prepared to take strikes to achieve gains in efficiency. But it should not be forgotten that unions also have a stake in preserving service for purposes of employment. To the extent that this can be communicated and fair exchanges negotiated, labor relations need not deteriorate.

1980s as Period of Change

The 1980s will bring considerable change and thus strain those transit agencies subject to a curtailment cycle. However, the change, by its very nature, will provide certain opportunities for reorganization. To the extent that this entails reassessment of goals and practices, this might be an occasion for renewal. The challenge to transit management lies not only in preserving a vital service to the public but in seizing the opportunities provided by these changes to rethink and reorganize the provision of a service that will better serve the interests of the public. Thought must be given to how the crisis might be used and not only survived.

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REFERENCES

1. Operating Statistics Report. American Public Transit Association, Washington, DC, 1980.
2. Catalog of Management Information System Applications. American Public Transit Association, Washington, DC, 1980.
3. Transit Actions: Techniques for Improving Productivity and Performance. Public Technology, Inc., Washington, DC, Oct. 1979.
4. A Directory of Regularly Scheduled, Fixed Route, Local Public Transportation Service in Urbanized Areas over 50 000 Population. U.S. Department of Transportation, Aug. 1980.
5. National Urban Mass Transportation Statistics: First Annual Report of Section 15 Reporting System. U.S. Department of Transportation, May 1981.
6. J.R. Meyer and J.A. Gomez-Ibanez. Improving Urban Mass Transit Productivity. Harvard Univ., Cambridge, MA, Feb. 1977.
7. J.L. Perry, H.L. Angle, and M.E. Pittel. The Impact of Labor-Management Relations on Productivity and Efficiency in Urban Mass Transit. Univ. of California, Irvine, March 1979. NTIS: PB294-721.
8. G. Smerk, S. Dodge, H. Gil, and C. Lee. Handbook for Management Performance Audits. Institute for Urban Transportation, Bloomington, IN, Oct. 1979.

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Design of Bus Transit Monitoring Programs

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A method is described for the design of a comprehensive, statistically based data-collection program that can support bus route planning and operations. A two-stage approach used in the design of the collection program is advocated. In the baseline phase, a detailed profile of each bus route is developed. This is followed by a monitoring phase in which limited data are collected to verify that the route profile developed in the baseline phase is still accurate. Both the desired accuracy and the inherent variability of the data items are considered in the design of the data-collection program. To reduce the overall cost of the data-collection program, consideration is given to the use of simple linear relationships between data items. The methodology discussed in this paper was developed under contract to the Urban Mass Transportation Administration and has been approved as meeting the Section 15 reporting requirements for passenger-related data.

In recent years, there has been a growing awareness of the need to use public transportation resources more efficiently (1). It has become more important to evaluate carefully all services, both current and planned. In response, many transit agencies, large and small, have developed on-going programs that use performance measures and standards to evaluate their transit services (2,3). Often, however, these evaluation programs have not been supported by adequate data-collection programs. Cost-effective programs are needed to provide the passenger-related performance data that are required for good service evaluation.

This paper describes a methodology for the design of a comprehensive, statistically based data-collection program that can support the service-evaluation process. This methodology was developed under contract to the Urban Mass Transportation Administration (UMTA). By using this methodology, most transit agencies will be able to develop and maintain comprehensive profiles on all their bus routes at a reasonable cost. Although the focus of the approach is route-level data collection, the approach also provides systemwide performance data (such as UMTA-required Section 15 data) through the aggregation of individual route data.

In this paper the overall approach to performance monitoring is described first, followed by a description of the data needed by transit agencies for short-range operations planning. The next two sections describe the available data-collection techniques and how they can be combined into a sampling plan. In the final section the costs of implementing such a program are discussed.

PROPOSED APPROACH TO DATA COLLECTION

The proposed approach consists of two distinct data-collection phases. In the first phase, or the baseline data-collection phase, the base conditions are defined by time of day for each bus route in the system. The base conditions include all the data needed for effective operations planning, including total boardings, loads at key points on the route, running times, revenues, origin-destination (O-D) data, and passenger characteristics. The baseline phase presents a snapshot of route performance at one point in time. Complete route profiles are developed from these data, which facilitate comparisons among routes in specific subareas, function types, or the system as a whole. Since the baseline phase includes the collection of all data items needed for service planning and evaluation, it also provides an excellent opportunity to analyze the potential for route improvements and reallocation of equipment.

In the monitoring phase of data collection, each route is checked periodically to verify that the base conditions (i.e., route profile) for the route are still valid. Only three data items are collected in this phase--bus arrival time, peak-point load, and passenger utilization. It is assumed that if neither peak-point load nor passenger utilization have changed significantly, the other data collected during the baseline phase (e.g., passenger origins and destinations and fare categories) have also not changed significantly.

