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TYPOLOGY FOR BUS TRANSIT

GORDON J. FIELDING, MARY E. BRENNER and KATHERINE FAUST
School of Social Sciences and Institute of Transportation Studies, University of California,
Irvine, CA 92717, U.S.A.

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Abstract—Peer groups of similar transit systems are needed for comparative analysis of transit performance and facilitation of econometric analysis. Cluster analysis was used to construct 12 peer groups based upon size, average speed and peak-to-base ratios of urban, fixed-route motor bus transit systems. Analysis of variance, discriminant analysis and a decision tree typology confirmed differences in operating characteristics among the peer groups. The peer groups were also found to be significantly different on seven variables representing the major dimensions of transit performance. Performance profiles are given for each peer group, and suggestions are made for using the peer groups in performance evaluations.

INTRODUCTION

Research on transit performance has been impeded by the absence of an acceptable classification that clusters similar systems together. Divisions are normally based on size, but there have been no definitive studies that have specified group boundaries and tested the relationship between size and other operational variables, or with performance. In this paper, hierarchical clustering techniques are used to define 12 peer groups for motorbus transit systems (including the motorbus mode in multimodal systems) based upon operating characteristics of size (measured by peak vehicle requirement and vehicle miles provided), peak-to-base ratio and speed. Validity of these groups is tested and relationships with seven dimensions of performance are analyzed. A typology is also constructed based upon a set of decision rules for assigning new transit systems to peer groups or reassigning systems when their operating characteristics change.

Two principal uses of the typology are, first, to assist comparison of performance between similar systems and, second, to aid econometric analysis of supply, demand and cost equations. It is the first use that is examined in this article. However, the econometric analysis of systems within each peer group provides an exciting challenge for additional research. For example, Nelson (1972) and Veatch (1973) estimated supply and demand equations that are widely cited. Nelson estimated his parameters using transit systems in urban areas: 51 firms in 1968 and 44 in 1960, although these systems were quite different in their operating characteristics. Veatch restricted his analysis to 29 firms operating in small- and medium-sized cities in an attempt to control for differences in the operating environment. These studies should be replicated with firms drawn from one or more of the peer groups defined in this research, as it may significantly improve estimation results.

Another research area that could be improved by using the results of peer group analysis are current studies of the effect of subsidies on transit performance. Pucher *et al.* (1983) used a national sample of 77 systems in 1979 and 135 systems in 1980 for which reliable data were available, whereas Cervero (1983) used a selection of 17 California systems. However, both studies included systems with quite different operating characteristics. Would their results have been the same if they had chosen systems that were relatively homogeneous in operating characteristics, but different in the amount and nature of public assistance? Such studies would result in a wider acceptance of their results. Within peer group differences are currently being used to determine the effect of organizational form on transit performance (Perry, 1984).

Comparison between systems

Using peer groups for performance analysis addresses the controversial issue of whether transit systems should be compared. Transit managers tend to reject comparisons, yet most of them use comparative data for internal management assessments. Peer systems are typically selected based upon operating and service area characteristics. Other comparative studies have limited analysis to a specific region or state, and then only include systems that are similar in size, type of service area and demographic characteristics (McCrossen, 1978; Holec *et al.*, 1980; Sinha *et al.*, 1980).

Governmental agencies are increasingly mandating comparative analysis of performance as a condition of financial aid. California, New York and Pennsylvania already require comparative studies. In addition, Section 9(g)(1) of the Surface Transportation Act of 1982 requires the U.S. Secretary of Transportation to initiate triennial audits of transit agencies. Results of this research can be used as a descriptive framework for comparative analysis. The orientation has been to provide a technique that would be useful for internal decision making within each transit agency. Performance results can be compared against those calculated for other agencies with similar operating characteristics and interpreted within the context of each agency's objectives and operating conditions. The proposed taxonomy merely formalizes what managers have been doing intuitively and improves upon other classifications.

Two national studies have used size as the differentiating characteristic for comparative studies. The National Urban Mass Transportation Statistics for fiscal years 1979 and 1980 grouped systems by the total number of revenue vehicles when summarizing performance, but cautioned that "care should be taken in the application and use of the data as presented" (U.S. Department of Transportation, 1981, p. vi). Vaziri and Deacon (1983) also used size as a differentiating characteristic, but their measure was a size "index" derived from population and environmental variables rather than the operating variables proposed by this research. Previous research by Anderson and Fielding (1982) used three performance indicators to cluster transit systems. This method was replicated in this research, but was rejected when it was found that the clusters based upon size, peak-to-base operating ratio and speed yielded superior results. The peer groups based on performance were neither as distinct from each other as those based on operating characteristics, nor did they capture as much of the variability of all seven performance indicators.

Separating transit systems into peer groups that share similar operating characteristics is analagous to separating any set of objects into a number of groups in which members of the same group are more similar to each other than to objects in other groups, and the groups differ from one another. Problems of this sort are common in the social and biological sciences and in applied settings like market research. Tardiff *et al.* (1977) clustered neighborhoods together to designate transit market areas for Sacramento, California. Researchers in the biological sciences often use cluster analysis as an aid to classifying plants and animals into groups based upon their anatomical similarity. The results of such analyses are the assignment of each object to one and only one group or cluster.

