process for promotion (to FTO) more formally structured and weighted more toward a merit rather than seniority basis.

3. A programmed hiring approach should be put into place to ensure that all newly hired and reassigned PTOs have adequate training time and reassignment of both PTOs and FTOs can be made more often to correspond to productivity changes identified by the scheduling department.

4. A range of short-term improvements should be made in planning and scheduling to more easily and quickly respond to changing work-force requirements and to allow a fine-tuning of MBTA service to better meet the region's travel demands.

Using Section 15 Data: Adapting and Evaluating the Magnetic Tape Version for Statistical Analysis

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ABSTRACT

Data reported as required by Section 15 of the Urban Mass Transportation Act of 1964 have already proved useful in transit decision making. Yet wider use of these data has been inhibited by the difficulty of access to it electronically. A set of strategies for extracting, reorganizing, and evaluating data originating in the electronic data files disseminated by Transportation Systems Center on magnetic tape is described. The current organization of information within the files is unsuitable for most statistical software packages. Therefore, it is necessary to extract information from the Section 15 files and rearrange it in a form suitable for analysis. Different classes of missing data are also defined and remedies for the problem are addressed. In addition the cross-validation of values and the computation of basic transit variables are considered. Many statistical models make assumptions about the distributional characteristics of variables. Differences of scale among transit systems on such measures as size of fleet often result in variables the distributions of which violate these assumptions. Transformations that remedy the problem are recommended.

Since its first release for FY 1979, the reporting system outlined in Section 15 of the Urban Mass Transportation Act of 1964 has proved itself a powerful tool in transit decision making. It has provided standardized definitions of transit activities and recording procedures (1); replaced burdensome and nonuniform data-collection efforts by local operators (2); allowed local, regional, and nationwide comparison of transit performance (3); and facilitated management, performance evaluation, and the allocation of financial assistance at all jurisdictional levels (4-7). In short, analysis of Section 15 data offers greater leverage for understanding transit performance than has hitherto been possible.

The most complete version of Section 15 available for analysis is distributed by the Transportation Systems Center (TSC), Cambridge, Massachusetts, in the form of 62 electronic data files stored on magnetic tape. Although this version promises to be the most useful in the long run, current use of the tape is inhibited by the difficulty associated with reading it and adapting the information to a form suitable for statistical analysis. Considerable time and effort must be allocated to the development of a system for accomplishing the adaptation.

As TSC adopts a new operating system and develops new software for Section 15 data, a wider variety of data tape formats may become available. However, the first 4 years of Section 15 data (FY 1979-1982) share the same organization described in this paper.

An alternative to the magnetic tape is the National Urban Mass Transportation Statistics, UMTA's annual report (8), which provides tabular summaries of Section 15 data. But there are two drawbacks to substituting the printed annual report for the tape version. First, the tape is a comprehensive set of data including far more information than the printed annual report. All levels of reporting are included in the tape, whereas only the required level of information is given in the printed annual report. Entire classes of data such as operating schedules and peak loads are available only on the tape. This additional information permits the cross-validation of values, a critical step in assessing the accuracy of these data. Second, for users who wish to analyze transit systems on a nationwide level or use many variables, the cost of making the printed annual report machine readable could rival or exceed that involved in adapting the tape. For example, the data to be used require keypunching. Then a number of preliminary computational steps, such as converting percentages back to raw values, must be carried out before actual analysis commences. Therefore, it would be useful if a set of strategies could be outlined that would facilitate the use of Section 15 data as it originates on magnetic tape.

This paper describes such a set of strategies. A conceptual scheme underlying the conversion of the magnetic tape data to a conventional statistical format is first described. This is followed by a

discussion of data preparation steps that precede statistical analysis and include the treatment of missing data. In conclusion there is a brief evaluation of the distributional characteristics of basic transit variables for FY 1980.

DATA REORGANIZATION

In this section a discussion is presented of why the tape data must be reorganized to make them acceptable to a statistical software package like the Biomedical Computer Programs (BMDP) and the Statistical Package for the Social Sciences (SPSS). The objective is to explain why a software package can "read" the data but cannot, without reorganization, perform a statistical analysis on them. Why reorganization is needed and what steps are required to reorganize are the focus points.

