Peer Comparisons in Transit Performance Evaluation

MANOUCHEHR VAZIRI and JOHN A. DEACON

ABSTRACT

A methodology by which to group urbanized areas for the purpose of peer comparisons in transit performance evaluation is presented. A suitable basis for grouping was found to be those market and environmental variables that effectively constrain attainable performance levels. By using U.S. Bureau of the Census data for 1980, homogenous clusters of urbanized areas were formed and the key market and environmental variables were reduced by means of factor analysis to one size index. Reporting-system data as outlined in Section 15 of the Urban Mass Transportation Act of 1964 were used both to evaluate adequacy of the grouping scheme and to establish attainable target performance levels. General relationships were observed between the mean transit performance of the peer groups and their mean size indices. It was concluded that regression models were the most effective way to eliminate the effects of market and environmental dissimilarities in establishing target performance levels. Models relating individual performance measures to significant market and environmental variables were calibrated for each peer group.

Comparative studies form an indispensible component of transit performance evaluation. Such studies include comparisons of performance changes over time, comparisons of actual performance with preestablished target levels, and comparisons of the performance of a subject system with that of other similar systems. This last type of study, sometimes termed peer comparison, is frequently used in the establishment of feasible performance targets. However, it is also used for other purposes such as evaluation of the effectiveness of management and has even been suggested as a basis for distribution or allocation of financial aid (1-4).

Regardless of purpose, peer comparisons offer great promise in the quest for improved transit performance. In the past, however, their application has been hampered by two restraints. First, detailed performance data were not consistently and uniformly reported by transit agencies. Second, procedures for the formation of reasonable peer groups were not well understood. Implementation of a uniform public mass transportation reporting system, mandated by Section 15 of the Urban Mass Transportation Act of 1964, as amended, has been instrumental in eliminating the first difficulty. The second is the primary subject addressed here.

The objectives of this research were primarily to

1. Develop a methodology for the classification of transit systems that would be useful for enlightened peer comparisons and
2. Apply that methodology to systems throughout the United States.

This research was part of a more comprehensive study of transit performance that has been reported elsewhere (5).

STUDY APPROACH

Central to the peer-comparison concept are two important notions, namely, that

1. All transit systems cannot be expected to achieve the same high level of performance and
2. The subject system can, with proper action by management, achieve performance levels demonstrated by the best within its peer group.

The first of these notions establishes one of the necessities for the formation of homogenous groups in peer comparisons. The second suggests a basis for selection of systems to make up each of the groups, namely, that systems within a given group should have the same attainable or potential levels of performance. Because potential performance levels cannot be measured directly, the formation of peer groups is not at all a straightforward process.

It is helpful, however, to understand that actual performance levels are dictated or determined by both controllable and uncontrollable variables; the distinction is made on the basis of whether the determining variables are within or beyond the influence of the transit provider. In this sense the controllable or endogenous variables are those manipulated by the provider to influence performance: They include such examples as fare, routing, maintenance, and vehicle replacement strategies. These are also sometimes termed policy variables. Uncontrollable or exogenous variables have no lesser effect on transit performance, but at the same time they cannot be reasonably manipulated by the transit provider. Uncontrollable variables can be exemplified by such diverse characteristics as size of population served, development density, automobile ownership, and extent of freeway development.

It is hypothesized that the level of performance attainable by a subject system is theoretically constrained by the uncontrollable variables, which reflects primarily the nature of the market served and the environment within which the service is provided. When these conditions have been identified, the controllable variables can be set at levels that will enable performance to reach its potential limits. Because potential performance cannot be directly measured, the formation of peer groups should be based solely on those uncontrollable market and environmental variables that significantly influence transit performance. This finding had a major impact on the structure of the data base used here and largely dictated the approach taken in the grouping or clustering procedure.

The first phase of this study was to create a data base from which performance and market and environmental data could be extracted for transit systems throughout the United States. Then, by means of factor analysis, these data were reduced to a simpler, nonredundant dimension. The reduced market and environmental data were next used with another multivariate statistical procedure, cluster analysis, to form homogenous peer groups. By means of analysis of variance, the resultant peer groups were analyzed to determine their similarities and dissimilarities. Finally, target performance levels were developed for each peer group.

DATA BASE

The nationwide scope and limited resources of this study required that centralized data sources be used. The only reasonable source of transit performance data was the Section 15 reporting system. Annual data, as reported for fiscal years ending between July 1, 1979, and June 30, 1980, were used (6). The most reasonable source of market and environmental data was the U.S. Census. Original plans were to use only 1980 data. However, reporting delays required some 1960 and 1970 data to be forecast to 1980.

The merger of Section 15 and census data required a common unit of analysis, that is, a comparable level to which data could be aggregated. Census data are reported both for various levels of governmental jurisdiction and for various geographical levels. Section 15 data, on the other hand, are reported only by transit operator. Limits of the transit-served region are not accurately defined in Section 15 reporting and there is often more than one operator in a particular geographic region. Given this situation, the most reasonable unit of analysis was judged to be the urbanized area, and where necessary transit data were aggregated to this level. The urbanized area is indicative of the entire transit-serviceable region and should serve as a better unit for comparison than that used in most peer comparisons, that is, the region often ill defined, served by the individual transit operator. Only 188 of the 366 urbanized areas were included in this study. The remainder were excluded either because they were not served by transit or because transit data had not been adequately reported.

