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Authors of the Papers in This Record

Anderson, Shirley C., School of Business Administration and Economics, California State University, Northridge, Calif. 91330

Attanucci, John, Multisystems, 1050 Massachusetts Avenue, Cambridge, Mass. 02138

Brög, Werner, Socialdata GmbH, Hans-Grässel-Weg 1, 8000 München 70, West Germany

Fielding, Gordon J., School of Social Sciences, Institute of Transportation Studies, University of California, Irvine, Calif. 92717

Förg, Otto G., Socialdata GmbH, Hans-Grässel-Weg 1, 8000 München 70, West Germany

Herzenberg, Anne, Service Planning Office, Massachusetts Bay Transportation Authority, Transportation Building, 10 Park Plaza, Boston, Mass. 02116; formerly with the Long Island Railroad

Kornhauser, Alain L., Transportation Program, Princeton University, Engineering Quadrangle, Princeton, N.J. 08544

Lerner-Lam, Eva, Planning and Operations, San Diego Metropolitan Transit Development Board, 620 C Street, Suite 400, San Diego, Calif., 92101

Markowitz, Joel, Metropolitan Transportation Commission, Hotel Claremont, Berkeley, Calif. 94705

Milione, Vincenzo, Center of Labor and Industrial Relations, New York Institute of Technology, Old Westbury, N.Y. 11568; formerly with UMTA

Mötsch, Günter, Verkehrs- und Tarifverbund Stuttgart, Rotebühlstrasse 133, 7000 Stuttgart 1, West Germany

Oram, Richard L., Greater Bridgeport Transit District, 525 Water Street, Bridgeport, Conn. 06604

Rinderle, Carolyn A., Transportation Program, Princeton University, Engineering Quadrangle, Princeton, N.J. 08544

Spielberg, Frank, SG Associates, Inc., 4200 Daniels Avenue, Annandale, Va. 22003

Vozzolo, David, Multisystems, 1050 Massachusetts Avenue, Cambridge, Mass. 02138

Ziering, Eric A., Caliper Corporation, P.O. Box 239, Waban, Mass. 02168; formerly with Charles River Associates

Public Transit Performance Evaluation: Application to Section 15 Data

GORDON J. FIELDING AND SHIRLEY C. ANDERSON

Performance indicators are quantitative measures that enable managers and policymakers to monitor the current position of an agency and outline strategies to improve performance. Because public services have many different dimensions of performance, a large number of performance indicators are normally used. In this paper a conceptual model is used to help select a few performance indicators that represent all the important performance concepts. Data were obtained from a national sample of 311 urban bus transit systems in the first year that data were reported under Section 15 of the Urban Mass Transportation Act of 1965, as amended. The steps in the performance-evaluation procedure involve defining a conceptual model of performance and designing a balanced set of performance indicators that represent all performance concepts. Factor analysis is then used to select the indicators that best represent all dimensions of performance. This small, representative set of performance indicators is used to analyze performance and to establish peer-group rankings.

The results of applying a performance-evaluation procedure for publicly owned enterprises to a national sample of 311 urban bus transit systems are presented in this paper. The research was sponsored by UMTA to test the usefulness for performance analysis of a new data bank resulting from the Section 15 reporting requirements (1). Section 15 of the Urban Mass Transportation Act of 1964, as amended, has improved the comparability and coverage of transit statistics by requiring a uniform set of statistics from all urban transit applicants for operating assistance. The first year of statistics reported under Section 15 [fiscal year (FY) 1978-1979] has been used in this study (2).

Federal and state government sponsors of local public services often attempt to evaluate relative performance of the service agencies to account for use of public subsidy funds and promote efficient and effective service delivery. Performance measurement is also important to management because performance indicators are the quantitative measures that enable managers and policymakers to determine the current position of an agency and outline strategies to improve performance.

But public services typically have many different dimensions of performance, giving rise to large numbers of performance indicators. In this paper a conceptual model is used to help select a few performance indicators that represent all the important performance concepts. This method reduces both data collection and analysis requirements.

PERFORMANCE-EVALUATION METHOD

The object of any peer-group performance-evaluation process, such as the one to be described, is to select from that group systems that have extremely high or extremely low performance. But two significant problems associated with performance evaluation must be considered. The first is the methodological problem of devising a complete and workable model of performance by categorizing performance objectives into concepts and using uniform quantifiable measures of each concept.

Evaluation of transit performance and the development of performance indicators is not new. In 1958 the National Committee on Urban Transportation specified service standards, objectives, and measurement techniques (3). Many of the measures and standards used by transit today were documented in this study. Because of the limited availability of transit statistics, early applications of performance evaluation relied on regional data. Adaptation of the theoretical work on performance evaluation to transit in California was accomplished by Fielding et al. (4) in 1977. The performance concepts developed by Fielding et al. are currently used by California, Florida, Iowa, Michigan, and Pennsylvania to develop performance monitoring and reporting requirements (5). The Fielding conceptual model has been used in this study. The 12 performance concepts selected are given in Table 1 as the group headings of 60 performance measures.

A second problem associated with use of performance indicators is the amount of data that needs to be collected. If many indicators are desired, then much data is required, and the output of the indicators is confusing and time consuming to analyze. In this paper current Section 15 data are used to analyze performance by finding a small, representative set from the 60 performance measures given in Table 1. By using factor analysis on a set of performance indicators that are numerically balanced across the different performance concepts, an optimal number of independent dimensions of performance can be determined. The most representative performance measures for each factor dimension will constitute a small set that covers the dimensions of the much larger set.

Factor analysis is a general method for identifying and analyzing patterns of variation in a data set. In this method linear combinations of the variables in the data set (called factors) are computed, which are then used to (a) summarize the variance in the original variables, and (b) organize the original variables into subgroups. These factors, which are uncorrelated with one another, can be used as a reduced set of summary performance indicators (6). Alternatively, as done in this paper, the factors can be used to identify a reduced set of performance indicators (those most strongly correlated with each of the factors), whose standardized values can then be used to rank the performance of the systems.

The following alternate approaches have been explored in previous research (7) to solve the data problem and to rank transit systems by performance:

1. Use of many performance indicators and a simple method of analyzing the averages and totals of the indicators;
2. Use of all the performance measures in factor analysis, but a reduction of the amount of output to be analyzed to the sum of the factor scores; and
3. Use of a conceptual model and factor analysis to select a few performance indicators that represent all the important performance concepts; both data collection and analysis requirements are reduced by this method.

The results of the three approaches to performance ranking were compared by using historical data on 57 U.S. bus transit systems. A Wilcoxon matched-

Table 1. Performance measures by concept.

Concepts and Performance Measures	Variable
Cost-efficiency measures	
I. Labor efficiency	
Vehicle hours per employee	TVH/EMP
Revenue vehicle hours per operating employee hour	RVH/OEMP
Vehicle miles per employee	TVM/EMP
Peak vehicles per executive, professional, and supervisory employees	PVEH/ADM
Peak vehicles per operating personnel	PVEH/OP
Peak vehicles per maintenance, support, and servicing personnel	PVEH/MNT
II. Vehicle efficiency	
Vehicle hours per active vehicle	TVH/AVEH
Vehicle hours per peak vehicle requirement	TVH/PVEH
Vehicle miles per active vehicle	TVM/AVEH
Vehicle miles per peak vehicle requirement	TVM/PVEH
Revenue vehicle miles per vehicle mile	RVM/TVM
Revenue capacity miles per vehicle mile[a]	RCM/TVM
III. Fuel efficiency	
Revenue vehicle miles per gallon diesel	RVM/FUEL
Vehicle miles (bus) per gallon diesel	TVM/FUEL
Revenue capacity miles (bus) per gallon diesel[a]	RCM/FUEL
IV. Maintenance efficiency	
Total vehicles per maintenance expense	TVEH/MEXP
Vehicle miles per maintenance employee	TVM/MNT
1,000,000 vehicle miles per roadcall	TVM/RCAL
V. Output per dollar cost	
Revenue vehicle hours per operating expense	RVH/OEXP
Vehicle miles per operating expense	TVM/OEXP
Revenue capacity miles per operating expense[a]	RCM/OEXP
Revenue vehicle hours per total labor and fringe expenses	RVH/TWG
Revenue vehicle hours per operations labor and fringe expenses	RVH/OWAG
Revenue vehicle hours per vehicle maintenance labor and fringe expenses	RVH/VMWG
Revenue vehicle hours per administrative labor and fringe expenses	RVH/ADWG
Service-effectiveness measures	
VI. Utilization of service	
Passenger trips per revenue vehicle hour	TPAS/RVH
Passenger trips per revenue vehicle mile	TPAS/RVM
Passenger trips per peak vehicle	TPAS/PVH
Passenger miles per vehicle capacity mile[a]	PASM/RCM
Passenger miles per passenger[a]	PASM/TPS

Concepts and Performance Measured	Variable
Service-effectiveness measures (continued)	
VII. Social effectiveness	
Revenue vehicle hours per service area population	RVH/POP
Passengers per service area population	TPAS/POP
Passengers per elderly population	TPAS/ELD
Passengers per automobileless population	TPAS/AUT
Frequency of service[a]	FREQ
VIII. Operating safety	
1,000,000 vehicle miles per accident	TVM/ACC
Revenue vehicle hours per accident	RVH/ACC
IX. Revenue generation	
Passenger revenue per peak vehicle	REV/PVEH
Passenger revenue per revenue vehicle hour	REV/RVH
Operating revenue per revenue vehicle hour	TREV/RVH
Passenger revenue per passenger	REV/TPAS
Passenger revenue per vehicle capacity mile[a]	REV/RCM
X. Public assistance	
Revenue vehicle hours per local capital and operating assistance[a]	RVH/LSUB
Revenue vehicle hours per state capital and operating assistance[a]	RVH/SSUB
Revenue vehicle hours per total operating assistance	RVH/OSUB
Revenue vehicle hours per total capital and operating assistance	RVH/TSUB
Passengers per local operating assistance[a]	TPAS/LOA
Passengers per total capital and operating assistance	PAS/TSUB
Passenger revenue per total capital and operating assistance	REV/TSUB
Urban area population per total operating assistance	POP/OSUB
Urban area population per total capital and operating assistance	POP/TSUB
Passenger revenue per total operating assistance	REV/OSUB
Passengers per total operating assistance	PAS/OSUB
Cost-effectiveness measures	
XI. Service consumption per expense	
Passengers per operating expense	PAS/OEXP
Passenger miles per operating expense[a]	PASM/OEX
Passengers per total labor and fringe benefits	PAS/TWAG
Passengers per gallon diesel fuel	PAS/FUEL
Passenger miles per total expense[a]	PASM/TEX
XII. Revenue generation per expense	
Ratio of operating revenue to operating expense	REV/OEXP
Ratio of total revenue to total expense	REV/TEX

Note: Definitions for statistics are provided in the Urban Mass Transportation Industry Uniform System of Accounts and Records and Reporting System, January 1977, Volume II.
[a]Dropped because of missing values or inconsistent data.

pairs sign-rank test indicated that all three rankings were essentially equivalent (at the 0.05 level of significance). It was also determined that the sum of individual factor scores (number 2) was slightly less accurate in representing the total set of indicators than a small set of one indicator per performance concept (number 3). Thus in this study the method of factor analysis and the selection of a small set of indicators to represent all dimensions of transit performance were chosen.

APPLICATION TO SECTION 15 DATA SET

The steps in the performance-evaluation procedure are as follows:

1. Define a conceptual model of performance for classifying the individual performance measures, as in Table 1;
2. Balance the number of performance indicators representing each concept in accordance with a desired conceptual weighting scheme;
3. Use factor analysis to find the set of factors that represent all the different orthogonal dimensions in the performance-concept space;
4. Select variables that have a high correlation with each independent factor to represent each performance dimension; and
5. Use the small representative set as performance indicators to analyze performance and to establish peer-group rankings.

Candidate Performance Measures

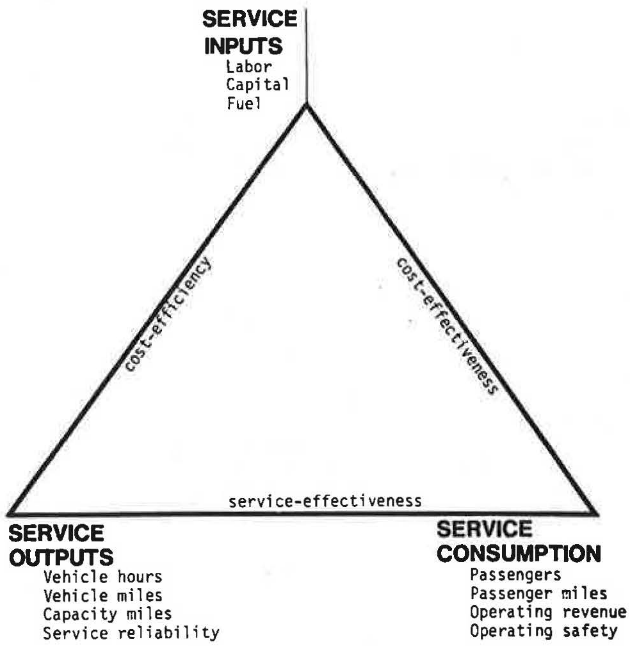
As shown in Figure 1, three types of statistics are available from Section 15 data and census reports to represent transit performance concepts: service input, service output, and service consumption statistics. Together they can be used to monitor both the costs of producing service and its utilization. The three categories of statistics yield three types of performance measures: cost efficiency, service effectiveness, and cost-effectiveness. Cost efficiency measures the resources expended to produce transit service (e.g., labor cost per hour); service effectiveness measures the extent to which service provided is used (e.g., passengers per hour); and cost-effectiveness measures the service used against the resources expended (e.g., passengers per dollar operating cost).

A wide range of transit performance measures is possible. As illustrated by the data in Table 1, 60 performance measures are listed and grouped into 12 concepts that can be calculated by using Section 15 data. There are other performance measures, but a sufficient number have been listed to demonstrate their use in transit analysis.

In selecting performance measures, consideration was given to the completeness and reliability of the data. Financial statistics are the most reliable. Passenger statistics are the least reliable--particularly passenger miles of travel.

Census data were added to calculate the popula-

Figure 1. Transit performance concepts.



tion and automobile ownership measures for social effectiveness and for the public assistance performance ratios in Table 1. All demographic variables were taken from the County and City Data Book, 1972; the Rand McNally Commercial Atlas and Marketing Guide, 1980; or the UMTA Transit Directory. The population figure used for each bus system is the total urbanized area population (where it could be obtained); otherwise the most relevant city population was used.

Controllability was another consideration in selecting performance measures. It is advantageous if performance indicators reflect those aspects that are under the control of the transit managers. Generally, system assets (fixed facilities) and system environment (service area and its characteristics) are more or less fixed and are not under operator control in the short run, whereas service input and output can be controlled to a greater degree. Service consumption (demand) is more difficult to control because demand for transit depends on system environment as well as disposable income, fares, and levels and quality of service.

Although the performance measures were limited by availability, reliability, and controllability, the list of feasible measures is far more than transit managers can use when analyzing transit performance. Parts of a transit organization may use many individual indicators, but a smaller, more representative set is required for system management.

From the list of 60 performance indicators, 12 had to be deleted because of missing data or measurement error. (Deleted indicators are marked with a footnote in Table 1.) All performance measures that used passenger mile data were deleted because fewer than 80 of the 311 systems reported passenger miles. Performance measures that used revenue capacity miles were also deleted because of both a high percentage of missing cases and because revenue capacity was inconsistently measured across systems; i.e., many systems reported the same value for revenue vehicle miles and for revenue capacity miles. Another deletion was the frequency-of-service variable, which was computed by using the number of line miles. This variable appeared to be double-counted for some systems. State and local assistance measures also were deleted because there was no way of ascertaining whether the reported value of 0.0 meant no assistance or a missing value.

The data used in the analysis were also carefully edited for unreasonable data values. Both the editing process and missing values eliminated 50 percent of the systems. Nevertheless, the remaining 155 systems constitute a substantial data set.

Preliminary Analysis

Several analyses were conducted before choosing the balanced set of 32 variables used to represent the performance concepts defined in Table 1 and shown in Figure 1. (Deleted variables are indicated by a footnote in Table 2.) First, a preliminary analysis was performed on the 48 variables listed in Table 2, which are grouped by the same 12 concepts used in Table 1. The rotated factor matrix indicated that 10 factors were sufficient to describe all 12 concepts. However, two of the factors represented the public-assistance concept, and one of these factors represented only the two public-assistance measures based on urban population. These two variables were then dropped because their factor was too narrowly defined to be useful, and also because the urban-population measure is not consistently related to the service-area population. For example, small bus systems in large cities could have the same urban-population measure as the regional transportation authority for that city, but actually serve much smaller populations.

Second, to assure that the definition of the simple structure of performance was not being distorted by data measurement error or by the paucity of measurements for the safety and fuel-efficiency concepts, the set of 46 indicators was further culled for insufficiently measured variables and was balanced by performance concept. Otherwise, given a weakness in data definition, the structure defined by the factor analysis with varimax rotation (which tends to spread the variability equally among the factors) might submerge the safety and fuel-efficiency concepts and might split other concepts into several subconcepts, such as public assistance and public assistance per population. Although only two indicators were available for fuel and safety, three indicators were used for each of the other concepts. The following criteria were used for choosing the best indicators for each concept:

1. The consistency and comparability of the data values; and
2. The ability of the variable to define a single factor; i.e., the retained variables were those with the highest loadings on a factor in the preliminary analysis.

Based on means, standard deviations, and the correlations among the performance measures calculated for the 311 bus systems, one performance measure (RVM/TVM) was dropped from further analysis because it had so little variance among systems that it could not act as a discriminator of performance. PVEH/ADM was dropped because it was not correlated with any other variables and therefore did not contribute to any factor dimension with eigenvalue greater than 1. This variable was subject to measurement error in the 1979 data set because purchased transportation (contract service) was recorded as an administration expense by many systems.

For labor efficiency, TVH/EMP and RVH/OEMP were dropped because they are more related to output per dollar and revenue generation than to any other efficiency measures. One maintenance efficiency mea-

Table 2. Variables used in analysis grouped by performance concept.

Concepts, Performance Measures, and Variable Number	Variable
Cost-efficiency measures	
I. Labor efficiency	
1[a]	TVH/EMP
2[a]	RVH/OEMP
3	TVM/EMP
4[a]	PVEH/ADM
5	PVEH/OP
6	PVEH/MNT
II. Vehicle efficiency	
7	TVH/AVEH
8	TVH/PVEH
9[a]	TVM/AVEH
10	TVM/PVEH
11[a]	RVM/TVM
III. Fuel efficiency	
12	RVM/FUEL
13	TVM/FUEL
IV. Maintenance efficiency	
14	TVEH/MEXP
15	TVM/MNT
16[a]	TVM/RCAL
V. Output per dollar cost	
17	RVH/OEXP
18[a]	TVM/OEXP
19	RVH/TWG
20	RVH/OWAG
21[a]	RVH/VMWG
22[a]	RVH/ADWG
Service-effectiveness measures	
VI. Utilization of service	
23	TPAS/RVH
24	TPAS/RVM
25	TPAS/PVH
VII. Social effectiveness	
26	RVH/POP
27	TPAS/POP
28	TPAS/ELD
29[a]	TPAS/AUT
VIII. Operating safety	
30	TVM/ACC
31	RVH/ACC
IX. Revenue generation	
32	REV/PVEH
33	REV/RVH
34	TREV/RVH
35[a]	REV/TPAS
X. Public assistance	
36[a]	RVH/TSUB
37[a]	POP/TSUB
38[a]	PAS/TSUB
39[a]	REV/TSUB
40	PAS/OSUB
41[a]	POP/OSUB
42	RVH/OSUB
43	REV/OSUB
Cost-effectiveness measures	
XI. Service consumption per expense	
44	PAS/OEXP
45	PAS/TWAG
46	PAS/FUEL
XII. Revenue generation per expense	
47	REV/OEXP
48	REV/TEX

[a]Deleted from initial set in order to form the balanced set of 32 indicator measures.

sure--TVM/RCAL--was dropped because it correlates only with subsidy per population. This may indicate reporting error because there was greater-than-expected variance on this popular indicator. The three output-per-dollar-cost variables with the highest factor loadings and smallest number of missing values reported were retained. Because REV/TPAS measures only average fare level rather than effectiveness in attracting passengers, it was dropped in favor of the other three revenue-generation measures. The many possible public assistance measures were reduced to three by concentrating on operating assistance ratios. Operating assistance was believed to be less biased against new systems than total, operating plus capital, subsidy. The 48 variables and the final set of 32 performance measures used in further analyses are given in Table 2.

The balanced set of performance measures, which puts approximately equal weight on each of the performance concepts, was then factor analyzed to determine the number of statistically independent performance concepts. From these results, a small set of representative indicators was drawn.

Factor Analysis

R-mode factor analysis (BMDP-P4M principal component analysis with varimax rotation) was performed to identify the basic patterns of variance among the set of 32 performance measures and to extract those factors that best represent the underlying structure of the data. The explained variance of each of the nine extracted factors is given in the VP (or eigenvalue) row at the bottom of Table 3. The sum of the explained variances equals 28.8, which is 90 percent of the total variance in the data. Only those factors with an eigenvalue greater than or equal to 1 were extracted and retained. This criterion ensures that only components that account for at least the variance of a single variable will be treated as significant. Only nine factors are significant, which implies that several of the performance concepts have the same statistical meaning; i.e., concepts V and IX, VI and XI, and I and II are highly related to each other.

The rows in Table 3 are arranged so that, for each factor, the variables most closely related to that factor are listed first. The concept associated with each variable is listed by Roman numeral in the left margin beside each variable.

Factor 1 is defined by the first five variables listed, which represent concepts V and IX. There is a minor loading by a variable representing concept IV, but this variable is more highly correlated with factor 7. Thus factor 1 represents concept V (output per dollar of cost) and to a lesser extent concept IX (revenue generation). Revenue generation is strongly negatively related to revenue hours of service per dollar through the impact of differences of city density. High revenue generation is associated with operation in dense cities, where high employee wage rates and slow average speed of operation result in low output per dollar of operating expense. Although factor 1 combines two performance concepts, it differentiates urban bus systems from suburban and rural systems.

Factor 2 represents concept VI (utilization of service) and the closely associated concept XI (service consumption per dollar expense). The ratio of revenue generation to peak vehicles is a complex variable that is associated with the two dimensions of performance: factors 1 and 2.

Factor 3 represents concept II (vehicle efficiency) and also one labor-efficiency ratio (peak vehicles per operator). Systems that rank high in service per peak vehicle also rank high in the number of operators per peak vehicle. Thus the relationship between peak vehicles per operator and vehicle efficiency is negative. The remaining two labor-efficiency measures (concept I) are associated with both factors 3 and 7.

Factor 4 measures only fuel efficiency, factor 5 represents public operating assistance, and factor 6 measures social effectiveness.

Although factor 7 is highly correlated only with one of the two maintenance-efficiency ratios, it appears to represent the maintenance-efficiency concept. Of the remaining three variables that correlate with this factor, one is the other maintenance-efficiency variable and another is peak vehicles per

Table 3. Factor analysis of 32 performance variables derived from performance concepts.

Concept	Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9
		Factor Analysis Results								
V	RVH/OWAG	0.935	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V	RVH/OEXP	0.927	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
V	RVH/TWG	0.924	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IX	TREV/RVH	-0.807	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IX	REV/RVH	-0.705	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
VI	TPAS/RVM	0.000	0.889	0.000	0.000	0.000	0.000	0.000	0.000	0.000
XI	PAS/OEXP	0.000	0.887	0.000	0.000	0.000	0.000	0.000	0.000	0.000
VI	TPAS/PVH	0.000	0.877	0.000	0.000	0.000	0.000	0.000	0.000	0.000
XI	PAS/TWAG	0.000	0.866	0.000	0.000	0.000	0.000	0.000	0.000	0.000
VI	TPAS/RVH	0.000	0.859	0.000	0.000	0.000	0.000	0.000	0.000	0.000
IX	REV/PVEH	-0.489	0.502	0.000	0.000	0.000	0.000	0.000	0.000	0.000
II	TVM/PVEH	0.000	0.000	0.885	0.000	0.000	0.000	0.000	0.000	0.000
II	TVH/PVEH	0.000	0.000	0.877	0.000	0.000	0.000	0.000	0.000	0.000
I	PVEH/OP	0.000	0.000	-0.802	0.000	0.000	0.000	0.000	0.000	0.000
II	TVH/AVEH	0.000	0.000	0.633	0.000	0.000	0.000	0.000	0.000	0.000
III	TVM/FUEL	0.000	0.000	0.000	0.987	0.000	0.000	0.000	0.000	0.000
III	RVM/FUEL	0.000	0.000	0.000	0.986	0.000	0.000	0.000	0.000	0.000
III	PAS/FUEL	0.000	0.000	0.000	0.958	0.000	0.000	0.000	0.000	0.000
X	REV/OSUB	0.000	0.000	0.000	0.000	0.989	0.000	0.000	0.000	0.000
X	PAS/OSUB	0.000	0.000	0.000	0.000	0.978	0.000	0.000	0.000	0.000
X	RVH/OSUB	0.000	0.000	0.000	0.000	0.977	0.000	0.000	0.000	0.000
VII	RVH/POP	0.000	0.000	0.000	0.000	0.000	0.926	0.000	0.000	0.000
VII	TPAS/POP	0.000	0.000	0.000	0.000	0.000	0.865	0.000	0.000	0.000
VII	TPAS/ELD	0.000	0.000	0.000	0.000	0.000	0.851	0.000	0.000	0.000
IV	TVM/MNT	0.000	0.000	0.000	0.000	0.000	0.000	0.934	0.000	0.000
I	PVEH/MNT	0.000	0.000	-0.483	0.000	0.000	0.000	0.784	0.000	0.000
IV	TVEH/MEXP	0.540	0.000	0.000	0.000	0.000	0.000	0.643	0.000	0.000
I	TVM/EMP	0.000	0.000	0.497	0.000	0.000	0.000	0.643	0.000	0.000
XII	REV/OEXP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.960	0.000
XII	REV/TEX	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.933	0.000
VIII	RVH/ACC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.944
VIII	TVM/ACC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.924
	VP	5.217	4.667	3.606	3.052	3.011	2.677	2.623	2.036	1.948

Note: The above factor-loading matrix has been rearranged so that the columns appear in decreasing order of variance explained by factors. The rows have been rearranged so that for each successive factor, loadings greater than 0.5000 appear first. Loadings less than 0.4500 have been replaced by zero.

maintenance, support, and servicing personnel (PVEH/MNT), which is an example of a variable that measures two concepts--labor efficiency and maintenance efficiency. The remaining variable measures labor efficiency (TVM/EMP). The labor-efficiency measures used do not represent a separately measurable statistical construct, but instead are closely related to the maintenance-efficiency and vehicle-efficiency factors. Because labor expense by function had many missing values, the information could not be used in the analysis. A more accurate and complete listing of labor expense by function in future Section 15 reports may provide a better definition for labor-efficiency measures than those used in this research.

Factor 8 is defined by the two revenue-generation-per-expense indicators: ratio of passenger revenue to operating expense and ratio of total revenue to total expense. Finally, factor 9 represents the two safety-performance indicators.

Table 4. Factors and representative performance indicators.

No.	Definition	Performance Indicators Chosen to Represent Factors
1	Output cost	Revenue vehicle hours per operating expense (RVH/OEXP)
2	Service utilization	Total passengers per revenue vehicle mile (TPAS/RVM)
3	Vehicle efficiency	Total vehicle miles per peak vehicle (TVM/PVEH)
4	Fuel efficiency	Total vehicle miles per gallon of fuel consumed (TVM/FUEL)
5	Public assistance	Passenger revenue per operating assistance (REV/OSUB)
6	Social effectiveness	Revenue vehicle hours per urban population (RVH/POP)
7	Maintenance efficiency	Total vehicle miles per maintenance employee (TVM/MNT)
8	Revenue generation per expense	Passenger revenue per operating expense (REV/OEXP)
9	Safety	Revenue vehicle hours per accident (RVH/ACC)

Selection of Representative Indicators

A small set of nine performance indicators was then created by using a single measure to represent each of the statistically independent dimensions of performance variation. Either the best statistical or the more logical measure was chosen from the variables that had the highest loadings on each factor. These measures are given in Table 4. All nine members of the set, except the first, were the variables that had the highest loading on a particular factor. Nevertheless, the variable RVH/OEXP, which had the second highest loading on factor 1, was chosen to represent that factor. Hours per operating expense appears closest to representing the range of cost- and revenue-per-hour variables that loaded on factor 1. The variable RVH/OEXP is widely and fairly consistently collected by transit systems, and its loading on factor 1 was only 0.005 less than the top-loading variable RVH/OWAG, for which data might be less consistent.

(Reviewers of this paper have commented on the emphasis given to the best statistical measure as the representative indicator for each of the 12 dimensions of performance. We acknowledge that other high-loading indicators might be more appropriate for some studies. Analysis of the FY 1980 data is currently in progress, and improvements in the data set may yield other indicators.)

None of the indicators for social effectiveness was particularly helpful. What is actually needed is a measure of the market share gained by transit within the transit service area. Population of service area is not reported in the Section 15 data,

and attempts to obtain sufficient data from operators were unsuccessful.

The objective of this paper was not to advocate the superiority of the nine indicators listed in Table 4. Rather the objective was to develop a methodology that could be improved by using subsequent, and more complete, Section 15 reports. Transportation agencies require unnecessarily large amounts of data from operating agencies for performance analysis when a smaller data set would satisfy the requirements. In this paper the thesis that a small set of data can be used to represent the major dimensions of transit performance is substantiated, and how the data might be used is described. Specification of an ideal set of indicators must wait until factor analysis can be conducted with a larger set of master variables on each dimension. The indicators given in Table 4 are proposed as being representative of the dimensions.

The representative set was used as the basis for ranking system performance and grouping the bus systems into peer groups. The standard or Z-scores (defined as the variable value minus its mean and divided by its standard deviation) was computed for each of the nine performance indicators.

Use of Individual Performance Indicators

Performance indicators based on individual factors can be used to identify strengths and weaknesses within a transit system relative to a standard, a peer-group average, or to its own past performance. The evaluation may be directed toward internal management or to external audiences such as state and federal funding agencies. One use of performance indicators might be in conjunction with a two-tier system of public financial assistance: a base level of support plus a second tier of incentive subsidies. The incentive subsidies would be designed to reward improvement of performance relative either to the previous year's performance or relative to some established standard or industry average. The incentive subsidies could also be designed to result in a loss of some portion of the subsidy for negative changes in performance indicators. The Los Angeles Transportation Commission has implemented such a two-tiered system (8).

The identification of relative strength and weakness in particular systems may require costly on-site visits to investigate the causes. Therefore, some method of distinguishing the most significant subgroup of high and low performers must be followed to ration scarce resources for costly follow-up analysis. An example of such a method was the pilot phase of the Michigan transit performance analysis program (9). Step 1 in the performance evaluation was to calculate indicator values that were outliers, which were defined as values beyond one standard deviation from the group mean. Step 2 was to sum the number of outliers for each system. The high- and low-performance systems (i.e., those with the largest numbers of outliers) were selected as candidates for follow-up analysis.

A similar method that used Z-scores was attempted. The number of Z-scores greater than 1 or less than minus 1 for each system were tallied, and the 50 systems with the largest number of such outlier values were identified. An alternative method would be to sum the nine Z-score values to distinguish the high and low performers.