The data reorganization process revolves around four questions concerning data files:

1. What are the basic organizational features common to all numerical data files?
2. What are the distinguishing features of a data file organized for statistical analysis?
3. How are the data files on TSC's magnetic tape different from the statistical convention?
4. What steps are required to reorganize them?

Basic Organizational Features

All data files are organized in rows and columns. A sample file is shown in Table 1. However, the meaning of the data is not inherent in this simple physical organization but must be conveyed to the computer by the programmer. The system or scheme used by the programmer to give meaning to the array of numbers is called the logical organization.

The specification of the logical organization is laid out in a document called a codebook. In a codebook the meaning of data is defined by the way the numbers are organized into sets of columns. A large number like $4,000,000 takes up seven columns, for example. The assigned sets of columns are called fields.

Table 2 shows a codebook from TSC's documentation. According to the codebook, columns 1-4 of the number array have been reserved for transit system numerical identification. Columns 5-12 are reserved for the fiscal year end date for the system identified in columns 1-4. Column 13 is assigned to the mode code. With the help of this scheme the computer can be informed about the meaning of the data by the way fields in the block of numbers are assigned. This process is called formatting.

TABLE 1 Sample Data Set

```
10010630198010114675000000
10010630198010221381000000
10010630198010317614000000
10021231198010142871000000
10021231198010258916000000
10021231198010338925000000
10021231198020154116000000
10021231198020273827000000
10021231198020391884000000
10040630198010148165000000
10040630198010218102000000
10040630198010317184000000
```

TABLE 2 Sample Codebook

Column	Name	Type	Description
1-4	TRSID	Integer	Transit system identification
5-12	FY	Date	Fiscal year
13	MODE	Integer	Mode code
14-15	EMCOD	Integer	Employee class code
16-21	OLABR	Real	Operating labor
22-27	CLABR	Real	Capital labor

In formatting, space is set aside in the array and named so that any number found in that space by the computer can be presumed to have the assigned meaning. Any number found in columns 1-4 of the sample block of data (Table 1) will mean Transit system identification number to the computer as long as it is formatted in that way.

It is important to realize that there is some flexibility in the way that data may be formatted. That is to say, there may be more than one meaningful logical organization for the same physical file.

Finally, an actual line of data like 10041114676 that can be formatted is called a record. A record may take up one or more rows and there may be more than one type of record in a data file.

Statistical Files

Statistical procedures operate by making systematic comparisons among objects. The objects are compared on those attributes that have been measured in some way. For example, in Section 15 analyses transit systems are compared on such attributes as size of fleet and speed.

In statistical data files the most important organizational units are cases (objects) and variables (attributes). A case may be thought of as the full collection of information items defined in the codebook for a single transit agency. If some defined item is missing, the statistical case is incomplete, and a place-holding code must be inserted to fill it out.

A variable, like a case, is a statistical concept. When all cases have been measured on a given attribute, the resulting collection of values is organized in a list called a variable. Statistical procedures compare these lists and depend on the fact that the cases always appear in the same order. Once again, if no place-holder resides in the position of a missing item, the order is disturbed and statistical results are rendered meaningless.

One danger to be avoided in comparing all numerical data files to a smaller subset of them, i.e., statistical files, is that the distinctions between their separate terminologies will blur. It is important to keep in mind the differences between the horizontal concepts such as the row, the record, and the case on the one hand and the vertical concepts such as the column, the field, and the variable on the other. In general use, the members of these trios are often used interchangeably. Because understanding the data reorganization process may hinge on the distinctions among them, a glossary is provided at the end of this paper.

Organization of TSC Tape Files

The organization of the TSC tape files is closely

linked to that of the reporting forms. Form 404, Transit System Employee Count Schedule, provides an example. Figure 1 shows Form 404 (top) and the information for one transit system as it appears in a data file on the tape (bottom). Spaces have been inserted between the fields for ease of reading. In the actual file there are no spaces.