Development of transit performance measures was an important task, which is described in detail elsewhere (5). The 25 measures that were ultimately used are identified, together with their means and standard deviations, in Table 1. Suffice it to say here that this list reflects the major performance dimensions available from the Section 15-census data base. It also reflects many of the major performance variables that have been used by other researchers and practitioners.

A composite measure of system performance was also developed to expedite the analysis. Termed overall sum of the Z scores (OSZ), this normalized variable reflects an equal weighting of those six dimensions of performance identified in Table 1, namely, output and input, consumption and input, and so on. In constructing OSZ, accidents per revenue vehicle mile (SCSO14) and the input-market variable set (SIMEs) were treated negatively. Increases in the levels of all other variables were taken to be indicative of improved performance.

Because the peer groups of urbanized areas were to be formed in consideration only of the exogenous market and environmental (ME) variables, selection of these variables was critical. The ME variables had to be significantly related to potential transit

TABLE 1 Performance Variables

Symbol	Variable Name	Mean	Standard Deviation	Unit
Output and input				
SOSI3	Rev Veh Hr/Opr Exp	0.047	0.024	Vehicle hours per dollar
SOSI5	Rev Veh Mi/Rev Veh	27,648.965	7,779.455	Vehicle miles per vehicle
SOSI8	Rev Veh Hr/Transit Empl	1,057.533	265.061	Vehicle hours per employee
SOSI12	Rev Veh Hr/Equiv Gal Gas	0.313	0.196	Vehicle hours per gallon
SOSI13	Pass Cap Mi/Rev Veh	1,660.531	1,242.439	1,000 passenger miles per vehicle
Consumption and input				
SCSI4	Rev/Rev Veh	54,203.054	24,669.277	Dollars per vehicle
SCSI6	Pass/Opr Exp	1.397	0.846	Passengers per dollar
SCSI8	Pass Mi/Opr Exp	4.840	3.684	Passenger miles per dollar
SCSI16	Rev/Veh Opr Cost	1.939	1.306	Dollars per dollar
SCSI18	Pass Rev/Opr Exp	0.311	0.124	Dollars per dollar
Consumption and output				
SCSO1	Pass Mi/Pass Cap Mi	152.633	99.561	Passenger miles per 1,000 capacity miles
SCSO3	Pass/Rev Veh Mi	2.662	2.492	Passengers per vehicle mile
SCSO9	Pass/Transitway Length	22,334.092	27,205.245	Passengers per mile
SCSO14	Accidents/Rev Veh Mi	77.357	93.707	Accidents per million vehicle miles
SCSO15	Rev Veh Mi/Tot Road Calls	4.132	9.840	1,000 vehicle miles per call
Input and market				
SIME1	Opr Exp/Pop	17.607	16.182	Dollars per person
SIME2	Opr Assistance/Pop	10.563	9.489	Dollars per person
SIME5	Rev Veh/Pop	0.314	0.174	Vehicles per 1,000 persons
SIME6	Transit Empl/Pop	0.646	0.427	Employees per 1,000
Output and market				
SOME1	Pass Cap Mi/Pop	540.113	508.906	Passenger miles per person
SOME2	Rev Veh Mi/Pop	8.443	4.974	Vehicle miles per person
SOME8	Transitway Length/Area	3.048	3.210	Miles per square mile
Consumption and market				
SCME1	Pass/Pop	23.341	25.290	Passengers per person
SCME6	Pass Mi/Area	215.253	343.107	1,000 passenger miles per square mile
SCME12	Avg Trip Dist/Equiv UA Radius	0.637	0.507	Miles per mile

performance, otherwise proper interpretation of the results of peer comparisons would be difficult or impossible. Some assistance in the selection was found in the literature (4,7,8), but to a great extent selection of the 41 ME variables of Table 2 was based on the authors' judgment. The rather large number of ME variables assures, it is hoped, that the critical market and environmental dimensions, as they can be extracted from census data, have been included.

FACTOR ANALYSIS OF ME VARIABLES

High correlations between pairs of ME variables could potentially cause a significant bias in groupings based thereon. For example, because housing