Although the baseline and monitoring data-collection phases differ in the number of data items collected, the two data-collection phases are designed in the same way. Four important inputs are required:

1. A list of data required by the agency,
2. An estimate of the required accuracy for each data item of interest,
3. Key agency and route characteristics, and
4. Existing data or data obtained in a special pretest from which sample sizes can be determined.

The following sections discuss how each of these inputs is used in the data-collection design process.

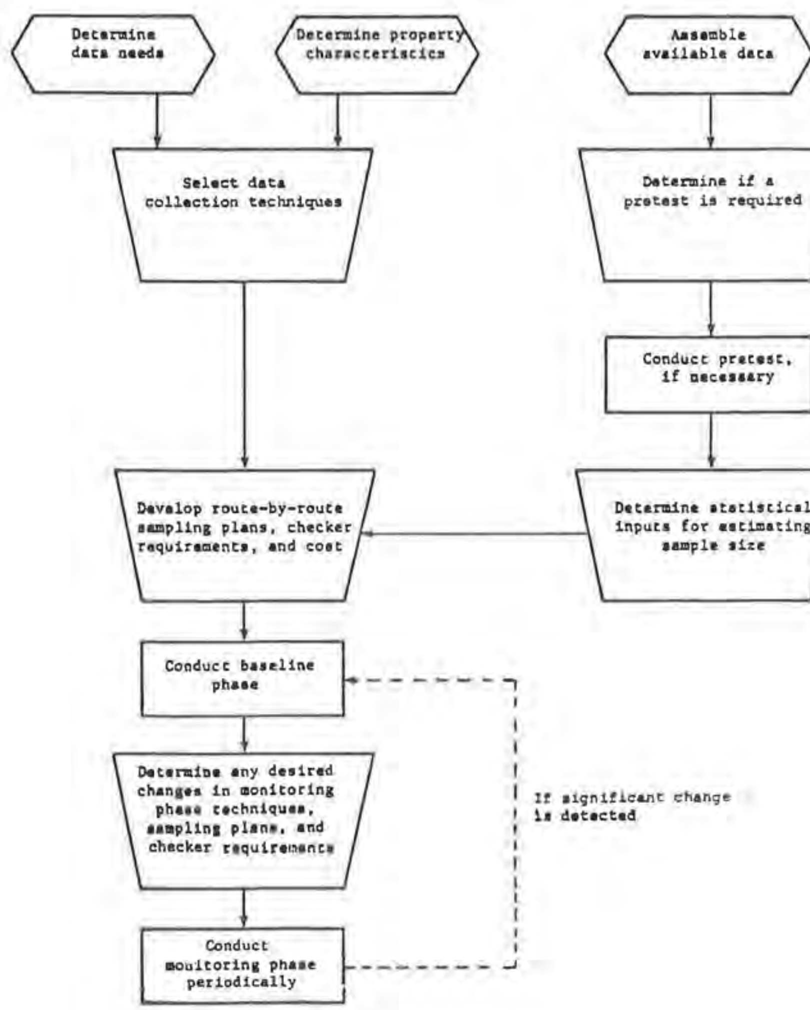
DATA NEEDS

The first step in the design of the data-collection program (Figure 1) is to specify the data required for planning and management activities and for external reporting. These data vary among transit agencies depending on the size and type of system operated, the specific management objectives, and the requirements for the external reporting.

To ascertain typical data needs of North American transit agencies, information from more than 100 bus transit agencies was examined. This included an analysis of the material collected from 71 transit agencies by the Massachusetts Bay Transportation Authority (MBTA) in Boston and the Tidewater Transportation District Commission (TTDC) in Norfolk, Virginia (2). These materials were supplemented by discussions with 41 other agencies that focused directly on the data desired by these agencies and the data-collection techniques currently employed (4).

Based on these efforts, a list of data items was developed that were used by or desired by a large number of transit agencies. Each data item listed

Figure 1. Data-collection program design and implementation.



was reported as being useful in one or more aspects of service management, including route planning, scheduling, marketing, cost reimbursement or deficit allocation, and external reporting.

