

1. The rising cost of providing parking to employees has encouraged many downtown employers to promote the use of transit by their employees.
2. Growing interest in energy conservation has encouraged employers to promote the use of transit by their employees.
3. Employers see contribution to employee transit as a relatively inexpensive and popular benefit to provide.
4. Employer distribution of transit passes increases convenience for employees, particularly where payroll-deduction systems are used. Since many companies have traditionally subsidized employee parking, transit contributions provide a good method of equalizing benefits.
5. Employer distribution of transit passes is part of an overall trend toward transit fare prepayment. Rising fares, more complex fare structures, modern marketing techniques, and automated fare-collection technology are among the factors contributing to increased interest in transit fare prepayment.

Employer-based transit pass programs have been administered primarily by marketing personnel and have been designed to increase ridership and create a positive image of transit in the community. Recent financial difficulties faced by many agencies, however, have resulted in conflicts between financial and marketing departments over the desirability of these programs. Monthly passes generally provide some level of discount for the daily rider at a time when there is strong pressure to maximize revenue. In addition, employer contribution to transit tends to encourage peak-hour ridership, and many agencies have no additional peak-hour capacity.

These conflicts result partly from the fact that programs of this type are often not evaluated in a systematic manner. A full evaluation would involve not only costs and benefits to the transit agency but those to the other participants, the employer, and the employee.

Included here is a discussion of costs and benefits of employer-based monthly transit pass programs. Although other passes, such as annual or weekly passes, are sold by some transit agencies, monthly passes will be the focus of this report. This paper is based on research involving 35 transit agencies and more than 30 employers throughout the United States conducted for the Urban Mass Transportation Administration. An evaluation methodology is developed for use in analyzing the costs and benefits of these types of programs.

ISSUES IN COST-BENEFIT EVALUATION

Because transit is a public service, nearly always requiring government subsidy, traditional types of cost-benefit analysis are often not appropriate to transit programs. Intangible benefits and the furthering of public goals such as reduction of traffic congestion and/or air pollution are desired benefits that may be difficult to quantify with a reasonable degree of accuracy. These intangible benefits may be important enough to justify implementation of a program that would not be implemented on a purely financial basis.

Evaluation of costs and benefits of these programs will vary for each of the three primary groups: transit agencies, employers, and employees. The cost-benefit considerations for each group are summarized below and are discussed in more detail in the remainder of the paper:

1. Employees decide whether to purchase a pass almost entirely on economic considerations. Although mode choice is influenced by qualitative variables such as comfort and convenience, an employer contribution to the employee's transit expense can influence mode choice in a very visible way.
2. An employer's decision to participate in a transit pass program will depend heavily on savings that can be achieved from reduced parking costs. The decision may also be influenced by long-term considerations, such as trends toward greater employee benefits and improving the public image of the organization.
3. Transit agencies have in the past been willing to sustain financial losses from existing riders in order to attract new riders with the pass discount. This is part of an overall marketing strategy toward cashless fare payment.

EMPLOYEE COST-BENEFIT EVALUATION

There is clear evidence that regular transit riders respond primarily to economic incentives in deciding whether to purchase a transit pass. Short-term monthly pass discounts provided under Service and Methods Demonstrations in Phoenix, Austin (1), and Sacramento (2) demonstrated that regular transit riders will shift from cash fare payment to passes when a clear economic incentive is provided.

Most transit agencies have set a monthly pass price based on 17-20 round trips per month. Although most months have 20-22 working days, travel, vacation, sick time, and occasional trips by automobile and carpool reduce the breakeven point for most commuters. Only in larger cities, where nonwork transit trips and transfer charges are common, have passes based on 20 round trips or more been sold in large numbers. An employer contribution of 20-25 percent of the pass price will reduce the breakeven point to approximately 15 round trips. This will make the pass attractive to marginal buyers (including those not currently using transit)

Table 1. Estimated employer transit contributions.

No. of Employees	Employees Participating No.	Employees Participating Percent	Subsidy (%)	Estimated Annual Cost ($)	Monthly Cost per Employee ($)
5000	3000	60	100	500 000	8.33
1300	465	36	17.5	16 000	1.02
1800	1030	57	12.5	40 000	1.85
1700	950	56	43	150 000	7.35
3000	340	11	21	26 000	0.72
1100	270	25	50	25 000	1.89
550	110	20	50	11 000	1.67
3050	676	22	12-33	135 000	3.68

Table 2. Parking fees charged by employers (September-October 1980).

City	Type of Business	Location	Type of Lot	Monthly Charge ($)
Seattle	Hospital	CBD periphery	Surface	25
Minneapolis-St. Paul	Government	CBD	Garage	35-65
Minneapolis-St. Paul	Bank	CBD	Garage	15
Chicago	Insurance	Non-CBD	Garage	8-15
Des Moines	Bank	CBD	Surface	8
Pittsburgh	Retail store	Non-CBD	Garage	25-30
Boston	Insurance	CBD	Garage	15

and enable the transit agency to maintain a higher price.

The sale of transit passes through the workplace provides both an increased level of convenience and the opportunity to educate employees on the relative costs of automobile commuting and transit commuting. Although a combination of marketing efforts and employer contribution may encourage some automobile commuters to switch to transit, the major beneficiaries of employer contributions will be regular transit riders.

EMPLOYER COST-BENEFIT EVALUATION

The primary cost of employer-based pass programs to the employer is the amount of contribution provided to the employee's pass cost. Direct administrative costs are small, generally representing one to three days of clerical time per month. The contribution to the cost of the pass represents the major commitment on the part of the employer. A common technique used by employers is to set a total dollar budget for the program and determine the percentage subsidy provided by estimating the number of employees expected to use the program.

Some estimates of employer contributions to employee transit costs are shown in Table 1 for October 1980. An obvious economic benefit of employer contribution to transit is its cost relative to providing parking. Employers in the central business district (CBD) particularly are finding parking increasingly scarce and expensive to provide. As more buildings are constructed on surface lots, demand for parking increases and supply decreases. Employers who must provide additional parking due to expansion are finding land-acquisition and construction costs to be rising at a rapid rate.

Employers contacted for this study estimated construction costs for new above-ground garages at between $5000 and $10 000 per space. Amortized over 30 years at 13.5 percent interest, monthly costs per space range from $57.54 to $115.08. Estimates of monthly operating costs for garage structures ranged from $25 to $45 for a total monthly cost (excluding opportunity cost) of $82-$160. For outdoor surface lots, construction and maintenance costs ranged from $23 to $36 per month, also exclusive of opportunity costs.

As Table 2 shows, many employers are charging fees that do not even cover operating costs and that are well below market rates (market rates range from $50 to $100 per month in large-city CBDs).

Employer contributions for employee transit ranged from $1 to $8 per employee in companies contacted for this project. Parking subsidies (including operating and maintenance costs) ranged from $8 to $17 per employee, and in the companies surveyed there were two to four employees per parking space.

In addition to being less expensive, contributions to employee transit provide a degree of flexibility in budgeting that does not exist with fixed parking facilities. Employee transit contributions can be changed on relatively short notice, whereas parking construction costs are committed over a long period of time.

More qualitative potential benefits to the employer include positive publicity for the organization and improved employee relations.

TRANSIT-AGENCY COST-BENEFIT EVALUATION

Transit agencies tend to evaluate pass programs primarily in terms of increased ridership, net changes in passenger revenue, or both. There are also potential operational cost impacts that will be felt when large numbers of passes are sold. A cost-benefit evaluation of employer-based pass programs by transit agencies should address several issues, including the following:

1. Three of the direct benefits of pass sales to the transit agency are improved operational efficiency through reduced boarding times, improved cash flow through receipt of sales revenue at the beginning of the month, and reduced costs in handling of farebox revenue. Measurement of these impacts is difficult and empirical evidence is limited. It is clear, however, that these impacts will be limited unless large numbers of passes are sold on high-volume routes.
2. Promotion of pass sales through employers may attract new peak-hour riders to the system at a time when many systems are saturated in the peak hour. Marginal increases in peak-hour service are very expensive to provide, and many agencies simply do not have vehicles available. These potential costs have been recognized by a number of agencies that promote their programs in areas where there is excess transit capacity or in conjunction with flexible-hour policies.
3. Because passes provide a certain number of free rides, there is a net revenue loss from existing riders. In order to show a positive impact on revenue, enough new riders must be attracted to the system to offset this loss. The major components of the program cost-benefit analysis can be summarized in the following equation:

$$NC = (RG - RL) + AD \quad (1)$$

where

NC = net program cost,
RG = revenue gained from new riders attracted by pass program,
RL = revenue loss from discount received by current riders, and
AD = administrative costs of program.

Employer contribution enables the transit agency to charge a higher price for the pass but still present an attractive price to the employee. The employer contribution can thus help to improve the overall revenue position of the transit agency.

SUMMARY

With reductions in public funding for transit service, increased involvement on the part of employers will be important to the viability of transit service. For employees, benefits are in the form of reduced commuting costs, whereas employers can either cancel or defer plans for costly new parking facilities.

