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TRANSPORTATION RESEARCH FORUM

The Michigan Transit Performance Evaluation Process: Application to a U.S. Sample

*by Shirley Coffer Anderson**

I. INTRODUCTION

THIS PAPER PRESENTS the results of an application of phase one of the State of Michigan's "Transit Performance Evaluation Program" to historical data, for 57 U.S. fixed-route bus transit systems. The comparative analysis shows the sensitivity of the Michigan process to the variables chosen as performance indicators as well as the results for sets of 27 and 7 performance indicators, and for a performance determination using factor analysis.

The object of any performance evaluation process, such as the Michigan program, is to pick out, from a peer group, systems having extremely high or extremely low performance. Throughout the transit industry, performance indicators are being applied and their use is expanding rapidly.

Two important problems associated with performance evaluation are considered. The first is the methodological problem of devising a complete and workable model of performance by categorizing performance objectives into concepts and utilizing uniform quantifiable measures of each concept. The Michigan program as described (6, 8) is not based on a clearly defined performance model; Thus the conceptual weights are unknown.

A second, technical problem associated with use of performance indicators is the cost of data collection and analysis—much data is required and the output of many indicators is confusing and time consuming to analyze. This paper explores alternate approaches to solving the data problem:

(1) Use many performance indicators and a simple method of analyzing indicator averages and totals. This is the Michigan process, as currently applied.
(2) Use all the performance measures but reduce the amount of output to be analyzed by factor analysis.
(3) Use a conceptual model to select a few performance indicators which represent all the important performance concepts. This method reduces both data collection and analysis requirements.

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In this paper, the question of whether the ease of handling reduced sets of performance indicators is worth a deterioration in preciseness of performance comparisons is analyzed by comparing system rankings to those of a set of 27 indicators, and assessing the relative accuracy of selection of best and worst performing systems.

II. THE MICHIGAN PHASE ONE PROCESS AND PERFORMANCE FRAMEWORK FOR REDUCING THE NUMBER OF INDICATORS

Phase one of the Michigan evaluation process has been described by Holec, et al., in a 1979 paper(6) and by Peat, Marwick and Mitchell(8) as the review of selected quantitative indicators of transit efficiency and effectiveness for each transit system and calculation of outlier values (from the peer group mean) for these performance indicators. The Michigan program uses three decision rules to determine which of the performance indicator values are outliers, using both a cross-section and a time series trend peer group analysis. The systems with the largest number of outliers are considered candidates for phase two—an intensive on-site interview and follow-up investigation of the extremely high or extremely low performance indicated.

The Michigan program has identified 47 potentially useful measures of performance. Using three decision rules, a 47-performance-indicator set gives rise to 141 measures of performance per system. However, it is possible to reduce the number of indicators while covering all important aspects of performance. To do this, one must refer to a conceptual model of performance such as that developed by Fielding, Glauthier, and Lave(4). Fielding, Glauthier, and Lave (F, G, & L) postulate that performance can be usefully categorized under the following eight concepts:

1. labor productivity,
2. vehicle productivity,
3. produced output per dollar of cost,
4. social effectiveness,
5. revenue generation,
6. consumed output per dollar of cost,
7. utilization of service,
8. energy cost per produced output.

The performance measures available for this study are listed by F, G, & L category in Table 1, and defined in Table 2. Of the eight concepts, data for 1969–1973 were available for the first seven.

The primary sources of the operating statistics used in this study were the American Public Transit Association's annual publications: "Operating Statistics" (1) and "Fleet Inventories" (2) for 1969-73. Two years of data were used for each included system: a base year and the year which was two years earlier than the base year. The base year for 39 of the systems was 1972; for 10 systems it was 1971 and for 8 systems the base year was 1973. The 57 systems were all fixed-route bus transit systems located in urban areas which ranged in population from 8,723,000 to 23,000. APTA operating expense, and revenue data were supplemented with data from transit development reports and a telephone survey. All of the financial variables were expressed in 1976 constant dollars. A formula slightly modified from Nelson(7) was used to calculate consistent annual capital cost values for each transit system. The method, based on the bus fleet, is described in detail in Anderson (3, p. 238–241).

