• Monitor project implementation and the achievement of scheduled efficiencies and
• Develop better cost and schedule estimations for future project proposals.

The procedure improves the likelihood of authorization for proposals that change standard operating procedures, staffing levels, and job responsibilities. The procedure was conceived with direct input from the line managers, finance, and top management and recognizes that they are the users and beneficiaries of the procedure and its results. A user's manual and microcomputer program were developed for applying value analysis as a result of the study.

The value analysis procedure has been adopted by the LT-Rail engineering departments and is currently in use. The procedure has been successfully implemented, and productivity tasks evaluated using the technique are now in the implementation phase. The standardized value analysis procedure is contributing to more effective communications between staff engineers, finance, and top management. It is still too early to compare actual-to-anticipated savings estimated using the technique, but this should be known in the coming year as projects are implemented and monitored at LT.

CONCLUSIONS

Although the value analysis methodology for developing, analyzing, and reviewing productivity alternatives was devised to meet the specific needs of London Transport-Rail, it offers broad applications to transit operators in the United States. The impetus for developing a program of continued productivity improvements is apparent in both nations. Use of a standard productivity development, analysis, and review procedure offers transit agencies several key advantages:

• Ideas for improving productivity can be generated by line staff, clerical personnel, supervisors, or managers in any discipline and still be compared and analyzed on a consistent basis.
• Interaction and early communications with others encourage wider development of productivity alternatives and identification of different implementation strategies. Further, soliciting involvement of other interested parties may broaden support for productivity projects.
• Use of an uncomplicated analysis technique, like the one presented in this paper, takes the mystery out of financial analysis and the time value of money.
• Net present value can be used to compare productivity options that require varying degrees of investment of funds and energy and provide different returns over incongruous time periods on an equitable basis.
• The results of the value analysis provide a sound basis for decision making and define a plan for monitoring implementation and achievement of cost savings.

The value analysis technique, as presented herein, would require some minor revisions for application at other agencies. The primary areas of modification are the reviewing groups, the minimum threshold for a detailed value analysis, and decision-making authority. The sequential development and review process and the two-level net present value technique remain valid for practical application anywhere. Development of a productivity program, such as LT's value analysis, is a major step toward making efficiency improvements a keystone in the transit operating environment.

Improving Section 15 Passenger Data Collection Techniques

ROBERT L. SMITH, Jr.

ABSTRACT

The Urban Mass Transportation Administration requires all transit systems that receive federal funds to collect basic data on transit ridership. The transit systems are required annually to furnish estimates of systemwide passengers, passenger-miles, and, until recently, passenger-minutes under the Urban Mass Transportation Act Section 15 reporting requirements. Many transit operators have complained that the collection of Section 15 passenger data is an unwarranted burden. Modern statistical sampling techniques, however, provide the opportunity for somewhat reducing the effort required by Section 15. The specific objectives of this study were (a) to identify the range of techniques used by large transit properties to collect Section 15 passenger data and (b) to identify and evaluate improved techniques for collecting Section 15 data. A review of the literature showed little application of statistical sampling techniques to bus passenger data collection until 1977. Two recent statistical approaches that are relevant to Section 15 data collection are reviewed. An inventory of 58 transit systems in the United States with 100 or more peak-hour buses showed four main Section 15 data collection techniques: (a) standard Wells random sample, (b) sample from extensive ride checks, (c) two-stage estimation, and (d) extensive ride checks. One or more case study transit systems were selected for each technique. Statistical sampling theory was applied to develop alternative sampling plans and estimation procedures. The analysis showed substantial potential for improvements in accuracy or reductions in data collection costs, or both.

The Urban Mass Transportation Administration (UMTA) requires all transit systems that receive federal funds to collect basic data on transit ridership. The transit systems are required annually to furnish estimates of systemwide passengers, passenger-miles, and, until recently, passenger-minutes under the Section 15 reporting requirements. The procedure recommended by UMTA for collecting the ridership data is to conduct ride checks (on/off counts) on three randomly selected one-way trips every other day. The recommended procedure is designed to achieve a precision of 10 percent for a 95 percent confidence interval. Other statistical sampling plans are acceptable as long as the required level of accuracy is achieved.

Since the introduction of the Section 15 reporting requirements in 1978, many transit operators have complained that the collection of the Section 15 passenger data is an unwarranted burden. Some operators assert that ride-check data are not at all useful to them, and others argue that the random sample obtained under Section 15 is too small and scattered to be useful for operational planning. The latter group may conduct extensive ride checks but not use a random sampling procedure so that following the UMTA sampling procedure requires an additional commitment of checker time.

The concerns of transit operators about UMTA's Section 15 "passenger service consumed" reporting requirements have been addressed as part of a broader study of transit passenger data collection techniques (1). In terms of Section 15, the specific objectives of the study were (a) to identify the range of techniques used by large transit properties to collect Section 15 passenger data and (b) to identify and evaluate improved techniques for collecting Section 15 data.

RESEARCH APPROACH

To provide results that transit managers can easily relate to their own needs, a case study approach was selected for the research. The first step was to document the data collection procedures that are currently used by transit properties in the United States. To keep the data collection effort manageable, only systems with 100 or more peak-hour buses were included. Both published reports and direct telephone contacts were used to document the full range of bus passenger data collection procedures used by each system. Only the procedures for collecting Section 15 passenger data are documented in this paper.

The second step was to develop classification schemes for the Section 15 data collection procedures and to classify the systems accordingly. The classification scheme was then used as the basis for selecting at least one case study system for each classification. Statistical sampling and analytical techniques were applied to identify the potential for improvements and the limitations of each class of procedures.

