A Methodology for Comparative Transit Performance Evaluation with UMTA Section 15 Data

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ABSTRACT

The obstacles to the comparative evaluation of transit performance lie chiefly in the nonconformity and inaccuracy of the early data and also the inadequate coverage of the local operating characteristics. With the publication of the annual reports required by Section 15 of the Urban Mass Transportation Act of 1964 since May 1981, the first obstacle has been overcome. However, because of human error in compiling the data and the format of the report, there have been many shortcomings in the first two annual reports. These shortcomings together with their solutions were outlined. In an attempt to overcome the second obstacle, a set of indices related to the costs, demand, and revenues was developed for each bus system. Each index is defined as the ratio of the difference between the actual and the expected performance measures to the expected performance measure. The expected performance measure was derived from the regression models fitted on the second-year Section 15 data. With this approach a positive index means that the bus system performs better than its expected performance and also better than its peers. A negative value, in contrast, denotes an inferior performance. A zero value of the index is thus the average. Only results for systems with 25 to 99 vehicles are presented.

To measure the performance of a transit company, performance measures or indicators are generally used. In the past the development of transit performance measures was difficult because of the lack of a systematic, consistent, and accurate database (1). The early financial and operating statistics of transit systems were found to have many errors and limitations because of the structure of the reporting system, the lack of precise definitions of terms, and the lack of cooperation from transit companies (2). As a consequence, most early researchers had to rely on the data from local transit systems for performance studies, which presented the problem of nontransferability (from one system to another). Hence, any comparative evaluation involving more than one system was considered impossible by some practitioners (3) and dubious by the transit association (4).

An attempt to correct many of the early problems was made through the amendment of the Urban Mass Transportation Act in 1974. Section 15 of this act requires that all transit systems receiving federal aid must report common data to UMTA (2). The result of this requirement has been the publication of UMTA Section 15 annual reports on common transit data since May 1981 (5). The reporting system employed in this publication is now regarded as the industry standard. For example, the presentation format of the 1981 edition of the American Public Transit Association (APTA) Transit Fact Book (6) was radically altered from the previous one to be in line with this standard; the same is also true for state data sources (7).

Because the Section 15 reporting system is in its initial stage, an analysis of the reported data is needed. The availability of the data also allows for the development of a comparative performance evaluation methodology. This is the primary purpose here. The specific objectives of this paper are to identify the shortcomings of the UMTA Section 15 data and to formulate indices for evaluating the performance of transit systems through the use of multiple regression analysis.

UMTA SECTION 15 REPORTING SYSTEM

Contents

Pursuant to Section 15, transit systems are required to use one of four reporting levels: Required, A, B, or C (8). Although the Required level contains the least compulsory transit information, level A, the most comprehensive level, is recommended for systems with more than 500 revenue vehicles; level B for systems with 101 to 500 vehicles, and level C for systems with 1 to 100 vehicles. The forms (9-12) for reporting transit data for the four levels cover information related to capital resources, revenues, expenses, and system characteristics. The total number of data items to be reported varies depending on the reporting level required, the size of the system, and the number of modes operated. This number may be as low as 396 items for single-mode systems with fewer than 25 vehicles and as high as 2,385 items for multimode systems with more than 25 vehicles.

Shortcomings and Their Solutions

The inauguration-year data of the UMTA Section 15 reporting system contain many errors; attempts by Anderson and Fielding (13) to fit cost models were not significant, in spite of a rigorous checking method employed (14). As for the second year (15) (covering the period between July 1, 1979, and June 30, 1980), there are also some inherent and acquired shortcomings.

Inherent Shortcomings

These shortcomings are ingrained in the reporting system and thus cannot be corrected for the current use of the data. However, in order to improve the quality of future data, the reporting system itself must be modified. Following are some of the problems found in the data.

Revenues Not Reported by Mode

The reporting forms do not require multimode systems to separate revenues by mode, making it impossible to estimate the revenues generated by each mode. Hence, data items for multimode systems must be omitted from any analysis that requires the revenue of an individual mode.

Service Area and Population Not Well Defined

The reporting forms do not require data on population and region served, but these two items are crucial for the building of the demand and revenue models. The values provided in the tape and the report are estimated according to the UMTA area codes. As a result, confusion arises. For example, 10 systems were reported to serve urban area code no. 2 in California. All systems are listed as serving the same urban area population, even though their revenue vehicles number from 4 to 2,731. To remedy this problem, the latest census of population and housing was used in estimating the population. As for the land use, the County and City Data Book (16) was consulted. The use of the land area data for this study was based on the assumption that the urban land area remained unchanged. Although this assumption is not true, no other sources of data were available during the research.