III. CREATION OF THREE SETS OF PERFORMANCE INDICATORS

A reference set of indicators (T27) and two reduced sets were constructed from the thirty-three potential performance measures listed in Table 1. The criteria used for choosing each set of performance measures were the following:

(1) availability of consistent and comparable data,
(2) comprehensive uniform coverage of all significant aspects of performance, and
(3) uniqueness of performance measures.

A. The Set of 27 Performance Measures (T27)

In no case where a pair of variables were correlated at the .9 level or above, were both variables used. High correlation between pairs of performance indicators was responsible for the elimination of "total vehicle miles per wage

TABLE 1

PERFORMANCE INDICATORS BY PERFORMANCE CATEGORY

	Performance Concept		Performance Indicators Used		
I.	Labor Productivity	**1.	TVH/EMP	2.	TVM/EMP
II.	Vehicle Productivity	**3.	TVH/BUS	4.	TVM/BUS
III.	Produced Output per Dollar of Cost	**5.	TVH/OP EXP	6.	TVH/WAGES
		7.	TVM/OP EXP	8.	S Miles/OP EXP
		*9.	TVM/WAGES		
IV.	Social Effectiveness	**10.	TVH/SA Pop	11.	TVH/ELD SA Pop
		12.	FREQ	13.	S Miles/SA Pop
		*14.	% Pop Served	*15.	SPEED
		*16.	TVM/SA Pop		
V.	Revenue Generation	17.	PAS REV/BUS	**18.	PAS REV/TVH
		19.	PAS REV/EMP	20.	OP REV/OP EXP
		*21.	PAS REV/TVM	22.	PAS REV/RPAS
VI.	Consumed Output per Dollar of Cost	23.	TPAS/OP EXP	**24.	RPAS/OP EXP
		25.	TPAS/EMP	26.	TPAS/WAGES
		27.	TPAS/BUS	28.	TPAS/S Mile
		29.	TPAS/TVH	30.	RPAS/TVM
VII.	Utilization of Service	31.	TPAS/Autoless Pop	**32.	TPAS/SA Pop
		*33.	TPAS/ELD Pop		

*Excluded from the set of 27 performance measures.
**Included in the set of 7 performance measures.

TABLE 2

DEFINITIONS OF PERFORMANCE MEASURES

1. FREQ is the average frequency of service over each system, defined as the ratio of total annual vehicle miles divided by total one-way route miles.
2. OP REV/OP EXP is annual operating revenue (in 1976 dollars) divided by annual operating expense (in 1976 dollars) for each transit system.
3. PAS REV/BUS is annual deflated passenger revenue (in 1976 dollars) divided by the size of the bus fleet for each system.
4. PAS REV/EMP is annual passenger revenue in constant 1976 dollars, divided by the total number of employees per system.
5. PAS REV/REV PAS is annual deflated passenger revenue, divided by number of total annual passengers for each system.
6. PAS REV/TVH is annual deflated passenger revenue, divided by total annual vehicle hours per system.
7. PAS REV/TVM is annual passenger revenue in constant 1976 dollars, divided by total annual vehicle miles for each system.
8. % POP SERV is population of the service area (as reported by each transit system), divided by the population of the urbanized area.
9. RPAS/OP EXP is the annual revenue passengers, divided by annual operating expense (with depreciation calculated by the Nelson formula—see Nelson (6), p. 137) in 1976 constant dollars.
10. RPAS/TVM is annual revenue passengers, divided by annual total vehicle miles.
11. S Miles/OP EXP is the ratio of annual seat miles of service to annual operating expense in 1976 constant dollars. Seat miles are total vehicle miles multiplied by the average number of seats per bus in each system's fleet.
12. S Miles/SA Pop is the ratio of annual seat miles to service area population for each system.
13. Speed is total annual vehicle miles divided by one-way route miles for each system.
14. TPAS/Autoless Pop is total annual passengers divided by the autoless population of the service area, as estimated from the percent autoless in the urbanized area.
15. TPAS/BUS is the ratio of total annual passengers to the number of buses in the fleet for each system.
16. TPAS/ELD Pop is total annual passengers divided by the elderly population of the service area, as estimated from the percent over 65 in the urbanized area.
17. TPAS/EMP is total annual passengers divided by total number of employees for each system.
18. TPAS/OP EXP is the ratio of total annual passengers to annual operating expense in constant 1976 dollars for each system.
19. TPAS/S Mile is the ratio of total annual passengers to total annual seat miles of service provided by each system.
20. TPAS/SA Pop is total annual passengers divided by the service area population.
21. TPAS/TVH is the ratio of total annual passengers to total vehicle hours of service.
22. TPAS/Wages is total annual passengers divided by the annual wages paid, in 1976 constant dollars, by each system.
23. TVH/BUS is the ratio of total annual vehicle hours to total number of buses in each system's fleet.