TABLE 2 ME Variables

Symbol	Variable Name	Mean	Standard Deviation	Unit
Automobile Ownership				
ME1	Avg Persons/Auto	2.088	0.379	Persons per automobile
ME30	Workers/Auto	0.998	0.246	Workers per automobile
ME31	Autos/Hsld	1.376	0.213	Automobiles per household
Urbanized Area Size				
ME2	1980 Pop	495.379	894.967	1,000 persons
ME7	Area	202.498	261.069	Square miles
ME37	Housing Units	193.505	344.298	1,000 units
Income of Residents				
ME3	Families < $5,000	6.680	1.865	Percent
ME4	Families > $10,000	75.847	12.973	Percent
ME13	Median Family Income	21,017.187	2,793.683	Dollars per year
ME32	Families < Low Income	7.605	2.745	Percent
Age of Residents				
ME5	Pop < 18 Yr	27.039	2.941	Percent
ME6	Pop > 65 Yr	11.264	3.123	Percent
ME15	Pop < 5 Yr	7.092	1.142	Percent
ME35	Median Age	29.855	3.027	Years
Occupation of Residents				
ME18	Pop in School	21.498	2.072	Percent
ME22	Pop Employed	40.029	3.655	Percent
ME23	Pop in College	5.535	3.112	Percent
ME24	Empl in Manufacturing	21.859	8.857	Percent
ME25	Empl in Sales	22.603	2.890	Percent
ME26	Empl in Construction	5.628	1.789	Percent
ME27	Empl in Government	15.575	6.287	Percent
Education of Residents				
ME20	Median School Yr Completed	12.544	0.349	Years
ME21	Pop Completed College	14.547	4.879	Percent
Gender and Race of Residents				
ME28	Civ Labor Female	19.267	2.625	Percent
ME29	Pop Female	51.964	1.134	Percent
ME34	Pop Nonwhite	16.701	11.407	Percent
Housing				
ME14	HU Renter-Occupied	36.014	5.914	Percent
ME36	Hsld Size	2.662	0.156	Persons per household
ME38	HU Single Unit	71.759	8.151	Percent
Land Use Distribution				
ME8	Area in Central City	43.988	25.192	Percent
ME9	Pop Density	2,271.002	766.456	Persons per square mile
ME10	Land Area	95.227	8.802	Percent of total area
ME16	Housing Density	881.812	291.949	Housing units per square mile
ME33	1900 Pop	61,521.074	99,014.069	Persons
ME39	SMSA Pop in UA	78.868	11.471	Percent
ME40	UA Pop in Central City	59.826	23.387	Percent
ME41	Pop Density Central City	3,851.457	2,356.825	Persons per square mile
Growth				
ME17	Pop Growth 70-80	14.169	26.863	Percent
ME19	Housing Growth 70-80	38.090	23.809	Percent
Climate				
ME11	Avg Jan. Temp	34.162	12.317	Degrees Fahrenheit
ME12	Annual Rainfall	35.907	12.265	Inches

TABLE 3 Factor Dimensions of ME Variables

Symbol	Variables with High Positive Loading	Variables with High Negative Loading	Interpretive Meaning of Factor Dimension	Percentage of Variance Explained by Factor
F_1	Families < \$5,000 (low income) Families < Low Income Avg Jan. Temp Housing Growth 70-80 Empl in Construction	Families > \$10,000 (high income)	Poverty	16.9
F_2	1980 Pop Area 1900 Pop HU	UA Pop in Central City	Size	13.5
F_3	Pop < 18 Yr Pop < 5 Yr	Pop > 65 Yr Median Age	Youthfulness	10.5
F_4	Pop in College Pop Completed College HU Renter-Occupied	Empl in Manufacturing	Education	9.3
F_5	Autos/Hsld	Avg Persons/Auto	Automobile availability	6.3
F_6	Pop Density Housing Density Land Area		Density	4.7

units and population are highly correlated, including both in the cluster analysis is equivalent to counting the effect of size twice. To eliminate such possible problems yet still retain all of the important ME dimensions, factor analysis was used. The Factor Analysis Program of the Statistical Package for the Social Sciences (9) with varimax rotation and a minimum eigenvalue of 2 was found effective in reducing the 41 ME variables into 6 factor dimensions that all together explained 61 percent of the total variance. In Table 3 the dimensions of these factors are identified and interpreted. The urbanized areas are thus characterized by the six dimensions of poverty, size, youthfulness, education, automobile availability, and density of development. These are clearly distinguishing characteristics that intuitively seem to be the most important determinants of potential transit performance.

PEER GROUPS

All clusters or peer groups were formed by using the Biomedical Computer Program cluster analysis with K-mean clustering (10). In this algorithm the Euclidean distance was used as a measure of the deviation of an individual case from the cluster mean. Initially all cases were considered in one cluster. With each succeeding iteration, a new cluster was formed until the requested number of clusters had been reached.

In each cluster analysis, the 188 urbanized areas were divided into two sets, one of 150 and the other of 38. The smaller set was considered to be a homogeneous peer group and was not included in the clustering. Such a procedure was required because some of the ME data were missing. Because each of the 38 areas had become newly classified as urbanized in 1970 or 1980, reasonable estimates of the 1980 forecast variables were not available and hence these variables were treated as missing. A complete set of data was available for the larger group.

Also in each cluster analysis, the number of clusters for the remaining 150 areas was preselected at 10. This was intuitively judged to be sufficiently large to assure the necessary intragroup homogeneity while retaining, on the average, a sufficient group size to permit intragroup statistical analyses. Actually, in preliminary analyses, 6, 8, and 10 groups were investigated. Both the maximum group size and the proportion of sparse groups were judged excessive when the number of groups was less than 10.

FORMATION OF GROUPS

Four different schemes for clustering the urbanized areas were subjected to detailed analysis. Two were based on the use of ME data, one was based on transit performance data, and one was based on a combination of ME and performance data.

In the first scheme, formation of peer groups was based on the six ME factors, as identified in Table 3. The 10 groups are described in Table 4.

The clusters that had been thus formed were intuitively appealing. However, there were inconsistencies within the groups when measures of transit activity and performance were examined. It was reasoned that perhaps the six independent factor dimensions were not of equivalent importance in their effects on transit and that a second set of peer groups should be formed on the basis of the singularly most significant factor.

In order to determine which of the six factors was most significant, correlation coefficients were computed between each of the six factor dimensions and summed, normalized scores (SZ scores) for each of the six sets of performance measurements as identified by Table 1. In Table 5, which gives a portion of the resulting correlation matrix, the second factor, that relating to size, is most significantly correlated with performance.