LITERATURE REVIEW

Overview

Until recently transit managers have had little technical documentation of appropriate passenger data collection procedures available to them. The recently reprinted 1947 American Transit Association Bus Scheduling Manual: Traffic Checking and Schedule Preparation (2) did provide guidelines for the frequency of maximum load point checks, but no statistical analysis was presented to justify the guidelines nor was any indication given of the accuracy of the resulting point-check data. The more recent (1976) fourth edition of the Manual of Traffic Engineering Studies (3) also gives no real guidance on how frequently ride checks should be made. Reference is made to an appendix on statistical procedures for determining the accuracy of a sample, but only the case of a simple random sample is considered.

Modern statistical sampling theory was first applied to the collection of bus passenger data by the Wells Research Company in 1977 (4). John Wells developed alternative sampling procedures for collecting Section 15 data. One problem faced by Wells was the lack of historical and even current data on the day-to-day and within-day variations in bus ridership. Two subsequent studies provided information on the data collection procedures used in the transit industry, but no indication was given that modern statistical sampling methods were being applied, nor were any accuracy measures presented (5,6). In 1977 Stone and others at the University of Utah applied statistical quality control techniques to monitor route-level performance on the Denver and Salt Lake City transit systems (7). Stone also measured the accuracy of the monthly passenger counts taken by Salt Lake City bus drivers.

A comprehensive, statistically based methodology for bus passenger data collection is presented in the recently published two-volume Bus Transit Monitoring Manual (8). Although the focus of the manual is on point- and ride-check data collection, the sampling procedure could be applied to driver-based data collection programs as well. Case study applications of the manual are in progress.

Contacting transit properties for this research revealed that several systems have contracted with consultants to produce statistically based data collection plans. The reports documenting the data collection plans are either "in-house" reports or reports that have received only limited distribution. To date none of this work has been reported in the standard technical literature. Similarly, statistically based work by local staff has generally gone unreported. One exception is a paper by Susan Phifer (9). Two key technical reports that are relevant for

Section 15 data collection procedures are reviewed next.

Wells Memorandum

In the Wells memorandum (4), John Wells of the Wells Research Company documents the sampling procedures recommended for Section 15 passenger data collection in UMTA Circular 2710.1. The basic design criterion was that annual total passenger-miles are to be estimated at a 95 percent confidence level with a precision of at least 10 percent. To minimize the potential impact of periodic variations by day of week and seasonal variations, a frequent and systematic sample of days throughout the year should be selected.

Wells developed alternative sampling plans based on the formula for the relative variance of a two-stage cluster sample and cited Hansen, Hurwitz, and Madow (10) as the reference. The formula is based on taking a random sample of days in the year in the first stage of the sample and then a random sample of one-way trips to be ride checked in each of the sample days. Wells assumes that a systematic sample, such as every other day or every third day, is equivalent to a simple random sample. The basic formula is

$$CV_{pm}^2 = [(M - m)/M](CV_b^2/m) + [(N - n)/N](CV_w^2/mn) \quad (1)$$

where CV_{pm}^2 is the relative variance of annual total passenger-miles; CV_b^2 and CV_w^2 are the between and within-day relative variances of total passenger-miles, respectively; M and N are the population sizes for number of days in the sample period and number of one-way trips per day, respectively; and m and n are the sample sizes for days and one-way trips, respectively.

In computing the maximum relative variance allowed by the 95 percent confidence level and a precision of 10 percent, Wells rounded the t value of 1.96 to 2.00, thus providing a slightly more conservative estimate of the accuracy of the sampling plans. The resulting coefficient of variation is $CV_{pm} = 0.1/2.0 = 0.05$ giving $CV_{pm}^2 = 0.0025$. To evaluate alternative combinations of numbers of days and trips sampled, assumptions about the between- and within-day relative variances were required. On the basis of limited data, Wells chose conservative values of $CV_b = 0.1$ and $CV_w = 1.0$. Analysis of passenger-mile data for this research indicates that Wells' assumptions are nearly always quite conservative.

The limiting case for number of days sampled per year is 365. Using Equation 1, only the within-day relative variance term remains. Thus, with m = 365 and sampling one trip each day (n = 1) so that (N - n)/N is approximately one, $CV_{pm}^2 = CV_w^2/365 = (1.0)^2/365 = 0.00274$, which is equivalent to a precision of 10.5 percent for t = 2.0 or 10.3 percent if t = 1.96. Wells rejects this sampling plan because the specified precision of 10 percent is exceeded. A sampling plan with three trips every other day (n = 3 and m = 183) gives $CV^2 = 0.002093$, which gives a precision of 9.1 percent. The sampling plan requires 3 x 183 or 549 sample trips, which is fewer than the other sample plans that have a greater interval between sample days.

On the basis of an analysis of Section 15 data for Albany, New York; Madison, Wisconsin; and Omaha, Nebraska, it appears that for most transit properties the within-day coefficient of variation (CV_w) and hence CV_w^2 are likely to be somewhat less than 1.0. Consequently most properties can justify a sample of one trip every day, which is a saving of about one-third over the minimum recommended sampling plan.

Bus Transit Monitoring Manual

The Bus Transit Monitoring Manual (BTMM) (8) provides a methodology for developing a statistically based route-level transit monitoring program. The focus of the sampling plan is on point and ride checks conducted by traffic checkers. The same two-stage cluster sampling plan used by Wells for Section 15 passenger data collection is applied in the BTMM methodology (see Equation 1 in the previous section). The time period over which the sample is to be taken will vary depending on whether monthly, quarterly, or annual performance estimates are wanted.