(continued on next page)

TABLE 2 (continued)

DEFINITIONS OF PERFORMANCE MEASURES

24. TVH/ELD Pop is total vehicle hours divided by the elderly population of the service area, as estimated from the percent over 65 in the urbanized area.
25. TVH/EMP is the ratio of total annual vehicle hours to total number of employees for each system.
26. TVH/OP EXP is the ratio of tota l annual vehicle hours to annual operating expense, in 1976 constant dollars and adjusted for depreciation (see Nelson (6), p. 137 for the depreciation calculation).
27. TVH/SA Pop is total vehicle hours of service divided by the service area population.
28. TVH/WAGES is the ratio of total annual vehicle hours to total annual wages, in 1976 constant dollars for each system.
29. TVM/BUS is total annual vehicle miles divided by the size of each system's bus fleet.
30. TVM/EMP is the ratio of total annual miles of service to the number of employees for each system.
31. TVM/OP EXP is total annual vehicle miles divided by annual operating expense, in 1976 constant dollars and adjusted for depreciation.
32. TVM/SA Pop is total annual vehicle miles per service area population.
33. TVM/WAGES is the ratio of total annual vehicle miles to total annual wages, in 1976 constant dollars, for each system.

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dollar," "total vehicle miles per service area population," "revenue per total vehicle mile" and "total passengers per elderly population." Vehicle hours was chosen as the more appropriate measure of produced transit service since vehicle mileage is more affected by congestion arising from city density and street configuration. The variable "speed" was eliminated because it tends to reflect congestion more than transit policy and performance. The variable "percent of urban population served" was eliminated because data were not available to calculate the desired ratio of coverage area population to service area population.

B. Set of 7 Performance Indicators (T7H)

A small set of seven performance indicators was created by using a single indicator to measure each of the seven F, G & L dimensions of performance. The set consists of the following performance measures:

(1) total vehicle hours per employee,

(2) total vehicle hours per bus,

(3) total vehicle hours per dollar operating expense,

(4) total vehicle hours per population served,

(5) revenue per total vehicle hours,

(6) revenue passengers per dollar operating expense, and

(7) total passengers per population served.

C. The Sum of Performance Dimension Scores (TFSCORE)

A single measure of performance was derived through factor analysis of the set of 27 performance indicators and summation of the factor scores.

Factor analysis is a general method of interpreting the underlying "sources" of variation in a data set. Performance indicators that show similar patterns of variance are grouped into one factor dimension. These statistically independent factor dimensions can be interpreted as performance concepts and used as a reduced set of performance indicators or summed to obtain a single performance measure. This use of factor analysis requires a logical conceptual framework, such as the F, G, & L model. The three steps in creating the single over-all measure of performance (TFSCORE) are set forth below:

1. An R-mode factor analysis, with varimax rotation, was carried out to identify the basic patterns of variance among the 27 performance measures in the base year. Six dimensions, which accounted for 90% of the covariance, are labeled by F, G & L concept in Table 3. The first dimension, or Factor 1, measures consumed-output-per-dollar of cost. The second dimension measures produced-output-per-dollar of cost. The third measures vehicle-productivity. The fourth factor measures two statistically indistinguishable performance concepts: social-effectiveness and utilization-of-service. The