1. Route- or stop-specific data:
    a. Load (peak or other) at specified points (not averaged throughout trip)
    b. Bus arrival time
    c. Total boardings (i.e., passenger trips)
    d. Revenue
    e. Boardings (or revenue) by fare category
    f. Passengers boarding and alighting by stop
    g. Transfer rates between routes
    h. Passenger characteristics and attitudes (age, handicap, sex, job status, attitudes toward level of service, income, automobile ownership, automobile availability, home location)
    i. Passenger travel patterns [origins and destinations, work and/or school trip location, time of day of work or (school) trip, work (school) trip mode, nonwork (school) travel patterns, trip frequency]
2. Systemwide data:
    a. Unlinked passenger trips
    b. Passenger miles
    c. Average unlinked passenger travel time
    d. Linked passenger trips

Although this list is comprehensive, not all the data items must be collected at the same frequency. The proposed methodology ensures that each data item is collected systematically but not necessarily at the same frequency. The following sections discuss data items requiring frequent monitoring and other data that are only collected during the initial baseline phase.

Data Needs in Baseline Phase

To develop comprehensive information on route performance in the baseline phase, all the items listed above are collected. The collection of these data permits direct comparisons among routes and the analysis of alternative service plans, including schedule modifications, route restructuring, and reallocation of vehicles.

With the data collected in the baseline phase, a comprehensive profile such as that shown below can be developed for each route:

1. General-effectiveness data:
    a. Boardings per trip per day
    b. Revenue per trip per day
    c. Maximum load per trip
    d. Running time by route segment
    e. Difference between scheduled and actual arrival times
2. Data for specialized analyses:
    f. Distribution of boardings and revenue by fare category
    g. Transfer rates per day
    h. Passengers boarding and alighting by stop per trip
    i. Average unlinked trip length per passenger
    j. Average unlinked trip travel time per passenger
    k. Passenger miles per day
    l. Passenger characteristics and attitudes
    m. Passenger travel patterns
3. Data-collection design items:
    n. Relationship between boardings and revenue per trip
    o. Relationship between boardings and maximum load per trip

For items a to e, an operator is generally interested in the mean value and in the variation within each time period and from day to day. These five items are generally used for operations planning and scheduling, which includes the development of performance measures for each route. Items f to m provide more-specialized information, which is used for detailed route, subarea, or system planning (e.g., evaluation of through routing, branching, short turning, and limited or express services) as well as for studies of the agency's fare structure and related policies.

Finally, items n and o provide information on the relationships between specific data items that may be closely linked. These relationships can be thought of as "conversion factors" that may allow an operator to estimate one data item by directly measuring another, thus reducing the cost of monitoring a route. The data collected in the baseline phase allow an agency to test these relationships for each route. If the statistical relationship is shown to be strong enough, the conversion factor can be used during the monitoring phase. For example, a strong relationship may be found between total boardings and peak-load counts. If this is true, then total boardings could be estimated from peak-load counts during the monitoring phase and would not have to be directly collected.

Data Needs in Monitoring Phase

Once a route profile is established during the baseline phase, an operator regularly monitors each route for significant changes. To do this at reasonable cost, a subset of the data listed above has been selected for periodic monitoring. The following three basic data items are used to track individual route performance: bus arrival time, peak-point load, and one of the following--total boardings, boardings by fare category, or revenue.

Bus arrival time must be collected periodically by all agencies to ensure efficient scheduling and reliable service. Usually this information is collected in conjunction with load or boarding counts. Load data are needed to determine appropriate service frequencies. Total boardings, boardings by fare category, and revenue are alternative measures of the utilization of the route. The choice of which utilization data items to monitor depends on the cost and feasibility of different data-collection techniques. Certain data-collection techniques yield two or more of these items at the same time, so that the agency may be able to monitor directly a greater number of route utilization measures.

This approach to monitoring is based on an assumption that if neither peak load nor total route utilization changes significantly from the baseline, neither do any of the other data items collected in the baseline phase. Passenger on/off counts, characteristics, attitudes, O-D patterns, transfers, and some of the systemwide data required for Section 15 reports are all indirectly monitored through the collection of load and utilization data. If significant changes are observed in an individual route during the monitoring phase, another baseline phase must be conducted to revise the route profile.

The accuracy with which the data items should be measured and the extent of change observed in the monitoring phase that triggers a new baseline phase are two important areas in the design of the baseline and monitoring phases. These topics are addressed in a subsequent section of this paper on sampling. First, however, data-collection techniques must be discussed.

DATA-COLLECTION TECHNIQUES

A large number of data-collection techniques are currently used by transit agencies. The seven principal techniques used by most agencies are shown below:

Technique	Description
Ride check	Check taken on board vehicle to record the number of passengers boarding and alighting at each stop and the bus arrival time at selected points;
Point check	Check taken from street to estimate passengers on board vehicle and record vehicle arrival time; peak-load count taken at peak-load point; multiple point checks include several points along route;
Boarding count	On-board count of total number of passengers boarding, most often broken down by fare category;
Farebox reading	Recording of farebox registered reading at selected points; requires registering fareboxes;
Revenue count	Count of revenue in farebox vault by bus;
Transfer count	Count of transfer tickets collected on each bus, which may involve specially issued transfer tickets; and
Survey	Variety of techniques in which passengers are asked to provide information.