Performance Ranking

Differences in performance across transit operators can be calculated from the standard or Z-score of each transit system on each of the nine performance indicators. The sign (positive or negative) of each Z-score indicates a value greater than or less than the group mean for each of the performance indicators. Also, the size of the standard value indicates the distance from the mean in standard deviation units.

A ranking scale was developed by summing the nine performance-indicator Z-scores for each transit system. The ranking scale, called ZSUM, indicates the overall performance of a bus system; a positive ZSUM value indicates overall performance greater than the mean for the group of 155 systems that had reported sufficient data to be included in the analysis. Each of the nine performance indicators was given equal weight in calculating ZSUM. If an agency wished to emphasize either the efficiency or effectiveness dimensions of performance, then the selected Z-score would be weighted more heavily, and different rankings would result.

The bus systems were then sorted in descending order by ZSUM value. After ordering the systems by the ZSUM overall-performance measure, the mean and standard deviation of ZSUM were calculated and six groups were created to indicate categories of deviation from the mean of ZSUM (see Table 5). The report by Anderson and Fielding (1) contains a complete listing of the nine performance indicators and the ZSUM score for each system, sorted into the six groups of Table 5.

Differences in system operating environments or data-collection methods, as well as in management practices, cause differences in transit system performance. The performance-evaluation methodology presented here can be used to make overall performance comparisons and to identify outlier systems. Additional information would be required to explain apparent differences in performance. For example, if outlier systems are defined as all those systems with ZSUM scores beyond one standard deviation from the mean, then systems in groups 1 and 6 (Table 5) would receive a follow-up investigation. Detailed evaluation of outlier systems might include employee questionnaires and personal interviews with management.

This study used inaugural year Section 15 data. When information from subsequent years becomes available and is more reliable, performance indicators can be used to compare a system with itself over time and to examine trends in performance in comparison with peer-group systems. Rate-of-change analyses of performance combined with peer-group comparison can identify systems with emerging problems or improving conditions relative to overall performance of the transit industry.

CONCLUSIONS

Performance evaluation should start from a conceptual framework that defines the different, measurable dimensions of performance and represents the desired weight of each in the analysis. Use of a

Table 5. Groups based on deviation from mean overall performance (ZSUM).

Group	No. of Standard Deviations from Mean	No. of Systems
1	Above +1	14
2	Between +0.5 and +1	28
3	Between mean and +0.5	33
4	Between mean and −0.5	43
5	Between −0.5 and −1	21
6	Below −1	16
Total[a]		155

[a]Total number of systems in analysis.

small subset of performance measures that represents each concept reduces the cost of data collection and focuses attention on a manageable number of performance indicators.

The comprehensive coverage of Section 15 data belies the many missing or erroneous values reported in the inaugural report (2). Only 155 of 311 bus systems could be used in this analysis. Data reporting could be simplified by selecting a conceptual framework of performance and requesting only two or three different performance measures to represent each performance dimension. Sufficient data would then be available to monitor trends in the transit industry as well as to provide data that management could use to improve the performance on each property.

ACKNOWLEDGMENT

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Method for Estimating the Costs of Drivers' Wages for Bus Services

ANNE HERZENBERG

To plan changes in bus transit service it is often necessary to estimate the costs of individual routes. Unfortunately, it is difficult to isolate the cost of one route from the costs of an entire network. A model for estimating only the marginal costs of drivers' wages for individual bus services is presented. The model shows that union work rules and an uneven demand for service influence labor costs, and that the marginal cost of drivers' wages is higher during peak hours than during off-peak hours. The model, developed for the Massachusetts Bay Transportation Authority (MBTA), is used to estimate how much the MBTA would save if any of 12 currently operating routes were dropped. This application reveals that the model is simple to use and can be applied by any agency considering increasing or decreasing bus transit service. The results demonstrate that the model is extremely accurate for routes for which the ratio of peak service to base service is similar to the ratio for the entire system. For peak-period-only bus service, or routes offering concentrated service during peak hours, a technique is presented for establishing a range in the cost of drivers' wages.

To plan changes in bus transit service it is often necessary to estimate the costs of individual services. For example, a transit agency might want to know how much it costs to run route x, or how much would it cost to add a bus to route y during the evening peak period. Such questions are difficult to answer because they force the agency to decide which, if any, administrative or overhead costs to allocate to individual routes. Furthermore, for agencies that assign individual drivers and buses to multiple routes, it is difficult to allocate the costs of wages, benefits, fuel, and maintenance to isolated services.

A model for estimating the marginal costs of drivers' wages for bus services is presented in this paper. The model deals only with drivers' wages for two reasons. First, drivers' wages are usually the largest single expense associated with bus services; therefore, an operator cannot estimate the total cost of a service accurately unless the drivers' wages are estimated accurately. Second, because the factors controlling drivers' wages (such as union work rules) are different from the factors controlling expenses such as fuel, maintenance, and administration, a separate model is necessary for drivers' wages.

The paper is divided into five sections. In the first section the difficulty of estimating the drivers' wages associated with individual services is

explained. In the second section techniques used elsewhere for estimating wages are briefly reviewed. In the third section the model is presented and calibrated for the Massachusetts Bay Transportation Authority (MBTA). The results of applying the model to 12 MBTA routes are discussed, and in the fourth section the techniques are given for estimating drivers' wage costs in cases where the first model appears likely to be inaccurate.

COST-ESTIMATION PROBLEM

The difficulty in calculating precisely how much a transit agency spends on drivers' wages for a bus route is that wage rates vary within agencies. If there were a single wage rate, a transit agency could calculate the cost of wages for a route simply by multiplying the flat rate by the number of bus hours associated with the route. However, union work rules and the peaked nature of the demand for transit service create such significant variations in wage rates that this simplistic approach would be unrealistic.

Spread penalties and the 8-hr guarantee create most of the variation in wages, and they appear in the union contracts of most transit agencies. (Note that a spread penalty is equivalent to a split-shift premium.) A spread penalty is a bonus paid to any driver whose daily assignment, or run, keeps him on duty more than a specified number of hours after he begins in the morning. For example, an MBTA driver receives 1.5 times the basic wage rate for the time he works in the eleventh hour after his run begins, and he earns double pay for work in the twelfth and thirteenth hours. (Note that this paper includes several examples involving the MBTA. These examples are out of date because the MBTA now hires part-time drivers and thereby avoids much of the expense associated with the work rules discussed. Nevertheless, the examples illustrate problems still facing the majority of public transit agencies.)

Accordingly, an MBTA driver's daily pay can be anywhere from $88.38 to $116.00. A driver earns $88.38 if he is on duty for 8 continuous hours because the hourly wage is $11.0475. If, however, the driver is on duty for 8 hr during a 13-hr spread, he can earn $116.00, as follows:

Item	Cost ($)
5 hr at $11.0475	55.24
2 hr at $22.095	44.19
1 hr at $16.571	16.57
Total	116.00

Although spread penalties lead to variation in daily pay, the 8-hr guarantee leads to even greater variation in the amount that drivers earn for each platform hour. [Note that a platform hour is an hour in which a driver is responsible for a bus. It can involve driving time (on, to, or between routes) or scheduled layover time between trips. A nonplatform hour is an hour for which a driver is paid, although he is not responsible for a bus.] An 8-hr guarantee forces a transit agency to pay each driver for 8 hr of work even though the total daily demand for service is too low to provide 8 hr of driving for every driver needed during the peak periods. As a result, many drivers are productively employed for fewer than 8 hr a day, and their runs include slack time or nonplatform hours.

To calculate how much a driver earns for a particular platform hour, the driver's daily pay is divided by the number of hours he drives a bus. For example, a driver who earns $88.38 per day and drives for 7 hr and 50 min costs the MBTA $11.28 per bus hour, but a driver who earns $116.00 and drives for 7 hr (3 hr during the morning peak period and 4 hr during the afternoon peak period) costs the MBTA $16.57 per bus hour. What then is the wage cost of the vehicle hour?

Many transit agencies answer this question by calculating an average cost per platform hour. They divide the total amount they spend on drivers' wages by the number of hours of service they provide. Then, to calculate the cost of wages for an isolated service, they multiply the average cost per platform hour by the number of platform hours associated with the service. In doing so they implicitly assume that drivers earning spread penalties or driving fewer than 8 hr per day are evenly distributed throughout the day. As Figure 1 shows, drivers earning high wages for each platform hour are heavily concentrated in the peak periods.

Figure 1 shows the number of buses in service from one MBTA garage during each 0.25 hr of a weekday. It also shows the number of drivers working on each of four different driver shifts. The horizontal axis gives the time of day, and the vertical axis gives the number of buses or drivers in service. The figure shows that there are more than twice as many buses in service during the morning and afternoon peak periods as there are during the rest of the day. It also shows that a high percentage of the drivers working during the peak periods have expensive shifts (with spreads between 12 and 13 hr), although none of the drivers working in the middle of the day has such expensive shifts. As shown in Figure 1, schedulers assign drivers to inexpensive shifts whenever possible, but in order to operate peak-period service, it is impossible to avoid spread penalties and slack time. It is a fine art to fill the driver requirement at minimum cost to a transit agency, and some agencies use computers with automated run-cutting programs such as RUCUS to aid this process.

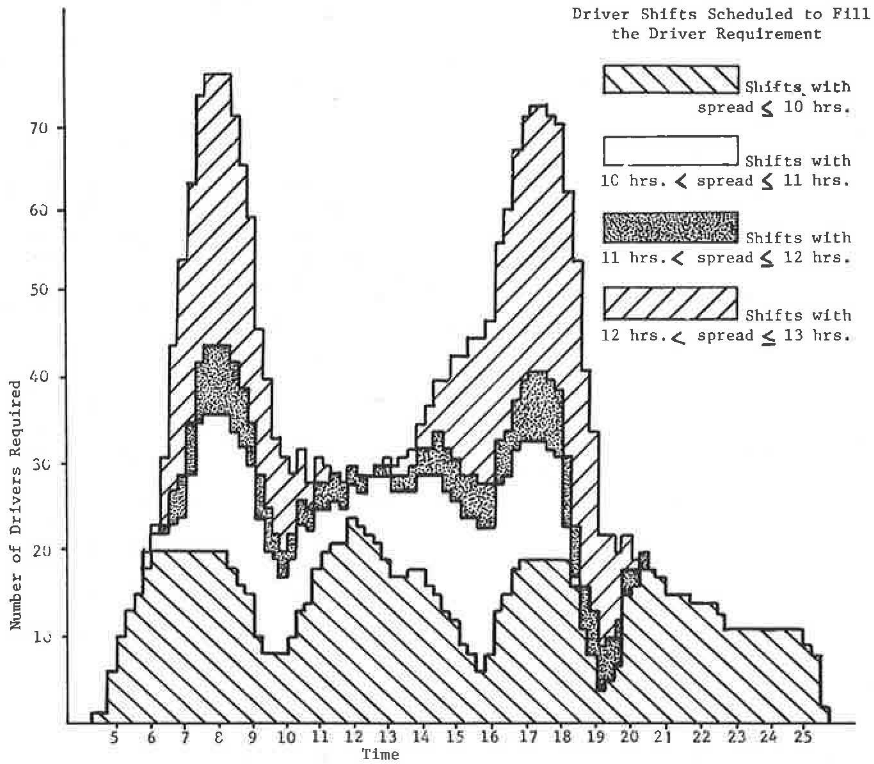
In summary, the cost-estimation problem is that drivers' wage costs vary throughout the day, and any accurate model must deal with this problem.

PREVIOUS WORK

Because drivers' wages depend on the scheduling process, the most accurate way to calculate the drivers' wages associated with a particular route is to compare the costs of two sets of drivers' runs, only one of which provides drivers for the route in question. For minor service changes, such as adding a route involving one bus and one driver, this may be a feasible technique, but for substantial changes that involve a number of drivers it can be prohibitively time consuming (except for agencies that cut runs by computer). Consequently, scheduling methods are rarely used to estimate costs. At the other extreme, the least-accurate method for estimating the cost of drivers' wages is average costing, which was described in the previous section.

To bridge the gap between these two extremes, transit agencies and researchers have developed a number of techniques for estimating driver costs without creating entirely new schedules. Cherwony, Gleichman, and Porter (1) reviewed some of these techniques and evaluated their applicability to service planning. As they explain, none of the available models is entirely satisfactory. The simpler models ignore the variation of labor costs throughout the day, and the models that reflect this variation (such as the Bradford model, the Northwestern model, and the Adelaide model) tend to be complex. These models express the cost of labor for a bus service as a function of the driver hours needed for the service. [Note that driver hours, which are also referred to as pay hours, worked hours, or man

Figure 1. Driver requirement for one MBTA garage.



Note that the figure shows the driver requirement for the Charlestown garage for the schedule period beginning June 22, 1981.

hours, include both actual driving time (platform hours) and slack time (nonplatform hours).] For example, the Bradford model expresses cost as a function of pay hours, and the Adelaide model involves worked hours, among other variables. Consequently, the application of these models involves three separate steps. First, the user must calibrate the model, i.e., the cost of 1 pay hour or 1 worked hour for the agency in question must be estimated. Second, the number of pay hours or worked hours required for a particular service must be estimated. Finally, the user substitutes the estimate of driver time into the calibrated model to estimate the wage cost of the service. The first two steps are complex because they force the user to consider the idiosyncratic work rules and scheduling practices of a particular agency.

Some simpler models that reflect the temporal variation of wages have been proposed, but few have been tested for accuracy. One such technique is the Arthur Andersen model, which assumes that a driver's pay for each platform hour is a weighted average of a fixed hourly pay for driving in the base period and a fixed hourly pay for driving in the peak period. This appears to be a reasonable approximation, but the model did not give reasonable results when calibrated for the MBTA (2).

After reviewing the available models, Cherwony and Porter (3) developed a model that, like the Bradford, Northwestern, and Adelaide models, reflected the variation in labor costs throughout the day and considered the scheduling practices of the agency in question. The Cherwony and Porter model shared several common shortcomings with these models:

1. Although the model reflects the temporal variation of labor costs, it assumes that the unit cost of driver time is constant during large segments of the day. (It divides the day into five segments: early morning, morning peak, midday, evening peak, and evening.)
2. The model expresses cost as a function of driver hours rather than vehicle hours. As a result, the user must consider the scheduling practices of the agency in question twice: once to calibrate the model (i.e., to estimate the cost of 1 driver hour), and again to estimate the driver time necessary for a particular service. The model would be easier to use if it expressed cost in terms of vehicle hours so that the user would only have to consider the scheduling practices of a particular agency once: to calibrate the model.
3. The model assumes that the cost of one unit of driver time during a specific part of the day is equal for all services operating during that part of the day. Unfortunately, this is not so. For example, both peak-period-only and all-day services operate during the evening peak period, but the unit costs of these services are not equal. An agency might be able to eliminate one split-shift driver by eliminating only 6 or 7 hr of peak-period-only service, whereas it would have to eliminate 8 hr of an all-day service in order to eliminate one straight shift.

MODEL FOR ESTIMATING DRIVERS' WAGES FOR A BUS SERVICE

The model presented in this section reflects some of the principles of the models mentioned previously but avoids some of the shortcomings. It uses a sample set of drivers' runs for the agency in question to calculate a separate unit cost of drivers' wages for each 0.5 hr of the day. It takes into account that

1. The mixture of shift types used to operate a schedule varies throughout the day, and

2. Slack time (nonplatform hours) and spread penalties are unevenly distributed among runs.

Other important features of the model are as follows.

1. Simplicity: The model expresses the cost of drivers' wages for a bus service as a function of platform hours. Because platform hours are equivalent in number to vehicle hours, a planner can use the model without estimating the total number of platform and nonplatform hours associated with a particular service.
2. General applicability: Any transit agency could calibrate the model to reflect its own union work rules and use it to estimate the drivers' wages associated with its own services.

Calibration

To calibrate the model for a particular transit agency, a sample of drivers' runs is used and a separate wage per platform hour for each 0.5 hr of the day is estimated. For example, to estimate the cost of a platform hour between 6:00 and 6:30 a.m., the steps are as follows.

1. Identify all runs (i) with at least one-quarter of a platform hour between 6:00 and 6:30 a.m.
2. For each run (i), divide the total daily wage (W_i) by the number of platform hours in the run (PH_i). This gives w_i, the average wage per platform hour for run i.
3. Find the average value of w_i over all i. This average is an estimate of the wage per platform hour between 6:00 and 6:30 a.m.

This can be stated as follows:

$$\bar{w}_{6:00 \text{ to } 6:30 \text{ a.m.}} = \sum_{i=1}^{n} [(W_i/PH_i)/n] \quad (1)$$

where

$\bar{w}_{6:00-6:30 \text{ a.m.}}$ = wage per platform hour between 6:00 and 6:30 a.m.,
W_i = total daily wage for run i,
PH_i = number of platform hours in run i, and
n = number of runs (i) with at least one-quarter of a platform hour between 6:00 and 6:30 a.m.

Figure 2 helps clarify this procedure. The figure represents all of the drivers' runs for one MBTA garage for a weekday. The horizontal axis gives the time of day, and each two-part horizontal bar represents one driver's run identified by the driver's number. For example, driver 1031 leaves the bus garage shortly after 7:00 a.m. and remains on duty until 11:00 a.m., when his first half ends. His second half begins at 2:00 p.m. and ends at 6:00 p.m. The figure shows only the platform hours in each run. Runs with fewer than 8 platform hours and with various spread penalties are also indicated.

The vertical column helps with the first step in calibrating the model by isolating all of the runs with platform hours between 6:00 and 6:30 a.m. From these runs, the planner can identify those with at least one-quarter of a platform hour inside the column, and then complete step 2 by calculating the wage per platform hour for each run. (Some of these costs are given in the figure as multiples of the basic hourly wage rate.) The final step is to average these wages per platform hour.

To calibrate the model completely, the planner must repeat the three steps for each 0.5 hr of the day.

Figure 3 is a plot of the wage per platform hour for each 0.5 hr of the MBTA day. The curve through the points is hand fit. The shape of the curve is not surprising, considering the mix of shifts used to fill the driver requirement at each time of the day (see Figures 1 and 2). In the early morning, midday, and evening hours most of the active drivers are on straight shifts (shifts with spreads less than 10 hr). In the peak periods, however, most of the active drivers are on swing shifts with high spread penalties. Figure 3 shows that the highest values of the wage per platform hour occur in the outer peak-period hours. As Figures 1 and 2 show, the MBTA schedules a group of runs with spreads of about 11 hr and low spread penalties between 7:00 a.m. and 6:00 p.m. Because these runs do not reach the outer peak-period hours, the MBTA has to use shifts involving higher spread penalties to fill the driver requirement in the outer peak-period hours.

Because the total driver requirement is much higher in the peak period than in the off-peak period, many of the runs with platform hours in the peak period include nonplatform hours, and the wage per platform hour for these runs is usually one-sixth to one-seventh of the total daily pay for the run. (The wage per platform hour for a straight run is about one-eighth of the total daily pay for the run.) This is one of the reasons that the wage per platform hour is higher in the peak period than in the off-peak period.

Application

Once the model has been calibrated for a particular transit agency, the cost of drivers' wages for an isolated service can be calculated as follows:

$$C_r = \sum_{\text{all } x} P_{rx} w_x \quad (2)$$

where

C_r = cost of drivers' wages for route r,
P_{rx} = number of platform hours required for route r in period x, and
w_x = wage per platform hour for period x.

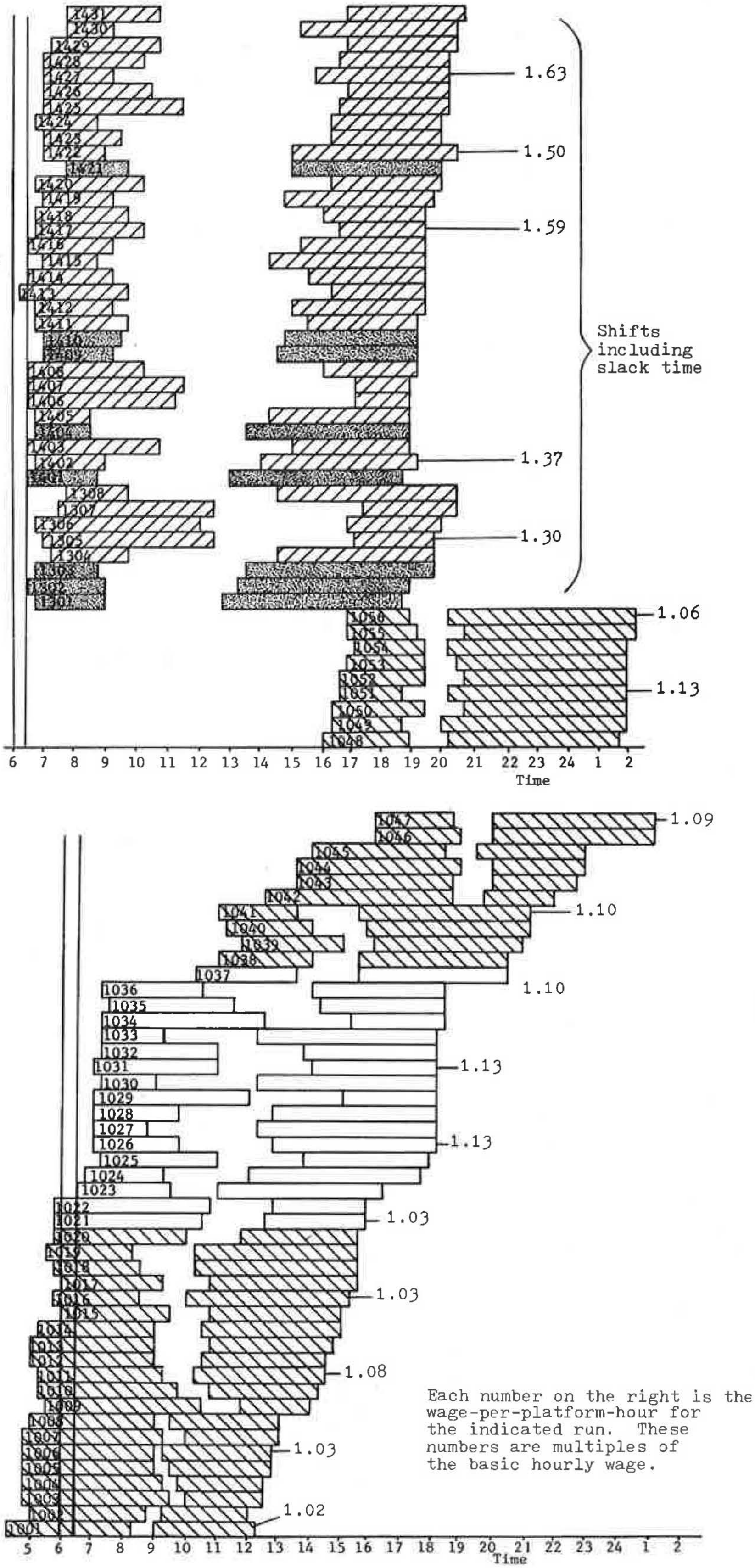
Figure 4 shows how the model is used to calculate the cost of drivers' wages for a single route. On the left of the figure a route profile shows the number of buses and drivers needed to operate the MBTA's route 60 during each 0.25 hr of the day. The first column gives the number of platform hours needed for each 0.5 hr of the day, and the second column gives the wage per platform hour for each 0.5 hr (expressed as a multiple of the basic wage rate). The third column gives the cost of wages for all drivers working on route 60 in each 0.5 hr (again as a multiple of the basic wage rate). Each entry in the third column is the product of the corresponding entries in the first and second columns. The total cost of drivers' wages for route 60 is the basic wage rate multiplied by the sum of the entries in the third column. In this case the total cost is $827.

In the example, each wage per platform hour is read from the hand-fit curve in Figure 3. (In using values read from the curve rather than the exact values calculated from a sample of runs, it is assumed that there would be a smooth, continuous relationship between the wage per platform hour and time if enough runs and sufficiently small time intervals were used in calibrating the model.)

EVALUATION

How accurate is the model? Ideally, this question would be answered by applying the model to actual

Figure 2. Driver runs for one MBTA garage.



Notes: The figure shows the driver runs for the Charlestown garage for the schedule period beginning June 22, 1981. See Figure 1 for a key to shift types.

Figure 3. Wage per platform hour for MBTA drivers.

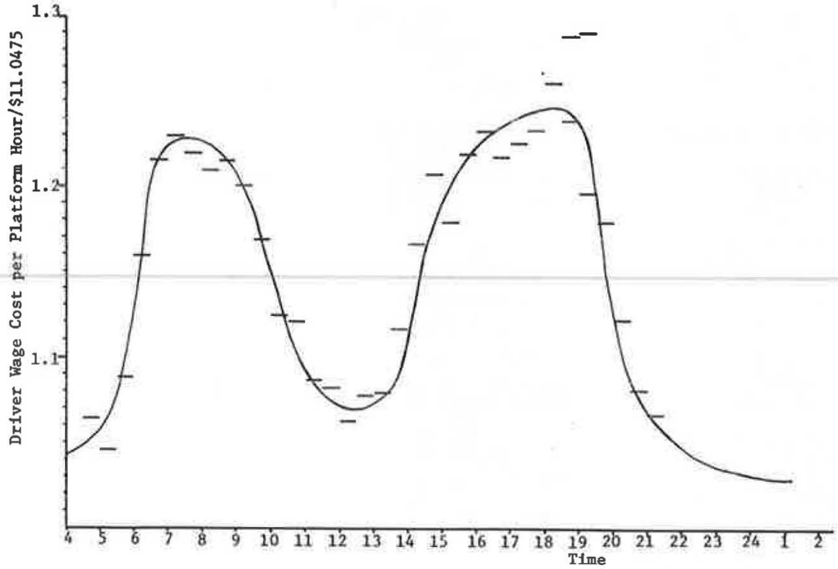
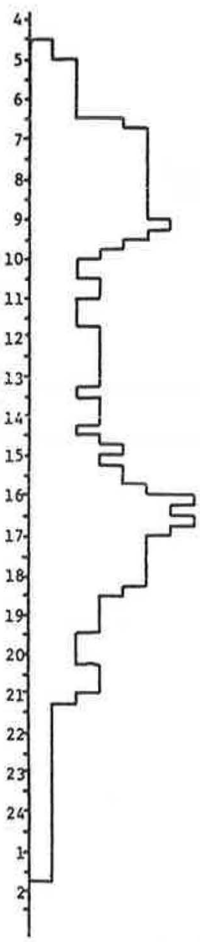


Figure 4. Application of model to estimate the cost of drivers' wages for MBTA route 60.



Platform Hours	Wage Cost per Platform Hour/$11.0475*	Wage Cost/$11.0475*
0.5	1.05	0.52
1.0	1.05	1.05
1.0	1.10	1.10
1.0	1.16	1.16
2.25	1.22	2.75
2.5	1.23	3.08
2.5	1.23	3.08
2.5	1.22	3.05
2.5	1.21	3.02
2.75	1.2	3.30
1.75	1.17	2.05
1.0	1.13	1.13
1.5	1.11	1.67
1.0	1.09	1.09
1.25	1.08	1.35
1.5	1.07	1.60
1.5	1.07	1.60
1.25	1.08	1.69
1.5	1.09	1.63
1.25	1.13	1.41
1.75	1.18	2.07
1.75	1.20	2.10
2.25	1.22	2.74
3.25	1.23	4.00
3.25	1.24	4.03
2.50	1.24	3.10
2.50	1.25	3.12
2.25	1.25	2.81
1.5	1.24	1.86
1.5	1.22	1.83
1.0	1.15	1.15
1.25	1.10	1.38
1.5	1.08	1.62
1.25	1.06	1.32
0.5	1.05	0.52
0.5	1.04	0.52
0.5	1.04	0.52
0.5	1.04	0.52
0.5	1.03	0.51
0.5	1.03	0.51
0.5	1.03	0.51
0.5	1.03	0.51
0.25	1.03	0.26
		74.83

Note: Cost of drivers' wages for route 60 = 74.83 x $11.0475 = $827/day.
*$11.0475 was the basic hourly wage for MBTA drivers in June 1981.

routes and comparing the resulting estimates with estimates developed through rescheduling, but this approach is beyond the scope of this paper.

A quicker alternative would be to compare the model's estimates for a sample of currently operating routes with the wages paid to the drivers actually assigned to these routes. But even this approach is complex because the drivers in many transit agencies each work on several routes during a single day. Nevertheless, the actual cost of drivers' wages can be estimated for the individual routes in a network by allocating each driver's wages to his multiple routes in proportion to the time spent on each route.

The data in Table 1 compare estimates that result from the model with the actual costs of drivers' wages for 12 currently operating MBTA routes. (The data also explain precisely how the actual cost of each route was calculated.) The results prompt some significant conclusions about the model.

The model yields extremely accurate cost estimates for routes on which the driver-requirement profile is approximately the same shape as the driver-requirement profile for the whole MBTA network. These routes include routes 60, 96, 220, 222, 300, and 700. (The driver-requirement profile for route 60 is shown in Figure 4.)

Table 1. Costs of drivers' wages for MBTA routes.

Route No.	Actual Cost[a] ($)	Model Estimate ($)	Upper Bound[b] ($)
60	824	818	NA
96	1,024	1,023	NA
220	849	838	NA
222	568	570	NA
300	766	737	860
302	298	268	328
304	860	914	1,148
305	562	511	607
325	285	289	332
326	296	294	347
700	651	639	NA
701	805	751	901

Note: NA = not available.

[a]Actual costs are calculated as follows:

$$C_r = \sum_{i \in I_r} (PH_{ri}/PH_i) \cdot W_i$$

where

C_r = daily cost of drivers' wages for route r,
PH_{ri} = platform hours that driver i spends on route r,
PH_i = number of platform hours in driver i's run,
W_i = driver i's daily pay, and
I_r = set of all drivers working on route r.

Thus, in order to calculate the actual cost of route r,

1. Identify all drivers working on route r,
2. Determine the fraction of each driver's platform hours spent on route r,
3. Multiply each driver's daily pay by the fraction found for him in 2, and
4. Sum the products found in 3 over all drivers identified in 1.

[b]The derivation of the upper bound is discussed in the section on Refinements.

Nevertheless, the model yields low estimates for routes on which most or all of the service is offered during the peak periods. Such routes include routes 300, 302, 304, 305, and 701. This result is not surprising because the estimates are based on the average wage per platform hour for all drivers with platform hours at a given time of the day. Strictly speaking, the cost of drivers' wages for a service is the marginal cost of wages, i.e., the amount the operator would save by eliminating the route. For peak-period-only services, or mostly peak-period services, the marginal cost of drivers' wages is considerably higher than the average cost because these services are responsible for spread penalties and slack time. If an operator eliminated a peak-period-only service, then the shifts that cost far more than the average could be eliminated.

Similarly, if an operator were to delete an all-day service with a steady driver requirement throughout the day, then only the shifts that cost less than the average could be eliminated. The cut would not allow for the elimination of spread penalties or slack time from the schedule. If the model were used, the savings from the cut would be overestimated because the model attributes the costs of spread penalties and slack time to all routes operating while any drivers with expensive shifts are on the road.

For the same reason, Chervony and Porter drew this conclusion about their model (3):

> Adjustments should be made . . . when the service-change profile significantly differs from existing service levels by time period. For example, a service change calling for an additional express trip in the morning and evening peak periods would not result in driver assignments and types similar to the entire system.