TABLE 3

ROTATED FACTOR PATTERN*

Performance Concept	Performance Indicator	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
I. Labor	1 TVH/EMP						0.865
Productivity	2 TVM/EMP						0.749
II. Vehicle	3 TVH/BUS			0.846			
Productivity	4 TVM/BUS			0.974			
III. Produced	5 TVH/OPEXP		0.899				
Output per	6 TVH/WAGES		0.875				
Dollar Cost	7 TVM/OP EXP		0.894				
	8 S MILES/OPEXP		0.650				
IV. Social	10 TVH/SA POP				0.932		
Effectiveness	11 TVH/ELD SA POP				0.864		
	12 FREQ				0.632		
	13 S MILES/SA POP				0.827		
V. Revenue	17 PAS REV/BUS			0.629		0.633	
Generation	18 PAS REV/TVH					0.700	
	19 PAS REV/EMP					0.770	
	20 OP REV/OP EXP					0.754	
	22 PAS REV/RPAS					0.867	
VI. Consumed	23 TPAS/OP EXP	0.868					
Output per	24 RPAS/OP EXP	0.883					
Dollar of	25 TPAS/EMP	0.790					
Cost	26 TPAS/WAGES	0.835					
	27 TPAS/BUS	0.514		0.732			
	28 TPAS/S MILE	0.893					
	29 TPAS/TVH	0.816					
	30 RPAS/TVM	0.867					
VII. Utilization	31 TPAS/AUTOLESS POP				0.775		
of Service	32 TPAS/SA POP				0.786		

*Factor Loadings < .5 are omitted from the table.

fifth dimension is revenue-generation and the sixth is labor-productivity. In every case the performance indicators which were expected to measure a given concept did load together on one factor dimension.

2. Each original performance indicator value was converted to a numerical factor "score" in order to measure performance in terms of the transformed performance variables, i.e., the factor dimensions.

3. A single over-all performance indicator (TFSCORE) was obtained by summing the absolute values of the factor scores across all six dimensions. (The TFSCORE values for each system are listed in Table 5.)

This approach is extremely flexible and can be modified to account for state and local policy. For example, if policy makers place emphasis on social product efficiency and utilization of service, the factor score on dimension 4 could be assigned an appropriate weight in the summation to emphasize the increased importance of these considerations.

Although the sum-of-the-factor-scores (TFSCORE) is a simple over-all measure of performance, it reflects only the base year and neglects the time-series aspect of the performance analysis. An alternative approach would have been to factor analyse both the base year and the earlier year and treat the factor dimensions as a set of six performance indicators in the Michigan evaluation process. This approach is not reported since it did not produce significantly different results.

IV. ANALYSIS OF PERFORMANCE INDICATOR OUTLIERS AND COMPARISON OF RANKINGS

A performance indicator value is considered an **outlier** in the Michigan analysis if it differs by more than one standard deviation from the group average indicator value. Using the set of 27 indicators (T27) as a basis of comparison, a test of the desirability of using a reduced set of performance measures was made as follows: (1) The Michigan decision rule outliers were collected for the 27 performance measure set and the systems ranked in order by number of outliers. (2) The total outliers were tallied for the reduced set of 7 performance indicators (T7H) and the systems again ranked by number of outliers. These rankings were compared to the rankings developed from the larger set of indicators. (3) The same comparisons were made using the rankings developed from the sum of the factor scores (TRSCORE).

A. Calculation and Interpretation of Performance Indicator Outliers

Table 4 displays the outliers calculated as a result of applying the three Michigan decision rules to the set of 27 performance indicators (T27). A brief glance at Table 4 will show how complicated an analysis can be with 3 decision rules and only 27 (rather than the full 47) variables.

Each line on the two pages of Table 4 shows, for one transit system, the performance values

TABLE 4

OUTLIERS PER SYSTEM FOR 27 PERFORMANCE MEASURES

(Continued on Following Page)

SYSTEM NUMBER	TVH/EMP ☆			TVH/EMP			TVH/BUS ☆			TVH/BUS			TVH/OP EXP ☆			TVH/WAGES			TVH/OP EXP			S Miles/OP EXP			TVH/SA Pop ☆			TVH/ELD SA Pop			FREQ			S Miles/SA Pop			PAS REV/BUS			PAS REV/TVH ☆			PAS REV/EMP			OP REV/OP EXP			PAS REV/PPAS		
	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U	W	X	U
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TABLE 4

OUTLIERS PER SYSTEM FOR 27 PERFORMANCE MEASURES

(Continued from previous page)