Some of these techniques are known by different names. For example, ride checks are also known as on-off checks and characteristic counts; point checks are often called standing checks or load checks. For consistency, the terms used in the above list are used throughout this paper.

The seven principal data-collection techniques provide a range of different data items depending on individual agency and route characteristics (Table 1). Together the seven techniques collect all the data needed for the baseline phase.

Ride checks provide the most complete data, especially if boarding passengers can be recorded by fare category. All the data items except transfer rates, passenger characteristics, travel patterns, and attitudes can be collected through ride checks. Ride checks, like boarding counts and farebox readings, provide reliable and complete data when performed by traffic checkers. If drivers are used to collect the data, experience in the transit industry suggests that the results may be less reliable, since data collection is secondary to the primary responsibility of operating the vehicle.

Point checks provide more-limited data. Multiple point checks (on the same route) increase the usefulness of this technique by providing information at more than just the peak-load point, especially on longer routes that serve more than one activity center. The utility of point checks may decrease somewhat, however, as buses with tinted windows become more common, since estimation of passenger loads is more difficult.

Passenger surveys also provide a wide range of data. Passenger surveys are the only method in which information on passenger characteristics, travel patterns, and attitudes can be collected. Passenger surveys should be used with great care since it is often difficult to ensure that the results will be accurate and unbiased. Because of this potential problem, surveys generally should not be used to obtain data items that can be observed directly by using alternative techniques.

Revenue boarding counts, farebox readings, and transfer counts provide information on a limited number of data items. Their use is very dependent on the operating characteristics of the transit agency.

To collect the required set of data items for the baseline phase, a combination of techniques must be used. The best combination of techniques depends on a number of factors including route structure, individual route characteristics, and operating policies.

The route structure of an agency can influence the relative desirability of using point and ride checks to collect load data. A radial route structure is likely to have routes with a single maximum-load point. Often the maximum-load points coincide (e.g., at points near the downtown area) with others. This enables a single checker to collect data on several routes. This is obviously more efficient than doing ride checks on every bus where one checker per bus is required. Grid systems, on the other hand, are less likely to have routes with single maximum-load points and may require multiple point checks. In this case, it may require fewer checkers to do rechecks than to do point checks.

The relative cost of the different techniques also depends on the number of buses on a route. To collect load data, the point check is usually the best technique when the number of buses on a route is large. The ride check is the best technique when the number of buses is small, since additional information besides load data can be collected.

The level of patronage is also an important factor when selecting techniques. As patronage on a route increases, boarding and ride checks may also become more difficult to perform reliably. This is particularly true for ride checks if they are used to measure ridership by fare category, since boarding passengers must be counted and recorded by fare category. Although this may be possible on a lightly patronized route, it is much more difficult and subject to greater error on a high-ridership route. Nonetheless, it is often better to perform ride checks to obtain detailed boarding and alighting data for heavily used routes, since scheduling and dispatching strategies such as turnbacks and branching can often improve the efficiency of such routes.

The operating policies of an agency directly influence the feasibility of certain data-collection techniques. For example, agencies that do not issue transfer tickets (i.e., have no free or reduced-fare transfers) have no easy mechanism to count route-to-route transfers. These agencies either may have to rely on a passenger survey to determine transfer rates or may conduct a special transfer survey.

There are two operating characteristics that effectively constrain the set of appropriate combinations of techniques to a small number. The first characteristic is the ability of vehicle operators to record reliable data. Where drivers can collect reliable data, the cost of a data-collection program can be dramatically reduced. Even though checker requirements are reduced, the reduced cost must be weighed against the possible reduced accuracy of the data obtained by drivers. Information obtained by drivers may be less accurate than that collected by checkers, since the drivers' primary responsibility is to operate the bus safely.

The second operating characteristic is the availability of registering fareboxes. Registering fareboxes allow a driver, on-board checker, or even a street checker to monitor route revenue and, often indirectly, total ridership. Regular farebox readings can often provide accurate route revenue fig-

Table 1. Data items obtained from principal techniques.

Data Item	Technique Used[a] Point Check	Ride Check	Boarding Count	Farebox Reading	Revenue Count	Transfer Count	Survey[b]
Load (peak or other)	X	X					
Bus arrival time	X	X	X[c]	X[c]			
Passenger trips	X[d]	X	X	X[e]			X[f]
Revenue		X[g]	X[g]	X[h]	X		X
Passenger trips (or revenue) by fare category		X[g]	X[g]	X[e]			X
Passengers on-off by stop		X					X
Transfer rates						X[i]	X
Passenger characteristics, travel patterns, and attitudes							X
Unlinked trips		X	X	X[c]			X[f]
Passenger miles		X					X
Unlinked-trip travel time		X					X
Linked trips		X[i]	X[i]				X

Note: X = applicable, blank = not applicable.