Other transportation researchers have used clustering techniques to facilitate research. Bottiny and Goley (1967) grouped urbanized areas for transportation analysis, and Golob *et al.* (1972) used similar procedures to group metropolitan areas for their analysis of arterial transportation requirements. No satisfactory classification has been developed for transit research, but the release of the national transit statistics has made such development possible.

DATA SELECTION

In order to create a valid, broadly applicable taxonomy of bus transit systems, several considerations were used to select an appropriate data base. The source of data should be national in scope, with most public transit agencies represented. The variables from the data base should be comparable across systems: They should be compiled using standard definitions and in similar ways for each agency, and they should be validated for accuracy. The actual variables used to form the taxonomy should be backed by evidence from other studies that they are indeed related to transit performance. And they should also be easily understood and used by the transit community.

Data reported in compliance with Section 15 of the Urban Mass Transportation Act of 1964 (as amended) were used. Other attempts to use published data from the census or industry statistics had failed (Anderson and Fielding, 1982; Vaziri and Deacon, 1983), as had an attempt to procure service area data directly from transit operators (Anderson and Fielding, 1982). Thus, direct measures of service area characteristics such as urban density and proportion of autoless people were unavailable from either secondary sources or from the Section 15 data base. However, studies of environmental factors have linked operating characteristics of transit systems with service area characteristics in terms of their impact upon transit performance (Miller, 1970; Nelson, 1972; Miller and Rea, 1973; Giuliano, 1981). So it was decided that operating characteristics could form a valid base for the construction of peer groups.

Data for fiscal year 1980 (the second year that data were collected) were obtained from the Transportation Systems Center (Cambridge, Massachusetts) in the form of a magnetic tape. A limited amount of the data is published by the U.S. Department of Transportation (1982) in an annual report, but the printed version is not as suitable for research as the data tape. The data were validated and prepared for statistical analysis using methods described elsewhere (Fielding *et al.*, 1983). From a large set of possible variables, a smaller set was chosen that could reflect the service area characteristics that constrain the decisions made by transit operators. From this set, three aspects of transit systems were used to characterize transit operations—system size, average service speed and the peak-to-base ratio. Size was judged to be the most influential characteristic and was measured in terms of the number of peak vehicles and the total revenue vehicle miles. Size reflects a number of constraints on transit management. Organized labor units are more influential in larger agencies. Efficient route scheduling is more difficult, and managing large numbers of employees is more complex (Sale and Green, 1979). These factors cause diseconomies of scale, reducing the advantages gained through service integration. Very small systems also suffer from constraints that restrict efficient use of resources. A U-shaped cost curve results when cost per vehicle hour from the Section 15 data is arrayed against system size. Therefore, the two size variables used in the typology reflect both managerial complexity in very large systems and resource underutilization in small agencies. Using two measures of size does emphasize this characteristic. Number of peak vehicles is the preferred measure, but total revenue miles helps differentiate agencies with extensive service areas that are more costly to manage (Giuliano, 1981).

Speed is related to several characteristics of the service area. High urban density and traffic congestion on major roads reduce a transit system's average speed. Speed also reflects the kind of service offered by a transit system. Express routes oriented toward commuters are notably faster than local routes. Speed was calculated by dividing the annual total of revenue miles by the annual total of revenue vehicle hours; it is a systemwide measure and does not reflect direct information about routes. By using revenue miles and hours rather than total miles and hours, deadhead miles and nonrevenue service time are eliminated, but layover time is included.

The peak-to-base ratio indicates whether a transit system is oriented toward work-bound commuters (high peak-to-base ratio) or transit-dependent populations who need service throughout the day. To some degree, the peak-to-base ratio will also reflect environmental factors that influence transit utilization such as insufficient CBD parking and highway congestion. The peak-to-base ratio also determines the labor needs of a transit system during different times of the day. A high peak-to-base ratio leads to inefficient use of labor, thus increasing costs significantly, since labor expenses form the major part of operating expenses (Oram, 1979). The peak-to-base ratio was calculated by the ratio of vehicles in service in the largest peak over the midday base vehicle requirement.

FORMATION OF PEER GROUPS

Forming transit systems into groups that are similar in operating characteristics requires both a way of assessing the degree of similarity among systems across a profile of operating variables and an objective means for grouping systems together based on similarity. Many analytic techniques exist for assessing patterns of similarities among objects. Factor analysis, multidimensional scaling and hierarchical clustering are commonly used techniques for this type of analysis. In the present study, hierarchical clustering was chosen as the technique for forming peer groups of transit agencies because, in contrast to multidimensional scaling and factor analysis, cluster analysis partitions the set of objects into mutually exclusive and exhaustive groups. In the current analysis, centroid method hierarchical clustering, as implemented in the BMDP package of statistical analysis programs, was used (Dixon, 1981). This method forms clusters, and links clusters together, on the basis of the minimum distance between cluster centroids. Euclidean distance is computed between the locations (centroids) of clusters (or individual unclustered cases) defined across the original variables. The Euclidean distance between two single cases (i and j) defined across the variables (k) is

$$D_{ik} = \left[\sum_{k} (X_{ik} - X_{jk})^2\right]^{1/2},$$

where X_{ik} is the value for case i on variable k and X_{jk} is the value for case j on variable k.