SYSTEM NUMBER	TPAS/OPEXP			PPAS/OP EXP ☆			TPAS/EMP			TPAS/WAGES			TPAS/BUS			TPAS/S MILE			TPAS/TVH			PPAS/TVM			TPAS/Auto-less Pop			TPAS/Service Area Pop ☆			No. Plus Outliers	No. Minus Outliers	Total Outliers
	B	M	C	B	M	C	B	M	C	B	M	C	B	M	C	B	M	C	B	M	C	B	M	C	B	M	C	B	M	C			
909	•	•	•	•	•	•	•	•	•	•	•	•				•	•		•	•	•	•	•	•	•	•	•	•	•	•	39	8	47
146	-		•	-		•	-		•	-		•	-	-		-			-		•	-		•	-	-	-	-	-	-	8	38	46
161				-	-		-	-		•	•	•	-	-				•			•	-		•	-	-					13	30	43
149			•			•			•			•				-					•	-	-		-	-		-			21	22	43
276		•			•		-	-	-							•	•		-	-	-				-	-	-	-	-	-	16	27	43
229	-	-	-	-	-	-	-	-		-	-		-	-			•		-	-		-	-	-	-	-					2	39	41
909	-	-		-	-		-	-		-	-		-	-					-	-		-	-			-			-		1	36	37
207		-	-			-		-					-	-									-				-	-	-	-	3	32	35
80	-	-		-	-		-	-	-	-	-		-	-			-	•	-	-		-						-			4	30	34
175					•		•				•		•			•	•		•	•		•	•	•			-	•		-	19	15	34
140	-		-			-		-	-			-	-	-		-	-	-	-	-	-			-					-	-	16	18	34
199	-	-	-	-	-	-	-	-	-	-	-			-		-			-	-			-		-			-			1	32	33
210							-	-					-	-					-	-			-	-		-			-		15	18	33
921	•	•	•	•	•	•		•			•		•	•						•			•				•			•	28	5	33
76	•	•		•	•	•	•		-	•			•		•	•		-										•			29	3	32
5		•			•			•			•									-	-				•						22	8	30
204			-		-	-			-			-					-				-			-	•						21	8	29
306	•	•	•						•	•	•	•															•			•	18	11	29
923	•							•												-				-	-	-		-	-		18	11	29
30	-	-		-	-					-						-				-							-		-	-	5	23	28
922	•	•	•	•	•	•		•			•									•			•				•			•	23	5	28
202	-	-	-		-				-			-					-	-			-									-	14	13	27
291	•						•						•			•	•		•			•	•		•			•			26	1	27
38	•	•		•	•		•	•			•		•			•	•		•	•		•	•								23	3	26
277		-					-	-	-					-						-			-				-			-	6	20	26
125		-	-		-						-			-						-						-	-		-	-	2	23	25
191								•								•	•			•			•			•		•	•		18	7	25
242		•									-		•	•									-								21	3	24
255	•	•		•	•			•		•	•			•					•	•			•		•	•	•		•	•	20	4	24
920		-			-			-			-			-						-			-		-						2	22	24
106	-			-					•			•		-				•			•			•			•			•	9	14	23
158					•		•	•			•			•					•	•		•	•		•	•			•		16	7	23
912																	•			-	-			-							20	3	23
19					-						-		•										•								9	13	22
24									•					•						•					•	•		•	•	•	16	6	22
62						-					-									-				-		-					15	7	22
142		•		•	•	•		•			•												•	•		-				-	10	12	22
183			-														•					•								-	13	9	22
235					•					-	-	-								-			•		-						9	13	22
250			•								•	•						•			•	-		•						•	13	9	22
274		-																							•	•		•	•		12	10	22
14	-									-	-					-					•										2	19	21
64					•		•	•					•						•	•		•	•			•		•	•		16	5	21
237		•			•			•			•		•	•						•			•			•			•		16	5	21
239		-	-		-	-		-						-							-		-	-	-	-			-		2	19	21
18			-			-					-	-								-			-			-			•		8	11	19
46			•			•			•					•										•	•	•	•			•	17	2	19
98																															11	8	19
222	-	-		-	-					-	-					-				-			-						-		4	15	19
249					-									•									-		•						17	2	19
[illegible]		-			-		-	-	-																						2	16	18
[illegible]								-						•		•	•														5	13	18
252								•						•												•					15	1	16
167																													•		12	3	15
227												-		-									-	-		-			-		5	7	12
241					•									•																	8	3	11
[illegible]		-																								-			-		1	6	7

that are significantly high (+) or low (-) for each of the three decision rules, "W," "X," and "U." Investigation and analysis of each of the plus and minus indicators in Table 4 would involve a massive commitment of resources and therefore it would appear that a simplified scheme would be desirable. This may be accomplished by using the reduced set of seven performance indicators (T7H), which is shown in the **starred** columns of Table 4. Alternatively, a simple ranking of systems can easily be carried out by employing the TFSCORE which is a single number, as shown in Table 5.