A comparison of the form and the data shows that the first three fields, transit system identification, fiscal year ended, and mode, come from the top of Form 404, and are repeated on every record in the data. The next two fields, employee code and operating labor, are taken from the Employee Classification and Operating Labor sections of the form. Figure 1 shows a one-to-one correspondence between the numbers assigned to employee categories on the form (11, 12, 13, etc.) and the values under EC in the data file. However, the one-to-one correspondence is not quite complete. If Form 404 were used to construct a codebook that acted as the logical organization for the data appearing in Figure 1, there would be a discrepancy between what the logical organization predicts and what actually appears in the physical file. There is no record appearing for category 22, Maintenance Support Personnel, in the data.

To reiterate, most statistical software packages require some entry to stand in for the missing category 22. Until a stand-in value is substituted, the information cannot be said to form a complete case. Therefore, all such instances of missing records must be remedied before statistical analysis can proceed. Only two widely available software packages, SAS and SPSS-X, are known to have methods for dealing with this problem.

Another important consequence of the correspondence between the data and the forms is the way in which values are being compared, that is, which values are making up the variables. Consider once again Figure 1. In a statistical routine, the OLABR value of 4.5000 cannot be compared with the OLABR value of 2.5000 beneath it. The 4.5000 must be compared with another value, not shown here, which also has an EC of 11. OLABR, therefore, is not one variable, but 11 variables (the number of employee classifications) collected together in one field.

Informing the computer of this relationship between the values in the OLABR field requires devising a new logical organization to replace that found in the TSC codebook. For statistical purposes, OLABR is too general a category to qualify as a variable. It would not be useful to compare the number of revenue vehicle operators in one system with the vehicle servicing personnel in another system. Instead, revenue vehicle operators must be compared with revenue vehicle operators. A variable, then, would be all instances of OLABR for category 11 or all instances of OLABR for category 00, Total Transit System Employees.

The TSC data file organization is common, economical, and often used as input to management information systems using customized software. In computer science it is referred to as hierarchical ordering.

To summarize, two major differences needing reconciliation between statistical files and TSC files are the omission of stand-ins for missing records and hierarchical organization. The concept of missing data is an important issue in its own right and is discussed more fully in a later section.

Form No. 404

TRANSIT SYSTEM EMPLOYEE COUNT SCHEDULE

Transit System ID [1056] Level [R]

Fiscal Year Ended [06] [30] [80] Mode motorbus Code [1]

EMPLOYEE CLASSIFICATION	OPERATING LABOR
11. Transportation Executive, Professional and Supervisory Personnel	4.5
12. Transportation Support Personnel	2.5
13. Revenue Vehicle Operators	47.8
21. Maintenance Executive, Professional and Supervisory Personnel	2.3
22. Maintenance Support Personnel	--
23. Revenue Vehicle Maintenance Mechanics	5.6
24. Other Maintenance Mechanics	.5
25. Vehicle Servicing Personnel	2.6
31. General Administration Executive, Professional and Supervisory Personnel	1.0
32. General Administration Support Personnel	2.3
00. TOTAL TRANSIT SYSTEM EMPLOYEES	67.1

```
ID   FY       M EC OLABR
1056 19800630 1 11 4.5000
1056 19800630 1 12 2.5000
1056 19800630 1 13 47.800
1056 19800630 1 21 2.3000
1056 19800630 1 23 5.6000
1056 19800630 1 24 .50000
1056 19800630 1 25 2.6000
1056 19800630 1 31 1.0000
1056 19800630 1 32 2.3000
1056 19800630 1 00 67.100
```

ID=ID NUMBER
FY=FISCAL YR END DATE
M=MODE
EC=EMPLOYEE CODE
OLABR=OPERATING LABOR
(CAPITAL LABOR
VALUES OMITTED)

FIGURE 1 Correspondence between reporting system forms and logical and physical organization of TSC data files.

Implementing Reorganization

The main goals of reorganization are to supply stand-in values for missing records and to reformat instances in which several variables have been grouped together in one field. A hypothetical example of the results of reorganizing is shown in Figure 2.

There are several noteworthy features in Figure 2. First, in File 1 under the field System Identification, there is no information for system number 1003, and systems 1002 and 1004 appear to have only half the information they need.