Accordingly, the size factor (F_2) was then used as the basis for a second clustering of the urbanized areas. The 10 groups were clearly distinguish-

TABLE 4 Peer Groups Based on ME Factors

Group	Distinguishing Characteristic
1	Large cities located throughout the United States
2	Florida cities with large retired populations
3	Southern cities with youthful, low-income, low-automobile-owning residents
4	Northeastern cities with older residents
5	Low-density cities predominantly in Midwest
6	Low-density and low-automobile-owning cities
7	Automobile-dominated cities of West
8	Average cities with younger residents predominantly in Midwest
9	Low-income cities of the South and West
10	Small university cities with highly educated young residents

TABLE 5 Correlation Matrix of Six Factor Dimensions of ME Variables with Six Dimensions of Transit Performance

Factor Dimension	SZ_1	SZ_2	SZ_3	SZ_4	SZ_5	SZ_6
F_1 (poverty)	NC	NC	NC	−0.290	−0.262	NC
F_2 (size)	NC	0.401	0.324	0.583	0.476	0.185
F_3 (youthfulness)	NC	NC	NC	−0.142	NC	NC
F_4 (education)	NC	0.152	0.237	0.329	0.206	NC
F_5 (automobile availability)	NC	−0.213	−0.206	NC	NC	NC
F_6 (density)	NC	NC	NC	NC	0.260	0.174

Note: NC = not correlated at level of significance of 0.05. Performance variables: SZ_1 = sum of normalized output-input variables; SZ_2 = sum of normalized consumption-input variables; SZ_3 = sum of normalized consumption-output variables; SZ_4 = sum of normalized input-market variables; SZ_5 = sum of normalized output-market variables; SZ_6 = sum of normalized consumption-market variables.

able from each other in terms of size variables such as population and area. Subjective analysis of the adequacy of this clustering scheme was favorable.

Clustering of urbanized areas based on transit performance has little utility in most peer comparisons. The motivation for comparing a subject urbanized area with others of similar performance is not compelling. At the same time, a comparison of performance clusters with market clusters offered potential for revealing new insights. Therefore, performance clusters were formed by using the overall sum of Z scores (OSZ) as a basis. The groups that were so formed were clearly different in their overall level of transit performance.

To complete the analysis, a final grouping was developed on the combined basis of overall performance (OSZ) and market (F_2). These 10 groups can be described as shown in Table 6.

TABLE 6 Peer Groups Based on Size Factor

Group	Size	Performance
1	Below average	Above average
2	Below average	Below average
3	Below average	Well below average
4	Below average	Average
5	Below average	Well above average
6	Above average	Below average
7	Above average	Above average
8	Above average	Well above average
9	Well above average	Average
10	Well above average	Above average

ANALYSIS OF GROUPS

Four complete sets of peer groups had been formed by using the four different bases for clustering, namely, six factors (market), F_2 (size), OSZ (overall transit performance), and the combination of F_2 and OSZ. The four sets were markedly different, and two additional procedures remained to be carried out. First was a determination, for each of the four sets, of the transit characteristics that were different among the groups. Second was the selection of one of the four sets for more-detailed analyses.

Previously described transit characteristics that were available for testing included the 25 performance variables. In addition there were 18 system-input (SI) variables, reflecting the resources dedicated to transit and generally including labor, capital, and operating monies; 15 system-output (SO) variables, reflecting the level of transit service that is produced and generally including vehicle miles, vehicle hours, and capacity miles; and 12 system-consumption (SC) variables, reflecting utilization of the service and including passengers, passenger miles, and revenue of various types. Analysis of variance was used to determine which of these variables were significantly different among the groups for each clustering scheme. Results of the analysis are summarized in Table 7. The larger entries in Table 7 are statistically preferred because they indicate a larger percentage of variables that are significantly different among the groups and hence a more discriminating clustering scheme.

TABLE 7 Percentage of Difference Among Groups of Variables at 0.05 Level of Significance

	Percentage by Clustering Basis			
Category of Variables	Six Factors	F_2	OSZ	F_2 and OSZ
SI (system input)	77	83	39	67
SO (system output)	86	87	67	87
SC (system consumption)	74	50	75	75
Performance	60	60	68	84
All	72	70	61	78

In addition to the summary statistics of Table 7, five consumption variables, including passengers, total revenue, passenger revenue, passengers per capita, and passenger miles per square mile, were judged to have special significance. Each of the four clustering schemes was successful in forming groups that differed with respect to these five variables. Because the number of groups had been held constant at 10, the degree of success is indicated by the η^2-statistic. This statistic assumes a minimum value of 0.0 if the grouping has been completely unsuccessful in reducing variability in the chosen measure and reaches a maximum value of 1.0 when all intragroup variability has been eliminated. More effective clustering techniques thus yield larger values of η^2. In Table 8 the η^2-statistic is summarized for the five selected consumption variables.