To accommodate the fact that the four operating variables—speed, peak-to-base ratio, number of peak vehicles and total vehicle miles—are measured on quite different scales, all variables were transformed to Z scores prior to analysis. The mean of a variable was subtracted from each value on the variable, and then the value was divided by the standard deviation of the variable. The resulting standardized variables all have means of 0 and SDs of 1.

Since centroid method clustering is a hierarchical technique, the result of the analysis is a series of increasingly inclusive partitions of the cases. Choice of the number of clusters in the data is made in light of the structure of similarities in the data, the substantive research problem and the usefulness of the resulting clusters.

Results from cluster analysis

The criteria used to choose the final cluster solution included the following. (1) The separate clusters should capture the important differences between types of transit systems. This suggests there should be a relatively small number of clusters because small distinctions on any of the clustering variables are not important for performance distinctions. (2) The number of systems in each group should be sufficient for comparative analysis within the group but not so numerous that the task of comparison is excessive within any one group. (3) The clusters should be formed at approximately the same level in the cluster hierarchy so that they reflect about the same level of differentiation from each other and the same degree of similarity within each cluster.

The final solution chosen is of necessity a compromise between these three criteria. Twelve peer groups were formed from the 274 transit agencies that entered the analysis. Thirty cases were dropped because of missing data. Another two cases did not become members of any cluster, and these were also excluded from further analysis. The two very small peer groups (1, 12) represent distinct types of transit systems, and within the cluster framework determined by the chosen computer algorithm, they were not similar enough to any other clusters to be combined with them. The largest peer groups (3, 6, 7) were each relatively homogeneous despite their sizes. Cluster analysis gave an option for dividing them into smaller groups, but that would have resulted in a typology with 21 different clusters. This was judged to result in meaningless distinctions between systems that were actually quite similar. Thus, the 12-group typology seemed to balance the three criteria, based upon practical considerations and internal evidence from the cluster analysis. Assignment of the 274 agencies to peer groups is presented elsewhere (Fielding *et al.*, 1984).

Validation of the peer group framework requires demonstrating that the groups both capture important differences in the operating characteristics of transit agencies and that these differences in operations are related to important and independent factors, such as performance. The remainder of this paper concentrates on this demonstration. First, it is shown that the peer groups do in fact reflect differences in operating characteristics of transit systems, and, second, it is shown that the peer groups that differ in operating characteristics also differ on seven dimensions of performance.

OPERATING CHARACTERISTICS OF PEER GROUPS

The 12 peer groups are distinct from each other in the profile of operating characteristics of the systems in each group. While there is some overlap across groups on any given operating characteristic, when all four characteristics are viewed simultaneously, the groups capture distinct combinations of values. This can be described in several ways. First, there is a statistical summary of the characteristics of each of the peer groups. Next, a verbal description of the systems in each peer group is presented, followed by a summary of the association between peer groups and operating characteristics. Finally, a decision tree typology is presented that allows for the classification of systems into the 12 peer groups. The typology is an intellectual device for clarifying the similarities as well as differences that exist in U.S. transit. Its adequacy will be determined by attributes of operation and its future use.

Description of peer groups

One of the most straightforward demonstrations that the peer groups differ in their operating characteristics is to examine the average characteristics of the transit agencies in each peer group. Statistics describing the total vehicle miles, number of peak vehicles, speed and peak-to-base ratios of the peer groups are presented in Table 1. Inspection of these values indicates that although there is variation within each peer group, the groups do differ from each other in their operating characteristics.

Table 1. Descriptive statistics on the operating characteristics of peer groups

Peer Group (n)		Peak Vehicles	Vehicle Miles (10,000)	Speed	Peak-to-Base Ratio
1	mean	13	193.8	27.88	1.02
	std. dev.	17	269.7	2.99	0.03
(2)	minimum	1	3.0	25.77	1.00
	maximum	25	384.5	30.00	1.04
2	mean	14	86.7	19.35	1.24
	std. dev.	12	98.8	1.42	0.39
(16)	minimum	1	6.6	17.21	1.00
	maximum	46	405.6	21.34	2.30
3	mean	20	101.6	14.51	1.10
	std. dev.	18	95.4	0.65	0.16
(44)	minimum	2	4.4	13.54	0.80
	maximum	74	435.1	15.65	1.50
4	mean	22	108.0	16.23	1.10
	std. dev.	15	89.8	0.38	0.05
(7)	minimum	10	39.2	15.88	1.00
	maximum	47	257.6	16.76	1.15
5	mean	26	83.7	8.91	1.32
	std. dev.	30	93.9	0.91	0.39
(15)	minimum	1	1.4	7.50	0.57
	maximum	107	318.5	10.86	2.10
6	mean	28	126.7	12.19	1.11
	std. dev.	36	168.0	0.63	0.12
(45)	minimum	2	7.3	10.79	1.00
	maximum	192	850.8	13.49	1.39
7	mean	57	203.7	12.80	1.83
	std. dev.	50	180.1	1.50	0.27
(78)	minimum	4	14.5	9.63	1.37
	maximum	223	817.7	16.26	2.47
8	mean	138	453.7	12.69	2.88
	std. dev.	104	366.0	2.03	0.32
(33)	minimum	3	4.7	8.33	2.31
	maximum	387	1349.4	18.14	3.61
9	mean	230	1259.3	15.72	1.40
	std. dev.	72	316.2	1.03	0.28
(8)	minimum	96	769.0	14.56	1.11
	maximum	329	1635.4	17.32	1.86
10	mean	393	1723.0	11.10	1.76
	std. dev.	94	451.1	1.78	0.33
(8)	minimum	260	1058.6	8.18	1.10
	maximum	506	2385.3	13.65	2.07
11	mean	889	3465.7	13.53	2.48
	std. dev.	251	1055.0	2.12	0.42
(13)	minimum	666	2405.8	10.17	1.66
	maximum	1573	5688.0	18.40	3.14
12	mean	2477	9850.2	10.58	1.74
	std. dev.	789	1331.6	3.62	0.22
(3)	minimum	1914	3843.4	6.45	1.60
	maximum	3378	10868.7	13.23	2.00
Total	mean	125	519.9	13.40	1.68
	std. dev.	316	1270.3	2.89	0.94
	minimum	1	1.4	4.81	0.57
	maximum	3378	10868.7	30.00	13.00
	number	297	279	277	297