For transit agencies, the cost-benefit issues are more complex. Many programs have been initiated with a pure marketing focus and with little concern for revenue impacts. With fare revenues likely to become a larger portion of total revenues, these programs will come under increased scrutiny, especially concerning the level of discount provided to regular riders. The continued existence of employer-based transit pass programs will rely heavily on rigorous analysis of their financial impacts on the transit system.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

Average Transit Trip Lengths by Racial and Income Classes in Atlanta: Equity of Flat Fares Based on Trip Length

JOHN W. BATES AND NORRIS ANDERSON

Transit fares that are the same for all trips made regardless of trip length have decreased in favor recently. New preference is being given to distance-based fares, which offer potential to financially pressed transit operators for increasing revenues without increasing all riders' fare payment. One argument that has been advanced favoring distance-based fares is that flat fares are not equitable. Since low-income riders generally make shorter trips than do high-income riders, high-income riders receive more benefit for the same fare payment. This generalization is based on the presumption that all transit trips are radial to and from the central area and that low-income riders live within or close to the central area, whereas high-income riders live in suburban areas. This presumption is based on a concept of urban development patterns and transit service distribution that may or may not be true in all urban areas. An analysis of trip-length patterns for low- and high-income minority and nonminority riders in Atlanta, Georgia, shows that there is no significant variation in trip-length distribution by race and income class, except that high-income minority riders generally make shorter trips than do both groups of low-income riders as well as the high-income nonminority riders. The generalization that low-income and nonminority riders make shorter trips than high-income nonminority riders is shown to be not valid in this one case and therefore may not be used as a general basis for supporting distance-based fare systems. Distance-based fare systems may be desirable in many instances but must be justified on individual merits and not as a general rule.

During the 1970s, transit fare policies were often guided by the following two basic precepts:

1. Fares should be stable; that is, they should be held at nearly constant levels over long periods of time; and
2. Fares should be low, both absolutely and relative to the cost of the service provided and to the cost of the competing mode.

These precepts were sometimes translated into practice, in part through systemwide flat fares with free transfer.

More recently these precepts have been more likely to be questioned. Rising costs, real and inflationary, have increased the necessity of generating more revenue through fares. A fixed amount of net revenue increase may be obtained by raising all fare payments by X amount or by raising some proportion of fare payments by an amount n*X. Distance-based fares are an example of this latter approach.

The distance-based fee approach has certain apparently logical imperatives. Generally (but not necessarily always), it costs more to provide for a long trip than it does for a short one. Also, the long trip must be worth more than the short one, since the rider is willing to spend more time making it. Extending this argument, some analysts have also supported distance-based fares vis-à-vis flat fares on the basis of equity, maintaining that wealthier riders make long trips (suburban trips to work), whereas low-income riders make short trips (within the central city). If this is true, then the high-income rider receives more value for the fare than does the low-income rider paying the same amount.

A general statement that flat fares are inequitable, for the above-stated reasons, carries certain presumptions about the income distribution of residents of urban areas. The presumptions are that what might be called the classical ring form of urban development is commonplace. This form of urban development is described simplistically as a central core in which all nonresidential activity takes place, an inner ring containing the residences of all low-income citizens, and an outer ring containing all the high-income residents. (There is also often a presumption that low income is synonymous with minority racial groups.) In this situation, on every working day all the high-income residents will pass through the low-income ring on the way to and from work and will make trips about twice as long, on average, as those by occupants of the inner ring.

Although this type of development is very illustrative in theoretical discussions, whether it actually exists is debatable. Yet transit-pricing theorists are apparently assuming that it does exist to suggest that distance-based fares should be more commonly applied.

This analysis examines the average trip lengths for different classes of riders in Atlanta, Georgia, to determine whether the presumption is borne out in that one instance. If it is not, the presumption does not hold true in this specific case, and then it therefore cannot be assumed to hold true in all cases.

ANALYSIS PROCEDURE

The procedure selected for analysis to determine whether there is a difference in the trip lengths between various population groups of riders of the Metropolitan Atlanta Rapid Transit Authority (MARTA) is as follows:

1. Selection of small sample of MARTA riders (100 trips) and stratification into four population groups: (a) low-income minority riders (incomes less than $10 000/year), (b) high-income minority riders (incomes equal to or greater than $10 000/year), (c) low-income nonminority riders, and (d) high-income nonminority riders;
2. Location of origin and destination for each sample trip and measurement of airline distance between;
3. Calculation of arithmetic mean and standard distribution for each of four subsamples (population groups);
4. Comparison of arithmetic means and standard deviations by statistical tests to determine whether there is statistical probability that sample means are different [note that a determination of similarity based on a comparison of sample means only is not conclusive; a sample mean is a measure of the midpoint of a statistical distribution; two samples may have the same sample mean but have wide variations in the distribution of individual cases making up the sample; for example, a sample of 100 cases each having the value of 50 will yield a sample mean of 50 but a standard deviation of zero; in this sample it may be concluded that the probability of any value in the universe other than 50 is very small; in another sample of 100 cases, however, if the 50 cases have a value of zero and the remaining 50 have a value of 100, the sample mean will also be 50, but the standard deviation will be very high; in this sample it may be concluded that the probability that any value in the universe is equal to 50 is very high; therefore, a determination of similarity between two sample distributions cannot be made on the basis of sample means alone but also must consider the dispersion of sample values about the mean value, measured by the standard deviation for the sample];
5. Selection of second sample independent from the first and repetition of analysis process (if subsample distributions are similar between two samples, samples are accepted as valid representations of total population); and
6. If comparison of sample distribution between subsamples shows that distributions are similar with reasonable statistical confidence, rejection of the presumption that high-income riders always make longer trips; if comparison shows that distributions between some subsamples are not similar but that changing MARTA fare structure from flat to distance-based fare could create inequities (i.e., give one population group preferential economic treatment that does not now exist at the expense of another group), the presumption may be accepted in theory but rejected in this case as trivial in practice.

SELECTION OF SAMPLES

Two samples of 100 transit trips each were selected on a random basis from interviews conducted by the Atlanta Regional Commission (ARC) in a survey of MARTA riders during October and November 1980. The ARC survey, conducted as part of the Transit Impact Monitoring Program, interviewed bus and rail passengers separately. From a random listing of bus interviews, 81 were taken for each of the two samples for this analysis, and 19 interviews were taken for each of the samples from a similar listing of rail interviews, reflecting the proportions in daily boardings for bus and rail services. Only those interviews that included information on origin, destination, income, and minority/majority classification were accepted for the sample listings.

STATISTICAL TESTING

After means and standard deviations had been calculated for each of the subsamples in both samples, a standard statistical test was applied to determine whether for all possible comparisons within each sample, the basic hypothesis for the analysis should be accepted or rejected. This basic hypothesis is that there is no statistical difference between the mean trip length of subsample A compared with the mean trip length of subsample B.

This statistical test is performed by comparing the value of a parameter Z calculated from the means and standard deviations of two subsamples to a standard value that implies a certain level of confidence. For a 95 percent level of confidence in the conclusion to accept or reject the basic hypothesis, the value of Z must be less than or equal to 1.96 to accept the hypothesis (equality) or greater than 1.96 to reject the hypothesis (difference). The value of Z is calculated by the following expression:

$$Z = (\bar{X}_1 - \bar{X}_2)/[(s_1^2/n_1) + (s_2^2/n_2)]^{1/2} \quad (1)$$

RESULTS OF ANALYSIS

The mean trip lengths and standard deviations calculated for each subsample in the two samples are shown below:

Sample	No. of Cases	Mean Trip Length	SD
Sample 1:			
Entire sample	100	6.55	4.31
Subsample			
Low-income minority	30	5.83	4.49
High-income minority	27	5.61	2.44
Low-income nonminority	16	7.49	4.20
High-income nonminority	27	7.75	5.23
Sample 2:			
Entire sample	100	6.53	5.15
Subsample			
Low-income minority	28	5.32	3.55
High-income minority	25	5.14	2.99
Low-income nonminority	17	8.34	6.33
High-income nonminority	30	7.01	6.53

Note that although there are arithmetic differences in the values for mean trip length comparing the two minority subsamples to the two nonminority subsamples in both samples, the differences are relatively small, and the standard deviations are very large relative to the mean in all cases. This implies that the individual trip lengths vary widely and the mean trip length alone is not necessarily a good measure for comparison.

The results of the statistical test for comparison of subsample means for the first sample are shown in Table 1. In all cases the value of Z calculated is less than the critical value for the hypothesis that there is no statistical difference in the values of the means to be accepted. Therefore, the findings from analysis of the first sample tested do not infer that differences exist in trip lengths for different population groups, and an allegation that such differences do exist is not supported. In one comparison, that of high-income minority riders with high-income nonminority riders, the value of Z calculated is very close to the critical value, and this is noted as a borderline case. However, the allegation of inequity speaks to a difference between the trip lengths of low-income riders compared with those of high-income riders, so this borderline case, even if it were not still in the acceptance range, is not necessarily pertinent.

A second sample was also analyzed. The potential exists for any small sample to be not representative of the entire population, so the second sample provides a basis for verification of the findings from the first sample. The first test made for the second sample provides a basis for verification of the findings from the first sample. The first test made for the second sample was a comparison of sample means from each sample separately. It was found that the Z values for comparison of subsample means from one sample to another were all small and well below the critical value. This comparison shows consistency between the two samples, from which it may be inferred that both samples are representative of the total population.

The results of the statistical test for comparison of subsample means for the second sample are shown in Table 2. In all cases the value of Z calculated is less than the critical value for the hypothesis that there is no statistical difference in the values of the means to be accepted. Therefore, the findings from analysis of the second sample tested do not infer that a difference exists in the average trip length for different population groups, and an allegation that such differences do exist is not supported.

FURTHER ANALYSIS

The large values of standard deviations relative to arithmetic means for each of the classes within both samples indicate a wide dispersion of trip lengths within each group. To consider what this dispersion might be, the two samples were combined into a single sample and frequency distributions for each of the groups in the larger samples were determined. These distributions are shown in Table 3. Here we see that for the combined samples, high-income minority riders actually have the shortest trip lengths. Distance-based fares would give this high-income group a price advantage over the other groups, including both low-income groups of riders.

Table 1. Conclusions from analysis of sample 1.

Hypothesis	Z-Value	Conclusion
Mean trip length for low-income minority group is not statistically different from that for high-income minority group	0.23	Accept
Mean trip length for low-income minority group is not statistically different from that for low-income nonminority group	−1.25	Accept
Mean trip length for low-income minority group is not statistically different from that for high-income nonminority group	−1.48	Accept
Mean trip length for high-income minority group is not statistically different from that for low-income nonminority group	−1.63	Accept
Mean trip length for high-income minority group is not statistically different from that for high-income nonminority group	−1.93	Accept
Mean trip length for low-income nonminority group is not statistically different from that for high-income nonminority group	−0.18	Accept

Table 2. Conclusions from analysis of sample 2.