The three Michigan decision rules are defined as follows:

1. If "W" is a "+" ("-") the system's performance on the associated performance measure in the **base** year is one or more standard deviations above (below) the group average. A **blank** value for W means the indicator value of the base year lies within one standard deviation of the group mean, and thus not defined an outlier.

2. Outliers based on the second decision rule are shown by the variable "X," which takes the value "+" ("-") if the value of the indicator is above (below) the mean in both the base year and the earlier year, **and** the rate of change from earlier year to base year is greater (less) than the group average rate of change. The form of the second decision rule follows the intent of the Michigan program (see reference 6, p. III-31) in focusing attention on the "extreme case" scenarios (a) and (c) (depicted in Figure 1 below), as opposed to scenarios (b) and (d).

3. The outliers calculated using the third decision rule are depicted by the variable "U." "U" takes the value "+" (or "-") if the growth of the indicator value from the previous period to the base year is at least one standard deviation greater (or less) than the group average rate of change over the two year period.

B. Comparison of System Outlier Totals and Ranks

The goal of Phase One of the Michigan performance analysis program is to distinguish exceptional from average performance in order to determine the systems eligible for follow-up investigation. Relative performance scores for all 57 systems are listed in Table 5 for each of the three indicator sets. The total number of plus and minus outliers per system has been used to rank each system's performance in descending order. For example, using the set of 27 performance indicators, system number 905 accrued a total of 39 high and 8 low performance outliers giving a total of 47. Since this is the largest number of outliers for any system, System 905 is ranked number 1 by the 27-performance indicator set. It also ranks number one under the seven performance indicator set (T7H) with its total of 14 performance outliers. However, System 905's total factor score ranks number 2 because its score is smaller than that of System 291.

The systems are ordered in Table 5 by their T27 rank. Tied performance indicator values are assigned the mean of their respective ranks. It can be seen that there are many tied rank values under both performance indicator sets T27 and T7H. There are, in fact, 50% more tied rank values for T7H than for T27. Thus reduction of the number of performance measures to obtain a small set of seven has obscured some of the performance differences among systems. TFSCORE has no tied ranks since it is a decimal, rather than an integer, value. However, although TFSCORE avoids the ties problem, its rank order of systems appears less similar than T7H to the T27 order.