The development of a sampling plan involves specification of the desired confidence level and precision and then selection of the number of sample days and the number of sample trips per day that meet the accuracy specifications. The maximum number of trips sampled per day is constrained by the number of checkers available. The trade-off between number of days and trips sampled per day is a function of the between-day and within-day coefficients of variation for the data item of interest, usually total passengers, passenger-miles, or running time.

To develop a sampling plan, estimates of the between-day and within-day coefficients of variation (CV_b and CV_w) are required. An intensive data collection effort is proposed in the BTMM so that route-level CV_b and CV_w can be computed. Other data sources such as counts by drivers can also be used.

The primary limitation of the BTMM is that it does not address a full range of sampling options. In particular, potential applications of stratified and systematic sampling are not considered. The manual, however, does provide a starting point for transit systems that do not have any expertise in developing statistically based sampling procedures.

STATISTICAL SAMPLING PROCEDURES

Reasons for Sampling

Sampling involves selecting a number of observations or elements of a population and using the characteristics of the sample to make inferences about the characteristics of the population. For example, if an estimate of the number of passengers using a particular bus route is wanted, the passengers on a random sample of one-way bus trips during a given day could be counted. Multiplication of the total passengers counted in the sample by the inverse of the sampling rate (expansion factor) will give an estimate of the total passengers that rode on all the one-way trips during that day. Statistical sampling theory provides measures of the accuracy of the sample estimate.

Sampling provides many potential advantages: (a) reduced cost, (b) greater accuracy, (c) more information, and (d) speed in processing. If the costs of collecting data on the entire population are high, then collecting data on only a fraction of the population can reduce costs substantially. The additional costs of preparing, monitoring, and analyzing the sample results must also be included.

Basic Sampling Techniques

The two basic methods for collecting the data on passenger-miles required by Section 15 are ride checks and automatic passenger counters. Because both methods are relatively costly, sampling techniques are essential to provide the required data. The four basic sampling techniques are (a) simple random sample, (b) stratified random sample, (c) cluster sample, and (d) systematic sample. Only a brief overview of each is presented here. More detailed treatments of survey sampling theory and practice are found in standard texts. Cochran (11) provides lucid explanations of the theory as well as of the advantages and disadvantages of the various techniques.

Simple Random Sampling

A simple random sample is a method of selecting n units out of a population of N units such that every unit in the population has an equal chance of being selected. If the sample is truly random, then the sample estimate of some characteristic of the population will be unbiased; that is, the mean value of the estimate taken over all possible random samples of size n is equal to the population value. A simple random sample also has the desirable property that the sample variance is an unbiased estimate of the population variance.

The key formula for a simple random sample is the variance of the sample mean $(\bar{y})$ given by

$$v(\bar{y}) = (s^2/n)(1 - n/N) \quad (2)$$

where s^2 is the sample variance, n is the sample size, and N is the population size. The term in parenthesis (1 - n/N) is the finite population correction factor (fpc) for sampling without replacement in a finite population of size N. Clearly, as the sample size approaches the population size, the fpc approaches zero and the variance of the sample mean also approaches zero. If n = N, there is no longer any sampling error. The population mean and variance are known.

Equation 2 shows that the sampling error in estimating the population value Y or $\bar{Y}$ can be made as small as desired simply by increasing the sample size. Confidence limits for the estimate of $\bar{Y}$ are given by $\bar{y} \pm ts_{\bar{y}}$ where $s_{\bar{y}} = v(\bar{y})^{1/2}$ is the standard error of the sample mean. For a 95 percent confidence level the t-value for large n is 1.96 or about 2.0. The meaning of the confidence interval is that in repeated sampling 95 times out of 100 the population mean will fall within the confidence interval.

The precision (r) of the sample for a given confidence level is given by the error in $\bar{y}$ divided by the sample mean, so $r = ts_{\bar{y}}/\bar{y}$. Thus, using Equation 2, the precision is

$$r = [t(s/\bar{y})/n^{1/2}](1 - n/N)^{1/2} \quad (3)$$

Because $s/\bar{y}$ is the coefficient of variation (CV) Equation 3 provides a convenient means of estimating the sample size given a desired precision (level of accuracy) and an estimate of CV. An initial estimate of CV may be available from a previous sample or from data for a similar transit property.

Stratified Random Sampling

Stratification is a method of dividing a population of N units into L distinct subunits or strata, N_1, $N_2, \ldots, N_L$. The sum of the units in the L strata must equal N. For stratified random sampling a simple random sample is drawn in each stratum with sizes n_1, $n_2, \ldots, n_L$. Stratification may be used for administrative convenience or to increase the precision of the population estimate by dividing a heterogeneous population into homogeneous subgroups.

For stratified random sampling, an unbiased estimate of the variance of the sample mean $(\bar{y})$ is given by

$$v(\bar{y}) = \sum_{h=1}^{L} W_h^2 (1 - n_h/N)(s_n^2/n_h) \quad (4)$$

where W_h equals N_h/N. Thus, $v(\bar{y})$ is simply the sum of variances for a simple random sample in each stratum weighted by the square of the relative size of the stratum.

Cluster Sampling

Surveys in which the sampling unit is a group or "cluster" of smaller units are called cluster surveys. The primary reason for sampling clusters is to reduce the cost of sampling. For a given size sample a smaller sampling unit usually gives a more precise estimate than a larger sampling unit. If the costs of collecting data for the large sampling unit are much less, then the sample size can be increased enough to offset the reduction in precision from using the cluster.