Peer groups are numbered from 1 to 12 in order of increasing size, measured by the average number of peak vehicles of the systems in each peer group. Verbal descriptions based on the demographic characteristics of the systems and their operating characteristics are as follows.

Peer Group 1. The companies in Peer Group 1 stand out because of their extremely high average speed. They are the smallest in size and the lowest in peak-to-base ratios relative to other peer groups. Both of the agencies in this group are private operators. Although membership in this group is low, based on fiscal year 1980 data, it is anticipated that many more of this type of agency will report in the future, because of changes in federal regulations apportioning operating assistance.

Peer Group 2. Peer Group 2 consists of transit providers located primarily in small urban or suburban areas across the United States with populations under 500,000. They are small (1–46 peak vehicles) and fast (17–22 mph), with average peak-to-base ratios.

Peer Group 3. Although Peer Group 3 is a cross-national group, southwestern systems are disproportionately represented. While a few systems are in the suburban fringes of major urban areas, most are in small cities or towns. These systems are small (2–74 peak vehicles) with low peak-to-base ratios (1.0–1.15) and above-average speeds.

Peer Group 4. Peer Group 4 draws from all parts of the country despite its small size. These systems serve small cities with suburban characteristics. Systems in Peer Group 4 have a high average speed (15.9–16.8 mi per revenue vehicle hour) and tend to be small (fewer than 50 peak vehicles) with low peak-to-base ratios. Their speed is consistent with their suburban locations and distinguishes this group from Group 3.

Peer Group 5. Peer Group 5 is unusual in that nearly half of its members are private bus companies in the urban New York City area, while most of the rest are small midwestern city agencies. The systems in this group are distinguished by their very low speeds. They are slightly below average in size and average in peak-to-base ratios.

Peer Group 6. Peer Group 6 draws systems from most regions of the United States but with a particular emphasis on the midwestern and south-central regions. While a few medium-sized cities are included in this group, many of the systems serve small towns or somewhat rural areas; three-quarters of these systems are in areas with populations under 250,000. Systems in this peer group range in size, but are generally below average in number of peak vehicles. They have low peak-to-base ratios.

Peer Group 7. Members of the largest peer group, Peer Group 7, are found in all parts of the United States.

They serve primarily small cities and large towns with populations of 77,000–500,000, although a number are in towns in metropolitan New York. Systems in this peer group are average in size and speed, but above average in peak-to-base ratios.

Peer Group 8. Peer Group 8 has primarily midwestern and eastern small- to medium-sized cities, although a few of its members are from the outer suburban sections of New York and Chicago. It differs from other peer groups in its high average peak-to-base ratio (all above 2.3). Systems in this peer group range widely in speed and size, though there are no systems with over 400 peak vehicles in this group.

Peer Group 9. Systems in Peer Group 9 are all from the southwestern areas of the United States. They predominate in suburban, low-density areas with populations between 0.5 and 1.5 million. Systems in this peer group are above average in size and speed and about average in their peak-to-base ratios.

Peer Group 10. Transit systems in Peer Group 10 are all public agencies in large urban areas (1–3 million population), in most regions of the United States except the northeast. These systems have an above-average number of peak vehicles (260–506) and usually below-average speeds, with a wide range of peak-to-base ratios. Peer Group 10 is similar to Peer Group 11, though the systems are smaller on average and have slightly lower peak-to-base ratio.

Peer Group 11. Peer Group 11 includes public transit agencies in major urban areas (1.4–16 million population) in all regions of the United States. They have a high number of peak vehicles (666–1573) and are second in size only to Peer Group 12. These systems are above average in peak-to-base ratio and are average in speed.

Peer Group 12. The transit agencies in Peer Group 12 are the major public transit providers in the three largest urban areas of the United States. All three have over 1900 peak vehicles. They are one of the two slowest groups of systems, and they have slightly above-average peak-to-base ratios.