As indicated by the data of Tables 7 and 8, the clusters of F_2 and those of the combined F_2 and OSZ are superior to those based on the other two

TABLE 8 η^2 of Selected Consumption Variables

		η^2 by Clustering Basis			
Symbol	Variable Name	Six Factors	F_2	OSZ	F_2 and OSZ
SC1	Pass	0.517	0.844	0.137	0.655
SC2	Rev	0.618	0.916	0.111	0.694
SC12	Pass Rev	0.522	0.884	0.122	0.700
SCME1	Pass/Pop	0.295	0.522	0.224	0.532
SCME6	Pass Mi/Area	0.234	0.371	0.412	0.601
Avg		0.437	0.707	0.201	0.636

Note: η^2 = between-group sum of squares divided by total sum of squares.

schemes. Objectively, the choice between clusters based on F_2 and those based on F_2 and OSZ is a mixed one. At the same time, clustering based on F_2 is simpler and more comprehensible. Furthermore, it supports the critical notion that ME variables in themselves largely dictate transit potential. For these reasons, clustering based on the size factor (F_2) was chosen as the preferred basis for further investigation. The resulting clusters are identified in Table 9. Distributional characteristics of the F_2 scores for these groups are summarized in Table 10.

COMPARATIVE TRANSIT PERFORMANCE

One objective in peer comparisons of transit performance is establishment of feasible performance targets. The assumption is that the subject system could achieve performance levels demonstrated by others of its peer group if the proper policy decisions were made. If the peer group were truly homogeneous, the subject system could even reach performance levels at least as good as the best demonstrated within the peer group. Most peer comparisons use average performance as the target, however, and this convention seems reasonable given the uncertainty in identifying truly homogenous peer groups. A three-level structure for comparative analysis is developed here, each level of which requires the use of averages.

The first level is an uncontrolled comparison. The peer group simply represents the set of all 188 urbanized areas, and the average performance levels are used in establishing first-cut targets. For some systems, however, such averages will be unrealistic targets because of ME constraints. For others, ME considerations will be so favorable that the averages will represent unacceptably low targets. Therefore, the use of uncontrolled comparisons is only recommended as a supplement to those of a more controlled nature and even then their findings must be cautiously interpreted and applied. Data useful for uncontrolled comparisons within the 1980 time frame are summarized in Table 1.

The second and third levels represent controlled comparisons: Performance of the subject system is compared with that of a more selective peer group. To the extent that the F_2 (size) clusters represent homogenous groups of urbanized areas having equivalent potential for transit, they are considered an appropriate basis for controlled comparisons.

In the second-level analysis, the performance target is the average performance of the peer group. Table 11 shows such averages for 10 of the peer groups. Since the original group 10 has only one member, Los Angeles, it is not useful for controlled comparisons and hence is not included in Table 11. In Table 12 it is demonstrated that rather distinct differences result from use of peer-group averages as target values rather than overall U.S. averages. For simplicity, only 6 of the 25 performance variables are included in Table 12, and tabulated values have a normalized value of 1 at the overall mean. It is apparent that there are distinct differences in the group means for each variable and that a general relationship seems to exist between the group mean and the size of the average urbanized area (with size increasing from top to bottom of the table). Because the second-level comparison significantly reduces the effects of dissimilarity among the urbanized areas, it is judged to be more reliable and useful than the uncontrolled comparison.

However, within each group, there remain inherent market differences that influence transit performance. To further control for these differences, a third-level comparison is sometimes useful in which the target becomes the expected performance computed from regression models of peer-member statistics. As in all controlled comparisons, the intent is to eliminate, insofar as possible, the effect of ME dissimilarities.

The stepwise multiple regression analysis of SPSS (9) was used. Two forms of regression equations were screened, the linear and the multiplicative. Because the linear is simpler and seemed to be of comparable or superior accuracy, it was chosen for the detailed analysis.

The independent variables were chosen from the set of 41 ME variables. In order to reduce collinearity, the following selection procedure was employed. The ME variables were first rank ordered with respect

TABLE 9 Recommended Peer Groups

Cluster	City
1	Amarillo, Bay City, Boise, Champaign, Dubuque, Eugene, Kenosha, Lexington, Lubbock, Madison, Pittsfield, Pueblo, San Angelo, Sioux City, Sioux Falls, Springfield (Mo.), Terre Haute, Topeka, Tuscaloosa, Utica-Rome, Wichita Falls
2	Altoona, Asheville, Beaumont, Billings, Cedar Rapids, Colorado Springs, Decatur, Duluth, Evansville, Fort Wayne, Fresno, Green Bay, Jackson (Miss.), Johnstown, Kalamazoo, Knoxville, Lewiston, Lynchburg, Manchester, Muskegon, Racine, Rockford, Spokane, Springfield (Ohio), Stockton, Waco, Wichita
3	Albany (Ga.), Albuquerque, Allentown, Austin, Bakersfield, Binghampton, Brockton, Canton, Charlotte, Chattanooga, Davenport, Des Moines, Erie, Flint, Grand Rapids, Jackson (Miss.), Lake Charles, Lancaster, Little Rock, Monroe, Montgomery, Nashville, New Bedford, Oklahoma City, Peoria, Portland (Maine), Reading, Reno, Roanoke, Saginaw, Santa Barbara, Shreveport, South Bend, Syracuse, Tucson, Tulsa, Worcester, York, Youngstown
4	Akron, Albany (N.Y.), Augusta, Aurora-Elgin, Baton Rouge, Birmingham, Dayton, Harrisburg, Indianapolis, Jacksonville, Lowell, Memphis, Mobile, Omaha, Salt Lake City, Savannah, Springfield (Ill.), Tacoma, Toledo, Trenton, West Palm Beach, Wilkes-Barre
5	Galveston, Hartford, Louisville, New Haven, Norwalk, Pensacola, Phoenix, Portland (Oreg.), Richmond, Rochester, Sacramento, San Antonio, Stamford, Tampa, Wilmington (Del.)
6	Buffalo, Cincinnati, Denver, Honolulu, Kansas City, Milwaukee, New Orleans, Providence, St. Petersburg, San Diego, San Jose, Seattle
7	Atlanta, Cleveland, Miami, Minneapolis, Pittsburgh
8	Baltimore, Dallas-Fort Worth, Houston, St. Louis
9	Boston, Detroit, San Francisco, Washington
10	Los Angeles
11	Alexandria, Anchorage, Anderson (Ind.), Appleton, Battle Creek, Biloxi, Bloomington, Bristol, Brownsville, Charleston (W. Va.), Daytona Beach, Fayetteville, Fort Myers, Gainesville, High Point, Lafayette (Ind.), Lafayette (La.), Mansfield, Melbourne, Modesto, New London, Orlando, Oshkosh, Oxnard-Ventura, Petersburg, Pine Bluff, Poughkeepsie, Raleigh, St. Cloud, Salinas, Santa Cruz, Santa Rosa, Seaside-Monterey, Tallahassee, Waterbury, Williamsport, Wilmington (N.C.), Winston-Salem