Despite this problem, the estimates given in Table 1 for peak-period-only routes are approximately 5 to 10 percent off the actual costs. (Note that the estimates for routes 325 and 326 are almost identical to the actual costs given in Table 1 for these routes, even though these are peak-period-only services. This is merely a coincidence, which shows that the actual-cost calculation used in Table 1 is inappropriate for these routes. Although routes 325 and 326 offer service only during the peak periods, their drivers, whose wages are reflected in the actual costs in the table, have about 8 platform hours each in their runs. If either route 325 or 326 were eliminated, schedulers might succeed in eliminating slack time from the schedule by assigning the drivers from route 325 or 326 to other peak-period-only routes and eliminating drivers with slack time in their runs from these other routes. Therefore, it appears likely that the actual costs given in the table for routes 325 and 326 are lower than the true marginal costs of these routes.)

REFINEMENTS

Because the model tends to underestimate the marginal costs of drivers' wages for peak-period-only services, two methods for obtaining more reliable estimates for such services are suggested in this section.

Some operators could recalibrate the model specifically for routes with high peak-to-base ratios. This would require a set of drivers' runs specially designed (or cut) to supply drivers for mostly peak-period services. Some agencies have this data. For example, the MBTA cuts independent sets of runs for each of its garages, and the peak-to-base ratio of the services operating from some garages is higher than the peak-to-base ratio of the system as a whole.

Even if an agency did not have the necessary runs on hand, it could cut them. This would be time consuming, but much less so than rescheduling runs to estimate the costs of wages for individual services (which would be done to obtain the exact cost of wages for a route). Inevitably, a planner would have to judge how much time to trade for accuracy. An agency willing to recut runs could recalibrate the model any number of times, and each version could be used to estimate the costs of runs with

peak-to-base ratios within a narrow range.

Without recalibrating the model for services with high peak-to-base ratios, a transit agency could use the model to determine a range for the drivers' wages associated with such service, assuming that the model gives the lowest possible cost of drivers' wages for routes with high peak-to-base ratios. An upper bound can be calculated by assuming that the upper bound for the wage per platform hour in a given period of the day is the wage per platform hour of the most expensive driver on duty at that time.

By using a complete set of drivers' runs for one agency, the steps for calculating the upper bound for the cost of drivers' wages for route r are as follows.

1. Identify all runs (i) with at least one-quarter of a platform hour during period x (see Figure 2).
2. For each run (i), divide the total daily wage (W_i) by the number of platform hours in the run (PH_i). This gives w_i, the average wage per platform hour for run i.
3. Rank the runs in descending order of wage per platform hour to determine u_{x1}, the wage per platform hour of the most expensive run in period x; u_{x2}, the wage per platform hour of the second most expensive run in period x; and so on.
4. Determine the number of platform hours needed for route r during period x (see Figure 4).
5. Calculate the cost of route r during period x by assuming that the first platform hour costs u_1, the second costs u_2, and so on.
6. Repeat steps 1 through 5 for each period of the day and sum the results. The sum is an upper bound for the daily cost of drivers' wages for route r.

The data in Table 1 give upper bounds for the costs of seven MBTA routes with high peak-to-base ratios.

SUMMARY AND CONCLUSIONS

The model presented in this paper can help any transit agency estimate the cost of adding or cutting service in an existing bus network. It simply and reasonably accurately predicts changes in drivers' wages caused by small or moderate changes in service.

The application demonstrated in the previous section of the paper indicates that the model is extremely accurate for service changes for which the required vehicle hours are distributed throughout the day in the same manner as the vehicle hours required for the entire system. The model is less accurate for service changes with unusually high peak-to-base ratios. Nevertheless, the model provides a lower bound for the costs of wages for peak-period-only services. Furthermore, the model can be recalibrated specially for service changes with atypical temporal distributions, although this procedure could involve considerably more effort than calibrating the basic model.

The model does not replace scheduling as a means of determining the exact cost of a service change. Nevertheless, it is a useful sketch-planning tool, and it is considerably simpler than the previously proposed models for estimating drivers' wages without scheduling. The essential simplifying step is to calculate the average wage per platform hour during each 0.5-hr period of a day, thereby capturing the impact of an agency's idiosyncratic work rules on the labor cost during each period.

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Assessment of Operational Effectiveness, Accuracy, and Costs of Automatic Passenger Counters

JOHN ATTANUCCI AND DAVID VOZZOLO

The research results of an assessment of the operational effectiveness, accuracy, and costs of various bus transit automatic passenger counter (APC) technologies are presented. The primary objective of automated passenger counters is to efficiently acquire accurate data on passenger activity and transit travel times. These data, which are essential for ongoing planning and scheduling activities, may include boardings, alightings, passenger loads, and vehicle running times. Automated techniques enable the reporting and analysis of these data in varying levels of detail. The current applications of APC technology in 12 North American transit properties are assessed on the basis of four technological factors: accuracy, equipment reliability, data turnaround time, and cost. Findings indicate that APC technology and its creative use may not be the magical solution to the bus transit monitoring dilemma; however, APC technology does offer a reasonable cost-effective option that operators can seriously consider to satisfy their data-collection needs.

The change in planning emphasis from capital-intensive transit improvements to short-range transit efficiency actions, plus growing fiscal pressures, have increased the importance of transit system surveillance. It is important to design a data-collection program to obtain reliable data at a reasonable cost. To do this transit managers need answers to questions such as how much data should be collected (i.e., what size sample should be obtained), which data-collection techniques are most appropriate, and how often data should be collected (e.g., once a year or at every schedule change).

The objective of a current UMTA-sponsored research study (known as the Bus Transit Monitoring Study) is to provide transit operators with the information they need to design their own comprehensive, statistically based data-collection programs. In the first phase of this study a technical manual was prepared for use by operators in the design of a data-collection plan consisting of manually collected data (1). As part of that effort, several observations were made.

1. The costs of manual data-collection activities and subsequent processing requirements are significant. For example, based on typical industry data requirements and property characteristics, a manually performed monitoring program would require 1 to 2 full-time checkers for a 50-bus property and 10 to 19 traffic checkers for a 1,000-bus property. In addition to relatively high costs, several properties that use manual techniques report difficulty in obtaining reliable data, and they experience long turnaround times between data collection and reporting.
2. A growing interest in automated surveillance techniques has been expressed by transit properties. The shift to automated methods is in response to the relatively high costs and operational problems associated with manual data-collection programs (such as the introduction of tinted window buses, which hinder wayside point checks).

Previous investigations of automated surveillance techniques suggest that they can be used successfully on a regular basis. Nevertheless, there has been no comprehensive assessment of how automated surveillance techniques have been and can be used in ongoing data-collection programs. Recent research attempted to synthesize available information about automated surveillance technologies and to report on their operational characteristics, overall cost-effectiveness, and current use in more than a dozen North American transit properties (2). One part of this research is reported in this paper--the assessment of the operational effectiveness, accuracy, and costs of various automatic passenger counter (APC) technologies.

HOW AUTOMATED PASSENGER COUNTERS WORK

Automated data-collection techniques count the number of passengers boarding and alighting a vehicle at each bus stop. Passenger activity is detected either by infrared beams or ultrasonic rays projected across the front and rear doors of the bus or by pressure-sensitive mats placed on the steps. Most of the experiments to date have involved devices that record the number of passengers boarding and alighting, the time of day, and an odometer mileage reading every time the bus stops and the doors open.

Most of the early research and applications focused on the use of APCs as components within an automatic vehicle monitoring (AVM) system (3-15). AVM systems are designed to provide continuous information on vehicle locations, emergency status, and schedule adherence. Automated passenger data are periodically transmitted through a radio or another communication network to a central processing location. This information is used by transit controllers to modify bus schedules as conditions warrant on a real-time, instantaneous basis. This information is also used off-line to perform operational analyses.

Recently, there has been considerable interest in using APCs as separate surveillance tools. The difference between this approach and AVM systems is that data are not transmitted instantly, but are stored on board the bus on either magnetic tape or solid-state memory. At a later time the data are transferred to a central processing location for validation and analysis.

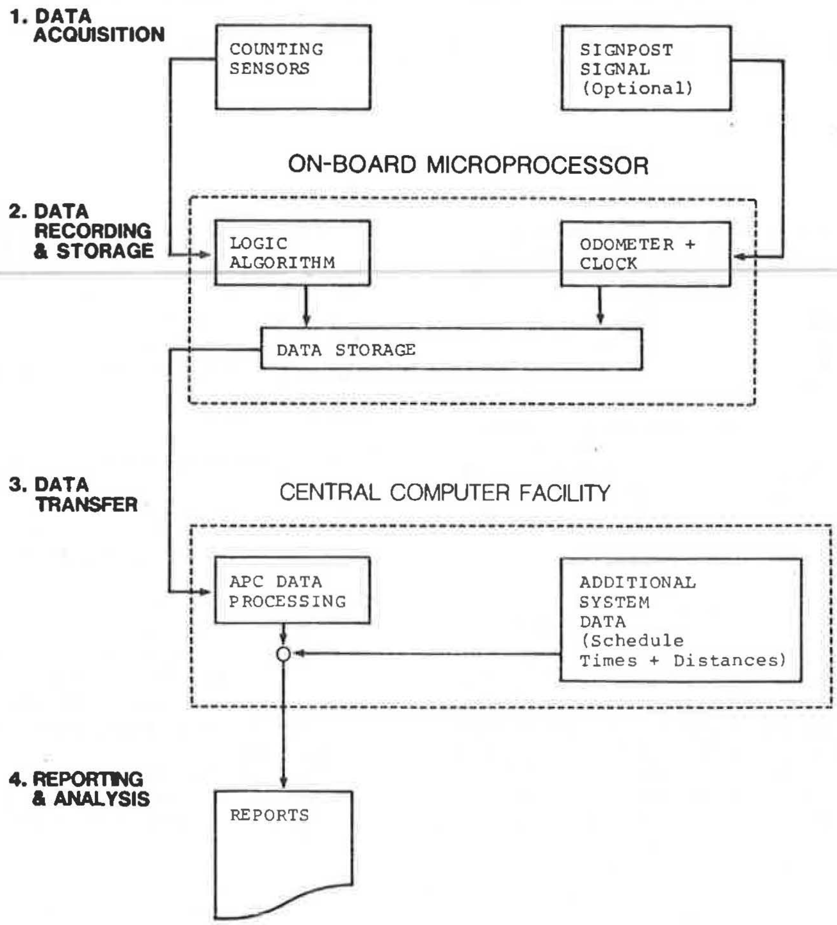
The primary objective of automated passenger counters is to efficiently acquire accurate data on passenger activity and transit travel times. These data, which are essential for ongoing planning and scheduling activities, may include boardings, alightings, passenger loads, and vehicle running times. Automated techniques enable the reporting and analysis of these data in varying levels of detail (i.e., route, trip, route segment, or bus stop).

There are four basic steps in collecting and analyzing APC data that are common to all APCs (see Figure 1):

1. Data acquisition,
2. Data recording and storage (on board),
3. Data transfer to a central computing facility, and
4. Reporting and analysis.

Several hardware and software components are used in these steps. Counting sensors located at each

Figure 1. Basic steps and components of APC techniques.



doorway of the bus detect passenger activity. A data-processing unit located on board the bus uses a logic algorithm to translate the counts into boardings and alightings. Generally, these boardings and alightings are then stored in a way that permits easy stop referencing of the counts. This is done through the recording of time or distance measurements, or from signposts (located at designated intervals along the route) that transmit coded signals to the bus. After the data have been stored for a period of time (usually several days), some mechanism is used to transfer the information from the on-board processing unit to a central computing facility. Finally, the data are input to software packages and the desired reports are generated.

CHARACTERISTICS OF CURRENT APC SYSTEMS

Twelve North American properties are now operating or are about to implement APC systems (Table 1). These properties can be grouped into three categories:

1. AVM systems (three properties),
2. Operational APC systems (non-AVM) (two properties), and
3. New APC systems (seven properties).

Three types of counting-sensor technologies have been used (i.e., dual infrared beam, multiple infrared beam, and treadle mats), although currently the dual-beam counters have proven most popular with eight systems in use (or proposed). Half (six) of the current systems use or plan to use signpost location referencing technology.

The earliest applications of APC techniques were in coordination with comprehensive AVM systems. In Cincinnati, the General Motors Transportation Systems Division experimented with an AVM system that used infrared-beam counters. Signposts located at scheduled time points transmitted location code signals to passing buses. At frequent intervals the raw data collected on the bus were sent over the radio to the computer for processing. (The full Cincinnati system has been moved recently to Windsor, Ontario, Canada.) In 1976 the Toronto Transit Commission designed and installed 100 dual-beam counter units and 16 signposts as a part of its overall AVM surveillance program. They have also been experimenting with treadle mats due to dissatisfaction with the accuracy of the beam-counting logic. Finally, an UMTA-sponsored demonstration in Los Angeles has implemented a broad-beam signpost AVM system that uses pressure-sensitive treadle mats for passenger counting. The 200 units have been used exclusively on four heavily patronized bus lines.

Two transit properties have extensive experience with APCs, which are used to collect passenger data and store it for later processing. The Seattle Metro installed a treadle-mat system on 56 buses in early 1978, and it has installed signpost identification systems in 1982. OC Transpo in Ottawa, Ontario, Canada, installed 49 dual-beam counters in 1978-1979 and acquired 16 more units in 1982.

Three U.S. systems have more recently installed,

Table 1. APC systems in North America.

Property	No. of Units	Type of Counter	Implementation Date
AVM systems			
Windsor (formerly Cincinnati)	27 counters, 37 signposts	Pro-Data dual beam	1981 (1977-1981)
Los Angeles	200 counters, 500 signposts	Dynamic Control treadle mats	1980
Toronto	100 counters, 16 signposts	Dual beam (self-designed)	1976
Operational APC systems			
Ottawa	49 counters (16 new units anticipated)	Pro-Data dual beam (Paul Isaacs infrared beam)	1978-1979; 1982 (new systems)
Seattle	56 counters (acquiring 250 signposts)	Dynamic Control treadle mats	1978
New APC systems			
Calgary	5 counters (demonstration)	Paul Isaacs infrared beam	1982
California Department of Transportation (Caltrans)	25 counters (obtaining 65 units from Los Angeles)	Dynamic multiple beam	1979 (purchase); 1982 (implementation)
Columbus	6 counters, 8 signposts	Pro-Data dual beam	1982
Kalamazoo	20 counters, 30 signposts	Honeywell dual beam	1982
Minneapolis-St. Paul	44 counters	Pro-Data dual beam	1979 (purchase)
Portland	50 counters	Paul Isaacs infrared beam	1982
Quebec City	3 counters (10 new units)	Pro-Data dual beam (Paul Isaacs infrared beam)	1980; 1982 (new systems)

or are planning to acquire, automated counter units. Michigan is sponsoring a demonstration in Kalamazoo. Twenty buses have been equipped with dual-beam counters, and 30 signposts have been installed for stop referencing. The purpose of the demonstration is to examine the applicability of APC techniques in the service monitoring programs of a small transit system within the state. Tri-Met in Portland, Oregon, implemented 50 dual-beam units in 1982. Tri-Met made the decision to initiate an operational program after 2 years of experience with two prototype units. The Central Ohio Transportation Authority (COTA) in Columbus has made a rather unique arrangement. A consultant has been contracted for a 14-month period to provide 6 dual-beam counters and 8 portable signposts, collect data on all routes and bus runs, and generate detailed reports appropriate for route planning activities.

The Metropolitan Transit Commission (MTC) in Minneapolis-St. Paul purchased 44 dual-beam systems in 1979. However, due to contractual difficulties with the manufacturer (and the resultant nondelivery of on-board storage units), use of these systems has been limited. Although the existing units display a cumulative count of boardings and alightings on board the bus, no mechanism for data storage is available. Drivers are required to record count readings at designated points in order to use the counters. Because these problems have not been resolved, MTC does not currently use the counters as part of their ongoing data-collection program.

In 1979 Caltrans began a demonstration program with 6 small transit systems in the state (Bakersfield, Golden Gate Transit, Montebello, Monterey, Sacramento, and Santa Cruz) by acquiring 25 multiple-beam counters. Caltrans is currently also negotiating for the acquisition of 65 units originally purchased for Los Angeles. The purpose of the test is to determine whether the APC technique is practical for small properties. Currently, all hardware (i.e., 25 units) has been installed, and processing software is being developed in Sacramento.

Four other Canadian cities have some experience with the implementation of APC systems. In Calgary five infrared-beam counter units are currently being installed on a demonstration basis. In Quebec City 13 units are being used in a systemwide monitoring program to identify problem routes that may require more detailed manual data collection to identify appropriate service changes. One APC unit is currently being tested by the London, Ontario, transit system to determine if a full-scale program should be developed. In Edmonton, Alberta, two prototype APC units were developed in 1977-1978, but after testing the program was discontinued primarily because of high development and implementation costs.

ACCURACY OF APC TECHNOLOGIES

Most assessment of automated counter techniques have concentrated almost exclusively on the issue of counter accuracy. As with manual data-collection techniques, the implications of selecting desired accuracy levels must be carefully considered. The use of the data and the increased cost of obtaining more accurate data must be weighed in selecting appropriate accuracy levels and, consequently, data-collection methods (1).

The results from accuracy tests presented in the research literature are addressed in the following sections. Findings from tests performed by several transit properties operating APC units are then discussed.

Research

In 1979 an evaluation of three commercial passenger-counter systems (one treadle-mat system and two infrared-beam systems) was conducted to assess their potential performance for the Los Angeles AVM system (15). Accuracy and environmental tests were conducted in the laboratory and on board an operating transit bus. Test data indicated that the counter that incorporated treadle mats exhibited superior counting performance over the two infrared-beam systems. The mat APC system yielded correct (100 per-

cent accuracy) boarding counts 93 percent of the time and correct alighting counts on 90 percent of the observations. In general, all three counter systems were more accurate on boarding counts as compared to alighting counts. Also, all three systems tended to undercount rather than overcount passenger activity.

In March 1982 UMTA, through the Transportation Systems Center, sponsored research to conduct a limited-scale accuracy field test to provide an indication of the relative performance of APCs and on-board, manually taken ride checks. The test covered a range of boarding conditions on routes exhibiting from 1 to 12 passengers boarding at any given stop. The field test was conducted on five properties: Seattle, Minneapolis-St. Paul, Columbus, Kalamazoo, and Los Angeles. The counter technology used on three of the five properties was a dual-infrared beam; on the remaining two properties, pressure-sensitive treadles (mats) were tested.

The results of the field test did not indicate a significant difference in performance between the APCs and the on-board ride checkers. A summary analysis of a composite sample of approximately 8,600 transactions yielded the following results. The APCs were in absolute agreement with truth for 78 percent of the transactions compared with 86 percent for conventional on-board ride checkers; with a variance of ±1, the performance of the APC was 95 percent compared with 96.5 percent for the ride checkers. In terms of total passenger counts for a sample size in excess of 20,000, the data acquired by using APCs was 94 percent of the truth compared with 96 percent for the on-board ride checkers.

Operator Experience

Most APC transit properties have undertaken loose accuracy checks and concluded that counters appear to be accurate enough for their purposes. Yet few properties have implemented extensive accuracy testing through comparisons of APC-generated counts with manual counts.

In the winter of 1978-1979, Seattle Metro undertook a series of accuracy tests on both standard and articulated buses equipped with automatic counters. In general, the treadle-mat counters were extremely accurate. For example, standard bus accuracy is 98 percent for boardings and almost 94 percent for alightings. These accuracy measures are even higher when examined on the basis of stop records being within ±1 or ±2 of manual counts. These findings are somewhat consistent with the 1979 Los Angeles AVM study, which indicated that the treadle-mat counters were highly accurate. Test results on standard buses also confirm previous findings that counters are more accurate for boarding measurements than for alightings. It is interesting to note that the articulated test results do not agree with this finding. Although there is a slight tendency toward more accurate measurement of alightings, accuracy levels are generally identical. In ongoing operation, Seattle Metro has found that about 80 percent of the boarding and alighting totals for a full-day bus operation are within 10 percent of each other (the standard established for retention use of the APC data in Seattle).

The London Transit Commission in London, Ontario, has been experimenting with one APC-equipped bus that uses pressure-sensitive treadle mats. A series of accuracy tests were performed during the winter and spring of 1982. In March 1982, peak hours were surveyed for 1 week by two checkers who manually recorded passengers boarding and alighting at each stop and recorded the count from the APC equipment. Accuracy was compared on the basis of number of passengers boarding at the front door, alighting at the front door, and alighting at the rear door. Tests concluded that APC counts for front-door boardings and rear-door alightings were extremely accurate in comparison with manual checks (93.9 and 97.6 percent, respectively), whereas front-door alighting counts exhibited 84.8 percent accuracy. The APC units tended to overcount on rear-door alightings. The test results present accuracy data separately for stops with relatively low passenger activity (1 to 5 boardings or alightings) and high passenger activity (6 to 10 boardings or alightings). Findings indicate that, at stops with high passenger activity, APC counts are 100 percent accurate within ±1 of the manual count. At stops with low passenger activity, APC counts were 98 to 100 percent accurate within ±2 of the manual counts.

Accuracy tests were also performed in Cincinnati as part of the evaluation of the transit information system. The Cincinnati results differed from previous findings in that alighting counts were more accurate than boardings. The Cincinnati results are consistent, however, in that the APCs tended to undercount.

During the winter of 1980-1981, the MTC in Minneapolis-St. Paul performed accuracy tests on its APC-equipped buses. Because MTC did not have a complete set of APC equipment on their buses (no on-board memory), the automated count data was tabulated by drivers reading off the counter at the end of each trip. These numbers were then compared with the manual count data on a trip and run basis. As a result of this methodology, no stop-level analyses were possible. The MTC tests indicated that the accuracy of APC boarding counts was extremely high (i.e., 95 percent). On the other hand, the accuracy of alighting counts was somewhat lower (i.e., 85 percent). The difference is particularly evident when the percentage of runs and trips that are within ±15 percent accuracy (90 percent for boardings and 54 percent for alightings) are examined. As with previous test results, the MTC data indicate that the automated counters tend to undercount rather than overcount passenger activity.

In the MTC test results, the fact that the accuracy of boarding counts is so high appears to indicate that the counting sensors are performing extremely well. Nevertheless, the significant difference between boarding and alighting accuracy may be due to the location of the sensor in the rear stepwell or some other minor flaw. Experiences in other APC properties have revealed that sensor location for infrared-beam counters is a major determinant in count accuracy. Even a slight movement of the light-beam sensor (also referred to as light-head) toward the skin of the bus can yield substantial improvements in count accuracy.

In addition to altering the location of counting sensors, there are other measures that can be taken to compensate for differences in boarding and alighting accuracies. In cases like the MTC, where there is a systematic error resulting in undercounts of alighting activity, these data can be factored by the boarding count on a trip or run basis in order to yield matching and consistent counts. For example, OC Transpo calculates and applies such a factor within their analysis and reporting software. For individual APC-equipped vehicles, the software calculates the systematic undercount of alightings (from the previous day's data) and computes a factor that is then applied to the count.

Generally, the available data have indicated that APC data obtained from properly installed and cared for units are reasonably accurate, especially when boarding counts alone are considered.

EQUIPMENT RELIABILITY

An issue of special concern that transit operators frequently raise when discussing APC technology is the reliability and durability of counting-sensor hardware, on-board microprocessing units, and electrical connections. Transit properties are not able to use 100 percent of the data potentially collected with APC equipment. Operators report that only 85 to 90 percent of the APC units are in working order at any given time and, of these, only about 80 percent produce acceptably accurate readings on specific bus runs. In some cases there have been mechanical problems that have hampered the effective use of the counting technology. Most properties have been able to overcome these technical difficulties; however, there remains skepticism regarding the reliability of the APC equipment.

Only one operational system (Seattle Metro) was able to provide an estimate of continuing equipment availability. In Seattle Metro's case, 35 to 36 (90 percent) of their 40 operating units are generally in working order on any given day. For those in working order, Seattle Metro generally has to discard about 20 percent of the individual vehicle trip readings because of unsatisfactory or inconsistent data.

The reliability issue is addressed in the following sections by examining typical mechanical malfunctions and the various actions taken to solve them. In general, problems of equipment reliability experienced by North American transit properties that have implemented APC programs can be grouped into the following categories: sensor malfunction or nonalignment, electrical disconnections, odometer readings, and environmental factors.

Sensor Malfunction

In Los Angeles the treadle mats with counting sensors were originally installed on the first and second steps of the stairwell at both the front and rear doors of the bus. The mat on the first step was often damaged or destroyed when buses turned close corners and hit the curb. To minimize damage, the installation procedures were changed and the mats were moved to the second step and the platform. This alteration successfully minimized the problem. In addition, Los Angeles experienced difficulty when mats tended to set on the stairwell; that is, after some time the mats occasionally settle in over the treadle pins, with the result that pins are no longer activated and counts are not registered. This malfunction can be corrected by replacing the mat and resetting the treadle pins.

One major difficulty with infrared-beam counting sensors concerns maintaining the proper alignment of the paired units of lightheads at each doorway. Improper alignment of the two lightheads means that the light source is being emitted, but it is never received; therefore, no counts are registered. Front-end collisions may damage or change the alignment of the lighthead sensors. The location of the sensor units within the doorway also makes them highly susceptible to general abuse and movement by crowded passengers. In addition, counting units may be vandalized on board the bus. To minimize these problems, the counting sensors require frequent monitoring and inspection to identify and correct problem units.

Electrical Disconnections

Buses have an extensive series of electrical connections weaved throughout the frame of the vehicle. The electrical wiring complicates APC installation procedures and often requires special body work to insert the wires and connectors for the APCs. Electrical disconnections or other malfunctions occasionally occur. For example, Seattle Metro experienced difficulty when its data dump operation would unexpectedly hang up. Maintenance personnel originally thought it was a noise spike from the bus electrical system. After examination, it was discovered that one of the electrical sockets merely had a bad connection. As a result, what was originally feared as a major electrical problem turned out to only require a few dollars for a new connecting socket. Clearly, there have been other instances where APC applications have experienced more extensive electrical malfunctions. One interesting note concerns the Los Angeles automated counter units. At one time Los Angeles was having difficulty on chair-lift installations because cables running under the mats on the floor were being guillotined by wheelchairs.

Odometer Readings

Another equipment problem is inaccurate odometer readings. Odometer readings are required to stop reference count data. Inaccuracies of the odometer readings can produce distance-calibration errors. Odometers are extremely sensitive measuring devices. Several properties mentioned problems experienced with distance calibration. For example, Caltrans and OC Transpo have both observed variation in odometer readings. OC Transpo keeps a record of distance-calibration accuracy for each APC-equipped bus and introduces a correcting factor that is applied to the distance measurement in the software processing.

Environmental Factors

Environmental factors can affect the accuracy and reliability of counting sensors. For example, Seattle Metro has problems with their treadle mats because of leaking and water penetration. Although the mats have been redesigned, there are still some linkage problems, particularly on the lower mats. Seattle operating personnel believe that the major defect is the design of the mats, in that they do not hold strongly in place on the step.

Infrared-beam sensors are also susceptible to environmental factors, particularly cold weather, ice, and snow. OC Transpo experienced malfunction problems with sensors, particularly lightheads located closest to the skin (exterior) of the vehicle, as a result of ice produced by the extreme cold weather. The problem was solved by redirecting the flow of warm air from a nearby heater vent toward the lighthead. The added warmth has been extremely helpful in minimizing the problem.

Another environmental problem is light reflections. OC Transpo observed that boarding and alighting counts are extremely inaccurate when APC buses are traveling directly into the sun, particularly in early morning and late afternoon periods. On the other hand, passenger counts are excellent when the vehicle is moving away from the sun. They have observed that vinyl clothing (e.g., raincoats, parkas) or other shiny objects reflect light and interrupt the operation of the light-beam counting sensors.

There are a number of specific actions that can be taken to minimize problems with equipment reliability. Preliminary testing of the equipment can help avoid potential technical difficulties. Many of the successful automated passenger counter programs started with a few prototype units before they introduced the total system. For example, Portland,

Ottawa, Quebec City, and Calgary all gained experience with prototype units and worked out the technical bugs before defining desired equipment and performance specifications. In addition, these properties shared information and were able to learn from the mistakes of others.

Proper installation techniques can also minimize reliability problems regarding beam alignment. For example, the appropriate location of the sensor, protective brackets, hidden wiring, and secure doors can protect the lightheads from vandalism and general abuse.

Finally, monitoring of the equipment and its performance can be critical to the effective use of APC technology. Several transit operating personnel stated that it is important to develop a close working relationship among APC supervision personnel and maintenance, body shop, and electrical staffs. Although it is clear that APC equipment needs a degree of special attention that other vehicle subsystems generally do not require, the properties that use APC systems believe that equipment reliability and maintenance needs do not pose major obstacles to the successful operation of an APC system. Yet greater industry acceptance of APC technology appears to hinge on an improvement (and solid documentation of this improvement) in the operational reliability of such systems.

DATA TURNAROUND TIME

One of the major concerns regarding the collection of transit operating data is the turnaround time between observation and analysis. The automated passenger counter technique appears to be superior to manual data-collection turnaround time. APC data are read directly from on-board storage into the central computing facility. Software is then used to generate the desired reports and analyses. Manually collected data, on the other hand, requires assembling all ride and load count sheets, keypunching, and finally reading the data into software packages. A significant amount of time can be saved by using an APC system. In fact, several properties that currently use manual data-collection programs have experienced excessively long turnaround times (e.g., up to 1 year) between observation and data reporting and analysis. The Southern California Rapid Transit District (SCRTD) in Los Angeles is currently experiencing this problem. The longest delay in the typical process includes the time for data validation, editing, and keypunching.

Specific information on data turnaround times for APC applications is limited. Little information was discovered on direct comparisons between turnaround times of APC and manual data-collection programs. Nevertheless, interviews with operating personnel from properties that implemented APC techniques did provide insights on turnaround time.

The average turnaround time at Seattle Metro is between 5 and 6 days. A portion of this time includes a day or two during which the data are stored on board the bus in solid-state memory. Because of personnel and APC scheduling conflicts, it sometimes takes 2 to 3 weeks to provide the information requested from a transit manager and the generated analyses. Despite these minor time lags within the data-collection program, Seattle Metro personnel noted that this turnaround time represented a major improvement over the manual system previously used.

OC Transpo assembles all APC-generated data into a series of management reports at the end of each quarterly service period. OC Transpo also assembles data from APC-observed bus runs for spot analyses for purposes of short-term planning and scheduling. APC count and time data are transferred from on-board storage to the central computer facility on the day following data collection. A series of automated processing procedures then separate each bus run into individual trips and segments. Finally, stop-by-stop listings of APC count data are produced and become available for spot analyses 1 or 2 days after the initial observation.

Metro Transit in Kalamazoo specified within their contract with the APC vendor a maximum of a 1-week turnaround time from pulling the data tapes from on-board storage to generation of reports. Currently, all data processing is undertaken at the vendor's computing facility. Operating personnel at Metro Transit stated that turnaround time may be reduced significantly if the processing capability is maintained in-house rather than off-site. Nevertheless, the current 1-week turnaround represents a significant time savings over the manual system.

COSTS OF APCs

An obviously critical step in the assessment of automated passenger counters is to examine the costs of acquiring and operating such systems. Two major aspects of APC cost factors are considered in this discussion: (a) the actual costs experienced by North American APC applications, and (b) the costs of APC systems as compared with the costs of manual data-collection programs (on a hypothetical basis).