Joint Expenses Not Reported by Mode

For multimodal systems, the direct and joint expenses by mode and object class are given in File 14 and File 17, respectively. However, there is no listing for joint expenses contributed by each mode. Therefore, the total expenses by mode and object class cannot be derived. In order to prevent the unnecessary omission of all multimodal systems in the study, a check was performed on File 17 to see whether any joint expense was zero. If the value was zero, the corresponding system was included.

Conflicting Demarcation Point in System Grouping

It is compulsory for systems with more than 25 revenue vehicles to complete Form 321 (Operator's Wages Subsidiary Schedule) and Form 331 (Fringe Benefits Subsidiary Schedule). However, in the annual reports, transit systems are stratified according to number of revenue vehicles, as follows: 1 to 24, 25 to 49, 50 to 99, 100 to 249, 250 to 499, 500 to 999, and 1,000 or more. Hence the compulsory transit data in Forms 321 and 331 are missing for the 25-revenue-vehicle systems (in the second group). This oversight has been made twice, and it is likely to be repeated again in the forthcoming reports.

Acquired Shortcomings

These shortcomings are acquired because of human error during the filing, keypunching, and checking of the transit data reports. They were corrected for the current use of the data based on the reasonableness of the values reported. The main errors found were as discussed in the following.

Missing Data

All missing data were replaced with zero values in both the tape and the report, which makes it difficult to know whether the zero value is real. To correct the situation, the reporting level of each transit system was examined. For the data items required to be reported, there are variables that cannot realistically assume a zero value, such as operating expenses and number of employees. Thus, if a zero value was reported, it must mean that data are missing. For data items that are optional it is harder to determine whether the zero is real or whether it indicates missing data. The nonzero variables identified at all reporting levels are given in Table 1 along with the number of bus systems having missing data items. It is quite obvious that the smaller the fleet size, the larger the number of missing data items. This may be because there were not enough personnel to handle the reporting task.

Data in Annual Report Do Not Match

Close examination of the report contents revealed

TABLE 1 Number of Bus Systems with Missing Data

	No. of Systems with Missing Data by System Size						
Nonzero Variable	1 to 24 (N=108)	25 to 49 (N=67)	50 to 99 (N=49)	100 to 249 (N=35)	250 to 499 (N=21)	500 to 999 (N=9)	1,000 or more (N=13)
Revenue vehicle operators (DR)	5	2	1	-	-	-	-
Operator's wages (DRWG)	10	-	-	-	-	-	-
Total employees (EMP)	3	2	1	-	-	-	-
Operating expenses (EXP)	1	-	-	-	-	-	-
Average fleet age (FLEETAGE)	9	-	-	-	-	-	-
Fuel consumption (FUEL)	6	1	1	1	-	-	-
Line miles (LM)	1	-	-	-	-	-	-
Material and supply expenses (MATX)	6	-	-	2	-	-	-
Unlinked passenger trips (PAS)	22	8	4	4	2	-	-
Unlinked passenger miles (PASM)	29	12	5	6	4	1	-
Passenger fare revenue (PASR)	2	-	-	-	-	-	-
Road calls—failures (RCAL)	12	-	3	1	-	-	-
Revenue capacity miles (RCM)	14	2	1	2	-	1	-
Time per linked passenger trip during weekdays (TRIPTIME)	28	10	5	6	3	2	-
Transportation revenue (TRR)	2	-	-	-	-	-	-
Vehicle hours (VH)	12	2	2	2	-	1	-
Vehicle miles (VM)	14	2	1	2	-	1	-
Vehicle operator expenses (VOX)	7	-	-	-	-	-	-
Vehicle revenue hours (VRH)	13	2	2	2	-	1	-
Vehicle revenue miles (VRM)	14	2	1	1	-	1	-
Employees' salaries and wages (WGX)	5	-	-	2	-	-	-

Note: Dash indicates no data.

that values representing the same variable in different tables were not the same. For example, total operating expense by function in Table 002.08.1 differed from the corresponding value by object class in Table 002.09.1, shown as follows (partial listing):

System Identification	Table 002.08.1	Table 002.09.1
4001	2,076,678	4,144,829
5029	1,028,048	720,393
8003	8,083	459,674
5030	1,071,857	1,192,799

These conflicts were solved by checking the same data in the tape.

Data in Tape and Annual Report Do Not Match

To illustrate the problem, total revenue variables with conflicting values in Table 002.01.1 and File 10 are listed in Table 2. In most cases, the data in the report are more reasonable. This is because there are fewer items in the report, which came out a few months after the tape. During this period, errors might have been found and corrected.