Hypothesis	Z-Value	Conclusion
Mean trip length for low-income minority group is not statistically different from that for high-income minority group	0.22	Accept
Mean trip length for low-income minority group is not statistically different from that for low-income nonminority group	−1.08	Accept
Mean trip length for low-income minority group is not statistically different from that for high-income nonminority group	−0.90	Accept
Mean trip length for high-income minority group is not statistically different from that for low-income nonminority group	1.18	Accept
Mean trip length for high-income minority group is not statistically different from that for high-income nonminority group	−1.05	Accept
Mean trip length for low-income nonminority group is not statistically different from that for high-income nonminority group	0.35	Accept

Table 3. Distribution of trip lengths by rider classification (N = 200).

Trip Length (miles)	Low-Income Minority		High-Income Minority		Low-Income Nonminority		High-Income Nonminority	
	Percent	Sum	Percent	Sum	Percent	Sum	Percent	Sum
<2	20.7	20.7	11.6	11.6	15.1	15.1	10.5	10.5
2 to <4	19.0	39.7	25.1	36.7	12.1	27.2	24.4	33.9
4 to <6	22.5	62.2	23.0	59.7	21.3	48.5	14.0	48.9
6 to <8	12.0	74.2	23.0	82.7	6.1	54.6	7.1	56.0
8 to <10	8.6	82.8	13.5	96.2	12.1	66.7	14.0	70.0
10 to <12	13.8	96.6	3.8	100.0	12.1	78.8	8.7	78.7
12 to <14	1.7	98.3	-	-	9.1	87.9	10.5	89.2
14 to <16	-	98.3	-	-	-	87.9	-	89.2
16 to <18	-	98.3	-	-	9.1	97.0	3.6	92.8
18 to <20	1.7	100.0	-	-	-	97.0	1.8	94.6
20 to <22	-	-	-	-	-	97.0	-	94.6
22 to <24	-	-	-	-	3.0	100.0	3.6	98.2
24 to <26	-	-	-	-	-	-	-	98.2
26 to <28	-	-	-	-	-	-	1.8	100.0
$\bar{X}$	5.58		5.39		7.93		7.77	
s	4.03		3.09		5.33		5.94	

Operational and Revenue Implications of Implementing Employer-Based Transit Pass Program

THOMAS E. PARODY

Findings are presented of a comprehensive evaluation that was made of an employer-based monthly transit pass program instituted in Jacksonville, Florida. The purpose of the demonstration, which was funded through the Service and Methods Demonstration Program of the Urban Mass Transportation Administration, was to assess the impacts that result when transit passes are sold, distributed, and promoted by employers to their employees. Three affected groups were examined—employers, employees, and the transit operator. Enrolling 30 firms to participate in the sale of transit passes was accomplished very successfully and efficiently by having staff members with first-hand knowledge of the local business community schedule a personal meeting with the chief executive officer at each firm. However, the monthly transit pass, which was initially priced at little or no discount compared with cash fares, was not purchased by many employees who use the bus mainly for commuting purposes. However, by instituting a modest $2.00 discount in the pass price and encouraging employers to provide additional subsidies, the number of passes sold increased from an average of 120 to more than 1000 per month at the end of the first year. By the eighteenth month of the program, one-third of the employers were selling the pass at a discount to their employees. While the employer-promoted pass program resulted in some new transit riders (about 20 percent of the purchasers had previously used other modes), more than 60 percent of the pass purchasers were already regular bus commuters. Revenues lost because of the program were small (about 0.3 percent of regular monthly revenue) since 75 percent of the employees use the transit pass only for commuting.

The concept of selling and distributing transit passes through employers is the logical outgrowth of two trends that have emerged over the past decade. The first is the rapid growth (or renewed growth) in transit operators' use of transit fare prepayment (TFP) instruments, such as transit passes that are valid for trips taken over a specific period such as a calendar month. In early 1970, relatively few transit agencies in the United States offered regular transit riders the use of monthly transit passes. However, a recent fare survey completed by the American Public Transit Association (APTA) revealed that currently about two-thirds of the transit systems surveyed sell some type of pass. The monthly pass is the most popular, currently being offered for sale by 51.9 percent of the surveyed systems (1,2).

Paralleling this growth in new transit pass programs has been the advancement of the concept that places of employment have particular advantages in terms of establishing and coordinating programs to achieve ridesharing and other broad transportation goals. For example, beginning with the 1973 oil embargo, many major cities and employers began carpool-matching programs and later employer-sponsored vanpool programs. Interest in improving air quality led to proposals that employee-provided parking be curtailed or reduced, especially by large firms located in major urban areas. With this trend toward relying more heavily on employers to assume additional responsibility in the commuting patterns of their employees came the notion that employers should participate in the sale, distribution, and promotion of the ever-more-popular monthly transit pass. In addition, to the extent that employers could be encouraged to subsidize the price of the pass to their employees, additional revenues could be generated by the transit operator, especially at a time when new revenue sources are much needed.

In order to advance the concept of selling passes through employers as well as to monitor and evaluate the resultant impacts on transit operators, employees, and employers, the Urban Mass Transportation Administration (UMTA) provided Service and Methods Demonstration (SMD) grants to Jacksonville, Florida, and Sacramento, California, to implement similar employer-promoted monthly transit pass programs. Except for the employer-based pass program in Boston (3), there existed little documentation when these demonstrations began in 1977 that transit agencies could use to gauge, a priori, the demand and the economic and institutional reactions of adopting this type of program.

DEMONSTRATION OBJECTIVES AND ISSUES

The principal objective of the Jacksonville demonstration was to evaluate the impact on sales of monthly transit passes that are marketed and sold through employers. The intent of the program was to place as few demands as possible on the employers enrolled in the program while increasing the convenience to employees of purchasing a pass and using the transit system. Employers were encouraged to institute a payroll deduction plan as a pass payment option to further increase the convenience of purchasing a pass. Many of the employers eventually began subsidizing part of the pass price (either as a new employee fringe benefit or in lieu of providing or expanding employee parking) as a further incentive for their employees to buy a pass. These actions added further useful insights into the responses of employees to this type of pass program.

Research issues important to the evaluation can be associated with one of the following three groups involved in this type of pass program:

1. The employer who must sell and distribute the monthly transit pass as well as perform the administrative tasks of collecting, recording, and remitting revenues obtained;
2. The employee who decides whether to purchase a pass at his or her place of work, which in turn may influence his or her use of the transit system; and
3. The transit operator who makes available the monthly transit passes and operates the transit system.

In many instances, there is a direct interdependency between issues and impacts to be evaluated within each group (e.g., transit trip frequency of pass purchasers) and between groups (e.g., effect of employer subsidy on employee pass purchase decision). The identification of these behavioral linkages can provide a useful framework both for structuring the evaluation issues and for presenting the findings of the demonstration.

IMPLEMENTATION OF JAXPASS PROGRAM

The Jacksonville TFP demonstration, like its companion demonstration in Sacramento, instituted a program by which monthly transit passes could be purchased by employees at their place of employment with a minimum of personal inconvenience (4). In Jacksonville, the monthly transit pass, called JaxPASS, was introduced and made available only

Although trips by the nonminority group for both low- and high-income groups do occur that are longer than the longest observed trip for the low-income minority group (20 miles or less), only 3 and 5 percent of the trips made by the two nonminority groups are longer. Obviously, a generalization that low-income and minority riders make shorter trips than high-income and nonminority riders do is misleading.

SUMMARY AND CONCLUSIONS

There may be many valid reasons to prefer a graduated or distance-based fare system for transit over a flat-fare system. Some of these reasons may be based on equity considerations. However, a generalization that equity requires distance-based fares because low-income and minority riders always make shorter trips than high-income and nonminority riders do is not proper. In the Atlanta area, based on the analysis here, it appears that there are no significant differences in the distribution of trip lengths by race and income group. In fact, distance-based fares would, in general, discriminate for high-income minority riders against low-income riders of both minority and nonminority classifications. Therefore, although there may be equity and other considerations that make distance-based fares more appropriate than flat fares, on the basis of current information such may not be maintained solely on the generalization that low-income riders travel shorter distances than high-income riders do.

FOLLOW-UP ANALYSIS

Review of the previous discussion identified one critical shortcoming: The sample size for the analysis is very small. The fact that two independent small samples that are mutually consistent yield the same result mitigates this somewhat, but the criticism is certainly valid. Follow-up analysis of transit trips for the Atlanta area, however, tends to verify the original conclusion.

In the follow-up analysis a larger sample (1045) of weekday transit trips (from the same 1980 survey) was stratified into three income and five distance categories. Percentages for all trips are shown in each of the resulting 15 cells in Table 4. The distribution is shown graphically in Figure 1. Review of these data is not "confused" by broad dispersions of trip lengths and misinformation that might result from simple considerations of average trip lengths. The sample is also sufficiently large to overcome the criticism of the earlier study.