Ranges of Actual APC Costs

The costs of acquiring and operating APC systems have been disaggregated into discrete cost components. These major cost components, divided into expenditures for hardware and software, are given in Table 2 along with the range of (unit) costs encountered by the 12 properties that use APCs. As noted in the data in Table 2, the costs of acquiring and operating APC systems (for both hardware and software) vary significantly among transit properties. Several different types of systems have been implemented to serve a variety of data analysis and reporting functions. Consequently, the costs of these systems also differ, depending on the type of information desired and the accuracy required.

APC hardware costs cannot be easily estimated because the market for such equipment is so small. Manufacturers of APC components have come and gone over the past decade, and virtually every procurement has involved tailor-made specifications. As a result there are few, if any, off-the-shelf components currently on the market or in production. Although it is difficult to make meaningful comparisons of the component costs among systems because of the different specifications and dates of acquisition, a potential user of APC equipment would do well to review the specific experience of the systems currently in use (2,16-18).

Table 2. APC system costs.

Component	Unit Cost Range ($)
Equipment	
Counting sensors	500-750/bus
On board microprocessor	2,000-3,500/bus
Signposts	300-450/location
Transfer mechanisms	2,000-6,000 (1 or 2/garage)
Installation	350-750/bus and post
Maintenance	450-1,000/bus annually
Software	
Development	150,000-250,000 initially
Ongoing processing	50,000-70,000 annually

Comparison Between APC and Manual Data-Collection Costs

The conventional method of data collection used by most transit properties involves the use of traffic checkers to perform point (or load) checks, riding checks, or the collection of boarding counts by the bus operator. To make a valid assessment of automated counter techniques, it is necessary to compare APC costs with typical expenditures for manual data-collection programs. Few of the transit properties that have implemented APC techniques were able to provide detailed comparisons between the current budget and previous expenditures for manual data collection.

COTA in Columbus awarded a $31,000, 6-month contract to a consulting firm to collect, process, and report data for each run in the system. Although a direct comparison is not available, one COTA representative stated that a similar effort attempted manually in-house would cost in excess of $200,000, and most likely would not be completed within the same 6-month time period.

OC Transpo previously employed eight full-time traffic checkers, with an annual cost of $160,000 for the manual monitoring program. OC Transpo currently operates 49 APC-equipped buses, and it is in the process of equipping 16 more vehicles. The current staff consists of two people who are now responsible for other administrative duties, but do occasionally perform trailing checks or load counts. OC Transpo believes that the APC system paid for itself in its first 2 years of operation. In addition, they believe that much more useful data are being collected and reported than was possible with the manual program.

Because there have not been many direct comparisons, an analysis was made of typical expenditures for APC and manual programs. Major cost components within a budget for manual data-collection programs generally include the following:

1. Personnel needed to collect data on board buses or on the street,
2. Administrative or supervisory tasks (e.g., the detailed scheduling of checker work assignments),
3. Data preparation (coding and keypunching of completed forms), and
4. Data processing, editing, and reporting.

Costs for manual checkers and supervisory personnel were based on an estimated $23,000 annual salary (including benefits). Software costs for manual data-collection systems were obtained by using professional judgment and experience. For example, the study team is currently undertaking a comprehensive software development effort as part of the Bus Transit Monitoring Study. The study team is currently spending approximately $125,000 for software development to analyze both ride and point checks as well as driver boarding counts. The APC hardware and software costs use ranges of expenditures actually experienced by APC properties of that size (and documented in Table 2).

In general, the cost estimates used in the analysis can be considered conservative in favor of the manual technique; that is, lower estimated costs were applied to the manual system, whereas higher estimated costs were applied to the automated counter system. The comparison considers the costs accrued over a 5-year period. Consequently, manual costs incorporate checkers' salaries (and benefits) over the 5-year period, and APC costs incorporate the initial purchase expenditure and installation and maintenance costs (assuming a 5-year useful life); both manual and APC system costs include software development and ongoing processing costs.

Estimates were used to develop a cost comparison between manual and APC systems for properties of different sizes (Table 3). The number of APC units and checkers required for each size property was estimated based on statistical sampling requirements as identified in the Bus Transit Monitoring Study (1). Unit costs for manual personnel and APC hardware acquisition, installation, and maintenance are the same for different sized properties. Administrative and supervisory personnel requirements change proportionally with varying property size. However, the estimation of software costs for both manual and APC systems does not change in strict linear proportion with the size of the transit property or with the number of APC-equipped buses. There is a relatively high initial start-up cost for software development and file creation that is difficult to minimize, even with small properties and few APC units. In addition, large properties with many APC units experience significantly higher processing costs because the volume of data increases and the processing routines become more complex.

The comparison of costs for manual and APC data-collection programs (Table 3) indicates that, for most sized properties, APC systems can be less costly than manual techniques. When costs are accrued over a 5-year period, the high up-front costs for APC hardware and software development are lower than the ongoing costs for manual checker salaries and benefits. Nevertheless, the analysis indicates that for those transit properties below 100 to 200 peak-period buses (using less than seven checkers or APC units), the difference in costs between the two data-collection techniques is minimal. Note that many of the costs associated with APC systems (e.g., equipment, installation, initial software development) are eligible for reimbursement from federal capital grants, whereas the bulk of manual collection costs falls into a local operating budget.

In addition to the difference in costs between manual and APC techniques, note the decreasing cost per APC unit as the number of APC-equipped vehicles increases. The decreasing marginal cost is primarily because software development and processing costs make up the major expenditures, and these costs tend to increase at a decreasing rate for additional units. The significance of the marginal cost is illustrated by noting that the annual cost of using one additional checker equals approximately $23,000, whereas the annual cost of using (installing and monitoring) one additional APC-equipped bus equals approximately $6,000.

CONCLUSIONS

This assessment of current applications of APC technology has reviewed a number of issues that should be carefully considered by any bus transit property investigating the utility of APC systems. Perhaps the most important issue is the realization that the technology currently exists to adequately count passengers and record time-related bus performance data with little or no direct human interaction. Nevertheless, it should be noted that some technological improvements are still desirable. In particular, more attention needs to be given to making the APC equipment more reliable, perhaps by standardizing the design of several of the most troublesome components. Also, it is clear that operators contemplating the use of APC equipment should be aware of related software needs (i.e., broadly defined in terms of the potential use of APC techniques, as well as potential data processing requirements).

Transit managers should be extremely careful in

Table 3. Cost comparison for different sized transit properties.

Peak Buses	No. of Traffic Checkers Required[a]	No. of APC-Equipped Buses[a]	Annual Costs[b] ($)		Annual Costs per Unit[b] ($)	
			Manual Program	APC Program	Manual Program	APC Program
25	1	1	59,000	82,000	59,000	82,000
50	2	2	86,000	84,000	43,000	42,000
100	4	4	142,000	121,000	36,000	30,000
200	6	6	200,500	141,500	33,400	23,600
300	7	7	227,000	149,000	32,000	21,000
500	13	13	385,000	196,000	30,000	15,000
750	15	15	436,000	225,000	29,000	15,000
1,000	19	19	532,000	245,000	28,000	13,000
2,000	38	38	1,027,000	398,000	27,000	10,000

[a]Assumes the maximum number of units (checkers or APC buses) required, as estimated in the Bus Transit Monitoring Study (1).
[b]Assumes a useful life for APC equipment of 5 years, and all other costs are accrued over a 5-year period (discount rates were not applied to annualized costs).

defining just what might be expected from APC data-collection techniques so that equipment and data processing needs can be anticipated in advance of any decision to proceed with a new data-collection program. If nothing else has been learned to date, experience has revealed that a number of current APC users initially underestimated the time and effort required to implement and maintain automated data-collection systems. A general lack of prior information and the need to use unproven equipment sometimes resulted in the trial-and-error efforts in installing equipment and maintaining it, much higher-than-expected data editing and processing costs, and the underutilization of available equipment capabilities. Fortunately, much can be learned from the experiences of users of current APC technology. Any operator contemplating a move to APC data collection would do well to contact the properties discussed in this paper.

A number of specific considerations should be reviewed in planning for the initiation of an APC system.

1. Both of the major types of APC units currently in use (infrared beams and treadle mats) perform satisfactorily. In general, the treadle mats have been found to be slightly more accurate, but they appear to require more maintenance and may need to be replaced more frequently than comparable infrared units.
2. The accuracy of the APC units currently in use is adequate for most purposes to which the data are put. Data from a recent U.S. Department of Transportation test revealed that the APC units were remarkably close to counts taken by a human ride checker.
3. For medium to large-sized bus properties (those with more than about 100 buses), the cost of an APC system compares favorably to manual (ride check) data-collection costs over the long run; however, because different equipment and data-collection techniques will provide different types of data (and data detail), a property should perform a careful cost analysis before moving forward with any new program.
4. Although the use of APC signposts for location referencing may reduce the overall cost of the postprocessing needed to get the raw APC data into usable form, recent developments by Portland Tri-Met indicate that an odometer-linked referencing system may provide an equivalent level of accuracy in stop referencing.
5. It is extremely important for potential APC users to define in detail the potential uses of APC data. These uses will affect the design of the data recording and counting algorithm internal to the APC counter units, as well as the extent of the data processing development that will be necessary to produce fully usable reports. A careful anticipation of the full range of potential uses and required data reports will undoubtedly reduce the overall cost of implementing a new system.
6. Potential users of APC equipment should be aware of the need to carefully install and maintain the equipment. Preplanning should include the discussion and agreement on interdepartmental responsibilities, and all personnel involved should fully understand the need for the APC data and the importance of regular, careful attention to ensure that the system operates to its fullest capability.

In addition, more attention should be paid to sampling issues concerning planning and use of APC technology. Initially, the number of APC units to be ordered should be based on a detailed design of an ongoing data-collection program (1). Several pilot units might actually be purchased or leased to help monitor a number of routes before the major procurement in order to calculate route data variances to be used in estimating route and system sampling rates. Once the necessary units have been obtained, it is important to determine individual line sampling rates so that all line data obtained are of comparable accuracy levels (rather than only having equal sample sizes). APC equipment also offers the advantage of allowing an operator to determine seasonal variation in line performance during the first several years of use, thus allowing a better determination of the number of times a year an individual line should be monitored.

More can still be learned about the use and capabilities of APC technology. With the initiation of fully supported operational programs in Portland, Kalamazoo, and Seattle, the information available regarding the potential problems and opportunities related to automated surveillance techniques will grow significantly during the next several years. Although APC technology and its creative use may not be the magical solution to the bus transit monitoring dilemma, it offers one more option that operators can seriously consider to more effectively satisfy their data-collection needs.

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Potential of Graphical Information Support for Transit Decision Making and Performance Evaluation

CAROLYN A. RINDERLE AND ALAIN L. KORNHAUSER

The objective of this paper is to examine the potential of the graphical information system (GIS) to increase transit operator control over performance by improving decision-making effectiveness. The GIS is based on the distinction between data and information; data are collected facts, but information is only that data useful for a particular purpose and perceived as such by the user. The GIS increases both relevant information and its perception. The GIS is effectively used in semistructured decisions where it enhances the ability of the user to apply creativity and judgment in solving novel problems. An example illustrates the potential of the GIS to convey patterns, trends, and relationships, thereby enhancing the ability of the user to filter relevant information from extraneous data. Several graphic profiles of a bus route are contrasted with the corresponding tabular summary. All are derived from the same data, but because of data format they convey significantly different information.

Inadequate information to support decision making is a fundamental problem in increasing the ability of the transit operator to control performance. Control is exercised through two types of decisions: (a) decisions that identify problems, and (b) decisions that specify problem correction. To increase control, the transit operator must be able to identify and correct problems effectively.

Effective decision making, however, is often constrained by a lack of information. Despite masses of collected data, little true information may be available to support decision making.

This paradox indicates the significant distinction between data and information. Data are a collection of facts, but information is that data subset that is useful for a particular purpose and perceived as such by the user. Information is knowledge for the purpose of taking effective action (1) and is context specific.

Graphical information systems (GISs) offer the transit operator a powerful tool to increase the information available for control decision making.

As referred to in this paper, a GIS is a type of decision support system (DSS) (2).

The GIS is a conversational, interactive computerized system that offers the user the capability to access and graphically interface with the analytical power, models, and data bases held in the computer.

The work in progress at Princeton University in developing a prototype GIS for New Jersey Transit Bus Operations (NJTBO) to support bus route monitoring and evaluation is presented in this paper. The two objectives of this work are to (a) characterize the decision contexts for which GIS is an appropriate technology, and (b) illustrate the potential of the GIS to increase the availability and perception of information.

MATCHING GIS TO DECISION CONTEXT

To increase the availability and perception of information, the GIS must be properly suited to the particular decision context as defined by the decision task and the decision maker.

The GIS is an appropriate technology to support semistructured decisions. These are decisions for which some aspects of the problem can be precisely defined or programmed, although other aspects are inherently intractable to structuring (2).

This type of problem is best solved through some combination of specified rules and subjective analysis. These problems typically require some manipulation or computation on a data set as well as the judgment and reasoning of the decision maker. Such problems are often solved iteratively; the decision maker specifies the necessary computations or modeling, assesses the results, and specifies the next step in the analysis. The process continues until the decision maker is satisfied that an adequate solution has been reached.

The majority of decisions under the control of the transit operator are semistructured. These include decisions involving performance evaluation, routing, scheduling, network planning, and demand analysis and forecasting (3).

Three characteristics of the GIS are particularly advantageous in solving semistructured problems. First, as a computer-based system the GIS can accurately search or manipulate large data sets and perform complex operations, thereby allowing the user to focus on analysis rather than computation. Second, as an interactive system the GIS rapidly interfaces with the user, thus allowing vaguely defined solution strategies or hunches to be pursued with minimal interference.

Finally, as a graphical system the GIS facilitates perception of semiquantitative information. This type of information is often critical in semistructured problems, especially in the problem-finding process. By presenting data in graphical rather than tabular formats, the GIS enhances the ability of the user to filter relevant information from extraneous data and facilitates perception of patterns, trends, relationships, deviations, and conformities.

CASE STUDY: NEW JERSEY TRANSIT BUS OPERATIONS

An example taken from NJTBO illustrates the potential of the GIS to increase the availability and perception of information in semistructured decisions.

Bus schedules are revised quarterly at NJTBO. Problem finding is the first step in this process, and it is primarily based on the trip summary report (Figure 1). This report details total weekday passenger data by trip, differentiated by inbound or outbound direction, for a 3-week period. The manager scans across the rows, attempts to determine trends for each trip, and balances the trends against prior knowledge of the system and external conditions (such as weather). This tabular format requires the manager to focus on detailed numbers; it hinders perception of semiquantitative information for problem finding.

In contrast, Figures 2-10 are examples of graphical formats available with the GIS. These graphs have all been derived from data recorded on the trip summary report, yet they convey significantly different information.

Figure 2 uses a linear time scale in plotting average inbound ridership versus trip time. Each vertical line represents an individual trip, and the line density indicates service concentration. This format allows the user to easily relate ridership to service frequency and may indicate where service could be more effectively timed. For example, the graph suggests increasing the headways between the 5:46 and 5:47 a.m. trips and the 7:40 and 7:43 p.m. trips to increase ridership.

This information would typically be complemented with the corresponding information on outbound trips, as shown in Figure 3. The operator may know that the 5:46 a.m. trip turns around and becomes the 7:00 a.m. outbound trip, which is well patronized; consequently, the operator may decide not to change the 5:46 a.m. trip.

Figures 4-6 contain the same data as Figure 2, but they are plotted by using a nonlinear time scale. As a consequence, these formats facilitate the comparison of ridership between specific trips. Figure 4 uses a bar chart to display totals, whereas Figure 5 uses a scatterplot and Figure 6 uses a lineplot. Although trips are discrete, and thus the line segments in Figure 6 have no inherent meaning, this format is preferable to the scatterplot for many users. The lines focus the user's attention on

Figure 1. Trip summary report. (Note that this is a copy of an original document.)

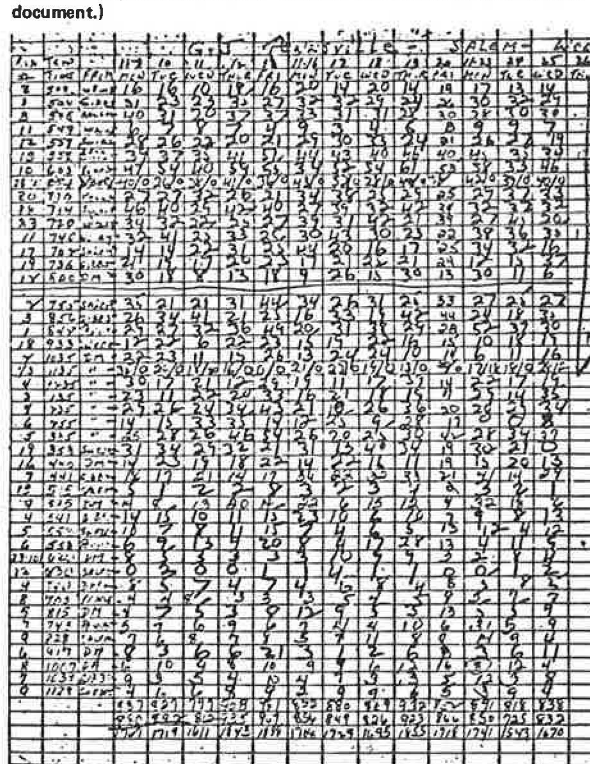


Figure 2. Average inbound ridership by trip.

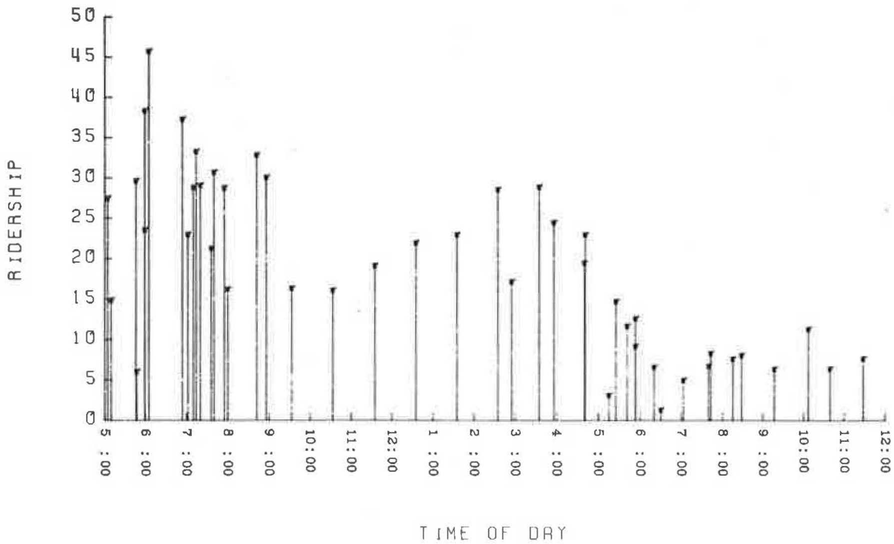


Figure 3. Average outbound ridership by trip.

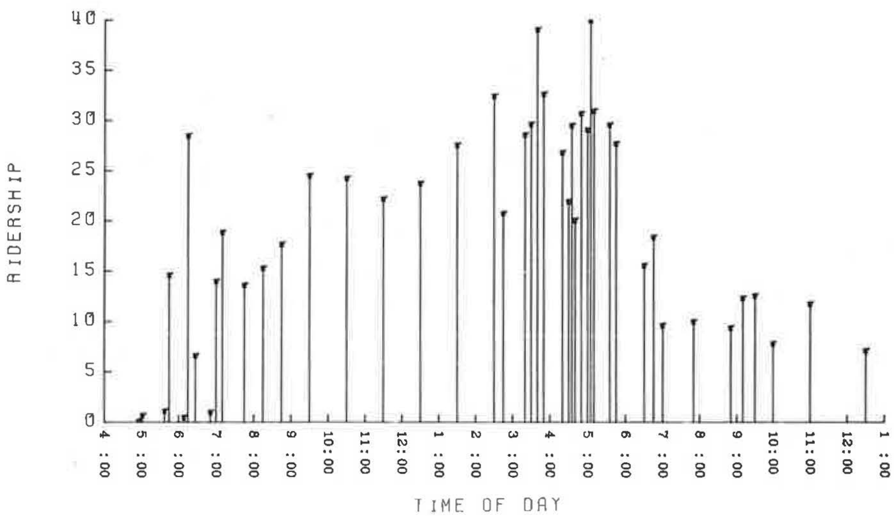


Figure 4. Average inbound ridership by trip (barchart).

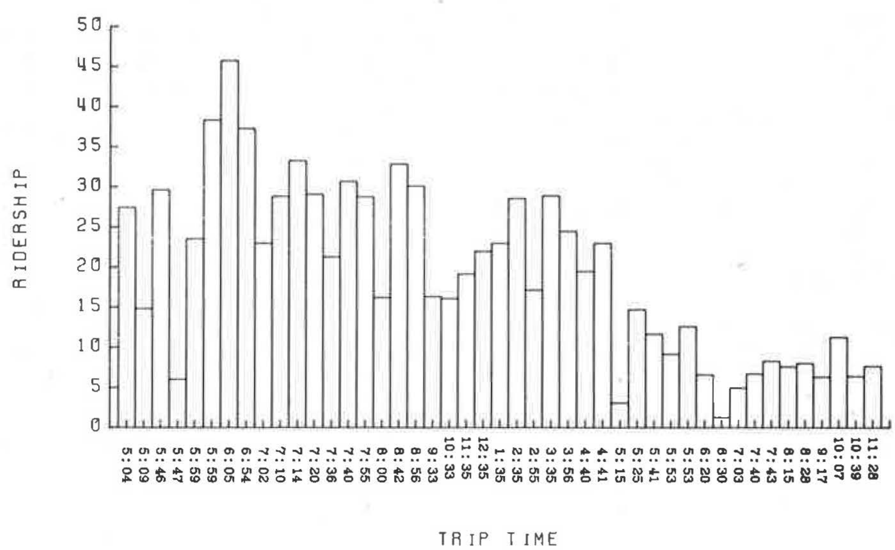


Figure 5. Average inbound ridership by trip (scatterplot).

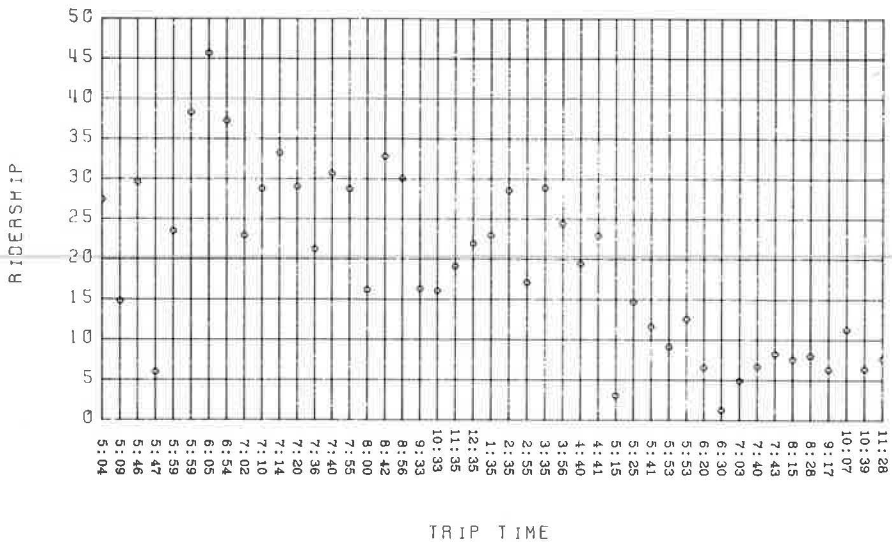
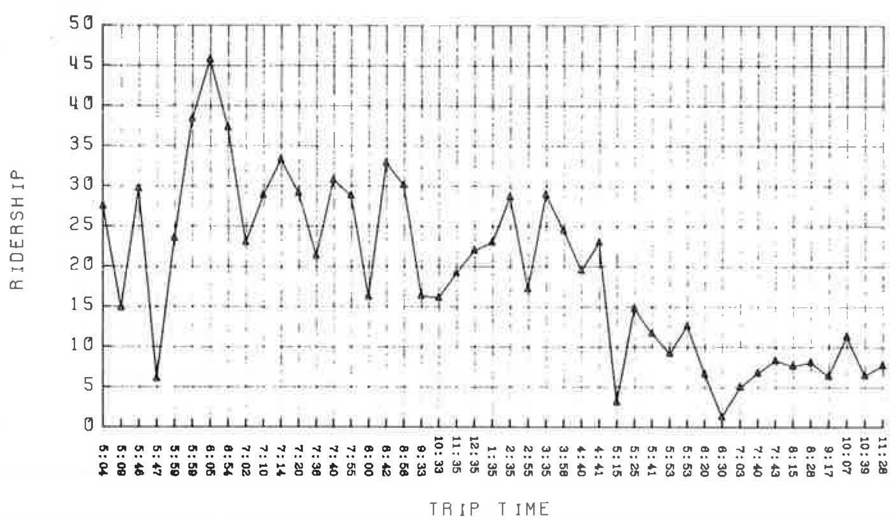


Figure 6. Average inbound ridership by trip (lineplot).



fluctuations as they occur by time of day, rather than permitting the eye to randomly jump around the display. The GIS allows the user to select whichever format is preferable.

Figures 7 and 8 are examples of how the GIS enables the decision maker to examine performance by day of week. Figure 7 plots total ridership by weekday, whereas Figure 8 plots ridership for an individual trip by weekday. This information allows the decision maker to discern cyclical ridership fluctuations; thus it indicates how service should be adjusted. In addition, unusual deviations by trip may suggest problems with on-time performance. For example, unusually high ridership may indicate that the bus was running late and picking up riders who would have normally taken the next bus.

Figures 9 and 10 plot cumulative inbound and outbound ridership versus time of day, respectively. These graphs enable the rate of ridership to be easily related to service frequency, either as an absolute measure or as a percentage of the total. For example, from Figure 9 it is quickly seen that 50 percent of the inbound ridership is achieved before 8:00 a.m. and 90 percent before 6:00 p.m. Service is heavily concentrated between 7:00 and 8:00 a.m., and the rate of ridership is high, with almost one-quarter of the total inbound riders gained in this period. Together these plots of inbound and outbound ridership may be used to indicate how service can be more effectively timed to increase patronage.

CONCLUSIONS

The GIS can greatly increase the decision-making effectiveness and ability of the transit operator to control performance. By increasing both the amount of available information and its perception, the GIS enhances the effectiveness of the decision maker in solving semistructured problems. It permits the user to rapidly access and filter relevant information from extraneous data, thus enhancing the ability of the user to apply creativity, judgment, and reasoning in solving novel problems.

Figure 7. Total ridership by weekday.

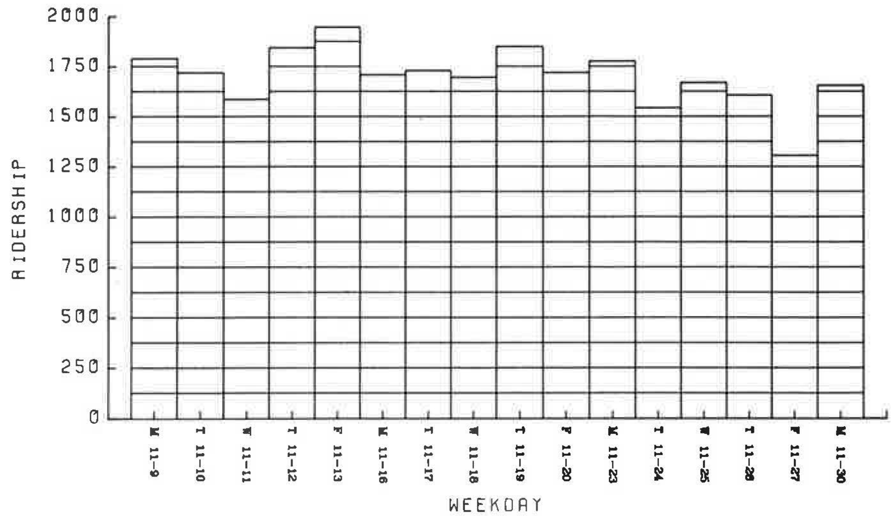


Figure 8. Weekday ridership on the 7:55 a.m. trip.

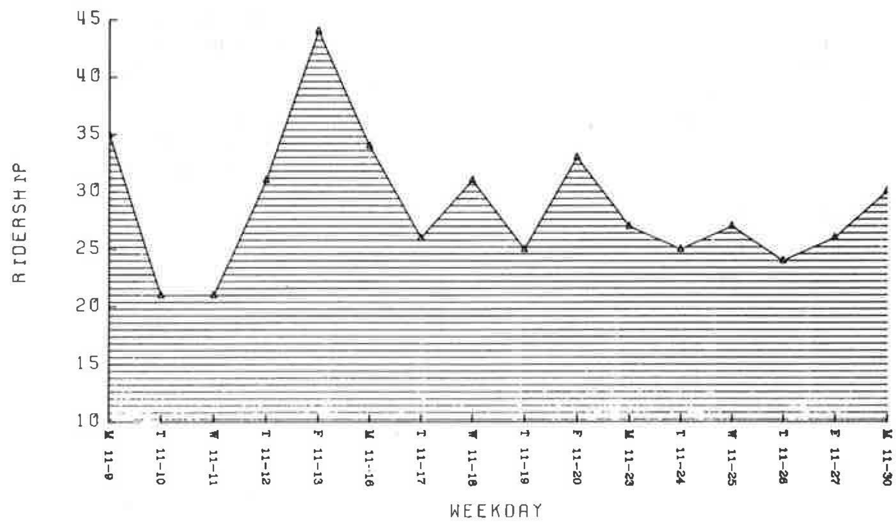


Figure 9. Cumulative inbound ridership.

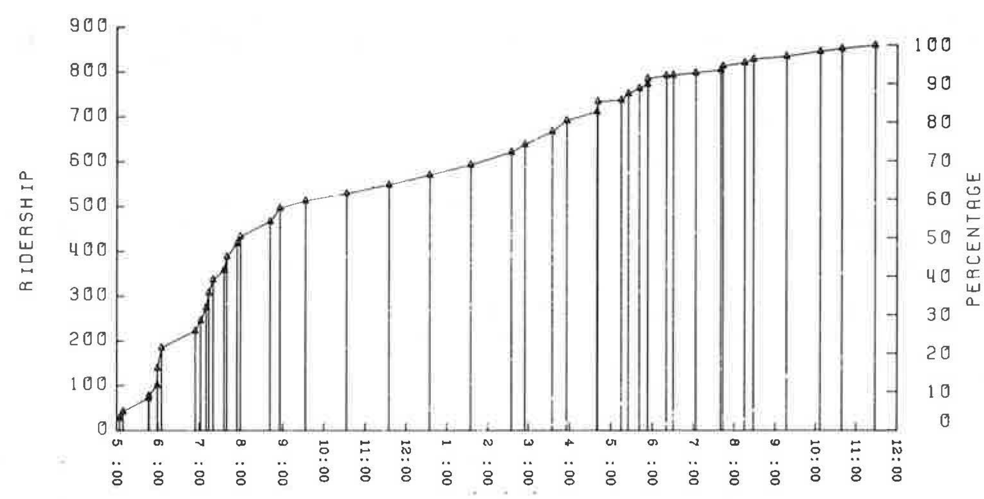
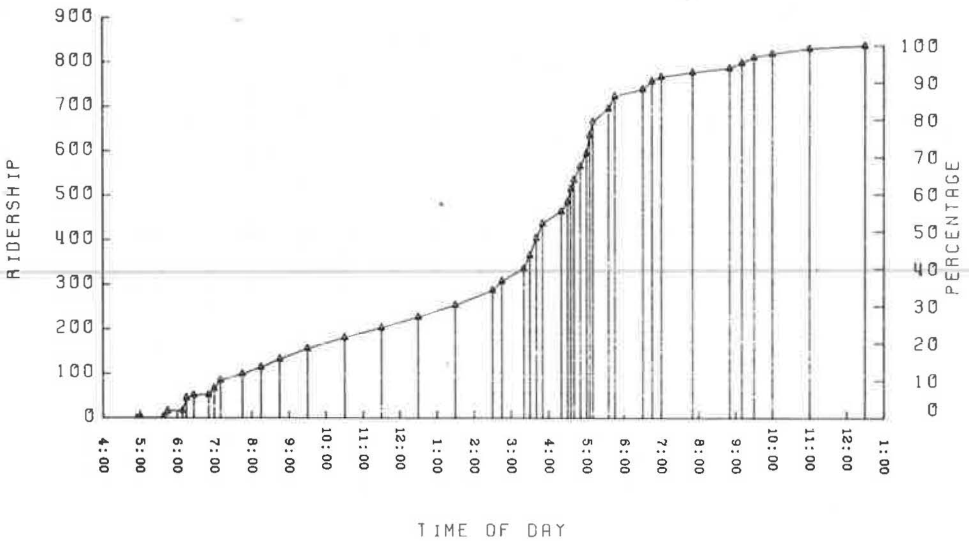


Figure 10. Cumulative outbound ridership.