Table 2. Relationship between operating characteristics and peer groups

Operating Characteristic	Eta	Eta^2
Total Vehicle Miles	.968	.938
Number of Peak Vehicles	.952	.907
Speed	.874	.764
Peak-to-Base Ratio	.915	.837

Relationship between operating characteristics and peer groups

The description of individual peer groups illustrates the relationship between peer groups and operating characteristics. However, summary measures of the strength of the overall relationships between peer group membership and each of the operating characteristics are useful. The eta coefficient provides a summary of the degree of association between a number of groups (such as the peer groups) and another variable (for example, an operating measure). The eta coefficient squared is interpreted as the proportion of variance in an operating characteristic that can be accounted for by peer group membership. Table 2 presents four eta coefficients, each describing the relationship between one of the four operating characteristics and the 12 peer groups. These results show that the peer groups capture a large portion of the variability among the agencies on all four of the operating variables.

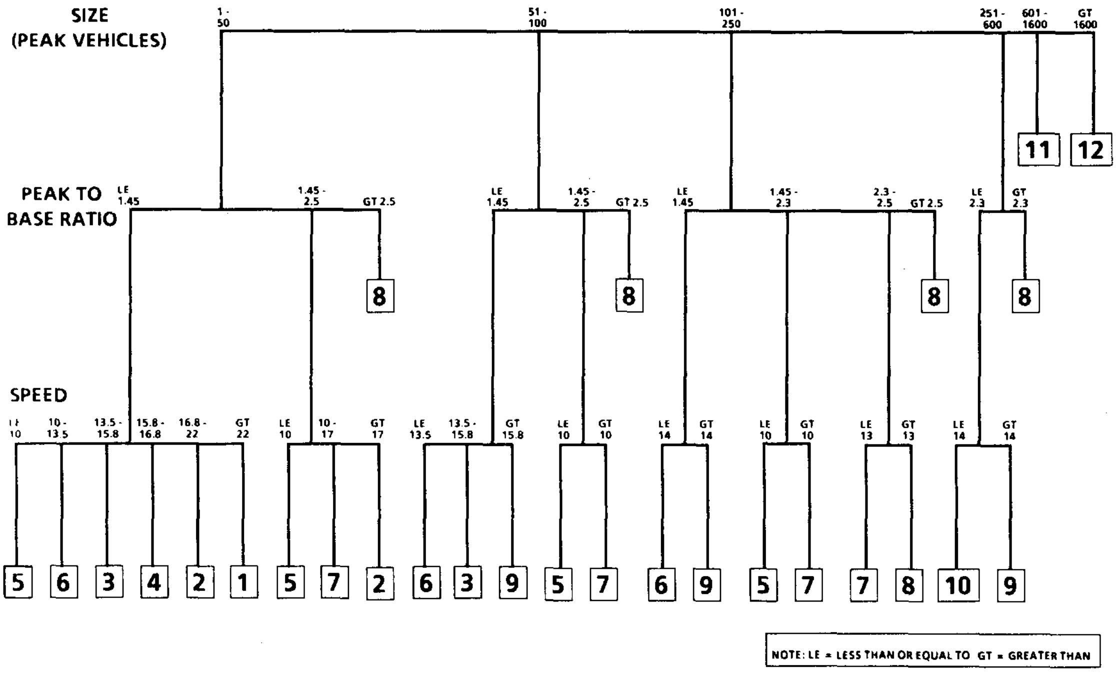


Fig. 1. Peer group typology.

Typology

Another way to demonstrate the differences among the peer groups on the operating characteristics is to construct a set of decision rules for assigning agencies to peer groups based on their operating characteristics. This has great practical significance since although cluster analysis constructs a set of groups from data on characteristics of the agencies, it does not handle the problem of the assignment of new cases or the reassignment of an agency when operating characteristics are changed by management.

Figure 1 presents a decision tree that makes a prediction of peer group membership for each transit system based on its number of peak vehicles, peak-to-base ratio and speed. Since total vehicle miles and number of peak vehicles are highly correlated for the sample of cases, only the number of peak vehicles was necessary in the decision tree to distinguish among the peer groups.

Starting at the top of the decision tree, and following the path corresponding to the operating characteristics of a system, a transit agency can be assigned to its appropriate peer group. A test of this typology correctly predicted peer group membership of 97% of the cases. This typology could also be used to predict the peer group membership for agencies that did not report data in fiscal year 1980 or whose data were incomplete.

PEER GROUPS AND PERFORMANCE MEASURES

Peer groups were constructed so that transit systems could be compared with other transit systems with similar operating characteristics. Each of the three variables used—size, peak-to-base ratio and speed—reflects characteristics of the service area, such as population density and daily variations in demand. The usefulness of the peer group taxonomy is a result of its ability to capture different performance patterns that are structured by the operating characteristics. To validate the peer group taxonomy, a number of analyses were done to show that these groups do capture major performance differences.

Performance indicators were selected on the basis of research concurrent to the present study (Fielding *et al.*, 1985). A large group of performance indicators was reduced to seven independent dimensions of performance through a series of principal component factor analyses with varimax orthogonal rotations (Nie *et al.*, 1975). Each dimension of performance identified is represented by a "marker" variable that best represents the dimension in terms of being highly correlated to it, reliably measured and easy to comprehend.

Table 3 lists the seven marker variables and the concepts they measure. The first three performance indicators represent the three major performance dimensions—cost efficiency, service effectiveness and cost effectiveness. Together they account for 55% of the variance in performance, while the last four factors account for 28.5% of the variance.