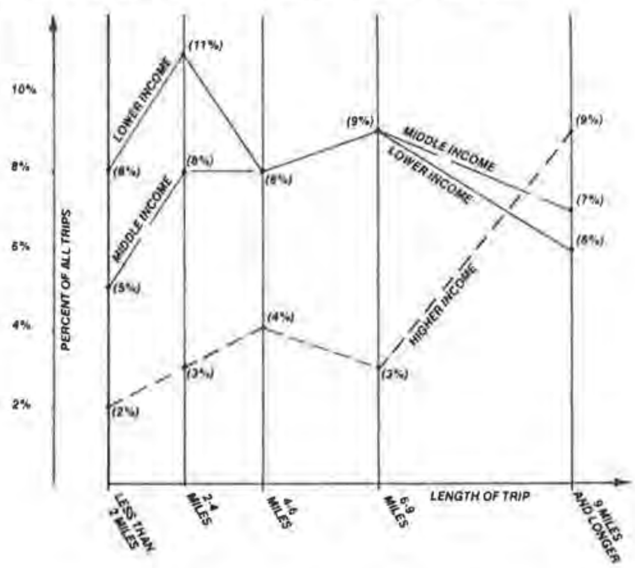
Consideration of the information in Table 4 and Figure 1 leads to the following conclusions:

1. The reason that average trip lengths for high-income riders may be longer is not simply that they are indeed longer but rather that there are very few short trips made by these riders.
2. The actual numbers of trips in the longest-trip-length category are similar for all three income groups; that is, trips by low- and middle-income riders tend to be just as long as those for high-income riders. A distance-based fare structure would charge higher fares to about as many, or possibly more, trips made by low- and middle-income riders as it would to high-income riders.

Table 4. Distribution of trips by length and income categories (N = 1045).

Trip Length (miles)	Trips by Income Group (%) Low (<$10 000)	Middle ($10 000 to <$25 000)	High ($25 000+)	Total
<2	8	5	2	15
2 to <4	11	8	3	22
4 to <6	8	8	4	20
6 to <9	9	9	3	21
9+	6	7	9	22
Total	42	37	21	100

Figure 1. Distribution of trips by length and income categories.



The conclusion drawn from the initial analysis and previously stated is therefore confirmed by this follow-up analysis. That is, distance-based fare structures cannot be supported solely on the generalization that flat fares discriminate against low-income riders because these persons make short trips whereas high-income riders paying the same fare make long trips. Such might indeed be the case in specific areas, and there may be other warrants for distance-based fares. There is at least one case, however, in which it has been shown that the generalization does not hold.

Publication of this paper sponsored by Committee on Transit Service Characteristics.

through a panel of employers enrolled in the demonstration. However, the Sacramento monthly transit pass, labeled PASSpoRT, was already being sold to the general public prior to the beginning of the employer-sponsored demonstration. It continued to be sold at regular sales outlets during the course of the demonstration (5).

During January and February 1979, various employers in the Jacksonville central business district were contacted and asked to participate in the TFP program. Orders for the monthly JaxPASS began in late February 1979 for passes valid for March 1979. Passes were initially priced at $14.00, reflecting a breakeven use rate of 40 one-way transit trips per month at the regular bus fare of $0.35. [The monthly JaxPASS was valid only on weekdays on regular bus routes in the inbound direction between 6 a.m. and 9 a.m. and outbound between 3 p.m. and 6 p.m. It was valid for unlimited travel at all other times on regular bus routes and at all times on the downtown shuttle. These restrictions were established so that the monthly pass would not compete with the higher-priced $7.00 unlimited-use weekly pass, which is designed exclusively for individuals who must make a full-fare transfer when commuting since Jacksonville Transportation Authority (JTA) does not have free or reduced-fare transfer privileges.] The JaxPASS was also usable on higher-fare routes by showing the pass to the driver and paying the difference in fare over the base fare.

After a disappointingly low level of pass sales during the first three months, the price of the pass was reduced by $2.00 to $12.00 starting in July 1979. This represents a breakeven use rate of 34.3 one-way trips per month. The pass price remained at that level throughout the remainder of the evaluation. (The JaxPASS price increased to $20.00 on September 29, 1980, at the same time base transit fares were increased to $0.50, but it continued to be sold to participating employees at a $2.00 discount. More importantly, when the demonstration grant ended, JTA continued to sell the pass at $18.00, leaving intact the $2.00 discount that previously had been funded through the demonstration grant.)

The following three sections describe the demonstration findings as they relate to employers, employees, and the transit operator.

EMPLOYER-RELATED ISSUES

Recruiting Employers

The enrollment of an initial panel of 30 employers to participate in the sale and distribution of monthly transit passes was accomplished very successfully; in fact, it was necessary to contact only 34 establishments. This very favorable response rate can be attributed to several key factors. First, a personal visit was scheduled with each potential seller. Second, the person contacted at each firm was a high official (usually the chief executive officer), who typically had the authority to make a direct decision to either participate or not participate in the program. Third, the representatives of JTA involved in signing up employers were very familiar with corporate concerns in general and with the Jacksonville business community in particular. Also, staff personnel were personally acquainted with some of the individual employers being contacted. Although a large percentage of employers may still have participated if other procedures were followed, these factors, either alone or in combination, certainly aided in the success and timely completion of this phase of the pass program.

An overwhelming majority of the employers who were contacted and who agreed to participate in the TFP program were in the single, standard industry classification--"finance-insurance-real estate." Of firms that participated throughout the first year of the program, 65 percent were in this industry classification. Within this group, 53 percent were insurance companies. It may be hypothesized that firms such as insurance companies take a strong interest in community affairs and employee welfare and thus are more likely to participate in a program of this nature. (Indeed, many insurance companies were also early participants of the very successful Massachusetts Bay Transportation Authority employer pass program that started in October 1974.)

JaxPASS Distribution Procedures

Employers, after having received the transit passes, were responsible for distribution and employee payment. Exactly 75 percent of the firms reported using some form of over-the-counter distribution procedure by which employees report to a designated place to pick up their pass. One medical facility distributes and sells passes through its gift shop because of its convenience and cash-handling capabilities. The remaining 25 percent of the firms hand deliver the passes to each employee. None of the firms reported distributing passes through their interdepartmental mail system, which is typically perceived to be a more theft-prone approach.

Initially it was hoped that many firms would institute a payroll deduction plan in order to maximize the perceived convenience of acquiring the pass each month and possibly as a way of minimizing the perceived cost of the pass. However, only 4 of the 23 firms (17 percent) that were participating at that time implemented payroll deduction as a means of collecting the pass price from their employees.

Employer Subsidization of JaxPASS

During the first nine months of the demonstration, very few employers were willing to subsidize the price of the pass to their employees (only one firm subsidized the pass by $4.00). However, as a few other firms gradually started to provide subsidies, a cascading effect seemed to occur so that by the eighteenth month of the program one-third of the employers were providing subsidies that ranged from a low of $4.00 (33 percent discount) to a high of $12.00 (100 percent discount).

It was initially hypothesized that firms would subsidize the pass if they lacked adequate employee parking. The information obtained from employer interviews indicates that this was true, but only to a limited extent because few employers appeared to have severe parking problems or would have saved money by reducing parking demand. The basic concept, however, is still a valid one, especially in areas that may have different parking supply characteristics.

Employer Administrative Costs and Benefits

The amount of time employers reported spending to set up and organize the JaxPASS program initially and then to maintain it on a monthly basis appears to have been quite modest. During the first pass-sale month, an average of about 4 person-h were necessary to accomplish the initial administrative activities. In the following months, the amount of administrative time required was reduced by more than 50 percent to an average of 1.6 person-h/month. The actual amount of time is dependent, of course, on the number of passes that are sold. Firms

Figure 1. Monthly JaxPASS sales: total and by subsidizing firms.

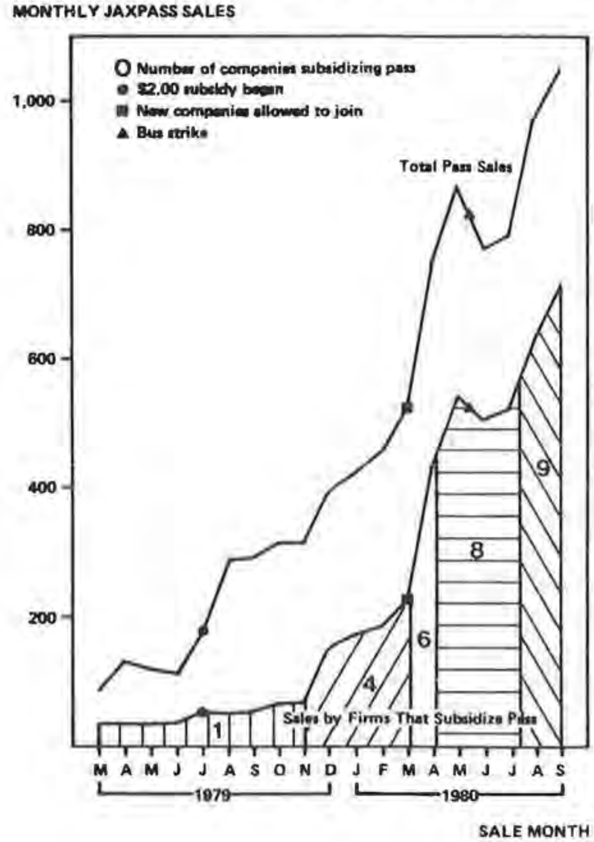
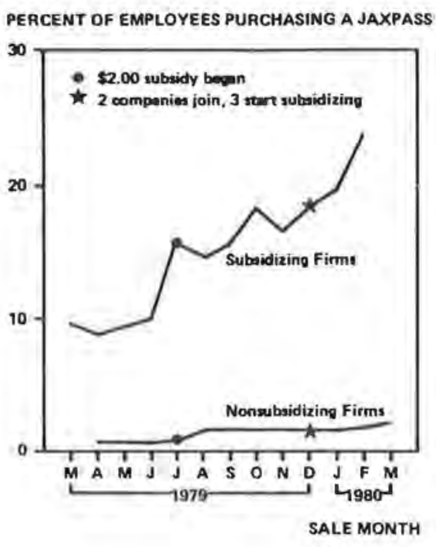


Figure 2. Percentage of eligible employees purchasing JaxPASS by subsidizing and nonsubsidizing firms.



selling more than 30 passes per month generally reported spending between 3 and 4 person-h/month, whereas firms selling less than 20 passes per month expended between 0.5 and 1 person-h/month. Because of the range of data, no information is available on the resources that would be required by employers selling 100 or more passes per month.