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The Fare Cutter Card: A Revenue-Efficient and Market-Segmented Approach to Transit Pass Pricing

RICHARD L. ORAM, FRANK SPIELBERG, AND VINCENZO MILIONE

Recently, many transit properties have studied or instituted prepaid passes as part of marketing programs designed to retain existing riders and attract new riders. At the same time, transit properties are facing severe financial problems. As a result there can be conflict between the marketing department that wishes to offer an attractive fare mechanism that offers a substantial discount and the financial department that is concerned about lost revenue and free rides. To resolve this conflict, the Greater Bridgeport Transit District (GBTD) has introduced the Fare Cutter Card as part of a comprehensive demonstration of market-based fare policies. This card (actually a permit) has a substantially lower initial cost than an unlimited-use pass but requires a $0.25 cash-drop for each ride. The card is therefore more affordable to low-income users while returning revenue to GBTD for all rides taken. Different approaches to implementing the Fare Cutter Card may enable a major extension of fare prepayment without additional loss or a major reduction in revenue losses allocated with fare prepayment, while maintaining the existing level of use. The GBTD experience to date with the Fare Cutter Card is preliminary, but the card appears to be popular with riders. In this paper the analytical issues associated with the assessment of permits as compared with unlimited-use passes are outlined, the benefits of tailoring prepaid mechanisms to the characteristics of user submarkets are summarized, and marketing-related benefits of the Fare Cutter Card approach are discussed.

Monthly or weekly passes were once quite common in the transit industry. Urban residents who used public transit regularly for work and nonwork travel found the pass efficient and economical. Because most transit users made at least some nonwork transit trips during the month, pass purchasers were not overly concerned with failing to receive full value from a pass if they missed a few days of work during the month.

During the 1950s passes tended to fall into dis-

use. For regular transit riders, the number of nonwork trips fell; therefore, purchasing a pass was no longer an assured saving. At the same time, transit properties faced with financial difficulties either raised the price of the pass (expressed as a multiple of trips per month) or eliminated it completely.

Currently there is renewed interest in passes at many transit properties. As riding habits have not reverted to earlier patterns and financial problems are again a major concern, the question is, Why have passes once again become a focus of attention?

The reasons are diverse, but they may be grouped roughly into two groups: convenience to the transit user and benefits to the transit operator.

TRANSIT USER PERSPECTIVE

Convenience to the transit user relates mainly to the ability of the user to avoid inconvenient cash payments for boarding or getting a transfer. The general adoption of the exact-fare requirement, the elimination of change-making on vehicles, and rising transit fares have increased user requirements for change, perhaps to 6, 8, or more coins per day. With zone travel, the change requirements can increase further; even for a local rider the need to have change can be an obvious inconvenience that may discourage some potential riders. Purchase of a pass with one single monthly outlay--often by check--eliminates the need for coins for a full month; this may greatly improve the convenience and overall image of using transit.

In addition to convenience, when the pass is priced at or near the level of use of regular commuters, it offers significant economic benefits to riders who make more than 10 trips per week. Because of the reduction of off-peak trip making, and because of the need to make the instrument attractive to the largest portion of the market, many transit agencies reduce the price of the pass to allow a savings of 20 percent or more to commuter-only users. Often, the greater the overall orientation of the system to commuting, the greater is the discount offered to commuters. Commuter rail lines are the extreme of this case, with pass discounts often approaching 50 percent of the regular fare.

Other fare prepayment demonstrations have indicated that pass users do trade off convenience with economic savings, which suggests that the total prepayment market can be disaggregated into primarily price- or convenience-sensitive submarkets (1).

TRANSIT OPERATOR PERSPECTIVE

For the transit operator, the benefits of passes can include stimulation of the riding habit, improved cash flow, decreased cash handling, improved operations, marketing benefits, and ability to integrate merchant and employer support programs. Some of these effects, however, become significant only when a substantial portion of the riders use the pass--perhaps one-third or more of total riders.

Even with these benefits, both users and operators have major concerns about passes that have combined to limit their market appeal and resulting positive effects. For the user, the problems are most frequently related to cost or concern over loss of a pass. Purchase of a pass requires a substantial up-front outlay, generally 32 to 44 times greater than a single cash fare, which is often perceived by less-affluent users as a preclusive barrier. Typically, pass purchase is far more prevalent among riders in the $10,000 to $20,000 (or greater) income range than among those with incomes less than $10,000, despite the higher trip rates usually associated with lower-income levels (2).

There is also the fear by the user that he will not be able to make sufficient rides during the month to recoup the cost of the pass. Even in cases where the pass price is set so low that it equals the cash fare for 16.67 round trips per month, or less than 4 per week, the effects of holidays, taking a few days off from work, being sick a day or two, driving some days, or even getting a ride from a friend on occasion may raise the uncertainty of pass use to outweigh the potential savings. Riders also tend to perceive a month as equal to 4 weeks rather than the operator's assessment of a month equaling 4.33 weeks. Because the majority of riders use transit only to and from work, there is little opportunity to make up for lost days by nonwork trips. The fear of paying more for a pass than would have been paid with cash is thus a substantial barrier.

The transit operator perceives the potential both for increased administrative costs and for loss of revenue from the most frequent riders who shift from paying cash fare to using a pass for all trips. Use of passes results in significant revenue loss from at least three sources: (a) discounts to regular users (twice daily), (b) discounts to intensive users (more than twice daily), and (c) fraudulent use of passes (e.g., multiple users). When offered at a discount, passes also stimulate peak-hour use, which may be more of a problem than a benefit for some systems. [Good design of a pass program can mitigate this problem, however (3).] On an allocated-cost basis, the commuter market is also least deserving of lower fares, which clearly results through passes. Equity issues also contradict discounting practices.

Overall, a transit property that decides to offer a pass is typically faced with conflicts between desires to increase convenience and promote ridership by offering a low-priced pass (33 to 37 monthly trips) and the increasingly vital concern of avoiding loss of revenue by giving away trips made by frequent riders for which cash fares are not, but could be, collected.

BRIDGEPORT PROGRAM

Since 1981 the Greater Bridgeport Transit District (GBTD) in Connecticut has been engaged in an ambitious program of pricing management. Under the sponsorship of the Office of Service and Management Demonstrations of UMTA, GBTD has undertaken to make fare programs and pricing of transit services an integral element of their operations and development strategy. To this end GBTD has introduced a market-segmented pricing structure and established innovative private-sector participation programs (e.g., merchant and employer contributions), and it also has established the full-time staff position of pricing manager to monitor, design, and coordinate all pricing and farerelated activities of the district.

The thrust of the GBTD pricing activities has been directed toward increasing ridership while maintaining revenues by (a) tailoring price structures and prepayment mechanisms to specific market segments and (b) involving the private sector in the promotion of specific prepayment elements.

Tailoring has been achieved by identifying the travel habits of specific market groups and offering a payment mechanism to these groups in ways that make it attractive to the target audience but does not result in loss of revenue from other rider groups. Tailoring also includes introductory and ongoing promotion efforts. For example, a commuter pass offered on the Fairfield Mini-Mover (suburban paratransit) service is aimed at those who use the

bus to access train service to New York. A distance-based fare scheme is incorporated into the pass system to equitably distribute relatively higher fares. Ticket sales have been introduced for off-peak users to reflect the lower fares and trip rates of elderly and youth riders. Promotion has focused on use of discount coupons rather than across-the-board fare reductions to naturally target discounts to price-motivated users and potential users.

Similarly, GBTD offers a Commuter Pass for its regular-route services that is based on 38 trips per month ($23) and is good only on weekdays before 9:00 a.m. and between 2:00 and 6:00 p.m. The effective cost of this pass is reduced by the innovative Value Fare program, under which participating merchants offer discounts to pass purchasers in exchange for GBTD advertising in the bimonthly Value Fare Merchant Discount List. The potential sum of the discounts, now available at more than 130 stores and restaurants, far exceeds the full cost of a pass (see Figure 1). The benefits of the pass program have been further extended through an employer participation program, in which companies administer the program and in many cases subsidize all or part of the pass price.

Nevertheless, it was obvious to GBTD that a major share of its market would not be attracted to the Commuter Pass. Surveys of GBTD riders indicated three essential factors. First, ridership is not significantly peaked; rather, the hours between 9:00 a.m. and 3:00 p.m. serve only a slightly smaller percentage of total patronage than do the peak hours. Second, much of the GBTD patronage is composed of low-income individuals. Third, a substantial proportion of GBTD riders make more than 10 rides per week, i.e., more than just rush hours on weekdays.

If GBTD were to offer to this submarket an unlimited-use pass based on 40 or fewer trips per month, there was the danger of a significant revenue loss. The actual ridership level of this group is 11 to 20 rides per week, or 47 to 95 rides per month (Figure 2). If the pass price was set at a price high enough to reduce the potential loss, few members of this submarket would be attracted to or be able to afford the initial cash outlay required. To meet the needs of this group, GBTD designed the Fare Cutter Card. Figure 3 shows the Fare Cutter Card and the characteristics of its users, as well as the companion Commuter Pass.

The Fare Cutter Card, also called a permit, allows the user to ride at any time during the month but requires a cash deposit of $0.25 (less than half the regular fare) at the time of each ride. The initial cost of the card is $15, which is 65 percent of the cost of a Commuter Pass, thereby making the card more affordable to typical riders. At the same time, potential for revenue loss to GBTD is limited. The break-even number of trips is just more than 42 trips per month, which makes the card a sound investment for frequent riders. Even after the break-even point, however, GBTD still receives revenue from card users.

The basic rationale behind offering both a monthly peak-period-only Commuter Pass and the Fare Cutter Card is market segmentation, i.e., design according to the different travel submarkets served by GBTD. As shown by the GBTD trip rate distribution (Figure 2), the peak at 10 trips per week represents commuter-only users. The Commuter Pass should appeal to this group, who presumably earn relatively higher incomes and are more sensitive to the convenience of a fully paid pass. However, if the monthly pass was unlimited (i.e., valid at all times of day), it could be used by the substantial proportion of the riders who make more intensive use of the system, which would cause a significant revenue loss. The Fare Cutter Card mitigates this problem. Moreover, GBTD also instituted token use when the passes were in- troduced, which appealed to less-than-commuter users and reduced pressure for pass discounts.

Figure 1. Excerpt from GBTD Value Fare Merchant Discount List.

The revenue effects of these different payment mechanisms are shown in Figure 4. The diagram shows that an unlimited-use pass would lead to a revenue loss to the system for all rides more than 38 per month. With the Commuter Pass and Fare Cutter Card, a second break-even is set at 43 rides per month; even for those riders taking more than 43 trips, there is a continued return of revenue to the system, albeit at a lower rate.

The GBTD prepayment strategy includes the following elements.

1. Due to restrictions on pass use (the limited-use Commuter Pass and cash-drop requirement of the

Figure 2. Market-segmented fare mechanisms.

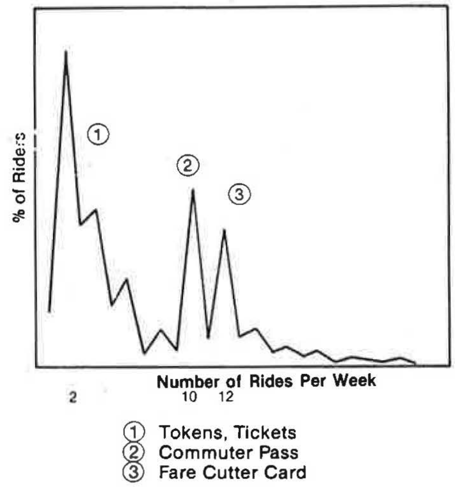
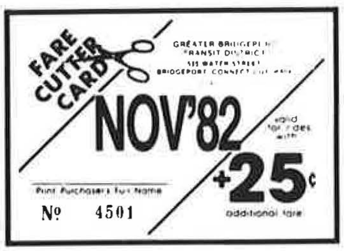


Figure 3. GBTD market-segmented and restricted-use passes.



User Characteristics*

- wide range of trip rate variation
- peak *and* off-peak use
- purchasers have higher sensitivity to front end cost
- purchasers have lower valuation of convenience
- purchasers have lower income

- narrow range of trip rate variation
- peak-only use
- purchasers have higher income
- purchasers have lower sensitivity to front end cost
- purchasers have higher valuation of convenience

* Per program design; market response evaluation pending.

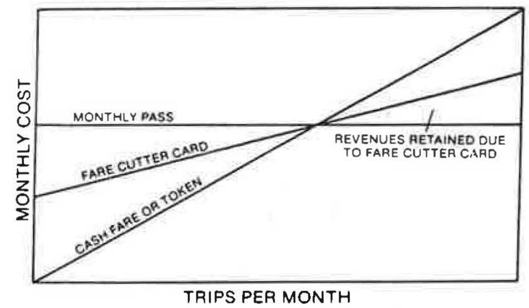
Fare Cutter Card), revenue loss is reduced compared with unlimited-use passes.

2. The low front-end cost of the Fare Cutter Card compared with the Commuter Pass or an unlimited-use instrument helps make prepayment affordable to a greater portion of the GBTD low-income market. The Fare Cutter Card approach may be a key for the efficient extension of prepayment in other cities.

3. GBTD has achieved market segmentation with tokens for infrequent users, the Commuter Pass for daily commuters, and the Fare Cutter Card for those who are heavy users of transit. The mechanisms are tailored to user characteristics.

Comparative pricing and revenue effects for the Fare Cutter Card versus the unlimited-use pass approach is detailed in Figure 5. In relation to an unlimited-use pass, benefits of the Fare Cutter Card can be summarized as (a) its purchase price can be up to 50 percent less, (b) the break-even trip level

Figure 4. Fare revenue variations.



can be reduced by up to 15 percent, and (c) revenue loss can be reduced by up to 50 percent. As noted, pass-related revenue loss is by no means trivial. If an average effective discount of 20 percent is absorbed by the pass program (as in the example cited in Figure 5) the total revenue loss can exceed $600,000 annually for a medium-sized property with a well-established pass program.

The three different price levels for the Fare Cutter Card cited in Figure 5 ($15, $12, and $10) actually represent different prices that the card has sold for in Bridgeport. A temporary price reduction and special coupon discounts have been used to stimulate development of the total pass program and to experiment with market responses to the instruments. The GBTD program is now just 1 year old, and full knowledge of the new fare instruments is clearly dependent on continued development of the program, which to date, for reasons particular to Bridgeport, has been slower than anticipated. Yet early evidence, based on limited observation, indicates that the Fare Cutter Card can fulfill its objectives. Although the Fare Cutter Card submarket is about 75 percent larger than that of the Commuter Pass, its sales have exceeded 3 times those of the Commuter Pass. Fare Cutter Card sales were particularly responsive to the coupon discount that reduced the price of the card to an extremely affordable price of $10.

It must be stressed that the data reported here are preliminary; they are more the product of conceptualizing and design than validated experience. Pass sales in Bridgeport have yet to reach 200; the target sales level is 800. The slow growth is not particularly discouraging because there had been no pass program in Bridgeport and because initial prices of the new passes were purposely set high. Limited outlets, marketing, and other Bridgeport problems do not reduce the validity of the Fare Cutter Card and market-segmentation approaches. A more complete evaluation is planned.

EVALUATION ISSUES

Although the Bridgeport experience has provided useful insight about transit passes, a great deal remains to be learned about the role that permits can play in improving transit revenues and marketing programs. Theory favoring permits over passes has also been noted (4).

Evaluation issues for investigation in Bridgeport include the following.

1. Is there a market group desiring a fully paid unlimited-use pass? Is the lack of such an instrument an impediment to a prepayment program? Are restricted instruments confusing?

2. Who are the primary users of the Fare Cutter Card and the Commuter Pass? How do the groups dif-

Figure 5. Comparison of Fare Cutter Card and unlimited-use pass: prices, break-even levels, and revenues.

Rider's Perspective (cost)

Fare Cutter Card price alternatives include:
A. $15 per month plus 25c per ride, yields break-even of 42.86 trips
B. $12 per month plus 25c per ride, yields break-even of 34.29 trips
C. $10 per month plus 25c per ride, yields break-even of 28.57 trips

Sales, i.e. market penetration increase with each reduction, and it may be assumed that the new purchasers have a slightly lower trip frequency than the previous purchasers.

Operator's Perspective (revenue)

A. At $15 per month, and assuming average use is for 45 trips per month, revenue is $15 plus (45 x .25) or $26.25. To have the same revenue yield, an unlimited use pass would be priced at 43.75 trips. This is 10 to 25 percent higher than the typical break-even level.
B. At $12 per month, and assuming the average use is for 42 trips per month, revenue is $12 plus (42 x .25) or $22.50. To have the same revenue yield, an unlimited use pass would be priced at 37.5 trips.
C. At $10 per month, and assuming average use is for 40 trips per month, revenue is $10 plus (40 x .25) or $20. For equal yield, an unlimited use pass would be priced at 33.33 trips.

Conclusion

Compared to the unlimited use pass, the Fare Cutter Card not only allows a lower front-end cost and thus increased appeal to low income markets, it also enables pricing at lower effective break-even levels, as seen by comparing columns (B) and (D) below. With these lower break-even prices, market penetration would be larger but revenue effects are the same. Equity is increased as total fares paid bear closer relation to actual trip rates.

(A) Fare Cutter Price	(B) Break-even Level @ 60¢ Fare	(C) Total Rev. (Same as Unlim. Use Pass Price)	(D) Equivalent Break-even for Unlim. Use Pass
$15	42.86	$26.25	43.75
$12	34.29	$22.50	37.50
$10	28.57	$20.00	33.33

Example

A medium-sized Eastern property currently sells unlimited use passes at $20 per month, which is 33.33 times the 60c fare. It could sell a Fare Cutter Card at $10, or only 28.57 times the prepaid fare component, to have the same revenue yield. Alternatively, it could sell a Fare Cutter Card at $11.65 per month (a more than 40 percent reduction in front-end expense), which would maintain the same break-even rate but enable saving over 50 percent of the revenue currently sacrificed through the pass program. For this property, the savings would amount to over $300,000 annually, on sales of 12,000 passes per month, or over 10% of total pass revenue.

fer in socioeconomic, travel behavior, and other factors?

3. What is the effect of lower front-end costs on pass or permit purchases? Is fear of pass loss reduced? Is fear of not making the break-even level of trips reduced?

4. What are the revenue effects of market-segmented and restricted-use instruments as opposed to unlimited-use passes?

5. Does the Fare Cutter Card induce additional trip making?

6. For Fare Cutter Card pricing, is a low front-end cost plus high drop-fare (i.e., $0.25) preferable to a high front-end plus low drop-fare (i.e., $0.10) combination?

7. Can the Fare Cutter Card be priced at a lower break-even rate to have the same revenue effect as an unlimited-use pass? Are transferability problems reduced?

8. Is the Fare Cutter Card perceived as a lower risk investment?

9. Have peak-period-only users (i.e., those intended for the Commuter Pass) been attracted to the Fare Cutter Card?

10. Is the market-segmentation framework a useful approach for improved transit marketing?

EXPERIENCE IN OTHER CITIES

Currently, use of reduced-fare permits in the transit industry is limited. (Identification cards used to show eligibility for elderly and student reduced fares are not considered permits in this discussion.) The current American Public Transit Association "Transit Fare Summary" (5) indicates that only three other systems currently use permits. In all three cases the permits used are closer to unlimited-use passes than to the Bridgeport Fare Cutter Card because the drop-charges are lower than the $0.25 charged by Bridgeport. Two of these systems have used permits for many years, and a larger number of systems relied on permits in earlier decades. It has been the premise of this paper that permits should be revitalized. A brief review of the other systems that currently use permits is warranted.

Pittsburgh

Before October 1982, Pittsburgh [Port Authority Transit (PAT)] had both weekly and monthly permits. At a $0.75 base fare, the weekly permit sold for $5.50 with a $0.10 drop, and the monthly permit sold for $21.25 with a $0.10 drop. The break-even levels were 8.46 trips per week and 32.64 trips per month. Sales of approximately 10,000 weekly permits and 20,000 monthly permits were common.

In October 1982, when PAT shifted to $1.00 base fare, the price of the weekly permit was raised to $8 plus $0.10 per trip, and a new monthly unlimited-use pass for $40 was instituted. The break-even trip rate on the weekly was raised to 8.89, an increase

of more than 5 percent beyond the fare increase. The break-even rate of the new pass is 40 trips. Preliminary sales patterns show marked adjustment, with the weekly instrument accounting for a 40 percent larger share and the monthly instrument accounting for a 20 percent smaller share. PAT sought to satisfy a long-standing request for a fully paid instrument and as can be seen, it raised the break-even level on the monthly pass.

Assessment of PAT's instruments is further complicated by transfer fees that pass users can avoid. Nevertheless, the mechanisms and their continued market response are clearly worthy of further investigation. If the market-segmentation and low front-end cost perspectives have merit, the additional features of the PAT weekly permits--the appeal of low purchase prices to low-income users and high-priced monthly passes for higher-income users--may be improvements over the Bridgeport design, albeit at the high administrative cost of reliance on weekly instruments.

Jacksonville

Jacksonville Transit Authority (JTA) has similarly found a permit attractive for many years, but it has applied permits and passes in the reverse of the PAT approach. Under a $0.50 fare, JTA sold a monthly permit for $18. It carried a fare value of $0.50, but because many JTA trips require one or more zone charges, the drop-fee reflects a distance surcharge. When JTA changed to a $0.60 fare, the permit was raised in price to $22 per month, a slightly larger increase than that of the base fare. JTA also has a weekly fully paid pass, but it is priced high ($10 and $12 under the $0.50 and $0.60 fares, respectively), as it is used almost exclusively by transferring riders who must pay double fares on the JTA system. If double fares are taken into account, the weekly pass break-even level is 10 trips per week, or 43.33 per month, as opposed to 36.67 for the monthly permit. Sales of both instruments are now constant at about 1,000 per month. The compatibility of a permit with distance-based fares is a useful observation from Jacksonville.

San Mateo

The experience in San Mateo, California, demonstrates that a permit is not always popular. San Mateo Transit has a low fare; $0.25 until recently, and currently $0.35. The permit reduces the fare by $0.15. Formerly, the user was required to pay an additional $0.10, and is now required to pay $0.20. The instrument sells for $5 per month and has a break-even level of 33.33. It has never been popular, perhaps because a reduced-fare permit is not sensible for low-fare systems. The recent change--making $0.20 extra fare required, leaves the instrument offering little in terms of savings or convenience.

MARKETING AND PROMOTIONAL APPLICATIONS

The benefits of prepaid passes in extending transit marketing opportunities (e.g., employer or merchant programs) are significant. The Fare Cutter Card approach may be able to increase these opportunities.

Employer involvement in pass programs is always contingent on there being a large enough number of riders and pass buyers. To the extent that a Fare Cutter Card increases the market for prepayment, employer involvement may increase to include smaller firms that otherwise would not participate. Merchant programs similarly require a critical mass of participants.

An additional benefit of the Fare Cutter Card is its perception as a fair split by employers willing to assist employees with their bus fares. The base cost component of the Fare Cutter Card can be (and has been) perceived as analogous to the free parking element of automobile commuting expenses that employers support, and the $0.25 per ride component of the Fare Cutter Card is perceived as being similar to gasoline expenses. Although the cost of an unlimited-use pass can be divided similarly, the ready-made perception of this fair split is conducive to ensuring good employer-support agreements.

The combination of prepaid and pay-as-you-go fares is perceived as reasonable and equitable from the standpoint of both employers and users. For the employers, the requirement for a fare-box drop serves to limit the number of employees who accept the subsidy to those who truly intend to use it. Moreover, even a minor subsidy (i.e., a few dollars) will make a Fare Cutter Card extremely affordable. In Bridgeport, a subsidy by General Electric ($5 per month) reduced the price of the Fare Cutter Card to only $7. A Fare Cutter Card does not, however, meet the needs of the employer willing to subsidize 100 percent of employee fares. The companion Commuter Pass does, however.

A further benefit of the Fare Cutter Card is that it readily facilitates additional fare variations, both as permanent policy and for intermittent promotional purposes. For example, the $0.25 per ride charge could not apply on Sundays, when ridership is particularly low. The $0.25 supplement could also be a peak-period-only surcharge. Or perhaps the $0.25 additional charge could be applied at all times except between the peak periods on regular weekdays, when lower fares are justified. If a large share of total riders use passes, this approach has benefits similar to a downtown free-fare zone in stimulating daytime transit use by commuters. The additional charge could also be suspended for occasional promotions, such as before Christmas or during other special shopping periods. Overall, the Fare Cutter Card enables more specific and targeted use and therefore is more cost effective in meeting the needs and opportunities that pricing and promotional policies can and should address.

SUMMARY

Although the Fare Cutter Card does not offer the full level of convenience of a flash pass, it can be a valuable instrument for many transit properties, particularly as fares increase and the search for operational and revenue efficiency increases. Because previous research and demonstrations have indicated that convenience is not the primary factor influencing pass purchase (1), lower initial price of the Fare Cutter Card and its justified pricing at lower break-even levels may be more operative factors in making prepayment attractive to a significantly larger proportion of the transit market. Moveover, as fares tend higher, the barrier of the front-end cost becomes more important and may limit or even reduce the market for conventional unlimited-use passes.

Thus the Fare Cutter Card approach may markedly extend the pass market and increase the benefits of prepayment for the operating agency. At the same time, the cash-drop aspect of the card diffuses concern over the free rides given to some users through unlimited passes, and the resulting revenue loss. The further ability to couple the Fare Cutter Card with targeted promotions and merchant and employer participation programs makes it an instrument that may be the contemporary choice for many operations.

ACKNOWLEDGMENT

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AC-Muni Joint Monthly Pass: A Look at the First Step Toward Fare Integration in the San Francisco Bay Area

JOEL MARKOWITZ

The first joint monthly transit pass in the San Francisco Bay Area was introduced in September 1981. Purchasers of the new pass were surveyed in October 1981, and the trends in joint and separate pass sales were monitored. The pass was targeted at a specific segment of the commuter market, and apparently it was successful in reaching that market. Purchasers of the new pass are extremely satisfied with it; administration is simple; distribution is centralized and inexpensive; and revenue losses from a promotional discount are minimal. Since introduction of the joint pass, however, sales have flattened, which reflects the restricted market and the diminishing value of the promotional incentive because of rising fares. Local efforts are continuing toward developing a more integrated regional fare system on which to base interoperator pass prices, a technological development project to adapt rapid transit station automatic fare gates to accept joint passes, and a promotional effort to increase pass sales through employers.

In January 1982 the final report of the Joint Fare Prepayment Demonstration Design Project was submitted to UMTA in three volumes (1-3). The project was carried out by the Metropolitan Transportation Commission (MTC) of the San Francisco Bay Area under a grant from the Office of Service and Methods (now Management) Demonstrations. The objective of the project was to identify, evaluate, and select alternatives for achieving joint fare prepayment arrangements (such as tickets or passes) among several of the large, independent transit systems operating in the area. The hope was that a joint prepayment scheme would help achieve a higher degree of fare integration in the region. In this paper the final project reports are updated based on the early experience with the first product of the joint fare program--a joint monthly pass.

BACKGROUND

The program was originally intended to design a joint fare prepayment demonstration that would then be implemented by the operating agencies in a subsequent phase of the demonstration. However, a succession of events, from initial project planning in 1978 to the present, reoriented the approach. State laws affecting transit finance and operator-MTC relations were some of the most significant external influences on the project.

A long history of concern for coordination among the several agencies (some studies date back 25 years) was finally catalyzed in 1980 by a crisis in transit financing that required concerted action by the three largest transit agencies to raise fares the same year. The identification of substantial local funds (from the sales tax) to pursue joint passes among these three operators obviated the need to independently press a follow-up UMTA demonstration. Instead, activities under the project grant were reoriented to support the local effort.

One of these activities was the description of the current market of transit pass users and the estimation of the market for future joint passes. Attention and resources were focused on a survey of purchasers of the two major existing individual system passes. The survey, conducted in October 1980, is described in a paper by Dittmar (4) and in Volume 2 of the project final report (2).

At the outset of the project there was no established date for introducing the first multioperator

pass. Nevertheless, about the time the draft of the project final report was completed (summer 1981), a firm date was set for introducing the first joint monthly pass. Remaining project funds were then reallocated to survey persons purchasing the new pass in October 1981. This survey provided the basis for much of the following analysis.

TRANSIT SERVICES IN THE REGION

Transit is supplied by a variety of public and private operators in the nine-county Bay Area. The focus of this project was on the three largest public transit systems that serve the central, urbanized part of the region. The total 1980 population in the three affected counties (Alameda, Contra Costa, and San Francisco) was 2.4 million.

Alameda-Contra Costa Transit

Alameda-Contra Costa Transit (AC Transit), the first multicounty transit district established in California, took over the operation of the private Key System in 1960. AC provides most of the bus transit in the heavily urbanized strip between San Francisco Bay and Oakland-Berkeley Hills, from Richmond in the north to Fremont in the south. In addition to local service throughout its East Bay service area, AC runs several routes across the San Francisco-Oakland Bay Bridge to the Transbay Terminal on the edge of downtown San Francisco. AC provides feeder service to all Bay Area Rapid Transit (BART) stations in its jurisdiction and local contract service in several outlying suburban areas. AC provides service with 2,200 employees and 922 buses to 250,000 patrons each weekday. It had a 1981-1982 operating budget of $96.8 million.

Bay Area Rapid Transit District

BART, the first of the new regional rail transit systems to be built in the United States since the early 1900s, was first established by state law in 1957. Planning, design, and financing put off construction until 1964, and service opened on the first segment in 1972 and the last in 1974. The 71-mile, 34-station system employs 2,000 people, and it had a 1981-1982 operating budget of $120.2 million. More than 185,000 patrons travel on BART each weekday.

San Francisco Municipal Railway

The San Francisco Municipal Railway (Muni), the oldest publicly owned transit system in the United States, operates a diverse service within the city and county of San Francisco--cable cars, streetcars (including the new light rail vehicles known as Muni Metro), diesel buses, and electric trolley buses, more than 1,000 vehicles in all. Muni employs 3,600, and the 1981-1982 operating budget was $142.3 million. Due in part to heavy use of passes, no firm patronage figures are available, but estimates range from 500,000 to 700,000 daily riders.