Also in File 1, the field Wages can be seen to contain six different variables. The values in the fields Mode and Employee Category must be used to find these variables. For example, the first wage value, 500, has a mode of 1 and an employee category of 0. These values indicate that the first 500 is for motor bus drivers' wages. Hence, the only other value it can be compared with is wages of 650, six lines down in case 1002, which also has a mode of 1 and an employee category of 0. There are six wage variables possible because in addition to the mode and employee category combination of 1 and 0 there are also the combinations of 1 and 1 or 1 and 2, and so on. Because there are two values of mode and three values of employee category, it takes two times three, or six, combinations to exhaust all pairs possible.

The six variables each have their own separate field in File 2. The information in the mode and employee category fields from File 1 has been incorporated into the new logical organization of File 2. Therefore, they disappear from File 2. File 2 also has full sets of information (complete cases) for all transit system identifications, although missing value codes of 999 had to be inserted to make this possible. For example, even though system 1002 has no trolleybusses, stand-in values of 999 were inserted in the three trolleybus variables for this case.

In summary the basic reorganization steps can be reduced to four:

1. Using the logical organization in the TSC codebook, in which a case is not a transit system but a single record, read and write the data, eliminating unwanted information;
2. Locate the positions in the retained data needing stand-in values;
3. Insert the stand-in values; and
4. Format the data with a new logical organization that considers all the records belonging to a single transit system as a case. Once the stand-in values have been inserted, this number of records will be the same for all transit systems.

Working with the Tape

The objective of this section has been to explain the reasons for data reorganization and the steps that are necessary to accomplish this task. A technical manual has been prepared that explains some of these steps in more detail (7). The complexity of

DATA FILE 1. HIERARCHICAL ORGANIZATION

SYSTEM ID	MODE	EMPLOYEE CATEGORY	WAGES	
1001	1	0	500	
1001	1	1	600	
1001	1	2	600	
1001	2	0	400	
1001	2	1	700	MODE
1001	2	2	700	1 = MOTOR BUS
1002	1	0	650	2 = TROLLEY BUS
1002	1	1	600	
1002	1	2	700	EMPLOYEE CATEGORY
1004	2	0	700	0 = DRIVER
1004	2	1	000	1 = MAINTENANCE
1004	2	2	000	2 = ADMINISTRATION

DATA FILE 2. STATISTICAL ORGANIZATION

SYSTEM ID	MTRBUS DRIVER WAGES	MTRBUS MAINT WAGES	MTRBUS ADMIN WAGES	TRBUS DRIVER WAGES	TRBUS MAINT WAGES	TRBUS ADMIN WAGES
1001	500	600	600	400	700	700
1002	650	600	700	999	999	999
1003	999	999	999	999	999	999
1004	999	999	999	700	000	000

999 = MISSING VALUE CODE

FIGURE 2 Hypothetical data file before and after reorganization.

the task lies not in the nature of the problems so much as in the large amounts of data that must be manipulated and the number of steps required to carry out the manipulations. Some statistics concerning the data files make this clear.

In FY 1980 there were 62 data files. Twenty were text files containing labels and 42 were numerical data files. The files ranged in size from approximately 300 records to 22,000 records, and all 62 files combined required 775,000 words or 3,800,000 characters. For comparison, the printed annual report is made up of approximately 2,100,000 characters.

The large number of steps required to reorganize a file is quite surprising. The most complicated expense file contained 22,000 records and required the use of more than 75 temporary data files during the process of inserting more than 2,000 needed stand-in values.

DATA PREPARATION

Once the data have been reorganized, additional data preparation is required before analysis can commence. There are three phases to preparing the data: calculating basic variables, identifying and flagging missing information, and validating existing data.

The Section 15 database contains a wealth of information too detailed for many purposes. The data to be used for statistical analysis must be customized. The purpose of this report was a comparative analysis of motor-bus performance in terms of general concepts such as labor efficiency and utilization of service. Thus aggregation of many small pieces of information into more comprehensive variables that contain only information about the motor-bus mode and that are applicable to an entire year's operation was necessary.