TABLE 10 Distributional Characteristics of Groups Developed by Clustering Based on Size Factor

Group	Min F_2	Center F_2	Max F_2	Standard Deviation of F_2	No. of Cases
1	-1.787	-1.089	-0.899	0.222	21
2	-0.884	-0.701	-0.518	0.114	27
3	-0.485	-0.299	-0.119	0.108	39
4	-0.075	0.089	0.270	0.099	22
5	0.327	0.474	0.665	0.099	15
6	0.778	0.983	1.169	0.137	12
7	1.468	1.661	1.791	0.144	5
8	1.876	1.932	1.993	0.050	4
9	2.622	2.771	2.929	0.165	4
10	5.499	5.499	5.499	0.0	1
11	N/A	N/A	N/A	N/A	38

Note: N/A = not applicable.

TABLE 11 Average Peer-Group Performance

Symbol	Performance Variable Name	U.S. Avg	Performance by Peer Group 11	1	2	3	4	5	6	7	8	9
SOSI3	Rev Veh Hr/Opr Exp	0.047	0.059	0.054	0.052	0.044	0.042	0.039	0.034	0.031	0.025	0.019
SOSI5	Rev Veh Mi/Rev Veh	27,600	29,900	25,400	28,000	27,100	26,400	27,200	29,900	24,300	26,500	26,700
SOSI8	Rev Veh Hr/Transit Empl	1,060	1,120	1,100	1,150	1,040	1,030	1,040	928	1,070	856	743
SOSI12	Rev Veh Hr/Equiv Gal Gas	0.313	0.338	0.321	0.312	0.292	0.269	0.253	0.279	0.659	0.374	0.345
SOSI13	Pass Cap Mi/Rev Veh	1,660	1,410	1,170	1,420	1,710	2,340	1,650	1,970	1,890	1,720	2,500
SCSI4	Rev/Rev Veh	54,200	45,300	39,700	48,600	52,200	52,700	53,100	80,100	75,700	100,000	124,000
SCSI6	Pass/Opr Exp	1.40	1.37	1.24	1.38	1.36	1.30	1.36	1.56	1.38	1.19	1.30
SCSI8	Pass Mi/Opr Exp	4.84	4.58	4.27	4.83	5.23	3.60	6.19	5.37	5.68	5.50	4.68
SCSI16	Rev/Veh Opr Cost	1.94	2.10	1.78	1.79	1.89	2.23	1.50	1.88	1.79	2.70	2.32
SCSI18	Pass Rev/Opr Exp	0.311	0.288	0.282	0.290	0.303	0.349	0.359	0.345	0.316	0.354	0.314
SCSO1	Pass Mi/Pass Cap Mi	153	133	166	151	141	112	197	189	215	222	200
SCSO3	Pass/Rev Veh Mi	2.66	1.81	1.78	2.16	2.35	2.99	2.77	3.43	8.14	3.29	5.33
SCSO9	Pass/Transitway Length	22,300	10,200	11,900	13,500	18,100	20,900	27,000	52,300	38,100	30,100	121,000
SCSO14	Accidents/Rev Veh Mi	77.4	45.9	52.5	72.2	72.4	91.0	73.2	92.8	326	149	86.1
SCSO15	Rev Veh Mi/Tot Road Calls	4.13	4.00	2.89	4.31	7.66	2.86	2.51	2.05	1.65	1.34	1.79
SIME1	Opr Exp/Pop	17.6	10.7	12.4	13.2	13.1	15.2	24.9	31.7	43.8	30.0	74.2
SIME2	Opr Assistance/Pop	10.6	6.51	7.90	9.03	8.99	9.33	11.1	15.8	20.7	19.8	53.6
SIME5	Rev Veh/Pop	0.314	0.239	0.299	0.285	0.269	0.307	0.379	0.448	0.594	0.391	0.688
SIME6	Transit Empl/Pop	0.646	0.472	0.531	0.542	0.531	0.624	0.746	1.10	1.27	0.861	2.015
SOME1	Pass Cap Mi/Pop	540	350	347	399	487	655	622	925	1,200	662	1,770
SOME2	Rev Veh Mi/Pop	8.44	7.12	7.62	7.53	6.98	7.95	9.86	13.4	13.7	10.3	18.7
SOME8	Transitway Length/Area	3.05	3.43	2.85	3.39	2.38	2.40	2.44	3.21	5.09	5.28	5.28
SCME1	Pass/Pop	23.3	12.3	13.7	16.5	17.5	19.5	28.5	48.5	58.9	36.7	103
SCME6	Pass Mi/Area	215	85.2	110	130	186	126	280	589	626	408	1,140
SCME12	Avg Trip Dist/Equiv UA Radius	0.637	0.832	1.02	0.755	1.04	0.362	0.546	0.343	0.289	0.276	0.203