Analysis of variance

The seven marker variables were used to determine if the peer groups were significantly different in performance. A one-way analysis of variance was done for each performance indicator using the SPSS program Breakdown (Nie *et al.*, 1975). Table 4 shows the *F* score, eta coefficients, degrees of freedom and level of significance for each performance indicator. For each performance indicator, there are statistically significant differences between groups. The measures of revenue generation and maintenance efficiency are slightly less differentiated between peer groups than the others as shown by their lower *F* scores and slightly lower eta coefficients. Vehicle efficiency shows the greatest differentiation between groups as shown by its larger *F* score (24.30) and large eta (0.71).

However, this analysis does not indicate which peer groups are most different or whether the differences are important. It is possible that one or two peer groups are radically different from the others, and the others are indistinguishable from each other. Therefore, profiles based upon the data were used to show the structure of peer group differences.

Table 3. "Marker" variables best representing the underlying performance concepts

FACTOR	PERFORMANCE CONCEPT	BEST "MARKER" FOR PERFORMANCE INDICATOR CONCEPT
1	Output per $ Cost (Cost Efficiency)	(RVH/OEXP) Rev. Vehicle Hour per Operating Expense
2	Utilization of Service (Service Effectiveness)	(TPAS/RVH) Unlinked Passenger Trips per Rev. Vehicle Hour
3	Rev. Generation per Expense (Cost Effectiveness)	(OREV/OEXP) Operating Revenue per Operating Expense
4	Labor Efficiency	(TVH/EMP) Total Vehicle Hours per Total Employees
5	Vehicle Efficiency	(TVM/PVEH) Total Vehicle Miles per Peak Vehicle
6	Maintenance Efficiency	(TVM/MNT) Total Vehicle Miles per Maintenance Employee
7	Safety	(TVM/ACC) Total Vehicle Miles per Accident

Table 4. Relationship between performance variables and peer groups

Performance Measure	Degrees of Freedom	F Score	Significance Level	Eta
Cost Efficiency (RVH/OEXP)	11/255	9.83	.0000	.55
Service Utilization (TPAS/RVH)	11/218	6.31	.0000	.49
Revenue Generation (OREV/OEXP)	11/254	3.46	.0002	.36
Labor Efficiency (TVH/EMP)	11/254	5.53	.0000	.44
Vehicle Efficiency (TVM/PVEH)	11/257	24.30	.0000	.71
Maintenance Efficiency (TVM/MNT)	11/240	4.44	.0000	.46
Safety (TVM/ACC)	11/241	5.85	.0000	.46

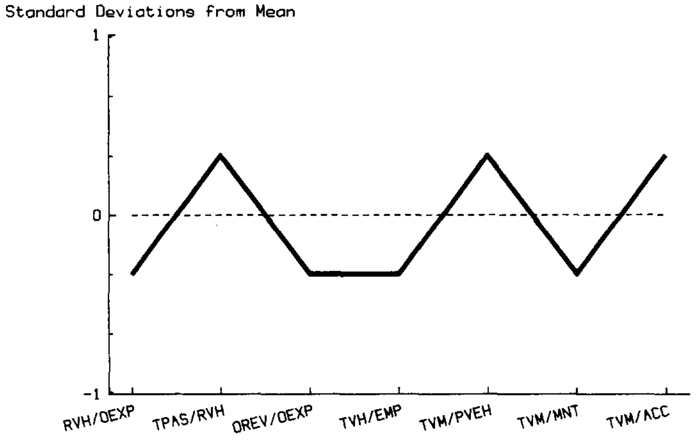
Profile analysis

A performance profile for each peer group was constructed by graphing the mean level of performance for the peer group on each performance indicator against the benchmark value of the national mean. The actual values graphed were the standard scores (*Z* scores) of the mean performance level for each peer group. Through comparison of these profiles, the relative strengths and weaknesses of each group were highlighted. Because of the way in which each concept was measured, a high score indicated relatively better performance.

It was found that no two peer groups shared the exact same pattern of performance. Figures 2 and 3 show the performance profiles of Peer Groups 4 and 12 as examples of the kinds of patterns identified through the profile analysis. Some peer groups, such as Peer Group 12, tended to be well above average on some measures and well below on others. Peer Group 12 had very expensive service as shown on the first performance indicator (RVH/OEXP), but quite high performance on the next two measures of service utilization (TPAS/RVH) and revenue generation (OREV/OEXP). Other peer groups, such as Peer Group 4, hovered just above or below the national mean on all measures. Peer Group 4 was slightly above average on service utilization (TPAS/RVH), vehicle efficiency (TVM/PVEH) and safety (TVM/ACC) and below on the other measures.