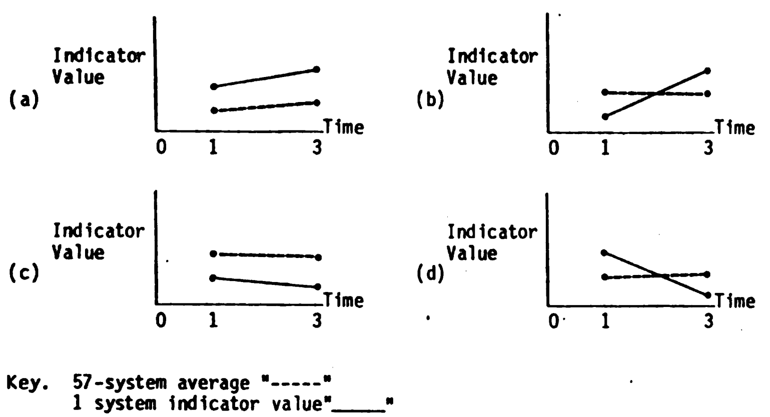

FIGURE 1

TABLE 5

TRANSIT SYSTEM RANKINGS AND OUTLIER COUNTS

TRANSIT SYSTEM NUMBER	TWENTY-SEVEN PERFORMANCE INDICATORS (Set T27)				SEVEN PERFORMANCE INDICATORS (Set T7H)				SUM OF SIX PERFORMANCE DIMENSIONS (TFSCORE)	
	System Rank	Number of Outliers			System Rank	Number of Outliers			System Rank	Total Factor Score
		Plus	Minus	Total		Plus	Minus	Total		
905	1.0	39	8	47	1.0	4	5	16	2	46.7631
149	2.0	8	38	46	2.5	1	11	12	3	46.5791
141	4.0	13	30	43	5.0	2	9	11	4	42.6060
169	4.0	21	22	43	5.0	5	6	11	8	33.6738
278	4.0	16	27	43	5.0	4	7	11	19	24.1737
229	6.0	2	39	41	14.5	0	9	9	5	40.1136
909	7.0	1	36	37	14.5	0	9	9	7	34.0377
297	9.0	3	32	35	9.0	0	10	10	18	24.6737
86	10.0	4	30	34	20.0	0	8	8	9	31.8698
175	10.0	19	15	34	20.0	4	4	8	6	37.8713
196	13.0	16	18	34	9.0	7	3	10	28	19.6372
199	13.0	1	32	33	14.5	1	8	9	12	33.5259
219	13.0	15	18	33	9.0	6	4	10	11	30.6309
921	13.0	28	5	33	14.5	7	2	9	20	23.7250
76	15.0	29	3	32	9.0	10	0	10	13	30.7636
9	16.0	22	8	30	2.5	10	2	12	29	19.1409
234	18.0	21	8	29	25.5	5	2	7	16	25.3535
906	18.0	18	11	29	25.5	6	1	7	26	20.5032
423	18.0	18	11	29	9.0	6	4	10	22	23.3714
30	20.5	5	23	28	14.5	2	7	9	37	17.9822
922	20.5	23	5	28	14.5	7	2	9	39	17.2343
202	22.5	14	13	27	39.5	3	2	5	30	19.0716
291	22.5	26	1	27	25.5	6	1	7	1	53.2337
38	24.5	23	3	26	48.0	4	0	4	15	26.0321
277	24.5	6	20	26	25.5	1	6	7	24	22.6802
125	26.5	2	23	25	20.0	1	7	8	45	14.4637
191	26.5	18	7	25	20.0	5	3	8	25	20.7435
242	29.0	21	3	24	39.5	4	1	5	32	18.7021
255	29.0	20	4	24	31.5	5	1	6	43	15.9562
920	29.0	2	22	24	39.5	1	4	5	13	30.2436
106	32.0	9	14	23	31.5	1	5	6	27	20.2532
158	32.0	16	7	23	48.0	3	1	4	35	18.4964
912	32.0	20	3	23	25.5	7	0	7	17	24.7467
19	37.5	9	13	22	31.5	3	3	6	38	17.8186
24	37.5	16	6	22	39.5	4	1	5	21	23.2982
62	37.5	15	7	22	31.5	4	2	6	47	13.6832
142	37.5	10	12	22	25.5	4	3	7	46	14.0479
189	37.5	13	9	22	53.0	3	0	3	23	22.7248
235	37.5	9	13	22	53.0	2	1	3	56	8.7543
250	37.5	13	9	22	31.5	3	3	6	41	16.2452
274	37.5	12	10	22	39.5	4	1	5	44	14.9515
14	43.5	2	19	21	48.0	0	4	4	40	16.4374
64	43.5	16	5	21	31.5	6	0	6	14	28.9019
217	43.5	16	5	21	48.0	4	0	4	33	18.6737
239	43.5	2	19	21	39.5	0	5	5	36	18.2215
18	48.0	8	11	19	20.0	6	2	8	54	10.9374
66	48.0	17	2	19	39.5	5	0	5	52	11.5303
99	48.0	11	8	19	39.5	2	3	5	42	16.0737
222	48.0	4	15	19	39.5	2	3	5	50	12.3519
249	48.0	17	2	19	53.0	2	1	3	34	18.5365
49	51.5	2	16	18	48.0	0	4	4	49	13.1053
926	51.5	5	13	18	48.0	2	2	4	51	11.5971
252	53.0	15	1	16	56.0	2	0	2	31	18.6482
167	54.0	12	3	15	39.5	5	0	5	55	9.8187
227	55	5	7	12	56	1	1	2	53	11.3455
241	56	8	3	11	48	3	1	4	48	12.6955
123	57	1	6	7	56	0	2	2	57	7.9919

The T27, T7H, and TFSCORE rank orderings are highly correlated. The Spearman correlation coefficient of T27 and T7H ranks was 0.85, and the correlation of T27 and TFSCORE ranks was 0.80. (Both correlations were significant at the 0.0001 level.)