TRANSIT FARES AND PASSES

Each of the major operators provides at least one form of transit fare prepayment, principally monthly passes or books of tickets.

The BART automatic fare collection (AFC) system is based on a magnetically encoded, stored-value ticket that the user may purchase from vending machines in each BART station in any value up to $20 (in $0.05 increments). Also, $10 and $20 tickets can be purchased at some banks. The ticket is then used until its dollar value has been reduced below that needed to pay for a trip. Then the remaining value may be transferred onto a new ticket. The operations of keeping track of value used and issuance of new tickets are handled by AFC equipment in the stations. Although the BART ticket is not a pass in the usual sense, it offers riders the opportunity to choose their preferred amount of prepayment.

AC Transit has a flat fare for bus service within its East Bay service area for all local routes. Express routes to downtown Oakland and transbay routes to San Francisco are zoned. In November 1979 AC introduced its first local monthly pass, which was good for unlimited rides on routes within East Bay. In March 1980 AC introduced its zoned transbay monthly passes, which were good both for unlimited transbay trips for the designated zones and for trips on all East Bay routes.

Muni has a flat fare for all its services. It introduced its monthly pass (called the Fast Pass) in 1974.

The current fare structures of these three systems, along with the previous fares charged, are summarized in Table 1. For ease of presentation, only the full-fare categories are shown. All three operators raised fares in 1980 and 1982.

DESIGNING A JOINT PASS

Based on the desire to minimize disruption to existing fare structures and collection methods, the three transit agencies agreed quickly to narrow the focus for joint fares to monthly passes, for full-fare patrons only, in the largest identifiable markets. The structure for the joint fare was to be based on some combination of the existing arrangements--San Francisco Muni has a flat fare, AC Transit has a fixed zone fare, and BART has a more finely graduated distance-based fare. Whatever structure is eventually chosen for the regional joint fare, it will represent a compromise in which one or more agencies will have to move toward the others' methods, but in which the result will be minimally disruptive to at least one of them.

The first joint pass to be introduced illustrates this approach. In September 1981 AC Transit began selling a joint monthly pass that allowed unlimited rides on AC local and transbay lines and on all Muni services. The joint monthly pass consists of a standard AC transbay pass (for zone 1, 2, or 3, depending on the commuting distance from San Francisco) with a Muni sticker affixed at the time of purchase. The AC bus drivers now are faced with a slight variation on the pass they normally see, and Muni drivers had to learn to look for their agency's symbol on the joint pass. Sales of the joint monthly pass are handled exclusively by AC personnel, who act, in effect, as Muni sales agents for the new stickers.

In the absence of a unified regional fare structure, the price agreed on by the two agencies was the sum of their existing passes minus $2. The $2 reduction was established to provide some promotional incentive for purchasers while limiting potential revenue losses. Any temporary revenue loss is to be covered by local funds set aside by MTC for the regional pass project.

The resulting price on introduction was $50 for zone 1 (principally the Oakland-Berkeley area), $59 for zone 2 (the Richmond area to the north and the San Leandro-Hayward area to the south), and $68 for

Table 1. Fare structure comparisons.

Fare Category	AC Transit 1978	AC Transit 1980	AC Transit 1982	BART 1975	BART 1980	BART 1982	Muni 1970	Muni 1980	Muni 1982
Cost of service ($)									
Base (local)	0.35	0.50	0.60	0.30	0.50	0.60	0.25	0.50	0.60
Express (local)	0.35	0.50	0.60	—[a]	—[a]	—[a]	0.30	—[a]	—[a]
Multizone East Bay	0.45-0.60	0.75-1.00	0.85-1.10	0.35-1.30	0.55-1.60	0.70-2.00	—[a]	—[a]	—[a]
Multizone transbay	0.75-1.25	1.00-1.50	1.25-1.75	0.70-1.45	0.90-1.75	1.10-2.15	—[a]	—[a]	—[a]
Local pass	15.00[b]	18.00	24.00	—[a]	—[a]	—[a]	11.00	16.00	24.00
Zoned transbay pass	30.00-50.00	36.00-54.00	45.00-63.00	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Cost of 20-ticket books ($)									
Local	7.00	9.50		—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Multizone East Bay	—[a]	9.50-19.00		—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Transbay	15.00-25.00	19.00-28.50	25.00-35.00	—[a]	—[a]	—[a]	—[a]	—[a]	—[a]
Pass multiplier	43[c]	36	40[c]	—[a]	—[a]	—[a]	44	32	40
(no. of equivalent cash fares)	40[d]		36[d]						

[a]Fare category not applicable. [b]1979. [c]Local. [d]Transbay.

zone 3 (the southernmost portion of the AC basic service area). The price has since been increased twice from AC and Muni fare changes to a current zone 1 AC-Muni price of $67.

The joint pass is sold, along with regular AC passes and tickets, only at the AC office in downtown Oakland or at the AC ticket booth in the Transbay Terminal, located on the southern edge of downtown San Francisco.

Almost all joint passes are sold at the terminal because all persons who use AC transbay service pass through there for every trip. In addition to the AC transbay routes that terminate there, the Transbay Terminal also is served by several Muni routes, San Mateo County Transit buses from south of San Francisco, and Golden Gate Transit buses from north of San Francisco. Market Street, which has the Muni light rail system and BART running beneath it, is one long block from the terminal.

INITIAL MARKET RESPONSE

The first estimate of potential AC-Muni joint pass buyers was the 3,000 persons who each weekday transfer between AC and Muni for work trips. The questions from the 1980 survey of separate system pass users (2) indicated that 38.7 percent of all AC transbay pass users were interested in an AC-Muni joint pass; if the price were set at the sum of separate passes, the favorable response dropped to 22.1 percent. At the October 1980 pass sales rate, this translated to 1,150 to 2,020 persons. Because the AC-Muni pass would primarily be for regular AC transbay riders who need to transfer to or from Muni to complete their trips, this range (1,000 to 2,000) can be taken as an approximation of the immediate market for the new pass. The 3,000 figure was used as the total market.

Sales in the first few months were 1,200 to 1,300 per month. Although too early to establish a pattern, these figures were encouraging in that they represented more than 40 percent of the maximum total market predicted (3,000), and an even higher proportion (60 to 120 percent) of the predicted immediate market (1,000 to 2,000).

Initial response was also a function of available agency budgets that restricted advertising principally to the Transbay Terminal and to the AC transbay buses. In August 1981 a major publicity event was staged by a related multiagency project concerning public information on regional transit routes and connections. Among other things, the ceremony included the first public announcement of the joint AC-Muni pass. Although the local press featured the new pass in articles, there was relatively little widespread publicity.

SURVEY OF JOINT PASS BUYERS

The same survey methodology applied in the 1980 survey of separate system pass buyers was repeated--a self-completion survey, which had a weekly trip table and $1 discount coupon incentive. Many of the 1980 questions were repeated, and others were added or improved.

The major purposes of the 1981 survey were to

1. Compare buyers of the new joint pass with those who bought the separate system passes,
2. Further probe buyers' preferences among sales and distribution options, and
3. Gauge consumer acceptance of the new pass.

The restricted-distribution system and the estimated market size meant that a 100 percent sample could be attempted. AC sales personnel agreed to distribute a survey form with every joint pass sold. A total of 675 usable responses were received by the processing cut-off date for about a 56 percent return rate, which was similar to that for the 1980 survey.

Sources of Buyers of New Passes

As expected, a majority of new pass buyers had formerly bought one or both of the two separate system passes. A question in the October survey asked if the respondent had bought the joint pass before (i.e., in September, the first month it was offered). The prior payment method appears to be related to both the residence of the buyer and when the buyer bought the pass for the first time. (First time means first bought the joint pass in October 1981; second time means bought the pass in September and October 1981.)

Data in the righthand columns of Table 2 indicate that the first people to respond to the new pass in September were those regular riders who had purchased both passes separately before. They realized both an immediate $2 monthly savings and the convenience of carrying only one card rather than two. Those who first bought the new pass in October, the second month, may better represent the future market. A higher proportion of these persons either previously paid by cash, only bought one of the two passes, or were new riders to one system or the other.

Comparisons with 1980 Survey Respondents

There appear to be some significant demographic differences between the joint pass buyers and the separate system pass buyers surveyed 1 year earlier. The income distribution of the joint pass users is

Table 2. Prior payment methods, by residence and timing.

Item	Total	First-Time Buyers[a] East Bay	First-Time Buyers[a] San Francisco	Second-Time Buyers[b] East Bay	Second-Time Buyers[b] San Francisco
No. of users	669	224	53	336	40
Percentage of prior AC or Muni users					
Bought both passes	60.1	47.3	39.6	69.6	72.5
Bought AC pass only	6.7	8.9	3.8	6.5	2.5
Bought Muni pass only	11.7	13.4	26.5	7.5	17.5
Paid cash for ticket	15.3	23.1	20.8	10.7	7.5
Total	93.8	92.7	90.7	94.3	100.0
Percentage of new riders (all methods) to					
AC	2.3	3.1	9.5	1.2	-
Muni	1.7	2.2	-	1.8	-
Both	1.9	1.8	-	2.7	-
Total	5.9	7.1	9.5	5.7	-
Total percentage of prior and new riders	99.7	99.8	100.2	100.0	100.0

[a]October 1981.
[b]September and October 1981.

closer to that of the Muni pass user than to the AC transbay pass user, but the proportion of females and minorities is higher for joint pass buyers than for either separate system pass. The basic demographics are compared in Table 3.

In the 1980 survey of AC transbay pass buyers, only 4.7 percent were San Francisco residents. The persons buying the joint pass the first month included 10.6 percent San Francisco residents, and in the second month 19.1 percent, for an average of 14.4 percent. This suggests a reverse-commute market that had not been expected.

The immediate attraction of saving $2 on the new pass may partly account for the high proportion of users from the lowest income category. It is also possible that the $1 survey incentive biased response toward lower-income persons, but this bias did not occur in the 1980 survey of separate pass buyers. Recall that the minimum price for the joint pass was $50; the 2 to 4 percent discount would not be expected to change response patterns.

It was expected that joint pass buyers would closely mirror AC transbay pass buyers because the data in Table 3 indicate that two-thirds of the joint pass buyers had bought the AC transbay pass before. It may be true, however, that those AC transbay pass users who do not need to use Muni to get to work have higher incomes than those who find the joint pass attractive. The explanation for this could be in the differentiation of the downtown San Francisco districts. The area closest to the Transbay Terminal is the financial district, home of many corporate headquarters and banks, law offices, and brokerage firms. Because this area is a fairly easy walk from the AC terminal, the workers in this district may not find the joint pass attractive. Farther west (up) along Market Street is the Union Square hotel and shopping area. For persons working in that district, which is beyond easy walking distance from the Transbay Terminal, the joint pass would be useful. Still farther west is the Civic Center area in which state and federal office buildings are located. It is plausible that the incomes of retail clerks, hotel personnel, and civil servants are lower than those for financial district workers. This explanation is purely speculative, because income and occupation data are not available in sufficient detail to allow a quantitative analysis, but it may account for the apparent attractiveness of the joint pass to lower-income persons.

Table 3. Demographic comparisons.

Category	1980 AC Transbay Pass Users (%)	1980 Muni Pass Users (%)	1980 AC-Muni Joint Pass Users (%)	General Population[a]: 1980 U.S. Census (%)
Female[b]	58.1	50.5	61.4	51.0
Minority[b]	42.3	45.7	49.8	37.1
Household income[c]				
< $15,000	29.2	46.3	41.4	38.2
$15,000-$24,999	33.5	30.6	31.3	23.7
$25,000-$34,999	20.5	12.2	14.6	17.4
≥ $35,000	16.8	11.0	12.7	20.7
Residence				
East Bay	94.9	1.1	85.3	72.2
San Francisco	4.7	94.8	14.4	27.8

[a]General population data from the three county BART area.
[b]Sex and race ethnicity data were derived from tabulations from census data for three counties (Alameda, Contra Costa, and San Francisco). In this tabulation minority includes Hispanics, regardless of their race.
[c]Income data are for the five-county San Francisco-Oakland standard metropolitan statistical areas ($).

Travel Patterns

More than 600 respondents (89.3 percent) provided usable data in their weekly trip tables. Pass buyers were asked for their one-way trips on AC and Muni in the full week preceding their purchase of the October joint pass. As indicated by the data in Table 2 for first-time pass buyers, that week may have represented a mix of payment methods. For second-time pass buyers, however, the preceding week is assumed to represent actual use of the new September joint pass. In this interpretation, comparison of first- and second-time joint pass buyers can be used as a rough before-and-after comparison. The comparisons between 1980 and 1981 data by residency are given in Table 4.

Use of AC does not appear to be much different for the regular AC transbay pass user or the new AC-Muni joint pass user; it indicates primarily work commuting connections (10 trips per week for a typical 5-day work week).

In each category, those people who bought the joint pass for the first time in October had fewer trips than those who bought it in both September and October. The greatest difference is seen for Muni trips by San Francisco residents. Additional trips by second-time users may reflect two factors: (a) a realization of expected new tripmaking, and (b) more frequent riders (who benefit most from passes) responding first to the new pass.

Considering the joint use of AC and Muni by buyers of the new pass, the previous conclusion that

Table 4. Weekly and monthly trips.

	1980 AC Transbay Pass Trips	1980 Muni Pass Trips	1981 AC-Muni Joint Pass Trips	
			First-Time Buyers (before)	Second-Time Buyers (after)
Mean weekly trips				
On AC				
East Bay residents	11.00		10.50	11.31
San Francisco residents	10.41		10.33	11.00
On Muni				
East Bay residents		10.40	10.42	10.96
San Francisco residents		13.53	12.96	14.34
Mean monthly trips[a]				
On AC				
East Bay residents	47.47		45.50	48.99
San Francisco residents	44.88		44.77	47.66
On Muni				
East Bay residents		44.87	45.14	47.47
San Francisco residents		58.56	56.15	62.15

[a]Monthly trips estimated as weekly x 4.333.

the standard 10-trip commuting pattern accounts for most weekly trips is again supported. Dividing total weekly trips on each system into five ranges, centered around multiples of five, illustrates the point. The second range (10 = 8 to 12 trips) represents typical commuting. The third range (15 = 13 to 17 trips) includes two or three additional round trips per week. These two ranges account for 86.3 percent of all respondents.

A similar breakdown of the data according to former pass use suggests that joint pass users will make slightly more trips per week than prior separate system pass users and nonpass users, but that 5 day per week commuting plus one to two additional round trips would be typical.

Turning the same question around to the revenue side, there was a concern that the new pass would give away too many trips. Again treating the first- and second-time buyers as proxies for before and after measurements of response to the joint pass, it was noted that only 0 to 2 trips per week were added.

Looking at the weekly trip distributions for the 1980 separate AC transbay and Muni pass buyers and for the 1981 joint pass buyers, the modal number of trips taken for both groups was 10 on each system. Nevertheless, the 10-trip category accounted for two-thirds of AC transbay pass users and only one-third of Muni pass users. The joint pass distributions tend to be a bit more tightly centered around 10 trips than the separate system pass users, but only the Muni distribution is significantly different (a mean of 13.5 trips versus about 11 trips for the others).

Expected New Trips

As an indication of the potential for increased trips in the future, respondents were asked if they expected to use Muni or AC local or transbay service more, less, or about the same as they had before purchasing the new joint pass. Overall, 43.6 percent said that they might make some new trips on one or more of the services (AC local East Bay, AC transbay, or Muni) for a variety of trip purposes. The data indicated that newcomers are most likely to make new trips; i.e., those new to an AC pass are most likely to take more AC trips, those new to a Muni pass are most likely to take new Muni trips, and those who used neither pass are about equally likely to take more local trips (AC or Muni).

Reasons for Buying Joint Pass

The formats for both the 1980 and 1981 surveys did not permit a true trade-off question ranking the various reasons for purchasing the passes. One aggregate proxy for this is the proportion of persons ranking a reason as very important.

The importance of saving money with all the passes remains a dominant reason for purchasing a pass. The price basis for each of the three passes was different, so the individual's calculation of savings must be quite gross--probably expected commute trips as a break-even point. The AC transbay pass was priced at 36 trips (or 18 work commuter trips), the Muni pass at 32 trips (or 16 commuter trips), and the joint pass at the sum of the two passes minus $2.

The data in Table 5 give the relationship between the importance scores and prior pass use (on the left) and income (on the right). The major difference across prior pass user groups is that those who used neither pass scored all four reasons higher (less important) than those who had used passes, although the score for saves money is not significantly different. Across income groups, the major point is what could have been expected--the lower the income, the more important the reason for saving money. Ability to take unlimited rides was consistently the least important of the reasons ranked, but that should be expected from users of a pass that was specifically targeted toward commuters.

Several respondents wrote in an additional reason for buying the joint pass. They said that they preferred the convenience of carrying only one type of pass for two systems. Some mentioned it in terms of less space taken up in their wallets or purses, whereas others wrote about the advantage of not fumbling around for the right pass to show a bus driver.

Sales and Distribution

The survey of joint pass users sought more information on preferences for payment methods and distribution points than was obtained in the 1980 survey. Most respondents ranked the current AC-Muni method as their most preferred--payment by cash or check at the Transbay Terminal. There may have been some response bias introduced by the format, which listed these options first, but it is more likely that a majority of people simply prefer the certainty of method and location that the ticket booth offers.

Currently, AC transbay passes are available at some East Bay supermarkets, and Muni passes are sold in a variety of retail stores and banks throughout San Francisco. There appears to be interest in expanding distribution of the joint pass beyond the terminal, indicated both by the preceding data and by write-in comments that the passes should be

Table 5. Reasons for buying joint pass.

Reason	Prior Pass Use: Used Both Passes	Used AC Pass Only	Used Muni Pass Only	Used Neither Pass	Household Income: < $15,000	$15,000-$24,999	$25,000-$34,999	≥ $35,000
More convenient than using cash								
Mean score[a]	1.14	1.13	1.29	1.32	1.20	1.15	1.27	1.21
Very important[b] (%)	86.5	87.2	75.3	71.7	81.6	86.2	73.6	82.3
Can take unlimited rides								
Mean score[a]	1.37	1.36	1.45	1.52	1.38	1.36	1.49	1.54
Very important[b] (%)	68.4	68.9	62.0	58.4	66.9	67.9	62.1	58.3
Saves money								
Mean score[a]	1.15	1.16	1.08	1.17	1.11	1.12	1.23	1.20
Very important[b] (%)	85.9	84.3	92.9	84.6	89.6	87.9	79.6	80.0
More convenient than paying twice								
Mean score[a]	1.31	1.32	1.41	1.43	1.29	1.36	1.42	1.42
Very important[b] (%)	73.9	76.6	69.1	62.5	76.1	71.3	60.2	65.3

[a]Mean score where 1 = very important, 2 = somewhat important, and 3 = not important at all.
[b]Percentage of respondents who rated the reason as very important in the survey.

available at specific locations, including banks, grocery stores, and college campuses. Interest is also apparent in credit card payment, which no transit agency currently offers.

Payment methods that elicited little interest were automatic bank account or payroll deductions. Few people were interested in purchasing passes through regular ticket agencies (the ones that handle entertainment events) or through BART station vending equipment. There were clear income-group distinctions among payment preferences. The lower the income, the more cash payment is preferred. Only the highest income group found credit card payment appealing, and no income groups ranked automatic deduction methods highly.

Reasons behind these preferences were not probed, so interpretation is speculative. The lack of low-income user interest in credit card payment, for example, may simply be because they are less likely to have credit cards. Nevertheless, respondents appear to prefer personal transactions to more automated or automatic procedures, and they do not appear to trust the mail to ensure that their high-value pass arrives safely and on time.

Patron Comments

More than 68 percent of respondents took the opportunity to write in open-end comments. A total of 459 respondents offered 611 separate types of comments. A total of 59 percent of the responses were positive, expressing general approval (such as "good idea") or saying how the pass is convenient for them or saves them money. Another 38 percent offered specific suggestions for expanding or improving the joint pass, or complained about some of its features (high price, limited availability). The remaining 3 percent were general complaints about transit service that were unrelated to the joint pass.

SALES TRENDS AND PRICE CHANGES

Examination of the sales trends of the Muni, AC, and joint passes indicate three main points:

1. The relative magnitude of Muni pass sales (which had reached 90,000 to 100,000 per month in 1981 and have leveled off at about 70,000 by the end of 1982) compared with the other passes is in part a function of the Muni pass being well established after nearly 10 years in a dense transit market;
2. The AC transbay pass sales have leveled off at 3,000 to 5,000 per month, with joint pass sales closely tracking that trend at 800 to 1,000 by early 1983; and
3. Muni pass sales are highly cyclical and seasonal, but a key consideration appears to be the apparent sensitivity of all pass sales to the pass multiplier (i.e., the number of cash fares the pass is equivalent to).

It may be that there have been so many changes in fares in recent years affecting persons who use both AC and Muni that informed choices have become harder to make. The data in Table 6 give the seven stages of successive changes in relative AC and Muni cash and pass fares since March 1980. For each change, the possible combined AC and Muni fares are computed, assuming 40 commute trips in a typical month. The savings from using a pass (compared with paying the separate cash or pass fares) are shown for buying both passes or buying the new joint pass. The right-most columns give the break-even point for purchasing the separate passes or the joint pass (the number of equivalent cash fare trips).

The greatest savings (lowest break-even point) occurred by accident. AC raised its cash fares effective July 1, 1980, but delayed raising the pass prices until September to allow enough time to make administrative arrangements with the large supermarket chains that distribute its passes in the East Bay. Consequently, for 2 months (July through August 1980), old (low) pass prices were in effect simultaneously with new (high) cash prices, accounting for the bulge in pass sales in the previous figures when it was expected that a seasonal summer fall-off of sales would occur. The 1982 cash and pass fare increases were accomplished at the same time.

The per-trip savings of the joint pass over buying the separate passes is only $0.05. Although the decision to limit the discount to $2 was understandable, the result is that successive fare increases make that less and less of an incentive.

FUTURE DIRECTIONS

The AC-Muni joint monthly pass was the first joint pass to be introduced because

1. There were no technological changes needed in fare collection;
2. The main distribution point was well established; and
3. The total market was relatively small, so that revenue-sharing arrangements and subsidies could be straightforward.

It is quite a different matter for the other components of the joint pass development program. The BART automatic fare gates allow unrivaled col-

Table 6. Fare changes affecting AC-Muni riders.

Date and Change	Fare Per Trip (40 Trips) ($) AC Cash plus Muni Cash	AC Cash plus Muni Pass	AC Pass plus Muni Pass	AC-Muni Joint Pass	Savings From Pass Use ($)	Break-Even Point for Purchasing Separate Passes	Joint Pass
March 1980:							
AC transbay pass introduced	1.00	1.025	1.025	-	0	41	-
April-June 1980:							
Muni fare increase	1.25	1.15	1.15	-	0.10	36.8	-
July-August 1980:							
AC cash fare increase	1.50	1.40	1.15	-	0.25-0.35	30.7	-
September 1980-August 1981:							
AC pass fare increase	1.50	1.40	1.30	-	0.10-0.20	34.7	-
September 1981-March 1982:							
AC transbay-Muni joint pass introduced	1.50	1.40	1.30	1.25	0.05-0.25	34.7	33.3
April-June 1982:							
Muni fare increase	1.60	1.60	1.50	1.45	0.05-0.15	37.5	36.3
July 1982:							
AC fare increase	1.85	1.85	1.725	1.675	0.05-0.175	37.3	36.2

lection of information on travel patterns and differentiation of fares by distance, but they present an obstacle to a simple, visual verification system such as the sticker-on-a-pass approach. The bulk of local funds to date in this project have been spent on investigating alternatives for modifying the BART fare gates to accommodate joint passes (1).

The first effort in this direction will be a joint Muni-BART pass, good for unlimited travel on either system within San Francisco. Because both agencies have a flat fare within the city, it was agreed that the Muni pass would serve as the joint pass. The BART fare gates will be modified to recognize the Muni pass magnetic code as a valid fare, along with the normal BART tickets. The technical work should be accomplished by February 1983. A revenue-sharing agreement was worked out in mid-1982 to allow reimbursement to BART for revenues Muni would be collecting, in effect, as BART's agent.

The eventual goal of the locally funded program is the development of a common distance-based pass to be used by AC, BART, and Muni. The first major step toward that level of fare integration was taken in January 1982 when the general managers of the three agencies endorsed the principle of a value-based monthly pass fare structure for the eventual multioperator regional pass. Under this approach, a distance-based fare, regardless of operator used, would be the basis for the joint pass price. The pass would be read by the BART automatic fare gates to allow any trip up to a predetermined trip value. For example, a pass marked $1.25 would allow unlimited BART trips of $1.25 value or less during the specified month. The dollar value would also be translated into the corresponding number of AC Transit transbay zones. Currently, for instance, $1.25 is the fare for AC transbay trips from zone 1 to downtown San Francisco.

CONCLUSIONS

The first attempt at a joint transit pass has been a limited success. A significant proportion of the expected market responded to the new pass, but sales have not increased. This is likely the result of several factors.

1. The pricing basis: The sum of separate system passes, minus a small discount, forces travelers to estimate whether they will use both systems enough to satisfy the break-even point, which will happen only if both systems are a necessity for commuting. The pass was not designed or priced for those who predominantly use one system and occasionally want to use the other. A limited market was sought, and that was what was achieved.

2. Marketing: Aside from the initial advertising in conjunction with an overall regional transit promotion, there has been little effort devoted to marketing the joint pass. Signs at the Transbay Terminal and on board some AC transbay buses and Muni vehicles are the only continuing advertising. It is likely, then, that only current AC transbay pass users are aware of the joint pass. The limited marketing effort is a direct result of severe budget constraints that keep agency efforts focused on basic public information activities rather than active promotion of a new pass.

3. Fare changes: The frequent changes in cash and pass fares affecting AC and Muni riders in the past few years may have created confusion among patrons, so that they tend to stay with their familiar methods of payment and travel patterns. A regionally integrated fare structure, complemented by simultaneous and consistent fare changes by transit agencies, could overcome this problem. Separate and uncoordinated fare changes can only make it more difficult for potential patrons to figure out what the fare is for multiagency trips.

The encouraging note is that those who did buy the joint pass indicated a high degree of satisfaction with it. The 1980 survey of separate system pass buyers indicated a strong demand for BART-Muni and AC-BART passes, so the future products of the local program should also be well received. A related effort may also help boost pass sales in general. California laws enacted in 1981 and 1982 provide state income tax incentives to employers and employees for purchasing transit passes. MTC and the regional transit operators are seeking federal funds to develop a program for providing employers with transit information that features the new tax incentives and the multioperator passes.

The first step toward fare integration was a difficult one for all agencies concerned. Some have feared that after all the work, no one would buy the new pass. The generally positive response from the public should reassure the cooperating transit agencies that continuing efforts at fare integration will be welcomed by patrons.

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Regional Transit Pass for San Diego: A Key to Operating Efficiencies and Rider Convenience

EVA LERNER-LAM

A regional transit pass was developed by the San Diego Metropolitan Transit Development Board (MTDB) in order to present transit services provided by multiple operators as a single unified system to transit riders. In an effort to reduce the total cost of providing transit service in the metropolitan area, the existence of multiple operators has been supported by MTDB during the past several years. The positive competition from multiple operators can lead to lower unit operating costs for the region. Nevertheless, lack of coordination among the various operators can result in rider confusion and a subsequent loss of ridership. The success of a regional transit pass depends on the coordination of many elements. If such coordination is achieved, the pass can present services provided by multiple operators as a single unified system. The regional transit pass program is described, the key steps toward its development and implementation are identified, and a preliminary assessment of the impacts of the program on operating efficiencies and rider convenience is presented.

Fixed-route transit services in the metropolitan San Diego area are currently provided by six different operators: County Transit System-Suburban, National City Transit, San Diego Transit, San Diego Trolley, South Coast Organization Operating Transit (SCOOT), and Strand Streaker. The main characteristics of these operators are given in Tables 1 (1) and 2 (2).

The San Diego Metropolitan Transit Development Board (MTDB) was created by the California State Legislature in 1975 and was made responsible for short-range (5-year) transportation planning. For its region of jurisdiction, MTDB develops the annual transportation improvement program (1) and administers the transit subsidy funds of the California Transportation Development Act (3). The MTDB region of jurisdiction is shown in Figure 1.

DESCRIPTION OF REGIONAL TRANSIT PASS PROGRAM

The regional transit pass program began on July 1, 1981, with the introduction of the monthly Ready Pass (see Figure 2). A red Ready Pass entitles the bearer to unlimited travel for an entire calendar month on all six of the fixed-route public transit services in the metropolitan San Diego area for $31.00. A blue Ready Pass entitles the qualified elderly or disabled bearer to the same services for $15.50.

Ready Passes are sold at more than 150 locations throughout the metropolitan area. Pass outlets are maintained by both MTDB and San Diego Transit, the largest transit operator in the region. All pass revenues are remitted to a single fund with two accounts (one for red Ready Pass revenues and one for blue Ready Pass revenues). The revenues are then distributed among the participating operators according to distribution instructions from the San Diego Association of Governments (SANDAG), the metropolitan planning organization for San Diego County. The operators in the region agreed that the distribution of revenues should be based on (a) actual pass use counts on fixed-route bus systems and (b) estimated pass use on the San Diego Trolley derived from sample surveys.

The administrative responsibilities and revenue distribution provisions are contained in the Regional Ready Pass Agreement as executed by MTDB, SANDAG, and the fixed-route operators (4).

KEY STEPS TOWARD DEVELOPMENT

The key steps toward development of a regional transit pass were integrating services, getting a consensus, and keeping everyone involved.

Integrating Services

The first step toward the development of a regional pass was to ensure that several basic service elements were integrated among the various transit systems. Coordinated transfer time points and a uniform fare structure had to be established. These and other service elements, including regional tran-

Table 1. Characteristics of fixed-route transit operators in the San Diego MTDB region (1).

Fixed-Route Operator	Primary Service Areas	No. of Vehicles	Total Miles: Miles	Total Miles: Percentage of Fixed-Route Systems	Total Passengers: Passengers	Total Passengers: Percentage of Fixed-Route Systems
County Transit System-Suburban	Unincorporated areas	20	935,000	6.5	600,000	1.8
National City Transit	National City	8	260,000	1.8	461,000	1.4
San Diego Transit	San Diego	340	11,225,000	77.5	26,730,000	80.2
San Diego Trolley	South Bay	14	1,310,000	9.0	4,687,000	14.1
SCOOT	Chula Vista	14	551,000	3.8	690,000	2.1
Strand Streaker	Coronado and Imperial Beach	6	207,000	1.4	148,000	0.4
Total		402	14,488,000		33,316,000	

Table 2. FY 1982 fare revenues for the San Diego MTDB (2).

Operator	Base Fares ($): Regular	Base Fares ($): Elderly and Handicapped	Total Fare Revenues ($)	Percentage of Areawide Fares
County Transit System-Suburban	0.60	0.40	219,000	1.3
National City Transit	0.60	0.40	136,000	0.8
San Diego Transit	0.80	0.40	13,646,000	79.7
San Diego Trolley	1.00	0.40	2,747,000	16.0
SCOOT	0.60	0.40	230,000	1.3
Strand Streaker	1.00	0.40	146,000	0.9
Total			17,124,000	

Figure 1. MTDB region of jurisdiction.