The information about transit employees is a clear example of too much information that must be summarized into broader categories. Ten employee categories are reported--three in vehicle operations (i.e., supervisors, revenue vehicle operators, support), five in maintenance, and two in general administration. These 10 categories are further subdivided into capital labor and operating labor. For the purpose of this report it was necessary to know the number of vehicle operators, the number of maintenance employees, and the number of administrative employees. The first step in creating these variables was to add together operating and capital employees because there was no interest in this distinction. At this point, the number of revenue vehicle operators was ready for use. The number of maintenance employees was calculated by adding together the five categories of maintenance employees. The number of administrators was calculated by adding together the supervisory personnel in vehicle operations and maintenance to the two categories of administrative personnel.

Other variables that must undergo this aggregation process include the total number of accidents, total amount of subsidies, and the miles of roadway used on bus routes.

Estimating Annual Data

The data on service supplied by a transit agency and the service consumed by passengers must undergo a different kind of calculation before they can be used in a general analysis. Although the Section 15 reporting system requires that all financial data be reported for a complete fiscal year, information on service variables such as unlinked passenger trips and revenue vehicle hours is collected by a sampling procedure and reported for an average weekday, average Saturday, and average Sunday. This information must be combined with a formula that annualizes it so that it is comparable with the financial data. A formula was used that allowed for 253 weekdays, 53 Saturdays, 52 Sundays, and 7 holidays (also calculated as Sundays); each of these numbers was multiplied by the given values for average weekdays, Saturdays, and Sundays.

A series of calculations was also needed to disaggregate data so that they applied only to the motor-bus mode. Revenue and subsidy information is reported in the Section 15 system for entire transit systems, not by mode. In addition multimodal systems have the option of reporting expenses as joint expenses between modes, and a few systems report most of their expenses in this way. A series of weighting formulas were designed that allow assignment of revenues or joint expenses to specific modes. For example, a proportion of passenger revenue is assigned to the motor-bus mode by multiplying the system's total passenger revenues by the ratio of motor-bus passengers to total passengers. Although the resulting values are only estimates, they are better than the distortions caused by using overly large figures or dropping the multimodal systems (32 percent of the systems reporting in 1980) from the analysis.

Missing Data

The second phase of preparing data for analysis is detecting those cases that have missing data and that therefore must be eliminated from further analysis. A database prepared for statistical analysis will usually have a special symbol such as -9 that indicates that information is missing. However, the Section 15 data tape has no such special symbol, and the analyst must therefore insert one during the process of calculating the variables. The analyst is able to detect missing-data problems by considering the logical properties of specific variables, by comparing a variable to other information in the database, and by comparing the Section 15 data with other sources of information (including the analyst's own knowledge of transit systems).

For some variables, detecting missing data is straightforward and quite logical. For instance, a transit system that has zero operating expenses can readily be assumed to have a missing-data problem. But most variables require more judgment on the part of the analyst. It is possible for a transit system to have zero accidents for a given fiscal year, but the larger a system, the less likely it is that it will have no accidents. The analyst must examine other transit systems of similar size to the one reporting zero accidents to see whether zero is a possible number. A cross-year comparison of reported accidents gives the analyst further evidence on which to base a decision. For this report it was decided that any system with more than 10 revenue vehicles could not have zero accidents, and a missing-data symbol was inserted for these systems. Other systems were then judged individually, taking into account their peak vehicle size (a better measurement of size than the revenue vehicle fleet), their safety record in other years as reported in annual reports or reports to the American Public Transit Association (APTA) (9), and the performance of like-sized systems.

Some judgments about missing data involve making decisions about whether a concept is adequately measured by a combination of several different variables. For instance, vehicle maintenance can be sup-

plied by employees on the transit agency payroll or by contract with other organizations. Thus if a system reports zero maintenance employees, the analyst would expect to have zero maintenance wages reported but a substantial expenditure for services indicated under either the maintenance function or general administration. In the absence of wages and service expenses, a missing-data symbol would be used to indicate that maintenance expenses are missing.

For some other variables, the decision is more complex because a zero value can be a real value or it can be an indication of a problem. The example of total vehicle miles will make this clear. Total vehicle miles, as noted above, is constructed from three variables--average weekday miles, Saturday miles, and Sunday miles. If weekday miles are zero, it can be assumed that information is missing. However, many systems do not offer weekend service, so a zero for Saturday or Sunday miles might be real or might be an indication of a problem. Because this information is based on a time-consuming sampling procedure, there is a definite possibility that a transit system failed to collect this information and thus has a missing-data problem. The Section 15 data tape includes information about the service schedule of each system. Therefore, it is possible to determine whether a system offers Sunday service and whether it has a missing-data problem. This kind of cross-checking of variables is possible only with the data tape because the annual report does not carry information on service schedules.