TABLE 2 Unmatched Data Between Tape and Report

System Identification	File 10 of Tape	Table 002.01.1 of Report (000s)
1047	536,107	351.2
2029	2,305,654	2,276.5
2044	6,280,910	6,503.9
3013	3,730,439	3,575.2
4025	2,513,384	2,566.3
6015	752,630	785.1
6005	4,138,832	4,530.3
7012	1,282,323	1,276.8

Vehicle Hours by Time of Day Excessive in Tape

This error was found when a need to calculate the values of new basic transit variables occurred (17). The error is in File 30. As an illustration, the average vehicle hours per vehicle during the nighttime period for system 1055 is (VH)/V = 300/4 = 75 hr, which is greater than the 24 hr allowed in one day.

After all errors had been eliminated, the database was established for the development of the proposed performance evaluation methodology as discussed in the following sections.

DEVELOPMENT OF A PERFORMANCE EVALUATION METHODOLOGY

To evaluate the performance of transit systems, measurements regarding their effectiveness and efficiency are usually employed (18,19). Effectiveness measures may cover a wide range of financial indicators of the transit systems as well as those related to the social well-being, economic development, and environmental quality of the community (3,20). The financial indicators, however, are greatly influenced by policy decisions, transit demand, management practices, and the local operating environment. Thus, for practical purposes, a performance evaluation methodology should provide information regarding the financial and operational characteristics of the system and enable a peer comparison for policy making. The proposed methodology presented here is an attempt to fulfill this purpose by using UMTA Section 15 data (with the adjustments discussed in the previous section).

Approach and Its Advantages

The cornerstones of the proposed methodology are the indices related to expenses, the number of unlinked passenger trips served, the passenger revenues, and the total transportation revenues (including fare revenues and such items as advertisement charges). The idea behind this choice of indicators is the opportunity to evaluate the cost effectiveness of transit systems from the points of view of management (expenses), service (passenger trips), and income (fare revenues or total transportation revenues).

All indices except the one for expenses were computed by using the following equation:

$$\text{Index }(i,j) = [\text{actual value }(i,j) - \text{expected value }(i,j)] \div \text{expected value }(i,j) \quad (1)$$

where i is the parameter of interest (i.e., unlinked passenger trips, passenger revenues, and transportation revenues) for bus system j.

Equation 1 ensures that a positive index implies a superior situation (i.e., actual performance is greater than expected performance), whereas a negative index implies an inferior situation. For the case of expenditure, a superior situation would be one in which the actual expenses are less than the expected expenses. Thus, in order to denote a positive index as the superior one, the following equation must be used:

$$\text{Index (expense, } j) = [\text{expected expense}(j) - \text{actual expense}(j)] \div \text{expected expense }(j) \quad (2)$$

Equations 1 and 2 show that an index of zero means that the transit system performs at the expected level compared with its peer. In this study, the expected performance values were estimated by using a set of multiple-linear regression equations the rationale and detailed description of which will be given later.

One of the advantages of using the indices is their simplicity and directness. By examining the sign (positive or negative) and the magnitude of the index, one can quickly gauge the performance of a transit system against its expected performance and those of its peers. This knowledge will facilitate the choice of corrective actions to improve the performance of the transit system. Another advantage is that they offer a straightforward basis for comparison, which may be illustrated as follows.

Transit performance comparisons may be grouped into three types: uncontrolled, controlled, and combined (21). In an uncontrolled comparison, an individual performance is pitted against a standard value or the average value of the peer group. The outcome of the comparison can be either better or worse than the peer group performance as shown in Figure 1A. In a controlled comparison, some form of equation, algorithm, or simulation is usually used to compute the expected performance for the whole group of systems. The expected performance is then used as a basis for comparing the performance of all individual systems. Hence, a company can perform better than, the same as, or worse than what is expected from it, as shown in Figure 1B. For the combined comparison, both controlled and uncontrolled concepts are used. There are four possible results, as shown in Figure 1C. They are