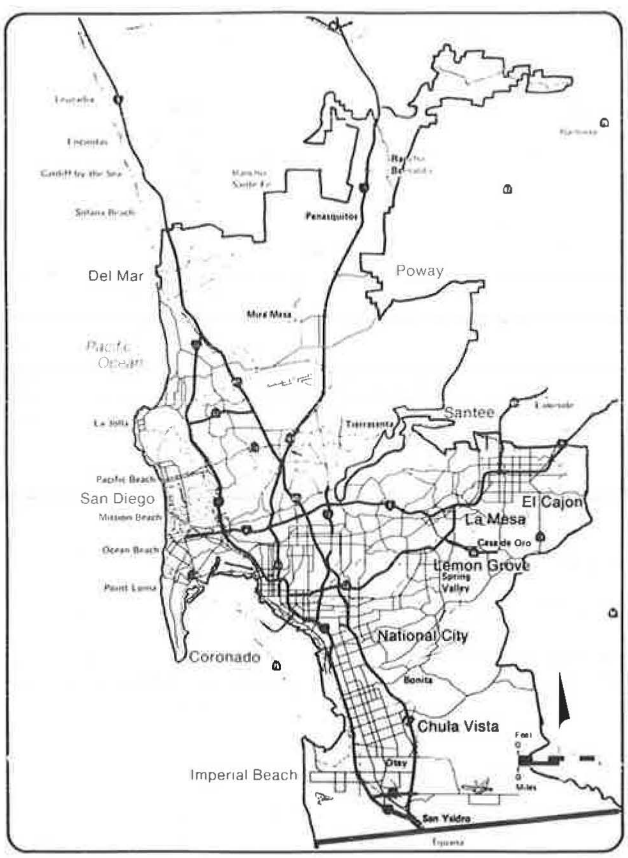
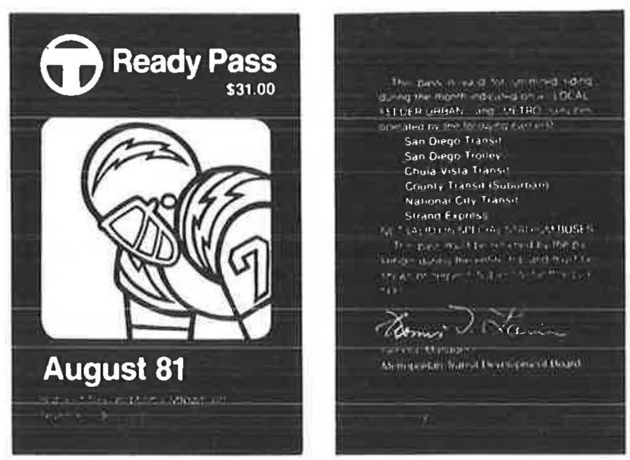
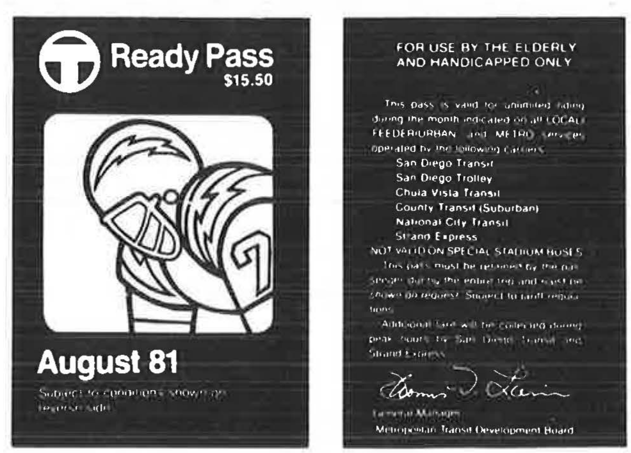


Figure 2. Ready passes.



Regular READY PASS (Red)



Elderly/Handicapped READY PASS (Blue)

sit telephone information, coordinated bus route numbering, and a regional transit guide, were developed in 1980 and 1981 by all fixed-route operators as a group in the San Diego metropolitan area. A group consisting of the general managers of all fixed-route operations had been established in the previous year by MTDB to consider, on a biweekly basis, transit issues of regional significance.

A Master Transfer Agreement (5), which established timed transfer points, uniform transfer slips, and a uniform set of transfer charges based on type of service (metro, urban, and local, regardless of operator), was executed and became effective January 1981. A uniform fare structure, which would establish a set of fares based on type of service (also regardless of operator), was proposed for implementation on July 1, 1981.

Getting a Consensus

The second step toward development of a regional transit pass was reaching a consensus in the transit operator community that the implementation of such a pass was a sound concept. A consensus was reached in early 1981 by the general managers' group. Although the decision by the group was based in part on the general perception that increased operating efficiencies and rider convenience would be achieved, a major factor in the decision, particularly for the smaller operators, was the prospect of additional fare revenues resulting from the distribution of revenue from pass sales.

Keeping Everyone Involved

The next step in the development process was to find a way to keep all the operators involved. In related discussions about the establishment of a uniform fare structure among the various systems, the general managers' group established a fare structure task force, which comprised technical staff members from each of the operating entities. The task force was directed to develop a uniform fare structure and a regional transit pass program. Thus the same technical staff members who worked on coordinating the fares of the various systems into a single uniform structure also designed the infrastructure for the regional transit pass. Those same staff members then had the technical responsibility to implement the pass on their own systems.

The fare structure task force met biweekly over a period of 2 months. Several of the operators decided against participating in fiscal year (FY) 1982. Those decisions were carefully considered and were based entirely on unique technical difficulties. For example, one operator did not have sufficient cyclometers available on its buses and thus could not supply the pass counts necessary for pass revenue distribution. The involvement of all possible participants at the technical staff level was essential to the eventual implementation of the regional transit pass by most of the area operators and to the maintenance of trust and confidence in the efforts of the task force by the remaining operators, all of whom expressed willingness to try to resolve the technical difficulties during the next year in order to ensure their participation in the future.

KEY STEPS TOWARD IMPLEMENTATION

The key steps toward implementation of the regional transit pass were (a) determining the basic characteristics of the Ready Pass, (b) establishing the types of Ready Passes, (c) setting Ready Pass prices, and (d) developing a revenue distribution formula and process.

Determining the Basic Characteristics of Ready Pass

There were many discussions at the meetings of the fare structure task force and the general managers' group concerning the basic characteristics of the Ready Pass, which resulted in a unanimous agreement on the following characteristics:

1. Acceptance on all fixed-route transit systems in the metropolitan San Diego area (with acceptance on demand-responsive systems to be determined at a later date);
2. Ease of use by transit riders, bus operators, and trolley fare inspectors;
3. Ease of administration (e.g., pass sales, accounting);
4. Transferability (pass should entitle no more than a single bearer at a time to ride; however, it should be possible to loan the pass to others at those times when the purchaser cannot use the pass); and
5. Elderly and handicapped distinction (separate pass or sticker).

Establishing Types of Ready Passes

The fare structure task force had agreed to a uniform fare structure based on the three functional levels of fixed-route transit services available in the metropolitan San Diego area--local, urban, and metro--with fares to be \$0.60, \$0.80, and \$1.00, respectively. Thus it was initially proposed that there be three corresponding types of Ready Passes. In addition, it was proposed that there be three additional corresponding passes for the elderly and the handicapped at reduced rates.

However, in the interest of operational and administrative efficiency, it was later decided by the general managers' group that the six types of Ready Passes should be consolidated into two types: regular and elderly and handicapped. The unanimous decision was based on the belief that any further categorization would cost more to implement than it would return in revenues.

Setting Ready Pass Prices

The setting of Ready Pass prices was based on many considerations, including base fare, average number of trips per pass, elderly and handicapped discounts, and political marketability. Initial assumptions were as follows: base fare = \$0.80; average number of trips per pass = 40; and elderly and handicapped discount = 50 percent of the regular price.

After considerable discussion, adjustments were made to the initial assumptions, and the final Ready Pass prices were determined: regular Ready Pass (red) = \$31.00, and elderly and handicapped Ready Pass (blue) = \$15.50.

Developing a Revenue Distribution Formula and Process

The members of the fare structure task force agreed that the revenues generated by Ready Pass sales should be allocated based on the proportion of total pass use on each of the participating systems. The distribution formula was as follows:

Proportion of revenues allocated to operator X = (Total ready pass riders on all operator X routes) ÷ (Total ready pass riders on all routes).

It was decided that each operator would be responsible for keeping counts of actual pass use and for reporting the counts on a monthly basis to SANDAG. Bus drivers were to register each boarding pass user on their cyclometers (two cyclometers were to be reserved for the counts: one for regular Ready Pass users and one for elderly and handicapped Ready Pass users). For the San Diego Trolley, which operates by using a self-service barrier-free fare-collection system, it was decided that SANDAG and MTDB would conduct surveys to estimate Ready Pass use.

The Regional Ready Pass Agreement (4) was drafted by MTDB and signed by all participating operators and agencies before the implementation of the Ready Pass on July 1, 1981. The specific administrative responsibilities of each of the signatories, as well as the revenue distribution formula, were outlined in the agreement.

IMPACTS OF READY PASS

During the first 6 months of implementation (starting July 1, 1981), the impacts of the Ready Pass on transit system operating efficiency and rider convenience appear to be positive. The benefits of the Ready Pass are reflected in (a) increased rates of pass use on all systems, (b) enthusiastic support for the Ready Pass from bus drivers, and (c) high proportion of pass users using more than one transit system.

Increased Rate of Pass Use

The rate of pass use has increased dramatically on participating transit systems (see Tables 3 and 4). Several impacts on operating efficiency from this increase have been cited by management, labor, and transit riders:

1. A reduction in the handling of paper transfers (Table 5) and cash fares (Table 6);
2. A reduction in the number of confrontations between drivers and boarding passengers regarding paper transfers;
3. An improvement in passenger boarding speed, particularly at high-volume stops; and
4. An increase in passenger revenues for those systems that previously honored transfers and passes from other systems with no compensation.

Bus Driver Support for Ready Pass

In an April 1982 survey of 222 bus drivers from all fixed-route systems, 89 percent of those responding believed that with the increase in Ready Pass use, passenger boardings are easier than before, and 94 percent stated that they would like to see further increases in Ready Pass use. The positive survey results reflect the general perception by the drivers that the Ready Pass improves transit system operating efficiency.

New Pass Users

In a recent survey of Ready Pass users, 67 percent of those responding either paid cash fares or did not ride transit before (Table 7). Fifty-two percent purchased the Ready Pass because of its economy, whereas 22 percent purchased it because it eliminates the need for exact change. The high proportion of new pass users reflects the attractiveness of the features of the Ready Pass to transit riders.

Use of Ready Pass on Multiple Systems

In the recent survey of Ready Pass users, more than 56 percent of those responding indicated that they would be using the Ready Pass on more than one transit system (Table 7). This high percentage supports the notion that the Ready Pass can contribute significantly to the effort of presenting transit services provided by multiple operators as a single unified system to transit riders.

Table 3. Rates of pass use.

Operator	Rate of Pass Use as a Percentage of Total Boardings: July-December 1980	July-December 1981	Increase or Decrease (%)
County Transit System-Suburban	4.7	13.1	+178.7
National City Transit	6.7	13.8	+106.0
San Diego Transit	17.8	29.7	+66.9
San Diego Trolley	–[a]	14.7	NA
SCOOT	12.7	15.5	+22.0
Strand Streaker	–[b]	28.0	NA
Total for all operators	17.4	27.6	+58.6

Note: NA = not applicable.
[a]Not in service.
[b]Data not available.

Table 4. Rates of pass revenues.

Operator	Rate of Pass Revenues as a Percentage of Total Revenues: July-December 1980	July-December 1981	Increase or Decrease (%)
County Transit System-Suburban	3.9	15.0	+284.6
National City Transit	–[a]	23.2	NA
San Diego Transit	12.9	22.1	+71.3
San Diego Trolley	–[b]	9.1	NA
SCOOT	–[a]	17.0	NA
Strand Streaker	23.0	30.7	+33.5
Total for all operators	12.7	20.0	+57.5

Note: NA = not applicable.
[a]No pass revenues.
[b]Not in service.

Table 5. Rates of transfer (San Diego Transit only).

Item	July-December 1980	July-December 1981	Increase or Decrease (%)
Total boardings	16,597,917	13,253,367	-20.2
Transfer volume	3,440,984	2,245,799	-34.7
Percentage of total boardings	20.7	16.9	-18.4

Table 6. Cash boardings.

Operator	Cash Boardings as a Percentage of Total Boardings: July-December 1980	July-December 1981	Increase or Decrease (%)
County Transit System-Suburban	67.0	64.7	-3.4
National City Transit	58.4	50.3	-13.9
San Diego Transit	61.5	53.4	-13.2
San Diego Trolley	–[a]	67.2	NA
SCOOT	69.9	62.8	-10.2
Strand Streaker	–[b]	57.6	NA
Total for all operators	61.7	56.2	-8.9

Note: NA = not applicable.
[a]Not in service.
[b]Data not available.

Table 7. Pass user survey results.

Survey Question	Percent
Primary reason for buying the Ready Pass	
More economical than cash fares	52
Eliminates need for transfers	13
Eliminates need for exact change	22
Faster boarding	13
Before the Ready Pass, did you buy another kind of transit pass?	
Yes	23
No	67
On how many different transit companies will you be using your Ready Pass?	
One	44
Two	33
Three	14
Four	9

Note: Data are from a survey of Ready Pass purchasers conducted by MTDB in March 1982 (N = 84).

SUMMARY

The San Diego regional Ready Pass has been successful in

1. Unifying the multiple operator system by granting the Ready Pass user unlimited riding privileges throughout the system;
2. Improving on-street operating efficiency by reducing the volume of paper transfers and cash fares, thus speeding passenger boardings; and
3. Enhancing transit rider convenience, which may in turn helps maintain and attract new riders.

The development of a regional transit pass for a multiple operator system requires the integration of basic service elements, a consensus among the various operators on the validity of the concept, and the involvement of the technical staffs from the various operators in the entire pricing and implementation process. Continued implementation of the Ready Pass in San Diego can help preserve the positive competition between multiple operators, which can help keep areawide operating costs competitive. At the same time, the Ready Pass can improve transit rider accessibility and convenience by presenting the multiple operators as a single unified system.

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Sketch-Planning Evaluation of an Employer-Based Subsidized Transit Pass Program

ERIC A. ZIERING

A sketch-planning evaluation of an employer-based subsidized transit pass program for the Southeastern Pennsylvania Transportation Authority (SEPTA) is described. The purpose of the evaluation was to determine if the project could produce substantial transit ridership increases, which could in turn lead to a reduction in automobile hydrocarbon emissions and justify the inclusion of the project in the state implementation plan. Constraints in data availability required that a coarse back-of-the-envelope analysis be performed by using limited empirical information from other cities. The results of this study indicated that a small ridership increase would occur along with an increase in SEPTA revenue, but that questions about the feasibility of implementing the proposed program made it unworkable. The methodology used in the evaluation, however, highlights the usefulness of planning techniques in preliminary program evaluation. The methodology also makes apparent the value of data from outside sources, particularly the extensive data available from projects in the UMTA Service and Management Demonstration program.

As part of a study for the Delaware Valley Regional Planning Commission (DVRPC), Charles River Associates was commissioned to identify transit strategies that would significantly increase transit ridership in the Pennsylvania portion of the Philadelphia region. The purpose of identifying such strategies was to consider them for inclusion in the Pennsylvania state implementation plan for reducing vehicular hydrocarbon emissions. A variety of transit projects and strategies was examined. One was an employer-based subsidized transit pass program for the Southeastern Pennsylvania Transportation Authority (SEPTA). Other projects included construction of an airport high-speed transit line, other rapid transit and light rail improvements, transit amenity improvements, a center city commuter connection, establishment of premium transit services, a transit permit payment system, and seasonal fare reductions during those times of the year when hydrocarbon emissions reach their peak.

For many of these projects, there were insufficient data to develop rigorous forecasts of transit ridership and other impacts, and fairly crude back-of-the-envelope techniques were required. A description of how this type of analysis was used to evaluate the impacts of the proposed pass program is given in this paper.

DESCRIPTION OF PASS PROGRAM

The employer-based subsidized transit pass sales program enables employees of participating firms to purchase weekly or monthly SEPTA transit passes from employers at a reduced price. These weekly and monthly passes have been and are widely available through public sales outlets. At the time of this analysis, approximately 56,000 SEPTA riders were using the Transpass weekly or monthly passes. Participating employers would sell the weekly pass (normally $9.00) to their employers for $7.50, and the monthly pass (normally $35.00) for $29.00.

To encourage employers to join the program, SEPTA would sell passes to employers at the reduced rates for the first month that a firm joins the program. After the 1-month incentive period, firms would purchase passes from SEPTA at the regular prices of $9.00 and $35.00 and subsidize employee purchases of the weekly and monthly passes by $1.50 and $6.00. The regular cash fare on the SEPTA system is $0.70, with a transfer charge of $0.15. The system experiences a relatively high transfer rate, with about 42 percent of all trips involving more than one vehicle. This is one factor that is responsible for current high levels of pass sales through public outlets.

Passes would be sold on consignment; that is, employers would receive an agreed-on number of passes from SEPTA to sell to employees each week or month. Unsold passes and payment received for passes sold would be returned to SEPTA shortly after the end of the pass sales period. Passes would be sold by employers on either a cash or payroll-deduction basis (which would be determined at the discretion of the individual employer).

To be eligible for the program and receive the 1-month incentive price break, employers must agree to continue to participate in the pass program for a minimum of 2 years. This means that an employer must be willing to subsidize employee pass purchases for a period of 23 months.

RIDERSHIP ANALYSIS

The analytical approach for estimating ridership impacts consists of three major steps.

1. The level of employer participation has to be determined. Specifically, estimates must be made of how many employers will participate in the program and the number of employees that work for them.
2. At participating firms the number of employees who will purchase the subsidized transit passes has to be determined. Three classes of pass purchasers must be identified: those individuals who previously bought the pass at public sales outlets, those individuals who previously commuted by transit but did not use a pass, and those who formerly did not use transit at all.
3. The effects of purchasing a subsidized pass on transit tripmaking by employees have to be estimated. Presumably, the trip rates of persons who previously bought a pass will not be affected, but the trip rates of the other two classes of individuals (as identified in step 2) will increase.

In the analysis presented in the following sections each of these steps is examined, and base-level projections are presented. In a later section a sensitivity analysis, which indicates the range of variability inherent in these projections, is presented.

Insufficient data are available nationally concerning employer-subsidized pass programs, such as the one under examination, to be able to model the ridership impacts in a formal way. Nevertheless, substantial evidence is available concerning pass sales for a variety of nonsubsidized pass programs that can be used for portions of the analysis. In addition, limited site-specific data about employer subsidies are available from Sacramento and a few other cities.

Step 1: Employer Participation

The results of the Sacramento Regional Transit (RT) fare prepayment demonstration are used as a model for estimating employer response to the proposed program. That demonstration involved employer-based sales of a monthly transit pass (PASSpoRT) that had previously been available through public sales outlets. As an incentive for employers to join the program, RT provided a 3-month-long pass price discount, similar in principle to that proposed in this program. The two pass programs are similar because they both involve the initiation of employer-based sales of an existing fare prepayment mechanism and a discount to employers for a limited period for joining the program. They are different in that the SEPTA program requires employers to continue to provide a subsidy to employees after the discount from SEPTA to employers is terminated.

The level of employer participation in the proposed program will be a function of several factors. Because weekly and monthly passes are already publicly available, the incentive for employers to participate is sharply reduced. This was a reason commonly cited by employers in Sacramento for not participating in that employer-based program. Employers did not perceive the distribution of passes as a significant benefit to their employees when the passes were already widely available through numerous public sales outlets.

One of the primary motivations for employers to subsidize pass purchases is to reduce parking expenses. In Sacramento and other cities, firms have distributed or subsidized transit passes to reduce the cost of leasing or constructing additional parking spaces for their employees. Several factors specific to Philadelphia significantly reduce this incentive. Few employers in the central city provide on-site parking facilities. Nearly all parking takes place at privately or publicly owned parking lots and garages. A recently conducted survey at 12 center city parking lots indicated that only a relatively small percentage (18 percent) of parkers receive subsidies for parking from their employers. In addition, the relatively high transit modal share (70 percent) in the Philadelphia central business district (CBD) increases the total cost to the employers of providing the pass subsidy. The net result is that employers are unlikely to recover the cost of the subsidy in reduced parking expenses.

This result can be demonstrated as follows. For a hypothetical firm of 1,000 employees, an average of 700 employees use transit and 300 commute by automobile. Assuming an average automobile occupancy of 1.25, 240 automobiles are used for commuting at this firm, of which 18 percent (43.2 cars) receive parking subsidies. Parking rates in Philadelphia average $4.29 per day. Assuming that monthly lease rates incorporate a 25 percent discount, the monthly parking cost per vehicle is as follows:

(22 days)($4.29 per day)(0.75) = $71.

If this hypothetical firm completely subsidizes 43.2 cars per month at this rate, its total expense is (43.2)($71) = $3,060 per month. Of the 700 employees who commute by transit, it can be conservatively assumed that 30 percent purchase passes. Therefore, subsidizing passes would cost the hypothetical firm

(700)(0.30)($6 subsidy) = $1,260 per month.

This cost is equivalent to 41.2 percent of the parking expenses for the hypothetical firm. Even under these conservative assumptions, this firm would need to convert more than 40 percent of its automobile commuters to transit to recover its costs through savings in parking expenses. This is an unlikely result of the subsidized pass program.

This brief analysis obscures variation in parking cost and transit modal share among individual firms. Some selected firms may have some combination of higher parking costs (although this is unlikely, given widespread competition among parking concession operators) and lower transit modal shares that make pass subsidization economically beneficial. In Sacramento the transit modal share was much lower (approximately 30 percent), and parking cost was also much lower (averaging $28 per month). In Sacramento only 9 out of the 100 employers participating in the pass program provide subsidies to their employees.

Nationally, employer participation in these types of pass distribution and subsidy programs appears to be encouraged most significantly by discounts provided to the employer by the transit operator. In Dallas transit passes are sold to employers at a $2 discount, provided that the employer matches this subsidy and resells the passes to employees at a $4 discount. Currently more than 460 companies participate in this program, most of which provide significant additional discounts to their employees. Approximately 20,000 passes are sold each month. In Dallas parking is restricted and expensive (generally more than $60 per month in the CBD), but the modal share to the CBD is much lower than in Philadelphia (less than 30 percent), so that pass subsidization is more cost effective as a method for reducing parking expenses. This type of continuing matched subsidy is now being considered for implementation in Sacramento as well. Transit agencies in both of these cities believe that the revenue gain from new transit users offsets the cost to the operator of providing the subsidy.

In Sacramento a 3-month, 25 percent discount in the price of passes sold to employers drew only a small proportion of private employers to the pass program (many of the participating employers were agencies of the federal and state governments). The 1-month, 17 percent discount proposed for SEPTA would nominally be expected to produce a much smaller response. The requirement that employers continue to subsidize employee pass sales for a period of 2 years could be expected to reduce the level of participation still further.

Therefore, it has been concluded that the bulk of employers will not have an economic incentive to participate in the subsidized pass program. In addition, the experience in Sacramento indicates that making a case directly to employers concerning the benefits of mass transit, energy savings, and other public-spirited issues were ineffective in generating participation in the program. The remaining incentive for employers to participate appears to be the value of the transit subsidy as an employee fringe benefit. In Sacramento the second major reason for employer subsidization of transit passes (parking cost was the first) was the response of organized labor to the concept of a discounted transit pass. Therefore, in Philadelphia it would appear that the marketing effort for the proposed program (to be described later) should be directed toward employees or transit users, who could then pursue the program with employers, rather than directly toward employers.

It was determined early in the analysis that the collection of disaggregate data by firm on transit accessibility, level of transit use, and parking availability and cost was not cost effective. As already noted, considerable uncertainty about many of the other parameters that affect employer participation overwhelms the probable impact of interfirm variability in this analysis.

Data were provided by DVRPC on the breakdown of large firms by number of employees and by one-digit standard industrial classification (SIC) code. Although the Sacramento data indicate that certain types of businesses are more likely to participate in the pass program (notably government agencies), insufficient evidence was available to deal quantitatively with each employer category. The same is also true of the size classification of firms. Therefore, in estimating employer participation in Philadelphia, all targeted firms (300 or more employees) in the CBD under consideration have been grouped together. There are a total of 95 such employers, with a total of 97,211 employees. Based on the experiences in Sacramento and Dallas, and accounting for major differences in the nature of the pass programs and exogenous variables such as modal share and parking cost, it was estimated that 10 percent of the employers might elect to participate in the subsidized pass program. Assuming homogeneity among participating firms, this suggests that roughly 10 firms might participate, comprising about 9,700 employees.

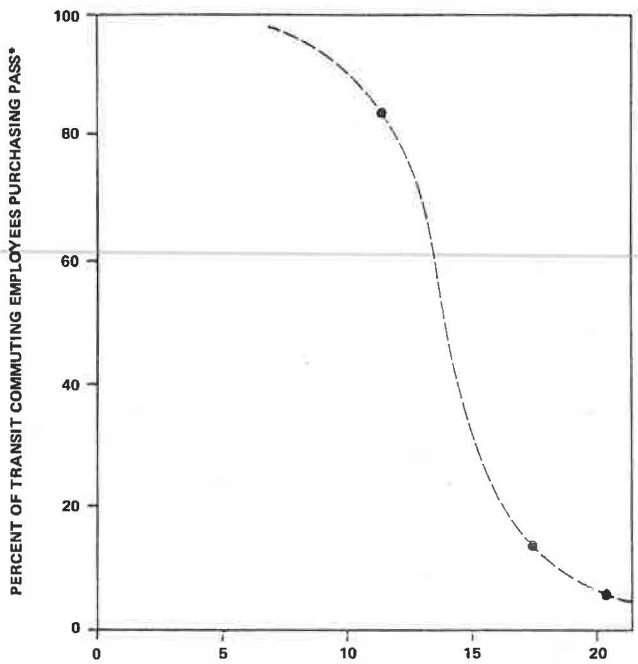
Step 2: Employee Pass Sales

Pass sales within each participating firm are the second major factor to be analyzed. The level of pass sales depends primarily on the price (level of discount) of the pass. By using data from the Jacksonville transit fare prepayment demonstration, Charles River Associates developed a curve that relates pass penetration rates to the level of discount offered to passholders (Figure 1). Given the existing level of pass penetration at current prices, the level of penetration at the discounted price can be determined.

Data from the Metropolitan Atlanta Rapid Transit Authority (MARTA) indicate that 30.3 percent of transit users traveling 10 or more times per week were passholders. Applying MARTA trip frequency distributions for cash and pass users to the actual number of cash and pass users on the SEPTA system, it was indicated that 38.6 percent of frequent ($\geq$10 trips per week) riders who transfer use passes, and 22.7 percent of frequent riders who do not transfer use passes. The weighted average of these two groups confirms the 30 percent penetration rate. This percentage is also roughly comparable to the estimate that 27 percent of daily trips on SEPTA are paid for with passes.

Note that this penetration rate is much higher than would be expected from the curve shown in Figure 1. This is because of differences in overall transit trip frequencies between Philadelphia and Jacksonville (for which the curve was derived). The curve is used only to calculate the change in the penetration rate that results from the institution

Figure 1. Sensitivity of pass penetration rate to break-even pass level.



*Employees commuting by transit 3 or more days per week

of a discount, not to estimate the penetration rate directly as a function of pass price. Of the 9,700 people estimated to work at firms enrolling in the discount pass program, 6,805 commute by transit (assuming a 70 percent transit modal share). Of this number, assume (as in Atlanta) that 30.3 percent (2,060) are passholders; the remaining 4,745 transit users pay cash.

To calculate the change in the penetration rate resulting from the subsidized pass, the curve for pass penetration and pass price shown in Figure 1 is used. The change in pass price is calculated by taking before-and-after weighted averages of the monthly and weekly pass prices. To calculate these prices, it is assumed that 42 percent of riders must transfer. Then, assuming that the current 56,000 passholders include 41,000 weekly and 15,000 monthly passes, the weighted average before price (expressed as a break-even number of one-way trips per month) is as follows:

(41,000/56,000) • {$9.00/[$0.70 + (0.42)($0.15)]}
x (52 weeks/12 months) + (15,000/56,000)
x {$35.00/[$0.70 + (0.42)($0.15)]}
= 49.8 one-way trips per month.

The weighted average "after" price is calculated in the same manner, with the subsidized prices of $7.50 weekly and $29.00 monthly replacing the original prices of $9.00 and $35.00. The resulting weighted pass price (break-even trip rate) is 41.4 one-way trips per month. The net discount in pass prices is therefore [(49.8 - 41.4)/(49.8)], or 16.8 percent.

Returning to the pass penetration curve, with a base penetration rate of 30.3 percent, a 16.8 percent price decrease at this steepest part of the curve would yield a resulting penetration rate of 73 percent among existing transit users. Therefore, of the 6,805 transit commuters at the participating firms, 4,967 would be passholders after the subsidized pass became available.

In addition, new passholders would be generated by former nontransit users who switch to transit. In Sacramento 10 percent of passholders during the 25 percent discount period were new transit users. The corresponding figure in Philadelphia can be expected to be lower for two reasons. First, assuming direct proportionality, a lower price discount of only 16.8 percent would yield approximately [(10 percent)(16.8)/25], or 6.72 percent new transit users among subsidized passholders. Second, the much higher initial transit modal share in Philadelphia would markedly reduce the percentage increase in transit users. In Sacramento a 30 percent transit share implied that there were 2.33 nontransit users per transit user, whereas in Philadelphia the corresponding ratio is 0.43. Therefore, the proportion of subsidized passholders who are new transit users is estimated to be as follows:

6.72 percent • (0.43/2.33) = 1.23 percent.

At first glance this number may seem low, but its magnitude can be easily confirmed by using elasticities. Commonly accepted cross elasticities of automobile demand with respect to transit fare are typically in the range of +0.05 to +0.10. By using a transit fare reduction of 16.8 percent and a cross elasticity of +0.10, the expected change in automobile demand would be 1.7 percent, thereby resulting in a transit demand change of 0.7 percent. The 1.23 percent increase in pass sales to new users resulting from the program is therefore somewhat greater than the 0.7 percent increase that would be forecast by using cross elasticities.

A final assumption in developing pass sales figures is that the subsidized pass program will not affect the distribution of pass buyers between the monthly and weekly passes (although a marginally larger subsidy is provided for weekly passes). With this assumption, final sales figures for subsidized passes at the participating firms can be summarized as follows:

	Sales Figures		
Buyers	Total	Weekly	Monthly
Former pass purchasers	2,060	1,508	552
Former cash-paying transit users	2,907	2,129	778
Former nontransit users	61	45	16
Total	5,028	3,682	1,346

Step 3: Trip Rates of Passholders

It is assumed that persons who previously bought passes will not change their transit trip frequency as a result of the subsidy. Survey results indicate that the trip frequency of these current SEPTA passholders is 14.0 trips per week, or

14.0 • (52/12) = 60.7 trips per month.

The second group to be considered are former cash users who now elect to purchase the subsidized pass. If it is assumed that new pass purchasers are individuals for whom the subsidized pass is economical, but for whom the unsubsidized pass was not, then the average trip frequency for these individuals may initially be assumed to be the average of the discounted and undiscounted pass prices in terms of one-way trips. This trip frequency is as follows:

(41.4 + 49.7)/2 = 45.5 trips per month.