For a simple random sample of n clusters, each containing M elements (subunits), drawn from N clusters in the population, the variance of the sample mean per element is

$$V(\bar{y}) \approx [(1 - f)/nM]S^2[1 + (M - 1)\rho] \quad (5)$$

where S^2 is the variance among the elements, f is the sampling fraction (n/N), and ρ is the intracluster correlation coefficient. The intracluster correlation coefficient is a measure of the homogeneity of the clusters. If within each cluster the values for y are similar, then $\rho \approx 1$ and the variance of the mean is obtained by dividing the population variance by n. When the values for y within a cluster are as diverse as the entire population, then $\rho \approx 0$ and the variance of the mean is essentially the same as if a random sample of n x M elements had been selected from the population.

Systematic Sampling

Selection of a systematic sample of size n from a population with N units ordered from 1 to N involves selection of every kth unit with a random start from among the first k units. This is called an "every kth systematic sample" with nk = N. The primary advantage of systematic sampling is that the sample is usually easy to draw and can be done accurately. Also, because the systematic sample is spread evenly over the population, systematic sampling may be more precise than simple random sampling.

One problem with systematic sampling is that estimation of the sample variance requires knowledge of the population variance. With unknown populations systematic sampling should be used with caution. If there is high correlation among the units within a sample, then the sample estimate may be an extremely poor estimate of the population mean. This is true if unsuspected periodicity is present in the population. In contrast, if the population is essentially in random order, then the systematic sample will contain the same information as a simple random sample of size n and have the same variance.

Extension of Basic Sampling Techniques

The most common extension of the basic sampling techniques is the use of multiple levels or stages of sampling. The basic sampling technique at one stage may be different from the sampling technique at the next stage. The two-stage cluster sample used by Wells and the Bus Transit Monitoring Manual is the most useful extension for Section 15 purposes. Another useful extension of the basic sampling techniques is the use of ratio or regression estimation. Ratio and regression estimation can improve the precision of an estimate when there is a high correlation between the variable of interest and a second variable and there is independent information available for estimating the second variable.

With ratio estimates an auxiliary variable (x_i), which is correlated with y_i, is obtained for each unit in the sample. The population total (X) of the x_i is known so that the population total (Y) can be estimated as

$$Y_R = (\bar{y}/\bar{x})X = RX \quad (6)$$

The increase in precision obtained from the ratio estimate depends on the relative variance (or coefficient of variation squared) of the ratio (R) given by

$$CV_R^2 = [(1 - f)/n](CV_y^2 + CV_x^2 - 2\rho CV_y CV_x) \quad (7)$$

which is equivalent to

$$CV_R^2 = CV_{\bar{y}}^2 + CV_{\bar{x}}^2 - 2\rho CV_{\bar{y}} CV_{\bar{x}} \quad (8)$$

If $CV_{\bar{y}}$ and $CV_{\bar{x}}$ are approximately equal, then it is easy to show that the precision of R results in an increase in the precision of Y_R when $\rho \geq 0.5$.

The ratio estimate is useful when the x_i are much cheaper to sample than the y_i so that X can be determined directly or when X is available from some other source. For Section 15 the ratio estimate of average passenger trip length can be used to estimate total passenger-miles on the basis of total passengers at the system level.

CURRENT DATA COLLECTION PROCEDURES

The concerns that transit managers have raised about the need for Section 15 passenger data reporting could possibly indicate a lack of interest in ride-check data collection and even a more general low level of interest in all checker-based data collection. The inventory of the passenger data collection techniques used by 58 transit systems with 100 or more peak-hour buses, however, revealed that there is a substantial commitment to ride checks. As the data given in the following table, which gives the distribution of transit systems by checker effort devoted to ride checks, indicate, all but 10 percent of the transit systems devote at least some of their checking staff time to ride checks.

Percentage of Checker Effort	Percentage Distribution
0	10
1 to 33	33
34 to 66	28
67 to 99	24
100	5

More than one-quarter of the systems devote at least two-thirds of their checking staff time to ride checks.

The large transit systems also devote substantial resources to passenger data collection in the form of a regular checking staff. As the data in the following table, which gives distribution of transit systems by size of transit system, indicate, only 17 percent of the systems had less than one checker per 100 peak-hour buses.

Size of Checking Staff (staff per 100 peak buses)	Percentage Distribution
Fewer than 1.0	17
1 to 1.9	42
2 to 2.9	22
3.0 or more	19

Clearly, most transit systems have the checking staff required to conduct the ride checks under the Section 15 data collection plan recommended by UMTA.

The inventory of the 58 large transit systems revealed a surprising diversity in the procedures used to obtain Section 15 passenger data. As the data in Table 1 indicate, only about 60 percent of the systems use the standard random sample ride-check procedures developed by Wells and recommended by UMTA in Circular 2710.1. Most of these systems also have an extensive ride-check program that may be partly or wholly integrated with the random sampling procedure.

TABLE 1 Distribution of Section 15 Passenger Data Collection Procedures

Procedure	Distribution of Properties [number (percentage)]
Standard Wells (random sample)	35 (60.3)
Minimum level only	12 (20.7)
Extensive ride-check program	23 (39.6)
Sample from extensive ride checks	11 (19.0)
Year-long program	8 (13.8)
Short intensive program	3 (5.2)
Two-stage program	9 (15.5)
Extensive program	3 (5.2)
Total	58 (100)

Eleven properties meet the Section 15 requirement by selecting a random sample of ride checks from their regular, extensive ride-check program. In general, these properties ride check all of the daily one-way trips in the system at least once a year. Thus, the sample will be unbiased in terms of coverage, but it may be biased as the result of seasonal and secular trends.