1. Better than the standard value (uncontrolled)

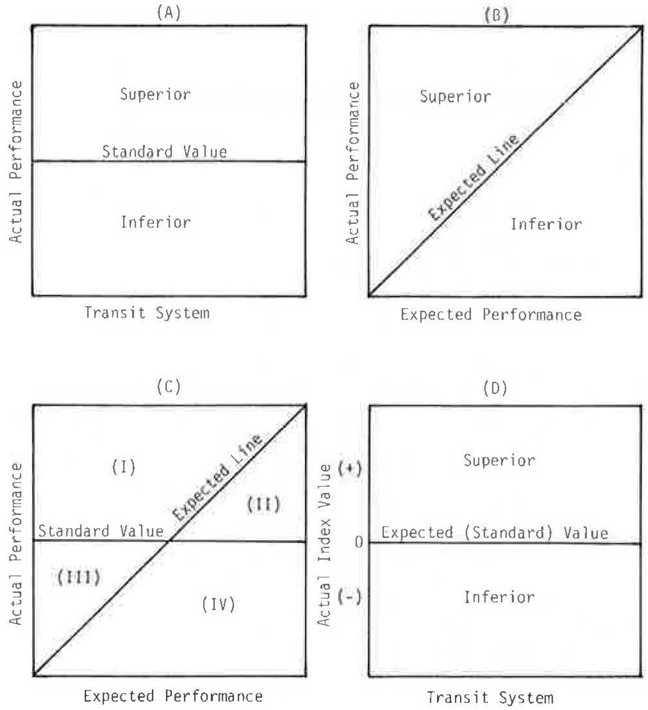

FIGURE 1 Comparison concepts in performance evaluation of transit systems.

and better than the expected value (controlled) (region I),

2. Better than the standard value but worse than the expected value (region II),
3. Worse than the standard value but better than the expected value (region III), and
4. Worse than the standard value and worse than the expected value (region IV).

It is obvious that the first type of result is superior and the fourth is inferior. For the second and third the performance of the company cannot easily be classified as good or bad.

If indices are used, ambiguous results will not occur in the comparison. The expected values obtained from the regression equations form the basis for a controlled comparison and the zero index value assumes the standard for an uncontrolled comparison. This way, there are three clear types of results: the company's performance is better than the expected and better than the peer-group performance, the company's performance is worse than both the expected and peer-group performance, and the company's performance is the same as the expected and the peer-group performance (see Figure 1D).

By having only distinctive results, the index can lend itself to the ranking of the systems according to their performance levels. The ranking will be based on the index values; i.e., a positive index will indicate a superior performance. The larger the magnitude of the positive index value, the better is the performance. Therefore the index not only shows the performance status of a company but also indicates how good or how bad its performance is.

Besides the above four individual indices, composite indices may also be developed to represent the overall performance of a system. Because the income of a transit system may come solely from the fare box or from the total transportation revenues, two composite indices may be suggested. They are the passenger-revenue-based composite index (CI_{pr}) and the transportation-revenue-based composite index (CI_{tr}):

$$CI_{pr} = W_e I_e + W_p I_p + W_f I_f$$

$$CI_{tr} = W_e I_e + W_p I_p + W_t I_t$$

where W_e, W_p, and W_f are the weighting factors for the expense, passenger, and fare-revenue indices, respectively. They are the subjective measures that represent the importance of each type of index (which may be obtained from an opinion poll, for example). I_e, I_p, and I_f are the index values for expense, passenger, and fare revenue, respectively. W_t is the weighting factor for transportation revenue and I_t is the index value for transportation revenue.

The composite indices can eliminate many inherent biases that generate from the operating policy of individual bus systems. For instance, if a system tries to attract more riders by reducing the fare, the index on passengers served would be high compared with that of the peer group. Moreover, if a system has a good revenue source from the local government (e.g., transit-dedicated tax), it generally does not stress revenue generation, but the system will always be viewed as effective if the passenger-based performance index is used. In addition, a passenger-based index will be biased against systems with a good charter service that generates a high level of revenue but not of passengers. On the other hand, a fare-revenue-based index alone may penalize the ingenuity of the transit manager to earn more income outside the traditional fare-box revenue.

In order to use Equations 1 and 2 discussed earlier, the expected value for each performance indicator must be estimated. A simple approach to estimating these values may be to use the mean value of each indicator. However, this approach would not provide a fair basis for comparison because of the nonhomogeneity of the transit systems' characteristics and environment, which are the primary determinants of the system's performance. Thus, to overcome this barrier, multiple-linear regression analysis was used in an attempt to explain the level of transit performance through causal indicators. [Nonlinear regression, however, was also employed; the results are presented elsewhere (17).] The main idea is that for each transit system with a certain number of characteristics (whether operational or environmental), there exists a reasonable expected value of performance relative to its peer. If this value is derived from the characteristics of all systems, biases may be greatly reduced.

Application

In UMTA Section 15 data, transit systems were stratified into seven groups according to the number of vehicles, as mentioned earlier. Ideally, the indices must be developed for each group to provide a complete basis for evaluating the transit industry. Unfortunately, because of the small number of observations available for the last three groups (i.e., 250 vehicles or more), regression analysis would not produce meaningful results. For the 100- to 249-vehicle systems, the propagation of missing data on basic variables prevents the formulation of meaningful regression equations. This leaves three groups that could feasibly be studied.