That is, before the subsidized pass became available, it was expected that the average trip frequency of this group was 45.5 trips per month. Once

these individuals elect to purchase the pass, their trip rate will increase because additional trips have a zero marginal cost.

As an upper limit, it can initially be assumed that the trip frequency of these individuals would increase to 60.7 trips per month (the trip rate of former passholders). This is an upper limit because these people clearly have other reasons for not traveling as frequently as former passholders, which thus places them in their original behavioral group. Nevertheless, if this maximum trip frequency were to be attained, these individuals would be receiving an effective fare discount of 25 percent. By using a fare elasticity of -0.20, a 25 percent fare discount would result in a transit trip frequency increase for these people of [(-0.20)(-0.25)], or 5 percent. Thus a 5 percent increase in transit travel is a logical upper bound. This would result in a change in trip frequency from 45.5 to 47.8 trips per month for these individuals.

The final group to be considered in this analysis is pass purchasers who formerly did not use transit. No data are available to estimate the trip rate of this group. A logical assumption is that their trip rate will be similar to that of the second group--47.8 trips per month. In any event, the final ridership projections are not highly sensitive to small changes in this trip rate because these persons make up only a small percentage of the riders. The change in tripmaking among all groups is given in Table 1. The net increase in monthly trips is 9,602, which implies an increase of 2,216 trips per week, or 385 trips on an average weekday.

Sensitivity Analysis

Although there is a certain amount of uncertainty associated with many of the parameters in this analysis, the bulk of uncertainty in the ridership forecast is associated with the projection for 10 percent employer participation. This estimate is based on limited data (unlike assumptions concerning transit trip rates, for example). It is conceivable that a participation rate of 20 percent might be achieved if an innovative and effective marketing campaign is combined with an unexpectedly high level of receptiveness among the chief executive officers of targeted firms. If this were to occur, ridership increases could be double those computed previously. The level of uncertainty associated with each of the other variables is small in comparison to the employer participation rate and not worthy of a detailed analysis.

PROGRAM COST AND OTHER IMPACTS

The primary costs to be incurred by SEPTA in the subsidized pass program fall into four categories:

1. Administrative costs associated with the program,
2. Advertising and publicity expenses,
3. The cost of the 1-month subsidy for passes sold to employers, and
4. Change in revenue.

Because the program results in a ridership increase of only 385 daily trips, it is assumed that there will be no additional costs for providing additional capacity.

At expected levels of participation, an additional 2,968 individuals will purchase passes as a result of the program (2,174 weekly and 974 monthly). This is a 5.3 percent increase over the current level of 56,000 passholders. In Sacramento administrative costs for employer-based pass sales

Table 1. Changes in tripmaking among all groups.

Buyers	No.	Trip Rate (trips per month) Before	After	Increase in Trips per Month
Former pass purchasers	2,060	60.7	60.7	0
Former cash paying transit users	2,907	45.5	47.8	6,686
Former nontransit users	61	0	47.8	2,916
Total	5,028			9,602

were $0.163 per pass. On this basis, the total additional annual administrative cost to SEPTA would be as follows:

(12 months x 794 passes per month) + (52 weeks x 2,174 passes per week) • ($0.163 per pass) = $19,980.

Advertising and publicity expenses can vary widely, depending on the intensity of marketing efforts by SEPTA. As discussed previously, marketing efforts for this type of program should be directed at the general public. This could result in a fairly high level of expenditures for promotion. SEPTA's original Transpass promotion in October and November 1979 cost more than $100,000. Other promotional activities for transit fare increases, the Gateway Transpass, new light rail vehicle trolleys, and commuter rail activities ranged in cost from $50,000 to $75,000.

Promoting the employer-based program would be a considerably less costly effort, but all general public awareness programs are expensive. The 2-year Sacramento employer-based pass program had a public-relations and advertising budget of more than $18,000. Because Philadelphia is a much larger city with much greater transit ridership, $40,000 (or $20,000 per year) is assumed to be a minimum cost of a comprehensive promotional and advertising program.

The direct cost of the subsidy of the pass will also be significant. The subsidy of $1.50 per weekly pass (for 4 weeks) or $6.00 per monthly pass (for 1 month) must be paid for all passholders at the participating firms, not only for new passholders. The total subsidy is calculated as follows:

[(3,682 weekly passes)(4 weeks)($1.50)] + [(1,346 monthly passes)($6.00)] = $30,168.

Because the subsidy would be paid only once to each firm, which would then continue the subsidy for 2 years, the annual cost of the direct subsidy would be one-half this amount, or approximately $15,080. This estimate is based on a relatively constant level of pass sales over time. Presumably the introduction of the program at each firm would be preceded by sufficient publicity so that interested employees would join the program at its inception. It is worth noting that the average annual cost of the subsidy to each participating employer would be $36,900, or $38 per employee.

The change in revenue that results from the program is a combination of two factors: revenue loss from those individuals who travel more than the break-even trip frequency, and revenue gain from new transit riders. To calculate the revenue loss, a comparison was made of the trip frequency of passholders with the break-even pass price trip rate. Note that the trip frequency before the introduction of the subsidized pass is used. Also, the unsubsidized pass price is used because the revenue received by SEPTA for a subsidized pass sale is identical to that received for a regular pass sale.

It was noted previously that the prior trip frequency of new pass purchasers who formerly paid cash

is 45.5 trips per month. Also, the weighted average pass price is the equivalent of 49.8 trips per month. Therefore, SEPTA actually experiences a net revenue gain from each of these individuals equal to the cash equivalent of (49.8 - 45.5), or 4.3 trips per month. The average cash fare (assuming a 42 percent transfer rate) is [($0.70) + (0.42)($0.15)], or $0.763. Therefore, the total annual revenue gain from this group is

(2,907 persons)(12 months)(4.3 trips per month)
x ($0.763 per trip) = $114,450.

Additional new revenue will be generated by those persons who switch to transit from other modes as a result of the subsidized pass. This revenue can be calculated as follows:

[(45 persons)($9.00 per week)(52 weeks)]
+ [(16 persons)($35.00 per month)(12 months)]
= $27,780.

Therefore, the net revenue increase that results from the program is $142,230. The total annual costs of the subsidized pass program are as follows:

Item	Cost ($)
Additional administrative expenses	19,980
Advertising and publicity expenses	20,000
Pass subsidy	15,080
Foregone revenue	-142,230
Total	-87,170

As mentioned previously, the forecast of 385 additional daily riders results in an annual ridership increase of [(300)(385)], or 115,500 trips per year. Therefore, the net revenue increase generated by the subsidized pass program on a per trip basis is approximately $0.755.

IMPLEMENTATION CONSIDERATIONS

A review of similar pass programs and discussions with SEPTA and DVRPC personnel resulted in the identification of four critical factors concerning program implementation. First, current SEPTA regulations prohibit the use of promotional fare incentives such as the 1-month discount proposed here, except through the adoption of a new tariff schedule that specifies the discount fare levels. This process would involve conducting public hearings (along with the associated lead time requirements) each time a new firm joined the subsidized pass program. The marketing department at SEPTA is taking steps toward adopting a tariff that would generally allow for promotional fare incentives without requiring a detailed specification of fares. Such a change would alleviate this restriction on program implementation.

Second, SEPTA believes that the level of subsidy offered in the proposed program is too large to be provided entirely by SEPTA. It has been assumed in the analysis, however, that other revenue sources would be available to support actions intended to reduce motor vehicle emissions. Therefore, the subsidy cost to SEPTA might, for example, be shared with DVRPC or with project-specific grant money from some other agency. In addition, the analysis clearly indicates that the additional revenues generated by employer subsidies more than offset the direct subsidy costs that would be incurred by SEPTA.

A third implementation consideration is based on the Sacramento experience, where marketing the pass program to employers, even through telephone and personal contacts, was generally ineffective in increasing program participation. In Sacramento it was found that informing transit riders and the general public directly and encouraging these individuals to contact their employers was far more effective. If marketing efforts for the program are directed at the general public rather than through employers, the targeting by employer size should probably be removed, so that employers of any size are encouraged to participate if they are willing to subsidize the pass. This will dramatically increase the cost-effectiveness of the promotional campaign because a greater proportion of those individuals who are exposed to the publicity will be exposed to the program. Also, there should be beneficial publicity fallout for all of the pass programs at SEPTA.

A fourth consideration that might affect the proposed program is that it does not offer employers any new opportunities to provide a benefit to their employees. That is, under the current public pass sale system, employers have the option of subsidizing pass purchases for their employees directly through cash rebates or special allowances. The proposed program incorporates a small discount from SEPTA to the employer, but also shifts the burden of pass sales and distribution to the employer as well. Therefore, those firms that elect to subsidize pass purchases may prefer to do so through the existing system instead of absorbing new administrative costs. This, of course, would be no less effective in increasing transit ridership.

These four observations concerning the implementation of the employer-based subsidized pass sales program suggest that its effectiveness might be increased by changing its emphasis toward promoting employer-subsidized transportation in general. That is, instead of marketing the subsidized pass to employers through a 1-month incentive discount, the program could be primarily a promotional program intended to generate public support for the concept of a transit allowance from employers to employees. Because the 1-month incentive will probably not be a major factor in an employer's decision to join the program, it could be eliminated. This would circumvent the need to establish special promotional tariffs for the program. In addition, interested employers could be encouraged to provide a subsidy through the existing pass system. For example, an employer might purchase expired employee transit passes at a price of $1.50 and $6.00 for weekly and monthly passes. (Some security measures would have to be taken to prevent the development of a black market for passes.) This would have an identical impact on employee pass purchases and on ridership, but it could reduce administrative costs to both SEPTA and to employers for the distribution and sale of passes.

If such a program were adopted, employers of all sizes could be allowed to participate, and the primary functions of SEPTA would be to market the concept as a valuable employee fringe benefit, and to provide support and assistance to employers who, by virtue of interest among their employees, become interested in different methods of subsidizing transit or employee transportation in general. Such a program is different in tone from the one that was originally considered, but it could be far more effective. It would also be considered much more innovative and ahead of its time. Employers are becoming increasingly concerned with employee transportation, although to date this interest has been most evident in the widespread growth in employer-sponsored vanpool and carpool programs. This program could generate a similar level of employer interest for supporting transit as a means of getting to and from work.

SUMMARY

A sketch-planning analysis of a proposed subsidized pass sales program has been presented. The analysis has demonstrated that rough estimates of the impacts of such a program can be developed by using relatively scarce information on similar projects in other cities. This back-of-the-envelope approach was sufficient in this case to determine that a more detailed analysis was not warranted. It did, however, identify certain counter-intuitive impacts, such as the net revenue gain to SEPTA of instituting the proposed program. Such an impact probably would not have been identified through a purely qualitative evaluation. Finally, apparent in this approach was the value of data drawn from other cities, particularly from projects in the UMTA Service and Management Demonstration program.

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Car Drivers Test Public Transportation: A Measure to Encourage Persons to Switch to Public Transportation

WERNER BRÖG, OTTO G. FÖRG, AND GÜNTER MÖTSCH

Most of the advertising created by managers of public transportation systems in the Federal Republic of Germany has necessarily adhered to the classical methods of product marketing, i.e., campaigns to improve the image of public transportation and advertising targeted at the general public. However, it is doubtful whether such methods are suitable for service-oriented industries, especially public transportation. A series of special studies have revealed that persons do not use public transportation because they are not informed about the supply and because of their subjective perceptions of different aspects of the public transportation system. This means that one of the primary goals of efficient advertising is to inform persons about the public transportation system. The Stuttgart Integrated Public Transportation System took a decisive step in this direction with its campaign, Car Drivers Test Public Transportation. In this campaign, persons who were willing to use public transportation on a trial basis for a period of 1 month were selected through their places of employment. The social-scientific study done by Socialdata to accompany the campaign had two basic goals: (a) determine what percentage of the test persons continued to regularly use public transportation after the month of testing had been completed, and (b) study the effect of practical experiences with public transportation on the attitudes that persons previously inadequately informed about public transportation supply would then have toward public transportation. For this purpose, surveys were done of travel behavior before, during, and after the test, and studies were done to determine the opinions of the persons surveyed.

In 1980 the Stuttgart Integrated Transportation System (VVS), together with the German Automobile Club, initiated a campaign called, Car Drivers Test Public Transportation. As part of the campaign, car drivers who were employed were given free monthly passes and were requested to use public transportation on a trial basis so that they might experience the public transportation system at first hand. This action was used as a new type of publicity campaign and to further public relations work. This idea was based on the theory that many persons do not use public transportation because they are unfamiliar with it and do not realize how attractive an alternative it can be (1).

A multistage social-scientific study accompanied this campaign in order to determine whether changes in attitudes toward public transportation and changes in travel behavior had taken place (2). Thus before and after the campaign surveys dealing with the attitudes and transport behavior of the test persons were done. Travel behavior during the month of testing was also surveyed.

The surveys, which were conducted before, during, and after the campaign, were done at 1-month intervals, and travel behavior was also studied 1 year after the campaign had taken place. The family members of the test persons were also included in the surveys on behavior because a change in the travel behavior of the first person could also affect other family members; e.g., a car no longer being used by the test person could now be used by another member of the family (3). A few of the most important results of this study are presented in this paper.

CHANGES IN TRAVEL BEHAVIOR

Mobility

Test Persons

The first factor used to describe travel behavior is the share of mobile persons, i.e., the percentage of persons who participated in out-of-house activities on the day of sampling. Due to the goals of the study, most of the test persons in the sample were employed. Therefore, this group is highly mobile; i.e., they almost all made trips on the sample days.

Before the test month and during the month of testing, the test persons had an almost identical rate of mobility. On the other hand, the percentage of persons with out-of-house activities in the month following the test was 16 percent less (Table 1).

Two factors were mainly responsible for the decrease in mobility.

1. The target persons received questionnaires five times within a period of 4 months. Although the response rate was satisfactory in all of the surveys, it can be assumed that at a certain point some

Table 1. Mobility.

Item	Total	Test Persons Before the Test	Test Persons During the Test	Test Persons After the Test	Family Members Before the Test	Family Members During the Test	Family Members After the Test
Base	3,876	472	472	472	820	820	820
Share of persons who did not leave their homes on the sampling day (%)	18.0	4.0	5.7	21.6	11.6	19.0	36.2
Share of persons who left their homes on the sampling day (%)	82.0	96.0	94.3	78.4	88.4	81.0	63.8
Share of persons (%) on sampling day who made							
1 trip	0.8	1.1	1.7	0.4	0.7	0.9	0.4
2 trips	33.5	35.2	45.0	35.7	30.9	31.7	29.1
3 trips	7.2	12.7	8.5	8.9	6.5	5.8	4.5
4 trips	22.7	24.6	21.7	17.4	27.2	24.2	19.1
5 trips	6.5	8.5	7.0	9.1	7.4	5.5	3.8
6 trips	7.3	7.4	6.2	3.8	10.3	9.4	4.6
≥7 trips	4.2	6.6	4.5	3.2	5.5	4.0	2.2
Avg no. of trips per person per sample day in relation to all persons for all sample days	2.85	3.41	3.06	2.58	3.28	2.89	2.11
Avg no. of trips per person per sample day in relation to mobile persons on the sample day	3.48	3.55	3.25	3.30	3.71	3.57	3.31

Note: Data for all days on which persons were sampled.

persons were no longer willing to respond; thus they simply wrote that they had made no trips on the given sample day (4).

2. The second and quantitatively more decisive factor also has to do with nonreported trips (5). Nevertheless, this second factor will be dealt with separately because it is directly related to the study. A number of those persons who partly or totally reverted to their old habits the month following the campaign tried to hide this fact by claiming that they were immobile on the sample days after the campaign.

Based on the sample days on which persons were mobile, the data in Table 1 reveal that from the time before the campaign to the time of the campaign, the median mobility fell from 3.55 trips to 3.25 trips per day and following the campaign it rose to 3.30 trips per day. This means that changing to public transportation had a significant effect on the activity programs of the test persons. Further results indicate that those activities that occurred on the way to work and back home (such as shopping) were excluded from the activity programs of the test persons during the time of testing. During the test, most of these activities were taken over by other family members. After the campaign, if the test persons decided to stop using public transportation, they resumed their previous activities (Table 2). The percentage of persons who made exactly 2 trips on the sample day (i.e., usually simply made 1 trip to work and 1 back home) increased by 10 percent during the campaign and afterwards reached its old level (Table 1).

Family Members

Far fewer of the family members of the test persons are employed than the test persons themselves. Therefore, the other family members make fewer trips. On the sample days, about 12 percent of the family members were immobile (Table 1). In the two following survey stages, their immobility drastically increased. The reasons for this were as follows:

1. Their increasing unwillingness to respond to each further survey stage; however, this tendency is not as systematically related to travel behavior among the family members as among the test persons; and
2. They did not understand why they should answer three sets of questions simply because one person in their family had decided to participate in the test.

Therefore, the average number of trips per sample day also revealed a declining tendency among the family members.

By looking at the data about the mobility of persons on the sample day, it becomes clear that a considerable decrease in the average number of trips occurs only with the third stage (after the campaign). One reason is that parts of the third survey stage took place during Pentecost, which is a vacation period in the Federal Republic of Germany. There were a considerable number of children among the family members who, as shown in the categorization of trips according to trip purpose and destination, made fewer educational trips but more recreational trips during this period.

That such particulars could be pinpointed indicates the high quality of the instrument of measurement.

Activities

As already noted, the test persons changed their activity programs as a result of the public transportation campaign. Those activities not necessarily restricted to the test persons (e.g., shopping) were engaged in less frequently during the test period than either previously or subsequently.

The median frequency of work trips per mobile person per sample day was identical in the first two stages; however, after the campaign had been completed (the third stage), the number of trips was reduced by almost one-fourth. Most important here were those work trips that were consciously not reported because they were made by car (Table 2).

Modal Split

Test Persons

Before the test, the test persons made the vast majority of their trips by car (i.e., 2.55 trips per mobile person per sample day). The number of trips made with public transportation before the test was 0.52 trips, which was almost the same as the number of trips made with nonmotorized modes--0.47 trips per day. During the month of testing, the public transport share almost quadrupled, whereas the share of trips made with private motor vehicles was reduced to less than one-third of its previous volume.

About 6 weeks after the test, an average of just less than 1 public transportation trip was made per mobile person per day. This means that

1. About 28 percent of the increased number of trips made with public transportation could be stabilized up until that time;
2. In contrast to the month before the test, a total stabilized public transportation trip increase of 81 percent could be attained; and
3. Approximately every other person in the test continued to use public transportation after the test had been completed.

The questionnaires given after 1 year revealed the following:

1. The total number of trips per mobile person on the sample day was again equivalent to what it had been before the test;
2. The average number of trips made with private motor vehicles increased by 10 percent; i.e., the theory that trips made with private motor vehicles were systematically suppressed during the month following the test was proven to be true; and
3. The number of public transportation trips per person per day increased minimally, which indicated that about half of the test persons became stable users of public transportation (Table 3).

An analysis of actual public transportation trips reveals the following.

1. The greatest increase in the use of public transportation during the test month was in the rapid train system. In this mode the greatest percentage of trips was stabilized; after the test there was an increase of 118 percent.
2. For subways and streetcars, there was also a high gain during the test month, but only a small number of these trips could be stabilized. Therefore, compared to the time before the test, a 6 percent increase remained (Table 4).

Family Members

The public transportation campaign hardly changed the modal choice of family members. Before as well as after the test they made a quarter of their trips by using public transportation. Relatively, it is possible to discern a slight increase in the number of trips they made by using private motor vehicles; however, this occurs solely at the cost of nonmotorized modes. Thus, although family members increased their use of the test person's car, this hardly caused a decrease in their use of public transportation (Table 3).

MULTIVARIATE ANALYSIS OF ATTITUDES TOWARD PUBLIC TRANSPORT

This study was designed to give information on the extent to which practical experiences with public transportation for 1 month would give the test persons a different, preferably better, picture of the quality of public transportation in Stuttgart. The study was also designed to determine whether (and to what extent) a positive change in attitude would cause a habitually increased use of public transportation.

Thus the general attitude that test persons have toward public transportation in Stuttgart was important, and not what their opinions of specific parameters were. A method of analysis (6) was therefore needed that would make it possible to summarize individual attitudes pertaining to specific parameters as a whole and to divide all of the persons studied into groups according to multiple factors.

Cluster analysis fulfilled these requirements.

Table 2. Activities.

Item	Total	Test Persons			Family Members		
		Before the Test	During the Test	After the Test	Before the Test	During the Test	After the Test
Base	3,180	453	445	370	725	664	523
Avg no. of trips per mobile person per sample day with the following activity							
Work	0.58	1.07	1.07	0.83	0.30	0.29	0.25
Business	0.11	0.27	0.24	0.18	0.03	0.02	0.02
Education	0.29	0.02	0.03	0.01	0.51	0.51	0.39
Shopping, visits to doctor, and so forth	0.48	0.41	0.29	0.36	0.65	0.57	0.42
Recreation	0.46	0.37	0.33	0.56	0.46	0.44	0.66
Home	1.45	1.29	1.24	1.28	1.63	1.60	1.46
Other	0.11	0.12	0.05	0.08	0.13	0.14	0.11
Total	3.48	3.55	3.25	3.30	3.71	3.57	3.31

Note: Data for all registered mobile persons on the sampling days.

Table 3. Modal split.

Item	Total	Test Persons				Family Members			
		Before the Test	During the Test	After the Test	After 1 Yr	Before the Test	During the Test	After the Test	After 1 Yr
Base	3,180	453	445	370	320	725	664	523	492
Avg no. of trips per mobile person on sampling days using the following modes									
Nonmotorized	1.07	0.47	0.42	0.59	0.62	1.59	1.42	1.35	1.61
Private motor vehicles	1.40	2.55	0.79	1.76	1.92	1.16	1.23	1.22	1.40
Public transportation	1.00	0.52	2.04	0.94	1.05	0.95	0.91	0.74	0.93
No response	0.01	0.01	0.00	0.01	0.00	0.01	0.01	-	-
Total	3.48	3.55	3.25	3.30	3.59	3.71	3.57	3.31	3.94

Note: Data for all registered mobile persons on the sampling days.

Table 4. Mode used.

Item	Total	Test Persons: Before the Test	Test Persons: During the Test	Test Persons: After the Test	Family Members: Before the Test	Family Members: During the Test	Family Members: After the Test
Base	3,180	453	445	370	725	664	523
Avg no. of trips per mobile person on the sampling days using the following modes[a]							
Walking, bicycle or mofa	1.07	0.47	0.42	0.59	1.59	1.42	1.35
Car as driver or passenger; moped or motorcycle	1.40	2.55	0.79	1.76	1.16	1.23	1.22
Bus	0.19	0.09	0.17	0.11	0.26	0.23	0.18
Streetcar	0.45	0.19	0.86	0.34	0.49	0.46	0.34
Subway	0.02	0.02	0.05	0.01	0.01	0.02	0.02
Rapid train	0.27	0.17	0.79	0.37	0.16	0.16	0.14
Train	0.04	0.04	0.15	0.09	0.01	0.01	0.02
Taxi	0.01	0.00	0.01	0.02	0.00	0.01	0.01
Other	0.02	0.01	0.01	0.00	0.02	0.02	0.02
No response	0.01	0.01	0.00	0.01	0.01	0.01	-
Total	3.48	3.55	3.25	3.30	3.71	3.57	3.31

Note: Data for all registered mobile persons on the sampling days.
[a]Only main mode used.

Cluster analysis makes it possible to combine the opinion profiles of individuals into similar groups. These groups are called clusters. Clustering makes it possible, to put it somewhat simplistically, to collect similar characteristic profiles into one cluster and to sort different characteristic profiles into different clusters. The variables used to define the groups (i.e., the active variables) were the result of a scale that had been used to measure the feelings (7) of persons that used public transportation before and after the test.

Description of Types of Attitudes

After several tests were done, a configuration of six types of persons proved to be the ideal solution. These types of persons are described as follows.

The first type of person is unreservedly in favor of public transportation. Thus it is natural to refer to these persons as having a "totally positive attitude". Fourteen percent of the respondents were in this category before the test, and 17 percent were in this category after the test. Thus the size of this group increased.

The second type of person also has a positive basic attitude toward public transportation. With two exceptions, all of the values that these persons gave to different aspects of public transportation were in the positive section of the scale. Mild criticism toward public transportation could be noted in the areas of flexibility and accessibility of destination. These persons can be said to have a "predominantly positive attitude".

Of all of the groups, this group includes the most persons. Before the test 28.6 percent of the total belonged to this group. After the test only 22.4 percent of the persons belonged to this group. An analysis of the changes in the clusters indicates the direction that these losses took place.

The third type of person evaluates most of the items pertaining to public transportation more positively than the second type. However, for two items the values are so negative that this group must be considered separately. The two items are (a) flexibility ("I can't come and go as I please when I use public transportation"); and (b) accessibility ("It's not possible to get everywhere I want to go with public transportation").

These persons appear to be at ease when using public transportation, but its dependency on a fixed network and time schedules gives these persons the belief that they cannot always organize things as they might wish to. These persons appear to think that public transportation should be unrealistically flexible. This desire for flexibility is the result of an exaggerated need for security, articulated by persons who more or less force themselves to be ever ready to expect the unexpected. Thus this group can best be described as being "perfectionistic". Their basic attitude toward public transportation is definitely positive, and it can be assumed that these persons are also a future potential for the Stuttgart public transportation system, which should not be neglected. Before the test, this group accounted for 18.4 percent of the total, and afterwards for 19.6 percent of the total.

The fourth type of person is a difficult potential client for the Stuttgart public transportation system. These persons evaluate their experiences with public transportation positively, but they believe that using public transportation negatively influences their social status. They believe that their colleagues would be surprised if they were to use public transportation, and they also believe that their families would look down on their use of public transportation. These persons orient themselves more to the effect of their behavior on others and place their own positive attitudes toward public transportation in the background. It is difficult to induce these persons to use public transportation. Thus this group could be referred to as "influenced by others".

This group accounted for 8.2 percent of the total before the test and 10.2 percent after the test; their relative share is thus small. Nevertheless, because of the special characteristics of this type, it was not appropriate to neglect this group in this paper.

The fifth type of person evaluated almost half of all of the items negatively. These persons tend to associate use of public transportation with hassles, but they also negatively evaluated the areas of flexibility and accessibility of destination. Therefore, this group was referred to as persons with a "rather negative attitude".

This group is quantitatively important because it initially accounted for 23.5 percent of the respondents; after the test it was reduced to 19.2 percent. Nevertheless, here too the analysis of the changes in the clusters indicates the direction of the changes.

The sixth type of person is diametrically opposed to the first type. These persons gave almost all of the items negative, and sometimes extremely negative, values. The only exception was that this

group deemed public transportation to be up-to-date as a mode of transportation. Thus this group was referred to as persons with a "totally negative attitude".

Before the test this group accounted for 7.5 percent of the total, and after the test 11.8 percent of the total.

Analysis of Changes in Clusters

The analysis of the changes in the clusters revealed how attitudes held before the test changed after the test had been completed. The test resulted in changes in all of the groups. The greatest increase can be discerned in the two types of attitudes on the extreme ends of the scale. This leads to the conclusion that the test resulted in a polarization of attitudes. Positive attitudes were reinforced, but negative attitudes were also reinforced.

An analysis of the changes in the clusters led to the construction of six types of attitudes. It was demonstrated that

1. About a quarter of the total had their negative or positive attitudes reinforced (i.e., their opinions were stabilized);
2. In about 17 percent of the cases a positive prejudice was turned about due to the unsatisfactory experiences that the persons had when using public transportation; and
3. In about 15 percent of the cases negative attitudes were improved by the test (Table 5).

Group Discussions

At the conclusion of the study, 60 participants were chosen according to the criteria "change in behaviour attitude". A total of five group discussions dealt with the following topics.

1. A systematic discussion of experiences and criticisms of the discussion by other participants.
2. Concrete suggestions to improve the public transportation system as a result of experiences made with public transportation. The participants in the discussion were first to use a brain-storming method to collect all possible suggestions, and then they were to list these in order of importance, in light of the effect that the costs for improvements will have on the price of public transportation.

The most important measures suggested by the participants were divided into the following areas:

1. Increasing the frequency with which different types of public transportation run;
2. Improved coordination of the scheduling of different public transportation modes;
3. Making the schedules easier to read;
4. Integrating privately owned bus systems into the Stuttgart public transportation system; and
5. Improving the possibility of taking along baby carriages and bicycles.

CONCLUSIONS

The campaign Car Drivers Test Public Transportation by the Stuttgart VVS was an attempt to use a new kind of publicity for public transportation in order to reach new target groups. When the VVS was introduced in Stuttgart, advertising and public relations work were aimed at informing the regular users of public transportation of alterations in the system and changes in the fare rates. The current campaign was aimed at familiarizing car drivers with the public transportation supply. The social-scientific study was to explain the expectations that car drivers have of the Stuttgart VVS; what transport mode was used before, during, and after the cam-

Table 5. Defining persons with different types of attitudes.

Category	Type of Attitude Before Test	Type of Attitude After Test	Change in Attitude
Type A	Totally positive	Totally positive	Positive attitude that is stable = 27.7 percent
	Totally positive	Rather positive	
	Rather positive	Rather positive	
	Rather positive	Totally positive	
	Totally positive	Perfectionistic	
	Rather positive	Perfectionistic	
Type B	Totally positive	Influenced by others	Deterioration of a positive attitude = 17.3 percent
	Totally positive	Rather negative	
	Totally positive	Totally negative	
	Rather positive	Influenced by others	
	Rather positive	Rather negative	
	Rather positive	Totally negative	
	Perfectionistic	Influenced by others	
	Perfectionistic	Rather negative	
	Perfectionistic	Totally negative	
Type C	Perfectionistic	Perfectionistic	Perfectionists with no change in their attitudes = 6.8 percent
Type D	Perfectionistic	Totally positive	Perfectionists whose attitudes improved = 9.1 percent
	Perfectionistic	Rather positive	
Type E	Influenced by others	Influenced by others	Negative attitude that is stable = 24.1 percent
	Influenced by others	Rather negative	
	Influenced by others	Totally negative	
	Rather negative	Influenced by others	
	Rather negative	Rather negative	
	Rather negative	Totally negative	
	Totally negative	Influenced by others	
	Totally negative	Rather negative	
	Totally negative	Totally negative	
Type F	Influenced by others	Totally positive	Improvement of a negative attitude = 15.0 percent
	Influenced by others	Rather positive	
	Influenced by others	Perfectionistic	
	Rather negative	Totally positive	
	Rather negative	Rather positive	
	Rather negative	Perfectionistic	
	Totally negative	Totally positive	
	Totally negative	Rather positive	
	Totally negative	Perfectionistic	

paign; and the experiences that the car drivers had with public transportation. Thus the study also examined the success of this relatively expensive public-relations work.

From the point of view of the Stuttgart VVS, the following results of the study were of special interest.

The decision of car drivers to use public transportation is influenced by the criterion "an economical form of transportation", and also by such criteria as speed, stress-free form of transportation, dependability, and comfort. Modern public transportation facilities and a supply geared to the needs of the users are capable of fulfilling these requirements.

Most of the car drivers who participated in the campaign are members of the middle to upper classes. This group is increasingly interested in the possibilities of public transportation.

More than half of the participants in the test are still using public transportation to get to work. Furthermore, the attitudes of many of the participants toward public transportation changed for the better during the campaign. Thus the campaign proved to be an effective instrument of goal-directed public-relations work.

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