The problem of missing data has received detailed attention because it is an inevitable problem with a database as complex as the one mandated by Section 15. More than 300 different systems must learn to interpret and fill out numerous forms, which range from 17 pages for a small, single-mode system to 90 pages for a large, multimodal system. Because 1980 was only the second year in which this information was reported, some systems were still in the process of instituting accounting systems compatible with Section 15 requirements. Although missing data will become less of a problem as transit systems become accustomed to the reporting requirements, there will always be new systems completing the forms for the first time. In 1980, 321 systems reported; in 1983, 414 systems are expected to report.

Missing data are not evenly distributed across variables or transit systems. In 1980 the most complete data available were for economic variables such as operating expenses and passenger revenue (see Table 3). The most incomplete information available was for passenger measures such as unlinked passenger trips and passenger miles.

The missing-data problem is particularly acute for small systems, those with fewer than 25 revenue vehicles. In 30 percent of these systems, information on passenger trips and in 6 percent information on expenses is missing. Although it is still possible to analyze the smaller systems, because more than one-third of all systems fall within this size category, generalizations to all small systems must be made cautiously.

The failure to identify missing values with a special symbol can greatly distort the results of a statistical analysis. If too many zeroes are allowed to remain in the data, the mean for a variable will be unrealistically low whereas the standard deviation will be too high or distorted. Unwarranted conclusions will also be drawn if care is not taken. For instance, it would look as though small systems carry many fewer passengers per peak vehicle because small systems are missing 30 percent of the data on this measure whereas the large systems are missing only 13 percent of the data.

TABLE 3 Distribution of Missing Data in Selected Transit Variables

Variable	Missing Values[a] (%)
Passenger revenue	0.7
Total operating expense	2.0
Total employees	2.6
Total vehicle miles	8.2
Unlinked passenger trips	18.1
Passenger miles	24.0

[a]Out of 304.

Data Validation

The final phase of data preparation consists of cross-checking the data for validity. Errors can enter the database in many ways--misinterpretation by a transit system of what number should be reported, miscalculation of totals, and keypunching errors as data are prepared for the computer. Four major methods were used to validate the data: recomputation of totals, comparisons of redundant information, comparisons of related information, and comparison with feasible value ranges. An example of each of these methods with specific variables will be given.

The total number of employees reported for each system was compared with the sum of the separate categories. In about 10 cases, the totals differed by more than could be accounted for by rounding errors. In most cases the differences were apparently caused by keypunching errors (e.g., reversal of digits) or simple miscalculations. For these cases, reported totals were replaced by the recalculated totals and cross-checks were made with the annual reports.

Much of the financial data are reported in several different places. For instance, the Revenue Summary Schedule (Form 201) summarizes the information on the Revenue Subsidiary Schedule (Form 203). Total operating expenses are also reported in two different places on the magnetic tape. A simple comparison of these numbers reveals differences and the correct number can often be identified by the other validation methods.

Different variables in the database are sometimes different measures of the same thing. For instance, employee counts and employee wages are two different measures of labor utilization. If a transit system has a large number of vehicle operators, it must have a proportionately large amount of vehicle operator wages. However, caution must be used in some of these comparisons. Maintenance-employee counts and maintenance wages are subdivided into distinct, noncomparable subgroups.

The final method of identifying mistakes is to look for values that lie outside an expected range for that specific variable. This method works best for measures that are combinations of two variables such as miles per hour or cost per passenger. Miles per hour (speed) has an expected range of about 5 miles per hour (dense urban areas) to 30 miles per hour (commuter service). If the values for any system fall outside this range or are in the wrong part of the range for the kind of service offered, there has probably been a mistake in its measure of either miles or hours.

A variable such as cost per passenger is a little more difficult to work with because inflation and difference in fiscal years cause the feasible range to change over time and the boundaries of a feasible range are indefinite. In this instance all cases

that lay more than three standard deviations from the mean as well as the largest and smallest cases were examined. Although some of these outliers had apparent, real causes, such as extremely long trip lengths, others were so different from the norm that they were obviously wrong. In these cases the correct values were sought in other parts of the database or in other sources. If a correction was impossible, incorrect values were designated as missing.