[a] Techniques as defined in text.
[b] For all survey-collected data other than total passengers, the quality of the data depends on the representativeness of the response.
[c] If time can be recorded.
[d] For pure feeder and express routes only.
[e] If electronic multiple fare registering boxes are available.
[f] If surveys are numbered consecutively and distributed to all passengers.
[g] If boarding passengers are recorded by fare category. This typically can only be done with riding checks if boardings are relatively low.
[h] If revenue can be counted by route, this can be substituted for farebox readings although time-of-day data are sacrificed.
[i] If transfer tickets are distributed, collected on terminating route, and identifiable by initial (and intermediate) route(s).

ures that can be used as a check on total ridership figures generated by driver trip sheets.

Several options for combining data-collection techniques were developed for transit systems with specific characteristics. While these recommendations generally provide the necessary baseline data at the lowest cost, specific local characteristics may make other combinations more desirable. Thus, the following recommendations and discussion were developed as guidance to be used by a property to select its own combination of techniques.

For the initial baseline data-collection phase, the following set of techniques is recommended:

1. Ride checks (possibly plus supplementary point checks),
2. Farebox readings or boarding checks, and
3. On-board surveys.

The ride check is included in the baseline phase in order to obtain boardings and alightings by stop, which can be used to estimate average loads on each route segment. Supplementary point checks are needed only when the number of trips to be sampled to assess load accurately exceeds that required to collect total-boarding data. (The calculation of the number of trips to be sampled is discussed in the next section.) Supplementary point checks are recommended in this situation because it is less costly to gather additional peak-load data by using a single point checker than by using on-board checkers.

Farebox readings or boarding checks provide complete route revenue information, although only the latter breaks down ridership and revenue by fare category. For this reason, boarding counts probably should be included by any agency that can reliably use operators to perform such counts. Finally, the on-board survey collects a variety of passenger information that cannot be obtained in any other way.

The recommended techniques for the on-going monitoring phase depend more heavily on agency and route characteristics. If an agency can use drivers to collect total boardings, the following combination of techniques is recommended:

1. Point checks,
2. Boarding counts (by operator), and
3. Farebox readings (if registering fareboxes are available).

Agencies that cannot depend on drivers to collect reliable data have several options. The best combination often includes direct monitoring of peak load, total boardings, and farebox revenue through ride checks (possibly plus supplementary point checks) and farebox readings (if registering fareboxes are available).

However, for routes that exhibit a strong baseline relationship between either peak load or revenue and total boardings, route performance can be monitored simply by using point checks. In this option, a street checker at the maximum-load point records passenger loadings and, if recording fareboxes are available, boards each bus and records the farebox readings. Although using either a load or revenue conversion factor to estimate total boardings requires a larger number of trips to be sampled than does measuring load or revenue alone, often the overall expense of this option is less since on-board checkers are not required in the monitoring phase. The key to using this option is the test of the relationship between the data items, which is described in the following section.

SAMPLING

Once the techniques have been selected, the sampling plan can be designed to incorporate the amount of data to be collected and the timing of the data collection. A sampling plan reflects two factors: the desired accuracy and the inherent variability of the data. As either one or both of these factors increases, so does the amount of data that must be collected.

The data-collection design manual (5) that was the product of this research details the procedures required to determine the desired accuracy and measures of inherent data variability. By using these, step-by-step procedures are presented to determine a sampling plan for any data item and for both observational and survey collection methods. The manual provides procedures for transit operations to apply actual sample-size formulas or to use a set of easy-reference sample-size tables that are included as Volume 2 of the manual (6). Because these procedures and the associated formulas are quite detailed and require substantial explanation, they will not be discussed further here. For further information, readers are referred to the Bus Transit Monitoring Manual (5,6).

USE OF CONVERSION FACTORS

Conversion factors can be used to reduce the total resources required for data collection in the ongoing monitoring phase. Conversion factors are most useful for estimating data items that are important but expensive to measure directly. The primary examples are the estimation of total boardings per trip from either peak-load counts or farebox readings.