Two groups (25 to 49 and 50 to 99 vehicles) were merged into one because of the small differences between them in labor utilization, unit expense, and patronage. This also enlarged the database for regression analysis. The smallest group, 1 to 24 vehicles, was treated independently because of their distinct characteristics of costs, fuel efficiency, and patronage. For the purposes of illustration, only the results of the study on the systems with 25 to 99 buses will be presented here. The study on the systems with 1 to 24 buses may be found elsewhere (17).

To formulate the regression equations for estimating the expected performance of all systems, a set of potential causal variables was selected from UMTA Section 15 data. This set includes all the basic transit variables, three generic variables [vehicle hour miles (VHM), vehicle revenue hour miles (VRHM), and revenue capacity hour miles (RCHM)], and a number of other performance indicators, as follows:

1. Forty-six indicators officially listed in UMTA Section 15 reports (5,15);
2. The important indicators suggested by Sinha (22), Anderson and Fielding (13), and the Organization for Economic Cooperation and Development (OECD) (23) that do not duplicate those of Section 15; and
3. Additional indicators derived by substituting vehicle hours (VH), vehicle miles (VM), and revenue capacity miles (RCM) for the generic variables VHM, VRHM, and RCHM, respectively.

Initially 170 variables were selected for regression analysis. This list was later reduced to a manageable size by eliminating redundancy, omitting variables with low values of correlation, and so forth.

With the reduced set of data, a default level of significance of 10 percent in the System Analysis Study (SAS) stepwise procedure was used in model formulation. This value applied to all the estimated coefficients of causal variables and the overall significance of the models. The degree of explanation for the variation of the response variables (R^2) was set at a minimum of 50 percent for the purpose of screening. The explanation of the variation could be improved by discarding outlier points. This, however, was not done in this study because there was more interest in learning about the actual variation phenomenon. The results of the regression analysis led to the selection of the following models:

Operating expenses

$$\begin{aligned}\mathrm{EXP} = &- 1{,}361{,}530.89 + 18{,}975.71*\mathrm{EMP} \\ &+ 22{,}915.85*\mathrm{FLEETAGE} + 243{,}062.60*\mathrm{MNFAC} \\ &+ 0.43022*\mathrm{VMCM} - 479{,}199.63*\mathrm{DRPT1PV} \\ &+ 232{,}489.19*\mathrm{DRWG1DRH} - 111{,}736.85*\mathrm{VMC1FUEL} \\ &R^2 = 0.9375,\ n = 92 \qquad (3)\end{aligned}$$

where

EXP = total operating expenses,
EMP = total number of employees,
FLEETAGE = average fleet age,
MNFAC = light-maintenance facilities,
VMCM = vehicle miles plus charter miles,
DRPT1PV = part-time drivers per peak-period vehicle,
DRWG1DRH = driver wages per driver hour, and
VMC1FUEL = vehicle miles plus charter miles per gallon of fuel.

This equation shows good correlation between transit expense and the causal variables selected. The use of part-time drivers and fuel-efficient vehicles greatly reduces the operating costs of the system.

Unlinked passenger trips

$$\begin{aligned}\mathrm{PAS} = &\ 77{,}540.35 + 206.48*\mathrm{POPD} + 26{,}531.77*\mathrm{PV} \\ &+ 1.4208*\mathrm{VRM} - 2{,}473{,}544.84*\mathrm{PASR} \\ &R^2 = 0.5961,\ n = 73 \qquad (4)\end{aligned}$$

where

PAS = unlinked passenger trips,
POPD = population density,
PV = peak-period vehicles,
VRM = vehicle revenue miles, and
PASR = passenger fare revenue.

This equation does not explain the correlation with the independent variables well. The demand characteristics of the urban region served are represented only by the population density, which does not completely indicate the operating environment of the system. If data related to the vehicle ownership in the region were available, the significance of the model could be greatly improved. It must also be noted that PASR is an indicator of the fare charged. This variable, however, has some degree of collinearity with the dependent variable and therefore should be replaced in future studies with some other variable that is more representative of the average fare (e.g., fare per trip mile).

Passenger fare revenue

$$\begin{aligned}\mathrm{PASR} = &\ 757{,}631.72 + 77.506*\mathrm{POPD} + 20{,}258.79*\mathrm{PV} \\ &+ 0.0046613*\mathrm{RCM} + 30{,}622.79*\mathrm{TRIPTIME} \\ &+ 624{,}889.26*\mathrm{PASR1PAS} - 286{,}565.57*\mathrm{PV1BV} \\ &R^2 = 0.8594,\ n = 69 \qquad (5)\end{aligned}$$

where

TRIPTIME = average time per unlinked passenger trip,
PASR1PAS = passenger revenue per unlinked passenger trip, and
PV1BV = peak-period vehicles per base-period vehicle.

The variable TRIPTIME in the equation reflects the average length of the trip. The sign of its coefficient should be consistent with this interpretation. Otherwise, travel time would have a negative impact on the demand.