In general, administrative cost concerns were not a high-priority item among firms selling transit passes. In fact, none of the firms that sold passes at any time during the course of the demonstration dropped out of the program because of the administrative requirements. Firms that dropped out of the program did so because of very low or no pass sales.

Of the employers that were surveyed, 87 percent believed that they obtained a net positive benefit by participating in the JaxPASS program. The majority of these firms stated that their involvement provided their employees a convenient way of purchasing passes at work. Thus, the companies felt that if their employees were benefiting from the program, then they were also. In terms of more tangible or direct benefits, about one-third of the employers felt that the demand on company-provided parking spaces was lessened.

EMPLOYEE-RELATED ISSUES

JaxPASS Sales

After an inauspicious first-month sale of 89 passes in March 1979 (priced at $14.00 on the breakeven basis of 40 trips per month), sales rose by almost 50 percent during the second month, to 131. However, this turned out to be a short-lived gain and in fact represented a peak, as pass sales declined in the following two months, first to 120 and then to 113. Because it was recognized that sales were unlikely to grow at any appreciable rate in the near term, it was decided that the funds allocated in the demonstration grant for a one- or two-month, deep-discount subsidy experiment be used instead to reduce the pass price by $2.00 from $14.00 to $12.00.

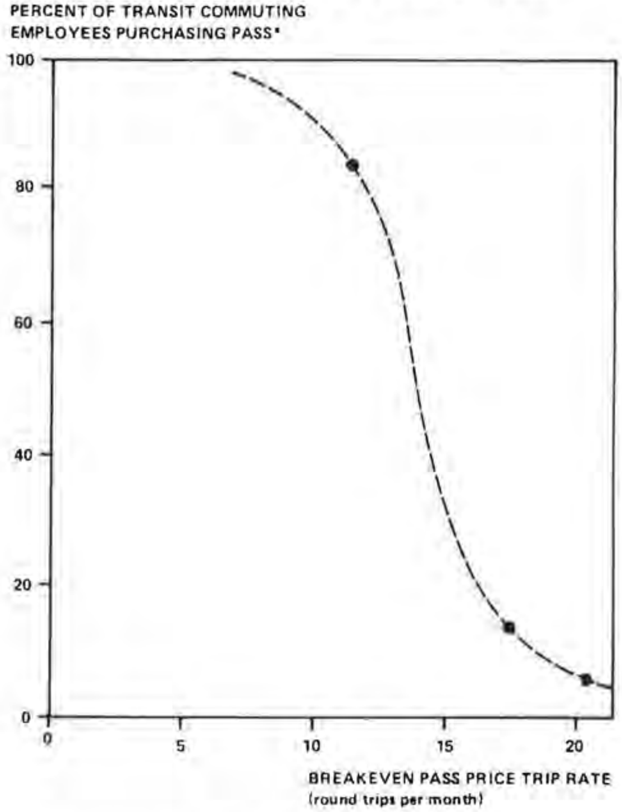
Figure 1 depicts the monthly variation in total pass sales from the start of the program in March 1979 until September 1980. Also shown are monthly pass sales for firms subsidizing the price of the pass (which amounted to $4.00 per pass for nearly all firms that subsidize) and the number of firms subsidizing the pass in any given month.

Figure 2 normalizes monthly pass sales by plotting the percentage of employees at participating firms who purchased a JaxPASS for both subsidizing and nonsubsidizing firms. This clearly shows the following:

1. Pass sales per employee are significantly higher for firms subsidizing the pass price compared with firms not subsidizing. In particular, over the first 12 months of the demonstration, JaxPASS penetration rates were 10 times higher for subsidizing firms than for nonsubsidizing firms. (Alternatively, JaxPASS sales per firm were 3 to 5 times higher for companies that subsidize compared with nonsubsidizing companies.)
2. Pass sales after the introduction of the general across-the-board $2.00 price discount increased more rapidly for nonsubsidizing rather than for subsidizing firms. For the firm already subsidizing the pass, average penetration rates (defined as percentage of employees buying a pass) increased 62 percent (from a three-month average of 9.4 percent to 15.2 percent) after the introduction of the $2.00 discount. However, the increase in pass penetration rates for nonsubsidizing firms was about twice as large, or 122 percent (i.e., from 0.6 to 1.33 percent).
3. Little or no secular growth in pass sales occurred over time for either subsidizing or nonsubsidizing firms. Given no outside changes (such as the introduction of a subsidy), the number of passes sold by a firm quickly reached a level of stability. The inference is that within one or two months all employees who are likely to buy a pass will do so, all else being equal.

Among three firms that began subsidizing passes

Figure 3. Sensitivity of pass penetration rate to breakeven pass level.



* Employees commuting by transit 3 or more days per week.

by $4.00 midway in the demonstration, average monthly pass sales (for a three-month period before and after the introduction of the subsidy) increased by a factor of 5 for two of the companies and by a factor of 7 for the third. These large changes suggest that pass sales are highly sensitive to a change in the inherent breakeven price of a pass. [Similar findings were also noted in an evaluation of TFP discounts in Austin and Phoenix (6)]. As an illustration of this point, Figure 3 depicts the percentage of transit users who purchased a JaxPASS versus the breakeven transit trip rate. (For the first four months of the demonstration the pass was priced at 40 one-way trips. When the $2.00 discount was instituted, it dropped to 34.3 trips. For firms providing an additional $4.00 subsidy, the effective breakeven rate was 22.8 one-way transit trips.) Figure 3 clearly shows that a relatively large change in pass penetration rates occurred when the breakeven level of the pass changed. Between 27 and 40 one-way transit trips per month, arc elasticities were computed and are fairly constant in the -5 to -6 range (i.e., a 1 percent decrease in the breakeven pass rate will result in a 5-6 percent relative increase in the percentage of transit users who purchase a pass). In the range of 20 to 25 trips, arc elasticities decrease to between -1.0 and -4.0, since at these lower breakeven rates most of the employees who could buy a pass would have already done so. Consequently, the percentage change in penetration rates, and thus elasticities, becomes smaller.

A two-week bus strike during the month of May 1980 resulted in a drop in pass sales in the month following the strike. The decline in passes sold per firm was twice as large among nonsubsidizing firms than among subsidizing firms (-13.6 percent versus -6.2 percent). Four months after the strike ended pass sales had not returned to their prestrike level. However, the difference was still twice as large for nonsubsidizing firms compared with firms that subsidize the pass (i.e., -7.6 percent versus -3.0 percent).

Socioeconomic Characteristics of JaxPASS Purchasers

Data from employee surveys conducted at the participating firms reveal that JaxPASS purchasers have socioeconomic characteristics that are very similar to those of employees who regularly commute to work by transit but continue to pay with cash fares. Characteristics were about the same for sex, age, number of licensed drivers in the household, and whether or not the individual holds a valid driver's license. The most significant difference between the two groups of bus commuters was the much lower household incomes of employees purchasing a JaxPASS compared with employees who use the bus but do not buy a JaxPASS ($13 080 versus $17 078). JaxPASS purchasers also tended to own fewer automobiles.

The group of employees who did not buy a JaxPASS and who did not use the bus regularly to commute to work contained proportionately more men, had much higher average household incomes ($21 231), owned more automobiles, were more likely to have a driver's license, and thus more household drivers, and worked overtime more often than both groups of bus commuters (i.e., JaxPASS and cash-paying users). Age was the only characteristic that was not significantly different among the three groups of employees.

Employee Changes in Travel Behavior

With respect to transit travel behavior, JaxPASS purchasers are distinguished particularly by the regularity with which the bus is used to commute to work; in particular, 92 percent indicated that they commute to work by bus five or more days per week. The transit use characteristics of these employees prior to buying a JaxPASS can be disaggregated into three groups. First, about 60 percent of the pass purchasers were already regular bus commuters and thus reported making no change in mode or transit trip frequency. The second group, representing about 20 percent of the purchasers, can be considered to have made a complete switch in modes and are therefore new transit users. The remaining 20 percent of the purchasers that make up the third group increased their use of transit by a more limited degree (e.g., by one or two days per week) since they previously used the bus three or four days per week to commute to work.

Assuming that commuting to work by bus is equivalent to taking two one-way commuter bus trips per day, JaxPASS purchasers made an average of 9.7 one-way commuter trips per week compared with an average of 8.0 for other bus commuters. Although these two means were statistically dissimilar ($t = 11.2$), as shown in Table 1, there was not a significant difference between the mean number of noncommuter one-way bus trips made on weekdays by JaxPASS (mean of 2.2) and non-JaxPASS commuters (mean of 1.9). Similarly, the means for the number of one-way bus trips made on weekends between the two groups (0.6 versus 0.4) is also not significantly different ($t = 0.9$). Thus, in terms of transit trip frequency, the major characteristic that distinguishes bus commuters who purchase a JaxPASS from those who do not is the degree to which transit is used to commute to work. The data indicate that JaxPASS purchasers are no more likely than other employed transit commuters to use the bus system at other times during the work week or on weekends.

Table 1. Comparison of means: employee travel behavior characteristics.