To test whether conversion factors are feasible, regression is used to estimate the best linear relationship between x, the independent variable (typically either peak load or revenue), and y, the dependent variable (typically total boardings), for the baseline data, separately for each route and time period. The variance associated with the resulting equation can then be used to define a confidence interval around the mean value of the dependent variable (e.g., total boardings). This confidence interval specifies the range of uncertainty associated with using the equation to estimate the value of y at a given value of x. If this confidence interval is larger than the accuracy desired for y (and thus less accurate), the equation cannot be used. It is then necessary to collect y directly rather than to estimate it. On the other hand, if the confidence interval is small compared with the accuracy desired for y (and thus more accurate), the equation is a satisfactory basis for estimating y.

Detailed formulas for estimating sampling requirements associated with using conversion factors are outlined in the data-collection design manual (5). The resulting sampling plan may or may not be less expensive than that developed for directly monitoring boardings per trip. However, results of field tests by using this approach in Chicago indicate that, for many routes, monitoring by using conversion factors is likely to be less costly than directly counting boardings (7).

SEASONAL CONSIDERATIONS

The timing of the baseline and monitoring data-collection phases raises the general question of how to deal with seasonal variation. Initially the baseline phase could be conducted during any season. For at least one year after the baseline phase, however, the monitoring should be conducted in each period of the year for which scheduling changes are made. If schedule changes are not normally made during the year (as in many small agencies), it is suggested that all routes be monitored during two seasons (one when schools are in session and one when they are not in session) during the first year.

This procedure allows the transit agency to determine the extent of route-level seasonal variation as well as to identify routes that exhibit significant ridership growth or shrinkage. Some simple rules of thumb were developed to determine whether measured ridership changes over the first year of monitoring indicate significant seasonal variation or an overall change in ridership:

1. If total boardings on a route changes by more than 25 percent over that first full year of monitoring (i.e., when comparing the baseline phase figure to a monitoring phase measurement during the same season one year later), an overall trend is assumed and a new baseline is taken on that route; and

2. If total boardings on a route do not change by more than 25 percent over the first full year of monitoring but do change (from the baseline phase) by more than 25 percent during any intervening season during the first year, seasonal variation is assumed.

Significant seasonal variation is important from two perspectives. First, it identifies those seasons during which the monitoring phase should be conducted. Second, for those routes for which an agency wishes to use conversion factors to decrease the cost of ongoing monitoring, it identifies those seasons for which separate conversion factors should be developed.

The selection of 25 percent as the value for a significant change is based on limited data analysis and professional judgment. As more knowledge is gained on the behavior of individual bus routes, a different value may be found more appropriate.

After the first year, the frequency of monitoring depends on the identified variability of the data items. At a minimum, however, the monitoring phases should be conducted during the season of the most recent baseline phase and any season showing a significant variation.

A new baseline phase should be conducted when it is probable that the baseline data are no longer valid. This could occur under two situations. First, when a significant change (e.g., ±25 percent) is observed in ridership or revenue through the monitoring process, a new baseline phase is required. Second, if a significant change is made to the route alignment or to the fare level and structure, there is reason to believe that conditions have changed and a baseline phase is needed.

SECTION 15 DATA REQUIREMENTS

The data-collection approach proposed here has been judged by UMTA to meet the reporting requirements for the Section 15 Transit Service Consumed Schedule (8). This schedule covers unlinked passenger trips, passenger miles, and average unlinked passenger trip time for specified periods of an average week.

If the monitoring phase of the data-collection program is based on ride checks, all data items required for Section 15 are measured directly. The accuracy of the systemwide statistics is based on the adequacy of the sample size and the acceptability of the sampling plan. It has been shown (4) that for systems with 10 or more routes, the suggested route-level 90 percent confidence interval of ±15 percent is consistent generally with the required Section 15 systemwide 95 percent confidence interval of ±10 percent. For smaller systems, it may be necessary to reduce the route-level tolerance to ±10 percent to achieve the desired systemwide accuracy.

The effect of seasonal variation on Section 15 data derived by using route-level data is assumed to be minimal as long as the following conditions are met:

1. The agency follows the suggested procedure of monitoring every route during each schedule period (or at least twice) for one year following the baseline phase to determine whether significant seasonal variation exists; if seasonal variation is indicated, the agency continues to monitor during the baseline season as well as in all seasons that exhibited a 25 percent change in total boardings; and

2. The route-level monitoring activity is spread throughout the year so that routes that are monitored only once a year (i.e., show no significant seasonal variation) are monitored randomly.

As discussed earlier, care is taken to ensure that the set of days to be sampled is selected randomly from all weekdays in the season. Similarly, the trips to be checked on a selected day are selected randomly from all trips operated during the period of interest.