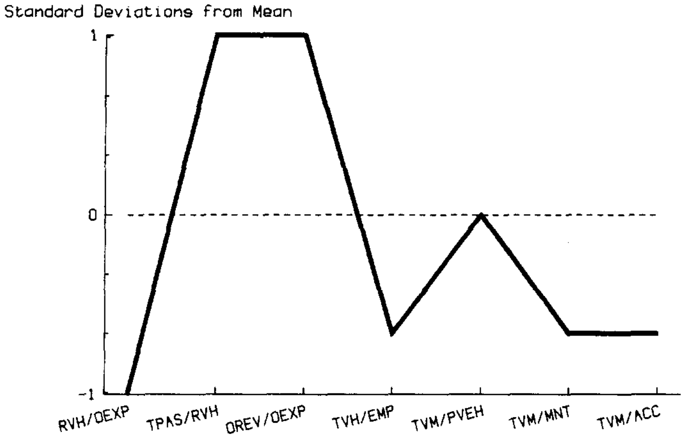
There were some structural similarities on the performance profiles that reflected the underlying operating characteristics. Peer groups of small systems (2, 3, 4) looked similar, and peer groups of large systems (10, 11, 12) looked similar. The large and small system peer group profiles were totally distinctive from each other. However, considering each performance indicator in turn revealed important differences between peer groups with similar profiles. For instance, Peer Groups 11 and 12 were both well above the national average of 32.8 unlinked passenger trips per revenue vehicle hour, giving them a similar profile on this measure. However, the difference between their mean values of 52.9 and 74.7 passengers/h, respectively, is not unimportant. Comparison of peer group profiles revealed that although each peer group is not distinctly different from every other peer group on all seven performance indicators taken individually, each peer group does have a unique profile across the seven performance measures.

Although comparison with the national mean has been used as a descriptive device in this section of the paper,



Zero on vertical axis indicates national mean.
N = 7

Fig. 2. Performance profile for Peer Group 4.



Zero on vertical axis indicates national mean.
N = 3

Fig. 3. Performance profile for Peer Group 12.

this does not imply that the national mean should be used as the general standard of performance. Each peer group should have its own set of norms particular to that group. The statistics in Table 5 provide one such set of norms. The systems that perform above the mean on a performance indicator are doing relatively well. The systems that perform more than one standard deviation above the mean are in the top 15% (approximately) of their peer group. All such standards must be used with caution, taking into account a system's own goals and objectives. Further, performance indicators must be used with particular care; each indicator provides an index for a performance dimension. Unique operating circumstance for one or more agencies can influence group achievement.

Comparison of performance data by peer groups

The presence of significantly different or unique patterns of performance across measures does not ensure that important differences are being captured. The previous two analyses of performance compared the average performance of peer groups. The following analysis took into account the range of values contained in any peer group to see if within-group comparisons would be uniformly valid.

The peer groups were compared by using bar graphs to mark the range of each group (Fig. 4). The mean of each peer group was indicated by an *X* on each bar. Similar graphs were constructed to see not only if the means varied by peer group, but also whether the range of performance was distinguishable between peer groups. In general, it was found that each peer group had its own range for each performance indicator. Differences between peer groups were gradual—no one peer group accounted for most of the variation in the total sample. The performance indicators with the highest etas in Table 4 (cost efficiency and vehicle efficiency) were indeed the most powerful for discriminating between peer groups. The lowest and highest performing peer groups did not overlap at all. However, the more moderately performing groups captured important differences at all points on the continuum of performance.

While most peer groups were found to be distinctive on each performance measure, there were a few specific instances where there was not adequate discriminating power. Revenue generation measures, for example, must be used with some caution. In the middle size range represented by Peer Groups 5, 6, 7 and 8, there were no important differences between peer groups on revenue

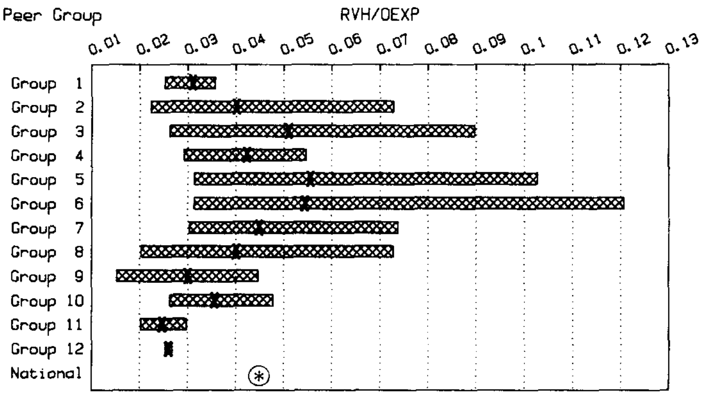


Fig. 4. Range of cost efficiency by peer group. Revenue vehicle hours per dollar of operating expense is the inverse of the commonly reported cost per vehicle hour. The *X* is the peer group mean and * the national mean.