The two-stage procedure involves multiplying estimates of passenger-miles per passenger by total passengers to obtain the required estimate of passenger-miles required by Section 15. The estimate of passenger-miles per passenger (average trip length) may be obtained from ride checks or from passenger surveys. With proper statistical sampling the procedure can be even more accurate than either of the first two procedures. In practice, however, the estimates of average trip length are based on whatever data are available.

A few properties such as Metro Area Transit in Omaha, Nebraska, have extensive ride-check programs that are based on a large random sample. The result is an accurate estimate of passengers and passenger-miles at the route level. Omaha uses traffic checkers. Automatic passenger counters (APCs) are also being used for extensive ride-check programs. A number of APC-based counting programs are currently being developed and more can be expected in the future as more experience is gained with the technology (12).

The four basic categories of Section 15 data collection procedures given in Table 1 provided the framework within which case study transit systems were selected to illustrate the potential for improvements and possible limitations of a particular procedure. Three of the six transit systems selected for the case studies were selected because the local transit staff had either developed an improved Section 15 data collection procedure or had analyzed Section 15 data in order to identify possible improvements. The other three case studies were selected as the result of data availability or the need to cover each of the four categories. Three case study transit systems were selected in the "standard Wells" category and one system was selected from each of the other categories given in Table 1.

CASE STUDY DATA COLLECTION PROCEDURES

Standard Wells: Madison, Wisconsin, Case Study

To develop the basic data needed to analyze alternative sampling strategies for Madison, the tabulation of the Section 15 ride-check data was computerized. The resulting data for 183 ride checks conducted during the first half of 1982 are summarized in Table 2. The computer file also included data on route, day of week, and time of day.

TABLE 2 Section 15 Sample Data for Madison Metro

Variable	Mean[a]	Standard Deviation	Coefficient of Variation	Precision[b]
Boardings	43.8	26.9	0.61	0.089
Maximum load	25.4	16.4	0.65	
Passenger-miles	157.0	110.0	0.70	0.102
Passenger-minutes	740.8	560.0	0.76	0.110
Average passenger-miles	3.47	1.25	0.36	
Average passenger-minutes	15.7	4.57	0.29	
Average speed	3.1	2.81	0.21	

[a] Based on 183 observations.
[b] For a 95 percent confidence level.

At the system level the primary interest is in reducing the sampling rate within the UMTA-imposed constraint of estimating total passenger-miles within 10 percent at the 95 percent confidence level. If the data in Table 2 are assumed to be based on a simple random sample of size 183, then the precision of the estimate of passenger-miles is almost equal to the required 10 percent level, and the estimate of average boardings per trip is even more precise (precision of 0.089). If the coefficient of variation does not increase significantly for the sample covering the entire year, then a sample of about 200 one-way trips instead of 546 trips would be adequate. Although not recommended, a minimal sample of 182 trips could be obtained by taking a simple random sample of one trip from every two-day period during the year.

With Madison Metro's current sample of one trip per day the annual sample of 365 trips will result in a precision for average passenger-miles per trip of 7.2 percent assuming a coefficient of variation of 0.70. The coefficient of variation could increase to nearly 1.0 and still meet UMTA's accuracy requirement. Thus, it is clear that Madison Metro's current sampling rate is more than adequate to cover substantially greater variations in average passenger-miles than currently occur.

Some minor improvement in the accuracy of the system-level estimate of total passenger-miles is made possible by stratifying the sample by day of the week. The average passenger-miles per trip for weekdays is 171 compared with 130 for Saturday and Sunday. This difference in stratum means appears to be large enough to make the additional effort of stratifying the sample worthwhile.

Other possible stratifications include time of day and route. One-way analysis of variance of average boardings stratified by time of day and considering only the five main routes on weekdays showed a highly significant difference between the evening period from 6 p.m. to 12 midnight and the three other periods (a.m. peak, midday, and p.m. peak). In stratifying by route there is a significant difference in passenger-miles per trip between the short university routes and the main-line routes. Although some improvement in the accuracy of the estimates of passenger-miles and total boardings could be achieved through stratification by time of day and route, the additional complexity of the resulting sampling plan would no doubt outweigh the benefits of the accuracy improvements.

Because Madison Metro now is obtaining 100 percent counts of passengers on a daily basis, the accuracy of the annual estimate of total passengers is only limited by the accuracy of the drivers' counts and clerical errors in recording the data. If the total passenger counts are assumed to be highly accurate, then substantial improvement in the accuracy of the annual estimate of passenger-miles can be obtained by using a ratio estimate of passenger-miles per passenger. Using Equation 7, the relative variance of the ratio estimate is given by

$$CV^2_{pm/p} = [(1 - f)/n](CV^2_{pm} + CV^2_p - 2\rho_{pm,p} \cdot CV_{pm}CV_b) \quad (9)$$

where CV_{pm} and CV_b are the coefficients of variation of passenger-miles and total passengers, respectively, and $\rho_{pm,p}$ is the correlation between passenger-miles and total passengers. For the Madison data $\rho_{pm,p}$ is quite high (0.916). Thus, using Equation 9, $CV_{pm/p}$ is found to be 0.021 on the basis of the available sample size of 183. The resulting precision of the ratio estimate of passenger-miles is 4.1 percent. If a precision of 10 percent is all that is required and $CV_{pm/p}$ is assumed to remain the same except for the sample size, then a sample of only 32 ride checks would be needed. Thus, use of the ratio estimate results in a reduction of the sample size required to give a precision of 10 percent from 183 to 32, or more than an 80 percent reduction.