The negative sign of PV1BV may be interpreted as the impact of relative services provided during peak and off-peak hours. If the off-peak service is poor, the overall efficiency of the system may be perceived as low, which leads to a decline in patronage.

Transportation revenue

$$\begin{aligned}\mathrm{TRR} = &- 1{,}486{,}294.38 + 75.126*\mathrm{POPD} + 0.72520*\mathrm{VMCM} \\ &+ 1{,}029{,}784.37*\mathrm{PASR1PAS} + 9{,}306.11*\mathrm{RCM1VRM} \\ &+ 30.924*\mathrm{VM1LM} \qquad R^2 = 0.7899,\ n = 73 \qquad (6)\end{aligned}$$

where

TRR = total transportation revenue,
RCM1VRM = revenue capacity miles per vehicle revenue mile, and
VM1LM = vehicle miles per line mile.

As for the overall transportation revenues, vehicle miles of travel is the determining factor. Also, charter miles are important in revenue generation as shown in Equation 6.

RESULTS

The indices for each category (i.e., expense, passengers, passenger revenue, and transportation revenue) were computed by using the data for each bus system considered. The results for most cases were reasonable enough for comparative evaluation. However, some problems were encountered during the analysis that will be discussed later.

The number of indices developed for each category depends on the number of valid data items reported. There were 92 indices for the expense category, 73 for passengers, 69 for passenger revenue, and 73 for transportation revenue. Only 66 systems could meet the requirement that all four types of indices be considered for each bus system. Thus, for illustration the results for these 66 systems are presented as shown in Table 3. Each type of index is discussed in the following.

TABLE 3 Results of the Application Analysis for Systems with 25 to 99 Buses

	EXPENSE		PASSENGER		FARE REVENUE		TRANSP REV	
RANK	ID	INDEX	ID	INDEX	ID	INDEX	ID	INDEX
1	4041	0.24	7012	1.21	6016	435.04	4005	12.22
2	1043	0.23	9020	1.03	4005	54.71	6016	7.31
3	4025	0.17	3012	0.92	5059	2.77	1002	5.32
4	5084	0.17	2058	0.75	5001	1.67	1043	1.75
5	6024	0.14	5097	0.67	7011	1.58	5045	0.77
6	1002	0.14	2034	0.54	1002	1.45-	7011	0.74
7	5097	0.14	3014	0.48	1056	1.16	2029	0.69
8	4007	0.12	5059	0.41	4023	1.02	4009	0.64
9	5001	0.12	4044	0.40	4009	0.98	1056	0.61
10	6019	0.11	6024	0.39	6001	0.82	2060	0.57
11	6033	0.10	2029	0.37	2029	0.55	2034	0.50
12	4035	0.10	3025	0.31	2025	0.54	6017	0.44
13	6021	0.10	2025	0.29	1043	0.51	1016	0.41
14	4002	0.09	2060	0.29	4044	0.42	3008	0.41
15	4043	0.09	1043	0.26	6021	0.39	4036	0.41
16	4012	0.09	6016	0.24	2034	0.29	2025	0.38
17	3008	0.08	6021	0.19	1016	0.28	5097	0.35
18	4009	0.07	1016	0.16	6024	0.27	3002	0.34
19	5011	0.07	9018	0.15	4036	0.23	2044	0.34
20	3001	0.07	4025	0.14	4038	0.22	4017	0.34
21	5044	0.07	3008	0.13	6017	0.20	4007	0.31
22	5006	0.06	4005	0.13	2044	0.20	5001	0.24
23	4005	0.05	1056	0.12	4007	0.19	6024	0.23
24	5058	0.04	6019	0.09	3025	0.18	4044	0.20
25	4044	0.03	4007	0.09	3014	0.17	4012	0.17
26	1056	0.01	2003	0.09	9020	0.15	1005	0.17
27	2029	-0.00	9035	0.09	4017	0.15	3012	0.16
28	2067	-0.00	4043	0.06	9	0.13	3025	0.14
29	5059	-0.01	4023	0.06	3001	0.11	4025	0.14
30	1016	-0.01	5058	0.06	3008	0.10	5059	0.10
31	5003	-0.01	7011	0.04	4043	0.08	4002	0.10
32	9020	-0.01	1002	0.04	2060	0.07	3014	0.09
33	9	-0.02	9	0.01	1005	0.05	2003	0.08
34	9006	-0.02	5052	-0.01	9018	0.05	4038	0.04
35	12	-0.03	4036	-0.03	4035	0.04	4023	0.03
36	5045	-0.03	4017	-0.04	2058	0.01	5044	0.01
37	5052	-0.03	9006	-0.04	3011	-0.02	2058	0.00
38	3025	-0.03	4035	-0.06	4025	-0.02	9018	-0.05
39	3002	-0.04	4002	-0.07	2003	-0.03	4043	-0.06
40	4017	-0.04	5045	-0.08	6033	-0.05	4035	-0.06
41	4023	-0.04	6033	-0.09	5045	-0.05	6033	-0.07
42	6017	-0.05	3007	-0.10	5084	-0.06	9020	-0.08
43	3014	-0.06	5044	-0.13	5044	-0.12	5058	-0.10
44	5060	-0.06	5001	-0.13	3007	-0.12	3007	-0.11
45	2034	-0.06	2044	-0.17	5056	-0.12	9	-0.15
46	4036	-0.07	1005	-0.19	4012	-0.12	3001	-0.17
47	5056	-0.07	4009	-0.19	9035	-0.12	6021	-0.17
48	7012	-0.07	4012	-0.20	4002	-0.13	9035	-0.21
49	3013	-0.08	6017	-0.20	5003	-0.14	4041	-0.21
50	4038	-0.08	5060	-0.21	3012	-0.14	5056	-0.21
51	3007	-0.09	4038	-0.23	5058	-0.20	6019	-0.25
52	2060	-0.10	3001	-0.24	5052	-0.21	5052	-0.30
53	9018	-0.10	5057	-0.24	4041	-0.26	3011	-0.35
54	7011	-0.10	5056	-0.24	5060	-0.26	6010	-0.35
55	1005	-0.12	4041	-0.25	6019	-0.28	12	-0.37
56	2058	-0.13	12	-0.27	3013	-0.28	3013	-0.38
57	6010	-0.13	3002	-0.28	7012	-0.29	6001	-0.39
58	2025	-0.18	5006	-0.36	5006	-0.30	5003	-0.41
59	5057	-0.18	5084	-0.46	9006	-0.31	2067	-0.43
60	2044	-0.19	2067	-0.50	12	-0.33	5006	-0.45
61	2003	-0.27	5011	-0.55	5097	-0.38	5057	-0.47
62	9035	-0.29	3013	-0.56	2067	-0.41	5060	-0.49
63	6016	-0.30	6001	-0.57	6010	-0.42	5084	-0.52
64	3011	-0.37	6010	-0.65	5057	-0.51	9006	-0.54
65	3012	-0.54	3011	-0.70	3002	-0.61	7012	-0.57
66	6001	-1.38	5003	-0.70	5011	-0.62	5011	-0.65