Table 5. Descriptive statistics on the performance of peer groups

Peer Group (n)		RVH/OEXP	TPAS/OEXP	OREV/OEXP	TVH/EMP	TVM/PVEH	TVM/MNT	TVM/ACC
1 (2)	mean	.031	11.5	.64	.073	3.0	15.3	2.9
	s.d.	.008	---	.32	.020	--	.1	.2
	minimum	.025	11.5	.42	.060	3.0	15.2	2.7
	maximum	.036	11.5	.87	.087	3.0	15.4	3.0
2 (16)	mean	.040	32.1	.34	.095	5.8	11.9	4.1
	s.d.	.014	25.6	.21	.024	1.4	5.0	2.2
	minimum	.022	9.7	.11	.047	3.5	5.8	1.5
	maximum	.073	84.5	.81	.133	8.8	25.7	7.4
3 (44)	mean	.051	30.1	.26	.118	5.3	9.7	2.6
	s.d.	.013	16.0	.09	.025	.9	3.9	1.5
	minimum	.026	9.2	.11	.028	3.7	1.8	.8
	maximum	.090	81.3	.47	.170	8.2	23.5	7.1
4 (7)	mean	.042	37.9	.30	.112	4.5	9.6	3.0
	s.d.	.010	18.2	.14	.014	.8	3.9	2.0
	minimum	.029	21.0	.09	.100	3.6	5.3	.9
	maximum	.055	71.5	.48	.140	5.6	14.0	6.9
5 (15)	mean	.056	24.6	.42	.145	3.0	6.1	1.7
	s.d.	.019	11.2	.29	.049	.7	2.8	.9
	minimum	.031	6.3	.08	.053	1.4	.6	.4
	maximum	.103	49.9	1.10	.229	4.4	12.3	3.7
6 (45)	mean	.055	28.8	.31	.124	4.5	9.2	2.3
	s.d.	.017	13.2	.14	.031	.9	3.7	1.6
	minimum	.031	5.4	.09	.031	2.2	3.0	.6
	maximum	.121	73.5	.76	.220	7.6	21.4	7.3
7 (78)	mean	.045	31.8	.36	.117	3.6	9.2	1.9
	s.d.	.010	10.6	.17	.017	.7	3.4	1.2
	minimum	.030	5.0	.11	.055	2.3	4.6	.7
	maximum	.074	58.0	1.11	.166	6.1	24.3	8.0
8 (33)	mean	.040	32.1	.34	.095	3.0	7.5	1.4
	s.d.	.012	14.2	.19	.023	.6	2.7	.7
	minimum	.020	7.1	.12	.045	1.6	2.5	.5
	maximum	.073	54.8	.93	.170	4.3	15.6	3.8
9 (8)	mean	.030	40.1	.24	.099	5.7	7.5	1.5
	s.d.	.009	15.4	.13	.023	1.1	2.2	.5
	minimum	.015	19.0	.07	.074	4.4	3.7	.6
	maximum	.045	72.2	.42	.14	8.0	11.0	2.2
10 (8)	mean	.035	46.9	.34	.106	4.4	6.2	1.5
	s.d.	.008	25.2	.11	.014	.5	2.8	.9
	minimum	.026	26.1	.19	.080	3.7	3.7	.5
	maximum	.048	89.8	.49	.128	5.1	11.5	3.3
11 (13)	mean	.025	52.9	.348	.095	3.9	6.7	1.23
	s.d.	.003	10.1	.120	.012	.6	2.0	.72
	minimum	.020	36.0	.178	.066	3.1	2.6	.50
	maximum	.030	69.0	.587	.116	5.0	11.0	3.00
12 (3)	mean	.026	74.7	.581	.098	4.2	5.4	1.00
	s.d.	.001	14.1	.210	.014	1.1	2.1	.34
	minimum	.025	58.5	.386	.085	3.2	3.2	.74
	maximum	.027	83.4	.807	.113	5.4	7.4	1.40
Total	mean	.045	32.8	.337	.113	4.2	9.90	2.40
	s.d.	.015	16.5	.209	.030	1.5	8.40	2.30
	minimum	.015	5.4	.070	.028	1.1	.68	.48
	maximum	.121	89.8	1.100	.229	8.0	25.70	8.00

Note: The figures for the total are for the entire set of transit systems reporting Section 15 data for FY 1980. Thus some of the transit systems included in the total are not in a peer group because they were missing data and could not be assigned to a peer group.

generation. Each of these peer groups covered close to the entire range of values, ranging between 10 and 90% of operating expense recovery from the fare box. Further, multiple correlation analyses revealed that differences in revenue generation were not clearly related to any of the four operating characteristics used to form the peer groups. This results from decisions on subsidy levels originating without regard to the operating characteristics of transit agencies.

The measure of maintenance efficiency (total vehicle miles per maintenance employee) was found to have less discriminating power for very small systems such as those in Peer Groups 2 and 3. A single measure of maintenance efficiency is unable to adequately compare systems that use different combinations of in-house and contract maintenance services. The small systems were most likely to be misrepresented by the maintenance efficiency measure. However, with some use of judgment, maintenance differences can be evaluated with these peer groups.

SUMMARY

It was found that fixed-route urban transit systems could be assigned to 12 distinctive peer groups based upon their operating characteristics. While the size of transit systems was most strongly related to the peer group structure, speed and peak-to-base ratio made important contributions to differentiating among the peer groups. A decision tree typology was constructed to aid in the assignment of new or changed transit systems to the appropriate peer group.

The 12 peer groups were also found to be significantly different on seven measures representing independent dimensions of transit performance. Performance profiles for each peer group revealed that each has a distinctive pattern: differences exist between peer groups in both their average performance and range of values. These 12 peer groups provide a descriptive typology of U.S. transit. They summarize important characteristics of operations that are related to the major dimensions of transit performance. They also suggest ways to segment transit agencies so as to improve the estimation of research results. For policymaking, the peer groups provide guidance for a meaningful disaggregation of agencies rather than a uniform treatment. This last attribute will be especially helpful for metropolitan, state and federal agencies that are responsible for implementing legislatively mandated audits of transit performance.

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