Characteristic	Pass Purchaser (A) Mean	Pass Purchaser (A) SD	Nonpass Bus Commuter (B) Mean	Nonpass Bus Commuter (B) SD	Nonbus Commuter (C) Mean	Nonbus Commuter (C) SD	t-Statistic[a] A-B	t-Statistic[a] B-C
One-way bus trips per week								
Commuter (N=86, 243)	9.67	0.992	7.95	1.73	NA	NA	11.2	-
Noncommuter (N=71, 215, 547)	2.21	4.296	1.87	3.319	0.19	0.891	0.6	-
Weekend (N= 85, 249, 574)	0.65	2.24	0.41	1.28	0.01	0.138	0.9	-
Total (N=67, 183, 513)	12.12	5.17	10.23	4.98	0.25	1.39	2.6	-
Walk time to bus stop (min) (N=78, 224, 434)	7.06	7.05	7.25	8.67	9.71	12.08	0.2	3.0
Automobile commute time (min) (N=66, 203, 844)	21.88	9.28	19.21	8.37	21.98	11.01	2.1	4.0
Bus commute time (min) (N=85, 246, 304)	33.94	12.20	31.15	13.25	37.89	15.32	1.8	5.5

Notes: Data from employee survey, December 1979 to February 1980.
Sample sizes are given in parentheses for each of the three groups studied.

[a] Between groups.

The mean total number of one-way bus trips normally made per week by employees who purchased a JaxPASS was 12.1 (compared with 10.2 for other bus commuters). Assuming that an employee works between 46 and 47 weeks of the year, JaxPASS users take an average of about 47 trips per month. This represents about seven more one-way trips compared with the breakeven level of 40 based on the normal $14.00 fare credited to JTA or about 12.7 additional trips compared with the breakeven level of 34.3 after taking into consideration the $2.00 subsidy that was in effect at the time the employee survey was administered.

Turnover Among Pass Purchasers

Although aggregate JaxPASS sales at most firms held steady or increased very slightly over time (assuming no change in pass price or level of employer subsidy), there was a fairly large amount of turnover in the particular individuals buying passes. Among three employers who had the highest pass sales during the start of the program, between 40 and 58 percent of the employees who had purchased a pass during the first sale month were not buying the pass one year later. Because aggregate sales did not decline, however, these employees were replaced by other employees. Based on responses obtained from employees who discontinued buying a pass, it appears that the decision was a reflection of normal changes in transit travel behavior and work-related factors. However, almost 10 percent of those who stopped buying the pass did so because of a reported dissatisfaction with the time and directional restrictions on the pass.

TRANSIT-OPERATOR-RELATED ISSUES

JaxPASS Program Expenses and Activities

The administrative costs required by JTA to maintain the monthly JaxPASS program (as distinct from start-up costs) appear very modest. During the course of the demonstration, a relatively fixed panel of 25 to 30 employers participated. Because recruiting of new firms was held to a minimum, only 2 to 3 person-days/month were expended by staff at the Jacksonville Coach Company Lines (a firm that manages the daily operation of the transit system under contract to the JTA), whereas between 1 to 2 person-days/month were expended by personnel at JTA. After data-collection tasks associated with the demonstration evaluation had been completed, the monthly pass program functions were able to be handled by existing staff personnel. Clearly, however, larger pass programs would require additional and possibly full-time staff members.

Ridership Impacts

Partly because of the constrained size of the pass program, relatively few new riders began using the system strictly because of the availability of an essentially undiscounted transit pass. Factors such as the $2 pass price discount, employer subsidies (typically $4.00 per pass), and the increasing cost of gasoline had a much more significant impact on an individual's decision to purchase a JaxPASS and use the bus mode for commuting.

Revenue Impacts

Revenue impacts (positive or negative) of selling JaxPASS through employers were also small. If the $2.00 pass discount that was being provided from demonstration grant funds is considered as revenue to JTA, then JTA experienced a net revenue gain of about $500/month. However, excluding this amount as revenue to JTA, the pass program resulted in a net revenue decrease of about $1500/month. This amount represents only 0.3 percent of the monthly farebox revenue collected by JTA. To the extent that more employers can be encouraged to subsidize the price of the pass as a fringe benefit to their employees, thereby inducing some of the marginal transit users to buy a pass, the potential revenue loss to the transit operator can be reduced. Positive revenue gains are in theory also possible from this new revenue source.

Although it is difficult to determine precisely, all available evidence indicates that very little revenue was lost because passholders lent their pass to others for use on weekends or during off-peak hours. This type of abuse was minimized in Jacksonville by having a color-coded pass for men and for women. Also, only individuals old enough to be working (e.g., 18 years of age or older) were eligible to buy a pass. Bus drivers could therefore screen the use of the pass by children or young teenagers.

Unauthorized use of the pass was further reduced by the time and directional restriction of the pass since once an individual arrives at work, the pass is not valid again (except on the downtown shuttle) until the morning peak ends.

Last, no cash-flow advantages of the JaxPASS were realized because of the relatively small amount of revenue obtained from JaxPASS sales versus the farebox and because some employers submitted pass-sale receipts toward the end of the month, which tended to offset the cash flow gains by employers who submitted receipts early in the month.

CONCLUSIONS

The Jacksonville TFP demonstration has provided a very useful data set for quantifying the impacts that result from implementing an employer-based monthly transit pass program. The main conclusions of the demonstration are highlighted below.

Although the pure convenience aspect of being able to purchase a pass at one's place of employment resulted in few individuals switching from other modes to transit, convenience did play a major part in a transit user's decision to buy a pass at work. This was revealed when 58 percent of the pass buyers stated that they would discontinue buying a pass if it was sold only through JTA's regular pass outlets.

In contrast to passes available to the general public, and thus to the entire transit-dependent community, passes sold through employers were typically thought of and used as commuter passes. Few new transit trips were taken by pass purchasers during off-peak hours or on weekends. Consequently, pricing the pass to provide little or no discounts over cash fares, with employees bearing all the up-front risks (e.g., unexpected sick days), resulted in a low level of pass sales. However, providing modest pass discounts and encouraging employers to subsidize the pass as an employee fringe benefit, or in lieu of an employer-provided parking space, resulted in substantial increases in pass sales.

Soliciting employers to participate in the program was successfully accomplished by relying on a personal meeting with a high executive officer at each potential firm. Most of the employers recognized the benefits to their employees by participating in the JaxPASS program. In fact, by the eighteenth month, one-third of the employers (9 out of 28) were providing partial (usually $4.00) or full subsidies to their employees who bought a pass. Administrative costs borne by the employer were small, ranging from 0.5 to 4 h/month. No firms discontinued their involvement in the program because of the administrative requirements associated with selling and distributing passes to their employees.

Administrative resources expended by the transit operator consisted of 3 to 4 person-days/month. These activities were handled by existing staff members. Of course, much larger TFP programs would require full-time staff.

The JaxPASS program resulted in some new transit users and the new revenue from these individuals helped to offset the revenues lost to the more frequent transit users who also bought passes. On balance, the introduction of the program resulted in slight negative revenue loss (about 0.3 percent of total monthly revenues). However, as additional employers join in subsidizing the pass price, thereby encouraging more marginal transit users to buy a pass, revenue losses because of the pass should decrease further.

ACKNOWLEDGMENT

The work described in this paper was performed under contract to TSC as part of the UMTA SMD program. The support of those agencies is hereby acknowledged. Particular recognition goes to Larry Doxsey of TSC, who served as technical advisor and monitor for this evaluation, and Vince Milione, who was the UMTA project monitor. In addition, Don Pill and Ruth Sargent of JTA, Leo Hall of the Jacksonville Coach Company Lines, and John Mullis and Rose Ella Feagin of Paragon Productions were helpful in providing much of the data from the site. Daniel Brand of Charles River Associates provided important insight and comments throughout the course of the evaluation.

The opinions and conclusions expressed in the paper are mine and do not necessarily reflect the views or policy of TSC, UMTA, or JTA.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

Abridgment

Graphical Person-Machine Interactive Approach for Bus Scheduling

AVISHAI CEDER AND HELMAN I. STERN

A highly informative graphical technique for the problem of finding the least number of buses required to service a given schedule of trips is described. The purpose is to develop the methodology for variable bus scheduling in which trip departure times can vary within acceptable tolerances. This is a continuation of a research project concerned with the problem of fixed scheduling where the timetable of trips and length of trip times are fixed. The motivation for this study comes from the Israel National Bus Carrier, Egged, which is responsible for scheduling an average of 54 400 daily trips by about 5200 buses. Consequently, the research takes on a practical nature. The approach used is based on the deficit-function theory where the deficit function at time t defines the total number of trips that have departed from a given terminal k less the number of trips that have arrived at k up to and including time t. The method developed is capable of aiding the scheduler to perform his or her tasks through a person-machine conversational mode. It allows

the scheduler to interject his or her own practical suggestions and to see immediately their effects on the final schedule. The method is based on the deficit-function graphical multiterminal display, which guides and advises the schedulers of possible directions in reducing fleet size. In addition, this methodology aids schedulers in evaluating the results of their own suggestions. The potential of this person-machine interactive bus-scheduling procedure is presented by using several practical examples.

The planner of bus work schedules is in charge of allotting vast resources, and naturally the aim is to allocate the buses in an optimal and feasible manner. A graphical approach to the problem of scheduling buses to trips is described. The approach is based on an algorithm capable of aiding the scheduler through a person-machine conversational mode. It allows the scheduler to select one of several computer-suggested directions, to interject his or her own suggestions, and to immediately see the effect on the final schedule through observation of a graphical representation on a cathode-ray tube (CRT) or computer-generated output.

This research is a continuation of an algorithm development described by Ceder and Stern (1,2). The motivation for the overall study comes from the Israel National Bus Carrier, Egged. Egged's operation (making up a fleet size of 5200 buses) is characterized by (a) a substantial number of deadheading (empty) trips in the schedule, (b) frequent changes in the schedule, and (c) a complex bus-route network with many different locations of trip departure and arrival points. Egged's buses perform an average of 54 400 daily trips, which are currently scheduled by a team of about 60 schedulers by using a trial-and-error Gantt-chart approach. The need to expedite many of the schedulers' tasks has led Egged's management to embark on investigating a more efficient procedure. The experience with Egged and the initial implementation of the approach proposed here are presented later.

The algorithms described previously (1,2) assume that the given timetable of trips is fixed. On the other hand, the experienced Egged schedulers consider variable trip departure times (within some acceptable tolerances).