Expense Index

Of the 92 expense indices obtained, 39 (or 42 percent) are positive and 53 (58 percent) are negative. The highest (positive) value is +0.24 and the lowest (negative) value is -1.38. This shows that the positive extreme is not far from the expected performance, whereas the negative extreme is much lower than the expected performance. A closer look at the magnitude of the indices reveals that 88 percent of all systems have an index value greater than -0.20 (which means that their actual expenditure is not greater than 120 percent of their expected expenditure).

To gain more insight into the reasonableness of the index values, an analysis was performed for a number of systems. The objective of the analysis was to compare the performance indicators of the selected systems to see whether they agreed with the performance implied by the indices. The indicators used were the ratios of expenses per driver hour, expenses per employee, expenses per passenger, expenses per passenger mile, expenses per peak-hour vehicle, expenses per vehicle hour plus charter hour, and expenses per vehicle mile plus charter mile. This analysis showed that the majority of the indicators agreed with the value of the index. That is, if a bus system has a higher index than that of another system, its ratios of expenses are likely to be smaller than those of the inferior system (see Table 4).

The analysis also reveals that bus systems with a high number of part-time drivers per peak vehicle are likely to have lower index values. This is because of the negative sign of the partial coefficient of this variable in Equation 3. The problem may be corrected and the regression equation would give more reasonable expected expenses if systems with part-time drivers were treated separately.

Passenger Index

The results show that approximately 45 percent of the bus systems studied have a positive passenger index (33 out of 73 systems). The range of the index is between -0.70 and +1.21 as shown in Table 3, and the majority of the systems (73 percent) have an index value greater than -0.20. The high value of the positive index in this case may be because some transit systems provide extensive services in return for financial assistance from other sources besides the fare box.