TABLE 12 Comparison of Target Performance from Peer-Group Average Versus Overall U.S. Average

Group	Ratio of Group Average to Overall Average by Variable SOSI3	SCSI4	SCSO1	SIME1	SOME1	SCME1
11	1.255	0.835	0.872	0.607	0.649	0.527
1	1.149	0.733	1.090	0.706	0.642	0.586
2	1.106	0.898	0.990	0.751	0.739	0.705
3	0.936	0.963	0.925	0.744	0.901	0.748
4	0.894	0.972	0.731	0.866	1.213	0.837
5	0.830	0.979	1.290	1.417	1.151	1.220
6	0.723	1.478	1.240	1.801	1.713	2.078
7	0.660	1.397	1.407	2.488	2.225	2.525
8	0.532	1.855	1.451	1.704	1.226	1.574
9	0.404	2.293	1.308	4.217	3.281	4.401

to the magnitude and frequency of their correlations with the 25 performance variables. The top-ranked ME variable was selected, and all remaining ME variables with which it was correlated (correlation coefficient of 0.4 or more) were discarded. The highest-ranked of the remaining variables was next selected, and again correlated variables were discarded. The process was repeated until the 16 variables of Table 13 remained. These variables made up the set of independent variables considered as candidates for inclusion in the models: Each variable is significantly related to transit performance but no pair is highly correlated.

The number of independent variables in each regression equation was somewhat arbitrarily limited to 5. This number seemed to be sufficient with regard to accuracy but not so large that the relationships became completely meaningless and the computations laborious. The best 5 of the 16 candidate variables were selected by the stepwise routine for each model developed.

An example of the regression models is that which relates passengers per capita to five ME variables for the group 5 urbanized areas. The calibrated model is

Passengers per capita = - 70 + 0.0085 x population density + 0.94 x HU renter-occupied - 0.28 x housing growth, 1970-1980 - 0.96 x population completed college + 1.8 x population employed.

TABLE 13 Independent Variables of Regression Models

Symbol	Variable Name
ME33	1900 Pop
ME4[a]	Families > $10,000
ME9	Pop Density
ME14	HU Renter-Occupied
ME21[a]	Pop Completed College
ME22[a]	Pop Employed
ME25[a]	Empl in Sales
ME34	Pop Nonwhite
ME19[a]	Housing Growth 70-80
ME31[a]	Autos/Hsld
ME29	Pop Female
ME30[a]	Workers/Auto
ME10	Land Area
ME37	HU
ME40	UA Pop in Central City
ME39	SMSA Pop in UA

[a]Variables that could not be included for regression models of group 11.

Intuitively, these five independent variables appear to have been appropriately selected and the signs of the coefficients appear reasonable. The coefficient of determination (R^2) was 0.79 and the adjusted coefficient, an indicator of the accuracy of the simulation for the entire population, was 0.67.

Other results of the modeling effort are too extensive to include here, but the complete set is available elsewhere (5). A total of 175 equations were calibrated, one for each combination of the 25 performance variables and 7 peer groups. Four of the original 11 peer groups (groups 7-10) were eliminated from this calibration because of small group size.

The adjusted coefficients of determination were judged to be quite acceptable. Table 14 presents, in summary form, the range in the adjusted R^2. To illustrate the meaning of the tabulated entries, consider those for the SOSI variables. After R^2 ranking, the 75th percentile of the 35 regression

TABLE 14 Range of Adjusted R^2 for Regression Models

Variable Type	R^2 by Percentile of Models		
	75th	50th	25th
SOSI (output and input)	0.72	0.43	0.23
SCSI (consumption and input)	0.74	0.51	0.24
SCSO (consumption and output)	0.65	0.47	0.19
SIME (input and market)	0.81	0.60	0.46
SOME (output and market)	0.76	0.56	0.33
SCME (consumption and market)	0.63	0.46	0.33

equations (5 performance variables and 7 peer groups) had an R^2 of 0.72; the 50th percentile (median), 0.43; and the 25th percentile, 0.23. In forming judgments regarding the acceptability of the adjusted R^2, it must be recalled that performance was being related only to the exogenous, ME variables: Policy variables related to the provision of transit, which also affect performance, were properly excluded.