The ratio estimate of passenger-miles per passenger can only be used to improve the precision of the estimate of total annual passenger-miles if the precision of an independent estimate of total annual passengers is about as good as or better than the ratio estimate. If an independent estimate of total annual passengers is not available, then the ratio estimate is likely to be less useful as a means of improving the precision of the passenger-miles estimate. At this point the dramatic increase in the precision of the ratio estimate compared with the direct estimate of passenger-miles should not be used to reduce the sampling rate because then the accuracy of the Section 15 estimate of total passengers would be reduced as well. The Section 15 estimate is needed to provide a check on the accuracy of the driver counts.

Standard Wells: St. Louis Case Study

As is the case with many systems, St. Louis collects Section 15 ride-check data independently of its regular ride-checking program. Because the Section 15 data have not been integrated into the regular data collection effort, there is an incentive to reduce the effort devoted to Section 15. St. Louis used Section 15 data on passenger-miles for each one-way trip stratified by time period and day of the week to develop a new sampling plan.

The first step in developing the new sampling plan was to assume a simple random sample over the entire year. On the basis of the observed coefficient of variation of passenger-miles for the 1981-1982 fiscal year of 0.971, a sample size of 362 is required to meet UMTA's accuracy requirements. This is the same basic calculation that was made using the Madison Metro data. There is clearly much greater variation in the St. Louis data, which probably reflects the much greater emphasis on express service and lower usage during midday in St. Louis. Nevertheless, St. Louis could have adopted Madison's one trip per day sample plan. Instead, St. Louis used an optimal allocation of trips to the four time periods of the day followed by a proportional allocation of trips to each day of the week. The objective of using a more complicated sampling plan apparently was not to reduce the sample size further but to provide a safety factor in case the new sampling plan is not as accurate as predicted by the available data.

The main question in evaluating St. Louis' two-stage sampling plan is whether the additional effort of stratifying the sample by time of day and day of the week is justified by the expected increase in accuracy. In analyzing the raw data obtained from St. Louis, a slightly lower coefficient of variation of 0.948 was obtained, which gives a lower sample size of 346. The required sample size is highly sensitive to the coefficient of variation.

In evaluating the accuracy of St. Louis' two-stage sampling plan, the order of the stratification was reversed and optimal allocation was used in both stages. A detailed calculation of the precision of the new sampling plan (new calculations based on two optimal allocations) resulted in a precision of 0.094. The gain in precision over a simple random sample is only 0.006, which is clearly not worth the additional effort required for stratification. The gain in precision can be translated into a reduction in sample size of about 30 trips.

Standard Wells: Denver Case Study

The Denver Section 15 ride-check procedure is of interest because application of the standard Wells sampling plan will not meet the desired precision of 10 percent for passenger-miles. As the data in Table 3 indicate, the precision of the passenger-miles estimate is only 11.6 percent. The lack of accuracy in the passenger-miles estimate is explained in part by the approximations used in computing the distance between stops. Because an up-to-date stops file with complete distances between stops was not available, the Denver Regional Transit District (RTD) allocated the known distance between time points equally to all stop-level segments. To the extent that passenger loads are concentrated on route segments that have closer spacing of stops, the assumption of equal distances between stops will tend to overestimate passenger-miles.

Because Denver does have an independent estimate of total passengers, the ratio estimate of passenger-miles per passenger can be used to increase the precision of the passenger-miles estimate. Although the correlation between passenger-miles and total passengers is relatively low ($\rho = 0.587$), the coefficient of variation of the ratio estimate from Equation 9 is low enough ($CV_{pm/p} = 0.0478$) to give a precision for the ratio estimate (9.4 percent) that is within the UMTA guidelines. Thus, if the independent estimate of passengers is accurate, the product of the ratio of passenger-miles per passenger and total passengers will give an estimate of passenger-miles that is within the UMTA guidelines.

Substantial improvements in the accuracy of the estimate of passenger-miles should be possible through stratification by route type. As the data in Table 3 indicate, there are large differences among the average passenger-miles per trip by route type. For example, Denver local service generates only 156 passenger-miles per trip whereas express and intercity routes generate more than three times as many passenger-miles per trip. Stratification by route type will eliminate that part of the total variance that is the result of the difference between the route-type mean and the overall mean. As the data in Table 4 indicate, the precision of both the passenger-miles and the passenger-minutes estimates is improved substantially by a stratified sample. In contrast, the precision of the passengers estimate is essentially the same, which is explained by the relatively small differences among the means of the route types.

TABLE 3 Denver Section 15 Data Stratified by Route Type[a]

Route Classification	Sample Size	Passengers		Passenger-Miles		Passenger-Minutes	
		Mean	CV	Mean	CV	Mean	CV
Weekday Only							
Denver local	260	40.9	0.631	156	0.872	692	0.843
Boulder local	15	21.1	0.829	63.8	1.28	262	1.046
Longmont local	12	4.2	1.07	8.3	1.23	22.0	0.658
Denver circulator	34	11.4	1.24	25.2	1.30	125	1.465
Intercity	16	28.3	0.88	552	1.13	1,118	1.097
Express	37	45.6	0.40	490	0.467	1,462	0.491
All routes	381	35.8	0.723	188	1.26	695	0.997
All Days							
All routes	538	31.6	0.796	157	1.37	582	1.09
Precision[b] (percentage)			6.3		11.6		9.2

[a]Derived from data in Beuthel *(13)*.
[b]Based on a simple random sample.