The analysis of the passenger indicators for individual systems shows a reasonable degree of consistency between the indicators and the index value. The indicators used were passenger miles per vehicle revenue mile, passengers per peak vehicle, passengers per line mile, passengers per vehicle revenue mile, passengers per service land area, passengers per employee, passengers per person in the population served, passengers per revenue capacity mile, passengers per vehicle hour, and passengers per vehicle mile. In comparing the values of the indicators for the selected systems, it was found that the population density of the region served (ranging from 500 to more than 19,000) has a great effect on the value of the index. For regions with lower population density, the expected number of passengers carried is quite low, causing an inflated value in the index. To avoid this problem, two approaches may be taken. First, as mentioned before, the population density does not accurately represent the demand for transit services and therefore should be replaced by some indicators of automobile ownership or the

TABLE 4 Analysis of Expense Indicators

Indicator	System Identification 4041	4025	3001	1056	5060	3011
Rank	1	3	20	26	44	64
Expense index	0.24	0.17	0.07	0.01	-0.06	-0.37
EXP/DRH	14.10	14.70	17.7	18.2	19.3	17.1
EXP/EMP	19,714	20,377	23,959	26,992	27,259	25,237
EXP/PASS	0.70	0.57	1.08	0.93	1.00	2.27
EXP/PASM	0.07	0.21	0.24	0.30	0.29	0.74
EXP/PV	45,806	62,622	73,138	72,445	89,474	50,473
EXP/RCM	0.02	0.03	0.03	0.04	0.04	0.05
EXP/VHCH	15.13	14.49	10.9	20.94	23.93	22.35
EXP/VMCM	1.04	1.36	1.42	1.94	1.89	2.18

availability of alternative modes. For the second approach, transit systems could be grouped according to the population density before regression equations are developed.

Passenger Revenue

The indices for this category are shown in Table 3. There are 36 positive indices out of a total of 69. The two highest-ranking indices with values of 435 and 54.7 are completely out of proportion. A check was made on their data and revenue indicators that revealed that the indices were inflated by the regression equation. These are the two points that are not well represented. The third-ranked system with an index of 2.8 was also misrepresented because of its reported average trip time of 1.1 min, which is not realistic. Thus, excluding these three systems, the reasonable range of the passenger revenue index is between -0.62 and +1.67.

An analysis of the individual indicators was also performed by using the ratios of passenger revenue per driver, passenger revenue per dollar of expenditure, passenger revenue per line mile, passenger revenue per passenger mile, passenger revenue per peak vehicle, passenger revenue per revenue capacity mile, passenger revenue per vehicle hour, and passenger revenue per vehicle mile. The indicators show a reasonable degree of consistency with the value of the index.

For bus systems with a value of passenger revenue per passenger greater than $1.00, the expected revenue estimated by the regression equation is high, which gives a low index value. However, their passenger-revenue-related indicators show that their performance is much superior to that implied by the index. The reason for the inaccurate estimates is that there are only three bus systems out of the 69 systems used to formulate the regression equation that have a value of passenger revenue per passenger greater than $1.00.

Because passenger revenue also depends on the demand for transit services, the same comments made on the use of population density hold here. In addition, if the fare rate per mile per passenger had been used, the estimates of the expected passenger revenues would have been more accurate.

Transportation Revenue

As shown in Table 3, transportation revenue indices vary from -0.65 to +12.2. The number of systems with a positive index is 40 of a total of 73 systems. The index values of the top four systems are significantly different from the other systems because of the biases created from the population density variable used in Equation 6. The problems encountered in the analysis of these indices are the same as those in the passenger-revenue category; that is, the regression equation causes the index values of those systems with a low population density to be inflated and those with a high value of passenger revenue per passenger to be deflated. Besides these special cases in which the index values are biased, other indices agree quite well with the transportation-revenue-related indicators of the individual systems.

CONCLUSION

Because of the uniform reporting of common transit data under the UMTA Section 15 reporting system, it is widely expected that these data sets will correct many previous problems on data adequacy for research and planning purposes. However, the inauguration-year data have so many errors that this study had to switch to the second-year data. Still, many errors remain, leading to the discussion of the shortcomings and the solutions to overcome them in this paper.

In order to improve the usefulness of the data, some modifications to the reporting forms should be made to give more specific information and to avoid ambiguity. In addition, the screening process should be improved to avoid missing data. From the point of view of data application, information related to the demand for transit services appears to be lacking. It was found in this study that although many transit systems have similar supply characteristics, their performance measures can be distinctively different because of the different demand environment. The data related to the population served, the service land area, and automobile ownership seem to be useful in representing the demand for transit services.

With respect to the performance indices, the main aim was to try to relate the performance of a system to its operating attributes and environment. Even with a limited set of data, the indices developed are indicative of the system's performance. They can be used to screen the weaknesses of a system so that improvements can be made. They are also useful in assessing the performance of the whole industry in any of the four categories considered; for example, if the majority of the systems do not perform at their expected level, corrective action needs to be sought in the attributes that the index represents.

The use of the indices can overcome the many differences in assessing transit performance. It is hoped that with the future improvements of the data, a more complete set of performance indices may be developed.

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