The purpose of this paper is to develop the methodology for variable bus scheduling in order to achieve further reduction in the number of buses required. The main aim is to allow the schedulers to use a person-computer interactive procedure that will guide and advise them on evaluating the results of their own suggestions, which include practical considerations.

BACKGROUND AND DEFINITIONS

An early development of the approach used in this paper is based on the deficit-function theory. A deficit function is simply a step function that increases by 1 at the time of each trip departure and decreases by 1 at the time of each trip arrival. Such a function may be constructed for each terminal in a multiterminal bus system. To construct a set of deficit functions, the only information needed is a timetable of required trips. The main advantage of the deficit function is its visual nature (3,4). Let $d(k,t,S)$ denote the deficit function for terminal k at time t for the schedule S. The value of $d(k,t,S)$ represents the total number of departures less the total number of trip arrivals at terminal k up to and including time t. The maximal value of $d(k,t,S)$ over the schedule horizon $[T_1,T_2]$ is designated $D(k,S)$.

Let t_s^i and t_e^i denote the start and end times of trip i, $i \epsilon S$. It is possible to partition the schedule horizon of $d(k,t,S)$ into a sequence of alternating hollow and maximal intervals. The maximal intervals $M_r^k = [s_r^k, e_r^k]$, $r = 1,2,\ldots,n(k)$, define the interval of time over which $d(k,t)$ takes on its maximum value. Denote the length of M_r^k as $\bar{M}_r^k = e_r^k - s_r^k$. Note that the S will be deleted when it is clear which underlying schedule is being considered. The index r represents the rth maximal interval from the left and n(k) the total number of maximal intervals in $d(k,t)$. A hollow interval H_ℓ^k, $\ell = 0,1,2,\ldots,n(k)$, is defined as the interval between two maximal intervals. Hollows may consist of only one point. In case a hollow consists of one point not on the schedule horizon boundaries (T_1 or T_2), the graphical representation of $d(k,t)$ is emphasized by a clear dot.

If we denote the set of all terminals as T, the sum of $D(k)$ $\forall$ $k \epsilon T$ is equal to the minimum number of buses required to service the set T. This is known as the fleet-size formula and was independently derived by Bartlett (5), Linus and Maksim (6), Gertsbach and Gurevich (3), and Salzborn (7,8). Mathematically, for a given fixed schedule S,

$$N = \sum_{k\epsilon T} D(k) = \sum_{k\epsilon T} \max_{t\epsilon[T_1,T_2]} d(k,t) \quad (1)$$

where N is the minimum number of buses to service the set T.

When deadheading (DH) trips are allowed, the fleet size may be reduced below the level described in Equation 1. Ceder and Stern (1,2) describe a procedure based on the construction of a unit-reduction deadheading chain (URDHC), which when inserted into the schedule allows a unit reduction in the fleet size. The procedure continues to insert URDHCs until no more can be inserted or a lower bound on the minimum fleet is reached (1).

In order to understand the URDHC procedure, a three-terminal example is briefly explained. The example illustrated in Figure 1 is referred to a fixed schedule because at this point we do not allow trip and departure times to be varied. The schedule is made up of nine trips with a trip-time matrix for both potential service (in parentheses) and DH trips, as follows:

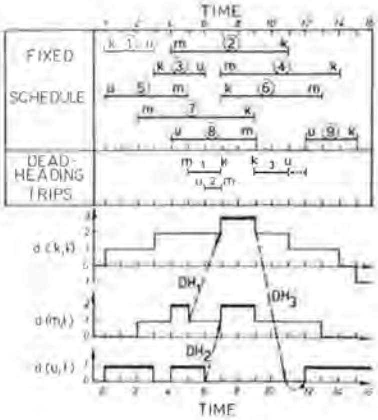
$[t_{ij}(t_{ij}')] =$

i \ j	k	m	u
k	0	2(6)	2(3)
m	2(7)	0	1(4)
u	2(3)	1(5)	0

where t_{ij} and t_{ij}' are the trip times of DH and service trips between terminals i and j, respectively. For the example in question, the minimum number of buses required (before insertion of DH trips) is $D(k) + D(m) + D(u) = 3 + 2 + 1 = 6$. The chain-construction method can be carried out by the first-in, first-out (FIFO) rule or by a chain-extraction procedure described by Gertsbach and Gurevich (3). The resultant six chains that use the FIFO rule are [1-8], [2], [3-9], [5-4], [6], and [7], according to the trip numbers indicated in the fixed-schedule part of Figure 1. These chains are assigned to individual buses.

By the insertion of DH trips, the scheduler is able to reduce the fleet size of the sample problem from six to five buses. Suppose that terminal k is selected as a candidate terminal for reducing its fleet requirement. A deadheading trip, DH_1, that departs from terminal m at t = 5 can arrive at k at $t = 7 = s_1^k$ based on the above trip-time matrix in

Figure 1. Three-terminal example of URDHC procedure using three DH trips to reduce fleet size by 1 at terminal k.



which t_{mk} = 2. This will have the effect of decreasing d(k,t) by one unit at and after t = 5. In order to eliminate the increase of D(m) at t = 7, another DH trip, DH_2, is inserted from terminal u to m at t = 6. Similarly, another DH trip is required, DH_3, to maintain the value of D(u) at and after t = 12. Note that a feasible insertion of a DH trip to link trip i at terminal u to trip j at terminal v (i,jϵS) requires the following:

$$t_e^i + t_{uv} \leq t_s^j \quad (2)$$

In the example shown in Figure 1, three DH trips are required to reduce D(k) from 3 to 2. An interesting observation is that instead of DH_3, another service trip can be inserted between terminals k and u from t = 9 to t = 12, since t_{ku}' = 3 (see the dotted line in Figure 1). In this way, the bus operator might increase the level of service for the passengers by using a technique to reduce its fleet size. After the DH trips have been inserted, the deficit functions are updated and the procedure is repeated until no further reductions of the fleet size are possible (1). The five chains can now be constructed through the FIFO rule: [1-8], [2], [3-DH_2-4], [5-DH_1-6], [7-DH_3-9].

DEFICIT-FUNCTION APPROACH WITH VARIABLE DEPARTURE TIMES

The following section is an analysis of bus scheduling through the deficit-function approach when variable departure times are allowed.

Variable Trip-Departure Times

A general description of a technique to reduce the fleet size for variable departure-time scheduling problems can be found in Gertsbach and Stern (4). This technique for job schedules uses the deficit-function representation as a guide for local minimization in maximal intervals, M_r^u $\forall$ uϵT. However, when variable departure times are considered along with a possible insertion of DH trips, the problem becomes more complex. The scheduler who performs shifting in trip departure times is not always aware of the consequences that could arise from these shifts. This section analyzes a method that will serve as a guide for the scheduler, particularly in a person-computer conversational mode.

Let us define $[t_s^i - \Delta_2^i, t_s^i + \Delta_1^i]$ as the tolerance time interval of the departure time of trip i, iϵS, where Δ_1^i is the maximum delay from the scheduled departure time (the case of a late departure) and Δ_2^i is the maximum advance of the trip scheduled departure time (the case of an early departure).

According to the definitions in the previous section, s_r^u and e_r^u, the start and end of the rth maximal interval M_r^u [r = 1,2,...,n(u)] at terminal u, uϵT, are associated with $t_s^{i_r}$ and $t_e^{j_r}$, respectively. That is, s_r^u refers to the departure time of a trip designated i_r and e_r^u to the arrival time of a trip designated j_r (where i_r, j_r can be selected from several trips that depart at time s_r^u and arrive at e_r^u, respectively). Now we can state a proposition that enables the scheduler to determine whether the fleet size can be reduced through shifts in trip departure times:

If $\bar{M}_r^u$ for all r [r = 1,2,...,n(u)] satisfies one or more of the conditions stated below, then by appropriate shifts (indicated in the conditions) of trip departure times, the fleet size at terminal u is decreased by 1 and remains unchanged for all other terminals. For the following four conditions, let $t_s^{i_r}$ be the departure time of trip i_r from terminal u to m and $t_e^{j_r}$ be the arrival time of trip j_r from terminal k to u.

Condition (a)

If $\bar{M}_r^u \leq \Delta_1^{i_r} + \Delta_2^{j_r}$, then $t_s^{i_r}$ and $t_e^{j_r}$ can be shifted in opposite directions so that the total shifting time is equal to $\bar{M}_r^u$ provided that neither D(m) nor D(k) increases as a result of this shift.

Condition (b)

If $\bar{M}_r^u < \Delta_1^{i_r}$, then $t_s^{i_r}$ can be shifted to the right by time $\bar{M}_r^u$, provided that D(m) does not increase because of this shift. The shifts in condition (a) can also be applied here.

Condition (c)

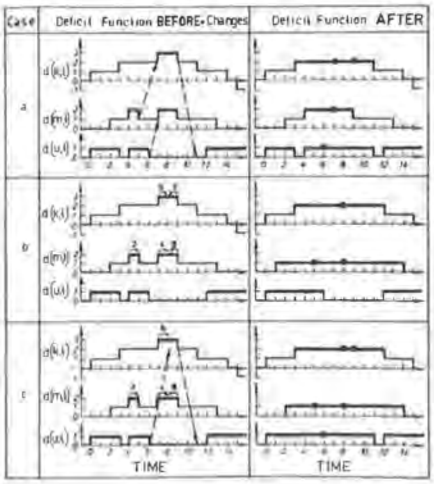
If $\bar{M}_r^u \leq \Delta_2^{j_r}$, then $t_e^{j_r}$ can be shifted to the left by time $\bar{M}_r^u$, provided that D(k) does not increase because of this shift. The shifts in condition (a) can also be applied here.

Condition (d)

If $\bar{M}_r^u \leq \Delta_i^{i_r}$ and $M_r^u \leq \Delta_2^{j_r}$, then condition (a), (b), or (c) could be considered.