In the future many of these validation procedures will be incorporated into the preparation of the Section 15 data tape. Beginning with the 1981 data, totals and internal measures of validity were checked for each transit system by TSC. However, the last validation procedure outlined in the foregoing will remain a useful procedure for the next few years because it looks at a transit system in relation to other systems. TSC also compares a system to itself across years as another validity check. Although this was done for specific problems in this validation procedure, it was not done systematically.

UNIVARIATE PROPERTIES OF VARIABLES

To be useful for statistical analysis, a data set must meet the basic assumptions of the specific technique to be used. One common assumption is that a variable is normally distributed. Another common assumption is that the variances of two variables are equal. Tables 4 and 5 show a set of variables from the Section 15 database and the statistics that show whether they are normally distributed.

The most striking characteristic of the Section 15 data is the great variation of values for many variables. The major reason for this is the great range in size of transit systems. As the number of peak vehicles in Table 4 shows, transit systems can be small or large. Most other variables such as expenses or passenger trips will have correspondingly wide variation.

A normal distribution can be described in terms of a few characteristics. The mean is an average value for a variable. Most values will be quite close to the mean. In fact, 95 percent of the cases will be within 2 standard deviations larger or smaller than the mean. As the value of a variable gets farther from the mean, fewer cases will have that value. In addition there are just as many values larger than the mean than smaller in a normal distribution.

The skewness of the variable shows, relatively, how many of the cases are either larger or smaller than the mean. A normal distribution has a skewness of zero because there is no difference between the number of larger and smaller cases. The kurtosis shows, relatively, how many cases are closely bunched together. A normal kurtosis is also zero.

As Table 5 shows, the Section 15 variables vary greatly in terms of how normal they are. In fact, most common variables that describe aspects of a transit system--such as number of peak vehicles, operating expense, and unlinked passenger trips--deviate greatly from normality. The distributions of these variables are greatly skewed because many more systems fall below the mean than above it. The distributions have a high kurtosis because the small systems are quite similar to each other, whereas the large systems are more disparate.

Figure 3 shows this graphically. The solid line shows a normal distribution. The segmented line shows a typical transit-variable distribution. The high skewness of the distribution can be seen in the way most cases fall to the left of the mean. The high kurtosis can be seen in the way the transit variable's peak is higher than that of the normal distribution.

Although many statistical techniques can tolerate some departure from normality, this work has shown

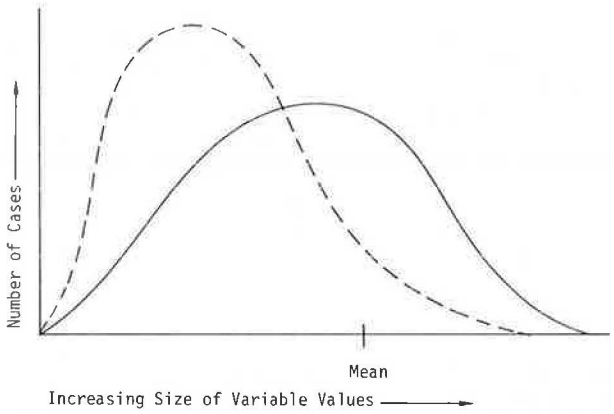

FIGURE 3 Comparison of normal distribution and distribution of nonnormal transit variable.

that the direct use of these variables produces meaningless results. For instance, a near-perfect regression correlation can be obtained between passenger revenue and unlinked passenger trips, but predictions are wrong by as much as 10,000 percent for small transit systems.

Table 5 also shows that the variances of different variables are quite different. Although transit systems show great variation in their size, this variation is exponentially increased in the variance measure. Thus great care must be used when variables are combined in statistical analyses. For some purposes, standardization will take care of variance problems. But for other purposes, the entire distribution must be transformed.