One problem in complying with Section 15 is the estimation of weekend statistics for the annual systemwide reports. Passengers, passenger miles, and passenger trip times generally will be quite different from the weekday figures. They also contribute much less to annual systemwide figures. There is no evidence to suggest that significant seasonal variation occurs for weekend performance compared with normal between-day variation. Routes on weekends are therefore treated as operating over a single year-long season, with Saturdays and Sundays of course treated separately. Either of the following two methods was found by UMTA to be acceptable for estimating Section 15 data for weekends:

1. Sampling 75 percent of all trips on at least one randomly selected Saturday and one randomly selected Sunday for each route in the system; or
2. Random selection of 260 total trips (or 3 trips/day) from all Saturday and Sunday trips operated systemwide during the year (the existing Section 15 sampling requirements for weekends).

Ride checks are required in either method to produce the desired Section 15 data for weekends. Also in both approaches, holidays are classified on the basis of the type of bus schedule operated as a weekday, Saturday, or Sunday and are included in the appropriate population for sampling. The differences in the two methods are cost and information obtained. While the second method is less costly, the first method provides substantially more information to transit planners and managers.

Another issue related to Section 15 reporting is the use of conversion factors. An analysis of numerous bus routes in Chicago and other cities suggests that average passenger trip length and average time per passenger trip on a specific route are quite stable over long periods of time (7). This is true as long as neither the service provided on the route nor the route ridership changes substantially (i.e., by more than 25 percent). This indicates that stable conversion factors can be developed relating total boardings, peak load, or trip revenue to passenger miles, as described earlier in this paper. UMTA has judged that the use of these conversion factors is acceptable for making Section 15 reports (6).

COST OF MONITORING PROGRAM

Cost is likely to be a manager's first concern when considering a data-collection program such as the one proposed in this paper. Although costs may vary widely depending on specific agency characteristics, a simple procedure is used to estimate costs for a given agency.

By far the most costly component of the program is the manpower needed to collect data on board buses or from the street. The translation of route-by-route sampling plans into total checker requirements begins with the sample size required for each data-collection technique selected. The following calculation is used to determine checker requirements based on the sample sizes required for load and total boardings for each route and on the selected techniques for each data-collection phase:

Checkers required for each time period = {[days sampled(load)] x (number of points)} + {[days sampled(boardings)] x [(sampled trips)/(total trips)] x (number of buses)}.

The terms of the calculation vary depending on the data-collection techniques used and the sample sizes required. It is appropriate for (a) sampling plans that require load data only at a number of points on a route, (b) sampling plans based on boarding data obtained by using a ride check, and in many cases (c) a combination of (a) and (b) when both point and ride checks are required.

By using an individual agency's policies and work rules, the individual time period checker requirements estimated by this calculation are transformed into checker assignments. If a point check is included for a number of routes, the total checker assignments are adjusted to account for the possibility that several routes might be counted by one checker.

Based on information from Chicago and other agencies, the range of checker resources required for typical bus system sizes was estimated by using average values for data variability, desired accuracy, and route characteristics. The full-time traffic checker staff requirements shown below are based on monitoring every route in the system four times a year. Generally, the low end of the range represents cases in which reliable operator data are available; the upper end of the range represents cases in which drivers do not collect data. The range also reflects differences in agency and route characteristics that directly affect required sample sizes and therefore total checker requirements.

No. of Peak Buses	No. of Off-Peak Buses	Avg Daily Service Hours	No. of Traffic Checkers Required
25	22	12	0.5-1
50	40	12	1-2
100	70	14	1.5-4
300	215	15	3-7
500	250	16	6-13
750	470	17	8-15
1000	600	18	10-19
2000	1100	19	20-38

Staff requirements for the baseline data-collection phase for most agencies fall near the upper end of the indicated ranges. In addition for the baseline phase, the cost of an on-board passenger survey on all routes must be added to the staff requirements given above.

In addition to the traffic checker cost, there are other costs associated with the program including program planning, data reduction, and data processing. It is very difficult to estimate the ranges of these costs, because of major differences among agencies. To minimize program planning costs, a data-collection program design manual was prepared in the development of this methodology. The manual includes detailed step-by-step procedures and sample-size tables (5,6,9). In Chicago, a draft version of this manual was successfully tested and used to design a data-collection program (7).

Data-processing costs depend on the amount of data collected and the availability of computer support and staffing for the technical analysis. In view of the wide range of possibilities, no attempt was made to present costs for this aspect of the program.

SUMMARY

This paper has presented a systematic, statistically based approach to data collection in the bus transit industry. A two-phase strategy is suggested: a baseline phase to produce detailed profiles of each service operated and a monitoring phase to verify that the baseline conditions are still valid. Basic statistical formulas are used in the design of the data-collection program.