To illustrate application of the foregoing procedures in establishing performance targets, consider a case in which a target is being established for passengers per capita in a hypothetical city within group 5. Alternative target measures are as follows:

Measure	Amount (passengers/ capita)
U.S. avg	23.3
Peer-group avg	28.5
Peer-group regression	30.6

These numbers suggest that a ridership of at least 30.6 passengers per capita is achievable if appropriate transit decisions are made. It is imperative to note, at the same time, that numerous factors must be incorporated into the development of performance targets, especially the importance or weight given by the community to various transit objectives. Although a ridership of 30.6 passengers per capita may be achievable, the community might appropriately decide that the commitments necessary to reach this level are not justified.

In summary, of the three levels presented, the regression models best eliminate the effects of market dissimilarities and hence best represent attainable performance levels. Analysts uncomfortable with their use should turn to the peer-group averages as a reasonable alternative. Availability of these two alternatives frees the analyst from reliance on nationwide averages and their attendant inaccuracies. However, it should be remembered that in each case the targets are scaled to average rather than to exceptional performance. Prudent transit decisions may well yield performance superior to the target averages.

CONCLUSIONS

Peer comparisons are an invaluable component in transit performance evaluations. A former impediment to such comparisons, the paucity of uniform statistical data, has been largely overcome by implementation of the Section 15 reporting system. Attention can now be turned to refined techniques for forming reasonable peer groups.

Comparable transit systems--that is, those within each peer group--should be homogenous with respect to their potential performance levels. Because it is practically impossible to quantify potential performance directly, attempts to form peer groups on this basis are not currently feasible. However, potential performance is a direct function of many exogenous ME variables. Properly selected, these variables offer great potential for identifying comparable transit sytems.

Data from the U.S. Bureau of the Census form a sufficient set for adequately characterizing ME conditions. Key dimensions can be identified by means of factor analysis, and cluster analysis using these key dimensions is an effective tool for formation of peer groups. The constituency of the various peer groups, however, is sensitive to the basis and method of clustering.

Target performance levels can be established by using either uncontrolled or controlled techniques. In uncontrolled comparisons the target levels represent means for systems throughout the United States without regard to homogeneity. Such targets must be augmented by others representing peer-group means if necessary recognition is to be given to key ME dissimilarities. A second level, controlled comparison using regression-based targets, is recommended to further account for ME constraints on attainable performance levels.

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An Assessment of the Use of Part-Time Operators at the Massachusetts Bay Transportation Authority

JOHN ATTANUCCI, NIGEL H.M. WILSON, and DAVID VOZZOLO

ABSTRACT

The impact of introducing part-time bus operators at the Massachusetts Bay Transportation Authority (MBTA) in Boston is evaluated and the likely impact of various future scenarios regarding the size and utilization of a part-time labor force at MBTA is analyzed. In January 1982 MBTA had no part-time operators; there are now 280, representing almost 19 percent of the surface-operator classification. Introduction of this number of part-time operators to provide the current level of service has resulted in an annual saving of more than $5 million through reduction in unproductive paid hours, spread penalties, and fringe benefits. However, three factors mitigate this financial benefit: higher accident rates, absenteeism, and turnover among the part-time operators compared with that among the full-time operators. Although there are clear opportunities to obtain further financial benefits from the introduction of more part-time operators, the high accident rate to date suggests that caution is appropriate in expanding their role. Strategies to improve productivity by using the existing complement of part-time operators are also discussed.

In January 1982 the Massachusetts Bay Transportation Authority (MBTA) introduced part-time operators (PTOs) on surface bus lines with the assignment of 20 PTOs to the Quincy bus garage. This was the result of enactment by the Massachusetts Legislature in 1980 of a bill that gave MBTA management, among other things, the right to hire and assign part-time employees as they thought appropriate, notwithstanding previous collective bargaining agreements and past labor practices. This right to use part-time employees, when applied to the typical bus-scheduling requirements of MBTA, provided an opportunity to make substantial savings by reductions in 8-hr work day guarantees and long working hours (called spread penalties).

The first 1 1/2 years of MBTA experience with PTOs is assessed and alternative uses of part-time employees in the Transportation Department are examined. An attempt has been made to evaluate all impacts of the use of PTOs, although the effort was limited by the relatively short period of experience to date and, in some instances, a lack of primary data on the particular issue at hand. Where possible, the impacts of the current and projected use of PTOs have been quantified.

BACKGROUND

The introduction of PTOs at MBTA has clearly been accomplished in an accelerated manner over the past year and a half. The initial 20 PTOs who were assigned to the Quincy garage in January 1982 were primarily from the ranks of former full-time operators (FTOs) who had been laid off in April 1981. In each quarterly timetable through March 1983, an increasing number of PTOs were trained and assigned a daily run of up to 6 working hr per day. Today, 280 PTOs are assigned throughout the bus system.

Throughout late 1981 and 1982, MBTA negotiated with the Boston Carmen's Union (Local 589 of the Amalgamated Transit Union) to set conditions for hiring and utilizing PTOs. These discussions did not result in an agreement, and so, while MBTA management pressed ahead with the hiring and assignment of part-time drivers, the Carmen's Union brought the matter to interest arbitration. Although MBTA maintained that the right to hire PTOs was not subject to collective bargaining or arbitration under Chapter 581 of the 1980 Acts and Resolves of Massachusetts, it presented a proposal that called for unrestricted use of PTOs under the following conditions:

1. A maximum of 30 hr of work per week;
2. A guarantee of 2 hr pay for each scheduled work day;
3. A schedule of work on a 7-day basis;
4. A 6-month probationary period after instruction;