The criterion of success for each of the reduced sets was its accuracy in choosing the same high- and low-performance systems selected by set T27. In the Michigan pilot performance evaluation test(8), 5 of the total of 14 systems were selected on the basis of outliers.

for follow-up analysis. The Michigan outlier analysis process does not define the number of systems to be selected. That figure presumably is imposed on the basis of budget restrictions and follow-up investigation cost. Following the Michigan example, the 19 systems with the largest total number of outliers would constitute the "extremes" requiring further investigation. In Table 5, the "extreme" systems can be identified as those with T27 rank < 20.

Relative to the top 19 systems chosen by T27, TFSCORE, with its tie-free ranks, correctly chose 14 of the same systems in its top 19. T7H more close approximated T27, however, by correctly choosing 17 of the same systems in its top 19 ranks. The first sixteen systems in the T7H list were all correct. The two errors involved systems ranked 17th and 18th.

In order to test whether the T7H or TFSCORE rank values were essentially equivalent to those of T27, a nonparametric statistical test, the Wilcoxon matched-pairs sign-rank test, was performed. The Wilcoxon test assumes that the variable under consideration has a continuous distribution underlying the scores, but does not make the assumption of normality which is made by the comparable parametric test, the t test. All three rankings were found essentially equivalent (i.e., have the same mean) at the 0.05 level of significance. The level of significance at which this null hypothesis could be refuted for T7H was 0.20 and for TFSCORE was 0.10.

V. CONCLUSIONS

This study suggests that an appropriate indicator set chosen for peer group analysis will reflect a framework of performance concepts, and represent the desired weight of each in the analysis. This is due to the fact that use of performance indicators which are independent of the conceptual framework will weight the analysis in an unplanned way, toward the concept most closely related in a statistical sense.

A small performance indicator set has the advantage of reducing cost and attendant confusion of analysis by focusing attention on a few important measures. This study has shown that sets of performance indicators can be considerably reduced in size if an error of 11 to 26 percent in choice of high and low performance systems is acceptable.

Employment of factor analysis and the sum of each system's factor scores as an over-all performance indicator has the advantage of tie-free rankings of systems. However, the sum-of-individual-factor-scores is less accurate in representing the larger set of performance indicators than a small set of indicators, which represents all important concepts.

Based upon these conclusions, evaluations similar to the Michigan program can realize cost savings by employing a few well-chosen performance measures.

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(See Appendix 1 on next page)

APPENDIX 1

CITIES UTILIZED IN ANALYSIS
System Number and Name (Base Year)

199	Akron, OH (72)
920	Anderson, SC (72)
49	Bridgeport, CN (71)
175	Buffalo, NY (72)
921	Charleston, SC (73)
277	Charleston, WV (72)
912	Charlotte, NC (72)
239	Chattanooga, TN (71)
202	Cincinnati, OH (72)
278	Clarksburg, WV (71)
922	Columbia, OH (72)
204	Columbus, OH (72)
249	Dallas, TX (72)
46	Denver, CO (72)
86	Des Plaines, IL (72)
905	Fitchberg, MS (72)
148	Flint, MI (72)
250	Forth Worth, TX (73)
14	Fresno, CA (71)
149	Grand Rapids, MI (72)
287	Green Bay, WI (71)
141	Greenfield, MS (73)
923	Greenville, SC (72)
227	Harrisburg, PA (72)
906	Holyoke, MS (72)
252	Houston, TX (73)
62	Jacksonville, FL (72)
106	Kansas City, KA (73)
98	Indianapolis, IN (72)
123	Louisville, KY (73)
9	Little Rock, ARK (71)
18	Long Beach, CA (72)
19	Los Angeles, CA (72)
242	Memphis, TN (72)
64	Miami, FL (72)
291	Milwaukee, WI (72)
158	Minneapolis-St. Paul, MN (72)
243	Nashville, TN (71)
142	New Bedford, MS (71)
125	Newport, KY (73)
229	New Castle, PA (72)
24	Oakland, CA (72)
167	Omaha, NB (71)
222	Portland, OR (72)
237	Providence, RI (72)
196	Raleigh, NC (72)
189	Rochester, NY (72)
255	San Antonio, TX (72)
76	Savannah, GA (72)
30	San Diego, CA (72)
38	Santa Monica, CA (72)
924	Spartanburg, SC (72)
909	Springfield, MO (72)
191	Syracuse, NY (72)
274	Tacoma, WN (72)
235	Wilkes Barre, PA (71)
218	Zanesville, OH (72)