A manual incorporating a step-by-step procedure for program design has been produced. With the existence of this manual, the real test will begin--in a climate of fiscal austerity will the transit industry see the justification for spending enough money to get the reliable information necessary to make better decisions?

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REFERENCES

1. G.J. Fielding, R.E. Glautheir, and C.A. Lave. Performance Indicators for Transit Management. Transportation, Vol. 7, 1978, pp. 365-379.
2. J.P. Attanucci, L. Jaeger, and J. Becker. Bus Service Evaluation Procedures: A Review. UMTA, Rept. UMTA-MA-09-7001-79-1, April 1979. NTIS: PB79-296314.
3. Urban Public Transport: Evaluation of Performance. OECD Road Research, Organization for Economic Cooperation and Development, Paris, Oct. 1980.
4. M. Flusberg, J. Kruger, and J. Curry. Bus Transit Monitoring Study: Data Requirements and Collection Techniques. UMTA, April 1979. NTIS: PB80-0161409.
5. J.P. Attanucci, I. Burns, and N. Wilson. Bus Transit Monitoring Manual: Volume 1--Data Collection Design. UMTA, Rept. UMTA-IT-09-9008-81-1, Aug. 1981. NTIS: PB82-122227.
6. J.P. Attanucci, I. Burns, and N. Wilson. Bus Transit Monitoring Manual: Volume 2--Sample Size Tables. UMTA, Rept. UMTA-IT-09-9008-81-2, Aug. 1981. NTIS: PB82-122235.
7. J.P. Attanucci, I. Burns, and N. Wilson. Bus Transit Monitoring Study: Chicago Data Collection Trial. UMTA, Interim Rept. 4, March 1981.
8. Sampling Procedures for Obtaining Fixed-Route Bus System Operating Data Required Under the Section 15 Reporting System. UMTA Circular, Feb. 1978.
9. L. Kish. Survey Sampling. Wiley, New York, 1967.

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Performance-Based Funding-Allocation Guidelines for Transit Operators in Los Angeles County

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During the last five years, transit performance indicators have been widely used in the transit industry. California and New York have used performance indicators to determine eligibility for funding. In Pennsylvania, transit performance measures have been used to provide incentive payments for superior performance, and in Michigan a detailed analysis of transit operations provides the basis for state managerial assistance. In Los Angeles County, nine transit operators, including Southern California Rapid Transit District, provide fixed-route transit service. Between 1977 and 1980, operating cost per vehicle hour increased from $28.52 to $38.76, a rate higher than the consumer price index for the Los Angeles area. In response to state legislation designed to maximize utilization of public subsidies for transit, the Los Angeles County Transportation Commission undertook the development of performance-based guidelines for allocating transit subsidies. The performance guidelines developed in cooperation with the local transit operators are presented here. In this program, service is classified into local and express categories. Seven indicators were chosen to monitor transit performance on a periodic basis. Three indicators were selected to establish standards to be achieved by all fixed-route service operators in Los Angeles County. Compliance with these standards will determine eligibility for discretionary funds (representing 5 percent of operating assistance) in the future. The methodology for quantifying loss of subsidy funds if an operator falls below the established standards is also described. The performance guidelines merit consideration for two reasons. First, they represent an attempt by a large metropolitan area to control transit costs, and second they initiate performance-based funding allocation rather than funding based on demographic characteristics or operating deficits. Both reasons are substantial advancements in the theory and application of performance-based guidelines to transit-financing issues.

A complex institutional structure supplies transit in Los Angeles (1). Thirteen operators provide transit service. Nine of these are fixed-route providers and the remaining are demand-responsive. Only the Southern California Rapid Transit District (SCRTD) is an independent agency. The others are municipal operators. Programming of state and federal funds is controlled by the Los Angeles County Transportation Commission (LACTC). Short-range transportation planning is sponsored by the Commission and long-range planning by the Southern California Association of Governments (SCAG).

The nine public transit operators providing fixed-route transit service in Los Angeles County operate 2287 vehicles in the peak period and 370 700 miles of service on an average weekday (Table 1). SCRTD, an independent agency created by the State of California, is by far the largest, operating 87 percent of the average weekday miles of service and carrying 88 percent of the total public transit ridership.

The other eight transit systems in Los Angeles County are governed by municipalities in the county. Together they provide the remaining 13 percent of service and carry 12 percent of ridership on an average weekday. None of the operators in the county, including SCRTD, have dedicated local sources of funding except for those state and federal funds that pass through LACTC. However, SCRTD and municipal operators can obtain funding from local sources at the discretion of county and municipal governments.

The total operating cost of average weekday fixed-route transit service in Los Angeles County is $885 960. The passenger revenue recovers about 39 percent of the operating cost on a countywide basis. The shortfall between operating cost and