Because the departures from normality are a consequence of the great range in size of transit systems, any correction for size will make a more nor-

TABLE 4 Extreme Ranges of Typical Transit Variables

Variable	Mean	Standard Deviation	Range Min	Range Max
Unlinked passenger trips per dollar cost (000s)	1.35	0.57	0.203	3.55
No. of passengers per peak vehicle (000s)	95.70	51.80	10.290	360.00
No. of peak vehicles	124.70	316.40	1.000	3,378.00
Operating expense ($000s)	12,462.00	41,560.00	10.000	441,060.00
Unlinked passenger trips (000s)	22,118.00	88,655.00	10.000	1,139,560.00

TABLE 5 Comparison of Normal and Nonnormal Variables

Variable	Variance	Skewness	Kurtosis
Unlinked passenger trips per dollar cost (000s)[a]	0.32	0.81	1.27
Unlinked passenger trips per peak vehicle (000s)	2683.24	1.57	4.47
No. of peak vehicles	100,109.00	5.98	46.40
Operating expense ($000s)	1,727,233,600.00	7.80	76.75
Unlinked passenger trips (000s)[b]	7,859,709,000.00	9.42	105.68

[a] Most normal.
[b] Least normal.

mal distribution. The first variable in Tables 4 and 5, unlinked passenger trips per dollar cost, shows this effect in action. Large numbers of passengers and high expenses tend to go together, so the ratio of the two corrects for the largeness or smallness of a transit system. This ratio variable is more normal than either of the variables that were used to compute it. However, some ratios such as passengers per peak vehicle are less normal because the original variables were not equally distorted by the effects of size, as shown in the greater differences in their variance, skewness, and kurtosis.

Another technique that corrects for nonnormality is a logarithmic transformation of a variable. This transformation causes the outlying, large systems to be more proportionately scaled to the rest of the transit systems. Other methods for coping with the nonnormality can be devised, including elimination of large outliers and analysis with smaller peer groups of transit properties that are relatively homogeneous with respect to size. However, these methods reduce the sample size and potentially eliminate important variance in the data. The method chosen should depend on the goals of the statistical analysis.

SUMMARY

The Section 15 reporting system has created a rich, new source of data for analyzing the performance of the transit industry for both researchers and transit managers. For those who want a limited amount of information on a few systems, the published annual reports provide easy access to basic information. However, for those who wish to use large samples, information in great detail, or information reported at the A, B, or C levels, the magnetic data tape provided by TSC is the better source.

In this paper methods have been outlined for using the magnetic tape, including the reorganization of data for use with statistical software, calculating basic variables, identifying missing information, and validating the data values reported. In addition, some cautions are given for using the data because the pattern of missing data makes the existing data not perfectly representative of the transit industry and many of the data variables are not normally distributed.

In coming years, access to valid, reliable data on the transit industry will become increasingly available. Missing-data problems will decrease as the transit industry becomes familiar with the Section 15 reporting requirements. Beginning with the FY 1981 data, TSC has begun extensive validation checks. In addition, the data are being distributed in new ways. The same information that is reported in the printed annual report for 1981 is now available on diskettes for minicomputers. A magnetic data tape in a sequential format is also available for the 1981 data. Although this data tape reduces the 62-file structure into two files, it has the same formatting problems delineated in this paper.

Beginning with the FY 1983 data, TSC will be using a new operating system and will begin to explore new ways of distributing the data for specific purposes such as statistical analysis. However, analysts who wish to work with the first 4 years of data will need to reorganize and clean the data before beginning further analyses.

GLOSSARY

- Case: A statistical concept; the full collection of information items defined in a codebook for a single transit company; to be distinguished from a row or a record.
- Codebook: The scheme by which data are organized in sets of columns; the logical organization of a data file. A sample codebook appears in Table 2.
- Field: A set of columns reserved for one kind of information, to be distinguished from a column or a variable.
- Format: The imposition of a logical organization on a physical file; the act of communicating to the computer how data are defined.
- Hierarchical ordering: A data file organization scheme in which a field may contain more than one variable and missing records are permissible.
- Logical organization: The scheme contained in a codebook by which data are broken up into fields. There may be more than one meaningful logical organization for a given data file.
- Record: A formattable string of numbers; not to be confused with a case or row.
- Variable: A statistical concept; when all cases have been measured on a given attribute, the resulting collection of values organized into an ordered list.

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