TABLE 4 Precision of Simple Versus Stratified Random Sample for Denver, Weekday Only[a]

Sample Type	Passengers	Passenger-Miles	Passenger-Minutes
Simple random sample	0.073	0.127	0.100
Stratified random sample (proportional allocation by route classification)	0.076	0.104	0.083

[a]Derived from data in Beuthel (13).

The ratio estimate could also be applied to the coefficients of variation obtained from the stratified sample. The resulting precision of the ratio estimate of passenger-miles per passenger should be substantially less than 10 percent and thus well within UMTA's guidelines.

The potential for stratification by a number of variables can be determined from Table 5. The between-class variation is eliminated by stratification. Thus, the greatest reduction in variance is achieved by selecting the classification with the highest between-day coefficient of variation. Stratification by route type is best for passenger-miles, whereas stratification by day is best for passengers and passenger-minutes. Based on the weekday data, stratification by day in Denver with a random sample of one trip each day would be adequate for both passenger and passenger-minutes estimates. A ratio estimate of passenger-miles should come close to giving a precision of 10 percent. A daily sample of one trip would represent a reduction of about one-third from the current sample rate of two trips every other day.

Sample from Extensive Ride Checks Case Study

Overview

A number of transit properties have extensive ride-checking programs in which every daily one-way trip is ride checked at least once during the year. At the end of the year ride-check data for at least one day are available for all routes so that comparisons of route performance can be made. One problem with spreading the ride checks over the entire year is that route-level comparisons are biased by seasonal variations and ridership trends. To avoid this problem, some properties concentrate their ride checks in a short period of a few weeks. In some cases both spring and fall checks are made.

A number of properties have used their 100 percent ride checks as the data base for satisfying Section 15 reporting requirements. Because all of these properties have considerably more daily one-way trips than the 546 trips required by the standard Wells minimum random sample, a random sample of 546 trips typically is drawn from the 100 percent ride checks. This two-stage sampling procedure is valid statistically if the first stage (the 100 percent ride-check data) gives an unbiased estimate of passenger-miles, passenger-minutes, and total passengers. The ride checks that are spread over the entire year should provide unbiased estimates as long as the checks for each route type such as local and express routes are distributed reasonably uniformly over the year. The ride checks that are concentrated in a short period, however, are likely to produce biased estimates because seasonal variations and secular trends are omitted. A partial solution in this case is to use a ratio estimate of passenger-miles per passenger as the basis for estimating annual passenger-miles. Passenger-miles per passenger measures average passenger trip length, which should be more stable over time than either passenger-miles or total passengers.

Milwaukee Case Study

A test of the validity of using 100 percent systemwide ride checks collected over a short period as the basis for Section 15 reporting requires data on average passenger trip length over time, which in turn requires an extensive ride-check data base. Milwaukee County Transit in Milwaukee, Wisconsin, has the required data base in machine readable format. Time series ride-check data for one crosstown feeder line, Route 55, are given in Table 6.

TABLE 6 Variations in Average Passenger-Miles per Passenger on Milwaukee Route 55

Month	Sample Size	Passenger-Miles per Passenger	Coefficient of Variation	Precision (r)
January	64	6.07	0.382	0.096
October	62	6.38	0.392	0.100
November	63	6.49	0.357	0.082

The passenger-miles per trip estimates given in Table 8 are not true ratio estimates but the average of the ratio of passenger-miles per passenger over the 100 percent ride check for that time period. The precision of the estimate, thus, is a measure of variation in the average of the ratios and is only an indirect measure of the variation in average passenger-miles per passenger over the entire day. Clearly, the average of the average trip lengths is

TABLE 5 Within- and Between-Strata Coefficients of Variation for Denver Weekday Section 15 Data[a]

Variable[bc]	Day	Day of Week	Time of Day: All	Time of Day: Denver Local	Peak vs Off-Peak	Route Type
Passengers	0.582[c]	0.714	0.681	0.476	0.696	0.647
(CV = 0.724)[d]	0.430[e]	0.113	0.242	0.209	0.198	0.323
Passenger-miles	1.01	1.24	1.17	0.659	1.18	0.972
(CV = 1.27)[d]	0.758	0.265	0.480	0.279	0.454	0.809
Passenger-minutes	0.821	0.982	0.905	0.627	0.917	0.849
(CV = 0.997)[d]	0.564	0.163	0.415	0.299	0.389	0.522

[a]Derived from data in Beuthel (13).
[b]Mean values: Passengers = 35.8, passenger-miles = 188, and passenger-minutes = 695.
[c]Within-day coefficient of variation, $S_w/\bar{X}$.
[d]Coefficient of variation.
[e]Between-day coefficient of variation, $S_b/\bar{X}$.

reasonably stable over time at least for Route 55. Pairwise tests for equality of the means between months showed that the null hypothesis of equality could not be rejected at the 5 percent level.

Although a sample of three 100 percent ride checks on one route over an 11-month period does not provide a definitive test of the hypothesis that average trip lengths are stable over time, the results for Milwaukee are encouraging. A complete evaluation of the hypothesis would require time series data on systemwide average trip lengths as well. The trip lengths for individual routes may not be constant over time but the systemwide average could still be relatively stable.

Two-Stage Estimation Case Study

Overview

As outlined in the Madison, Wisconsin, case study, a ratio estimate of average trip length (passenger-miles per passenger) can improve the precision of the estimate of passenger-miles if the correlation between passenger-miles and passengers is high and if an accurate, independent estimate of total passengers is available. Total passenger-miles are computed as the product of average trip length and total passengers. If a random sample of ride checks is used to compute the ratio estimate, then the ratio and the resulting estimate of total passenger-miles will be unbiased.