Another possibility is to consider variable trip departure times along with the DH trip-insertion procedure. In that case, the feasibility

Figure 2. Before and after deficit-function representation for reducing fleet size through (a) URDHC procedure, (b) shifting trip departure times, and (c) mixed procedures.



requirement shown in Equation 2 is changed to the following:

$$t_e^i - \Delta_2^i + t_{uv} \le t_s^j + \Delta_1^j \quad (3)$$

Multiobjective Criteria

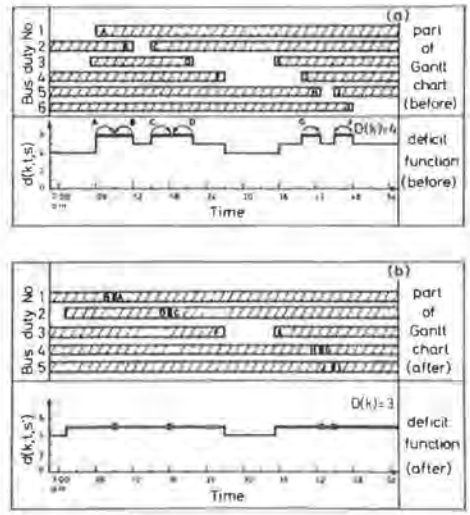
The main goal in the bus-scheduling problem is to reduce the fleet size, especially during major peak periods in a normal daily operation. This reflects the real possible saving in capital cost. However, when a person-machine conversational mode is incorporated into the scheduling process, secondary objectives can be adopted. In this way, the scheduler will be able to evaluate the results of his or her own suggestions in order either to reduce operating costs or to examine whether the resultant schedule follows a given policy.

In the proposition given above, four conditions are mentioned. If condition (b) or (c) or (d) is fulfilled, the scheduler might face an optional decision: to reduce the number of shifts or to keep the shift times as small as possible. For example, in the first option, a single trip departure time is shifted by time $\bar{M}_r^u$. In the second option, two trip departure times are shifted, each by time $\frac{1}{2}\bar{M}_r^u$. If the policy is to minimize changes in the timetables, the first option is preferable. If the policy is to adhere as closely as possible to a planned timetable, the second option is given priority.

A trade-off is also observed between insertion of DH trips and shifting trip departure time. For example, Figure 2 includes three scheduling cases for the fixed schedule presented in Figure 1. In case (a), as in Figure 1, the fleet size at terminal k is reduced by 1 through insertion of three DH trips. In case (b), the fleet size is reduced by 1 in both terminals k and m through shifts of trip departure times. In case (c), a mixed operation on the deficit function enables a reduction in the fleet size by 2 [the same result as that in case (b)] both through shifting trip departure times and inserting DH trips. Note that the indicated numbers of the shifted trips and the DH trip times are the same as the example in Figure 1. In addition, $\Delta_1^i = \Delta_2^i = 1$ time unit for all the nine trips in the schedule.

In this trade-off situation, there are two clear secondary objectives. The first is to minimize the changes in the planned timetables and to attempt the use of DH trips instead of shifting trip departure times. The second objective is to minimize the operational cost and to attempt shifting trip departure times rather than inserting DH trips. The first objective might be associated with the transport authorities' desire to maintain a highly reliable timetable for the passengers, whereas the second objective generally expresses the view of the bus operator.

Figure 3. Demonstration of superiority of deficit-function representation over Gantt-chart approach.



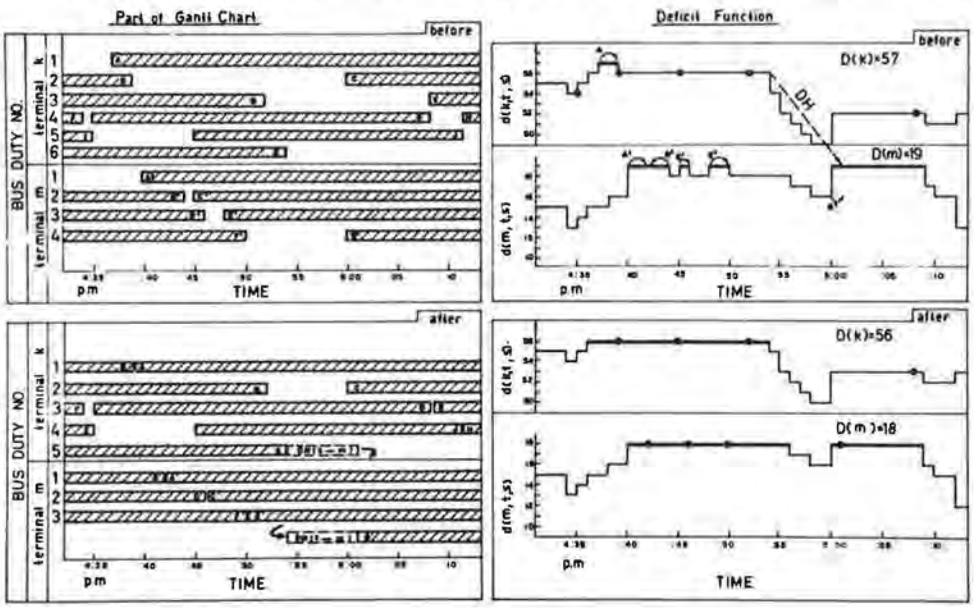
INITIAL EXPERIENCE WITH BUS COMPANY

As mentioned in the introduction, this research was motivated by Egged, the Israel National Bus Carrier. The need for a quicker response to timetable changes has led Egged management to investigate the use of a fully computerized scheduling system. This system is based on an optimization technique reported by Gavish, Schweitzer, and Shlifer (9) and discussed by Ceder and Gonen (10). Attempts to implement the computer-generated schedule have failed because of the inability to meet a number of necessary practical constraints. Such constraints include the need to plan for more than 2500 bus trips (the program maximum capability), consideration of drivers' meal breaks and relocation, constraints imposed by nonidentical bus types, etc. It was also felt that the optimal schedule provided had no advantage over the traditional methods. Furthermore, the schedulers were not confident in using the optimal technique because of their lack of knowledge of the operation of this method.

It was therefore decided to continue the search for an approach that would combine the advantages of modern electronic computers while at the same time allow the scheduler to make his or her own contribution to the scheduling task. Because of its visual nature, a deficit-function approach was selected to be used on a person-machine interactive system. The implementation of the deficit-function approach is now gradually being introduced so that the schedulers can gain confidence in this approach and reach the conclusion that this method is very useful in increasing the speed and accuracy of the scheduling tasks.

Two simple real-life examples are given here to demonstrate the implementation stage at Egged. In the first example, illustrated in Figure 3, the schedulers claimed at the beginning that it was

Figure 4. Two-terminal case in which two buses are saved through shifting departure times and modified URDHC procedures.



impossible to further reduce the fleet size from their Gantt-chart scheduling results. In Figure 3, only a small part of the Gantt chart and the corresponding deficit functions is shown, that part undergoing changes. The schedulers allow for an acceptable shift in trip departure time for all trips by $\Delta_1^i = \Delta_2^i = 3$ min. By illustrating d(k,t,S), we saved a bus by shifting six trips, each by 3 min. In the Gantt chart, before changes (Figure 3a), trips are designated by letters for identification. This is for the sake of clarity in referring to shifts and reconstruction of the Gantt-chart chains in Figure 3b.

From Figure 3, the problem appears easy to handle. However, in Figure 3a only 6 out of 52 bus duties are shown, and those 6 rows in the Gantt chart were spread among the other 46 rows.

Following this demonstration, the schedulers were not wholly convinced. They argued that with a little more effort on their part, they too could have saved the bus as in Figure 3. Therefore, a more complex example was decided on, as shown in Figure 4. This second example refers to an afternoon schedule of two Egged branches, Ramle, terminal k, and Lod, terminal m. On the left-hand side of Figure 4, only those trips involved with changes are exhibited in the before and after Gantt-chart representation; trips are designated by letters. On the right-hand side, the deficit functions of the complete schedule are illustrated, which include trips not shown on the left-hand side. The schedulers again claimed that no further reductions could be achieved from the D(k) + D(m) = 57 + 19 = 76 fleet-size requirement. The information given was that $\Delta_1^i = \Delta_2^i = 2$ min and that the DH trip time between the terminals is $t_{km} = t_{mk} = 7$ min.

As seen in Figure 4, six shifts in trip departure times and a single DH trip are required in order to save two buses and to reduce the fleet requirement to 74 buses. It was only after this second demonstration that the schedulers began to take a serious interest in the deficit function. This was due particularly to its simplicity and visual nature. The schedulers expressed their positive feeling about the valuable aid of this gradual approach.

CONCLUDING REMARKS

This paper attempts to develop a methodology for variable bus scheduling in order to further reduce the fleet size in comparison with the developed algorithm (1,2) for a fixed bus-scheduling problem. The approach used here employs a highly informative graphical technique based on deficit-function theory and is designated primarily for operation in a conversational person-computer mode. For example, the fixed bus-scheduling algorithm (1,2) has been programmed for use with a PDP 11/40 video screen and light pen. This allows the scheduler to insert and delete trips quickly and to immediately see the effects on fleet size through the updated deficit-function display. In this way, the scheduler can use the light pen to shift a trip departure time and to see the effect on the number of buses required. The objective of the proposed approach is also to allow the scheduler to consider multiobjective criteria through evaluation of his or her own suggestions.

Work is continually in progress at Egged in three parallel directions: (a) providing the Gantt-chart schedulers with a computer-generated graphical representation of deficit functions, (b) preparing the ground for a person-machine interactive system, and (c) conducting further research to provide an algorithm with an enhanced flexibility to incorporate a large number of practical considerations.

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Publication of this paper sponsored by Committee on Transit Service Characteristics.

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