In some cases ratio estimates of average trip length have been based on intensive ride checks conducted over a short period of a few weeks. The assumption is made that the ratio estimates are stable over time. The limited time series data on average trip length for one route in Milwaukee that were presented in the previous section support the time stability assumption, but systemwide data were not available. Although the assumption of time stability may be a good assumption, there is always the possibility for change. Thus, a random or otherwise unbiased sample over the time period of interest is the only method for assuring that an accurate estimate of total passenger-miles is obtained.

Albany Case Study

As part of its transit route performance monitoring study, the Capital District Transit Authority (CDTA) implemented a new ride-check program using the sampling techniques presented in the Bus Transit Monitoring Manual (8,14). The primary purpose of the ride-check program was to estimate route-level average trip length and revenue per passenger within 15 and 10 percent, respectively. Because accurate estimates of route-level total boardings are available from 100 percent counts by drivers, it was estimated that system-level estimates of average trip length and revenue per passenger would be within 5 and 2 percent, respectively.

The number of trips per route that is to be sampled for the ride-check program varies from a low of 2 to a high of 16 for weekdays. For weekends, the range is from 4 to 13 trips. The results of ride checks for three routes are given in Table 7. The variation in average trip length (passenger-miles per passenger) as measured by the coefficient of variation is less than that for passengers and for passenger-miles. The precision of the estimates of average trip length is computed in two ways: (a) direct computation based on the coefficient of variation of the trip lengths for each observation and (b) ratio estimate based on the coefficients of variation of passenger-miles and passengers and the correlation between passenger-miles and passengers. The direct estimates of precision are within the specified 15 percent level, and two of the ratio estimates are slightly above the 15 percent level.

The CDTA's total ride-check program requires 503 weekday and 233 weekend ride checks. The total program of 736 ride checks is considerably larger than the minimum Wells' sample of 546. The advantage of CDTA's approach is that precise estimates of trip lengths and average fare are obtained at the route level. If only systemwide estimates are of interest, then the sample size can be reduced substantially particularly when the ratio estimate for average fare is used as was shown for the Madison, Wisconsin, case study.

Extensive Ride-Check Case Study

Overview

An extensive ride-check program in which every daily one-way trip is checked at least once a year can be conducted either manually or with automatic passenger counters (APCs). Properties with extensive manual count programs are generally interested in total passengers, load profiles, and running times. Passenger-miles are usually not of direct interest so they are usually computed only for a sample of trips for Section 15 reporting purposes. In contrast, with APCs passenger-miles can easily be computed for all sample trips with essentially no extra effort.

TABLE 7 Estimation of Average Trip Lengths from Ride Checks—Albany[a]

		Passengers	Passenger-Miles	Passenger-Miles per Passenger		
					Precision[d]	
Route	No. of Observations	Mean (CV)[b]	Mean (CV)	Mean[c] (CV)	Direct	Ratio
9	16	24.4 (0.450)	44.8 (0.531)	1.86 (0.331)	0.145	0.161
12	15	16.1 (0.442)	42.4 (0.710)	2.47 (0.299)	0.136	0.151
8	9	19.3 (0.304)	40.0 (0.355)	2.05 (0.180)	0.112	0.126

[a] Derived from data in Transit Route Performance Monitoring Study *(14)*.
[b] Coefficient of variation.
[c] Average of the ratio of passenger-miles to passengers. The unbiased estimates of passenger-miles per passenger for the three routes are 1.84, 2.63, and 2.07, respectively.
[d] Direct estimate of precision is based on the formula for a simple random sample. The ratio estimate is based on a ratio estimate using passenger-miles and passengers; that is, $CV^2_{pm/p} = CV^2_{pm} + CV^2_p - 2\rho CV_{pm} CV_p$.

Because of the expense of the APC counting units, only a small fraction of the fleet can be equipped. Various sampling strategies can be developed depending on the data needs of the property and the logistics of assigning buses.

Columbus, Ohio, Case Study

The Central Ohio Transit Authority (COTA) contracted with a consultant to undertake a comprehensive ride-check program using APCs. The APCs provide route-level data on passengers, passenger-miles, passenger-minutes, vehicle-hours, vehicle-miles, and running times so that both route- and system-level performance measures can be computed. A weekday productivity analysis report is produced every 4 months.

Because passenger-miles are obtained routinely from the APCs, the Section 15 reporting requirements are easily met. The six APC-equipped buses could cover the entire fleet of 234 peak-hour buses in about 8 weeks. During the course of a year each vehicle block could be sampled five or six times. Thus, the primary concern is not the sample size but the need for an unbiased sample. Although the precise details of the sampling procedure used by COTA were not available, the sampling procedure appears to involve a trade-off between coverage and route- or corridor-level problem solving. All vehicle blocks have been covered at least once. Multiple checks have been made for a few select routes.

For system-level estimates a random sample of vehicle blocks each day will give the best results. In contrast, for evaluating route operational characteristics, 100 percent checks done route by route are likely to be more useful. The result is a point estimate of demand at the route level. The system-level estimates should still be reasonably accurate as long as the routes are selected in random order.

SUMMARY AND CONCLUSIONS

The three cases of alternatives to the standard Wells random sample approach demonstrate that substantial reductions in sample size are possible within the UMTA-imposed constraint of a precision of 10 percent. In Madison, Wisconsin, a reduction of the sample rate to one trip per day still provided a more than adequate level of accuracy. Further improvements in accuracy were made possible by using a ratio estimate of passenger-miles per passenger. Stratified sampling with stratification by day of the week and route type appeared to have some potential.

St. Louis chose a fairly complicated two-stage stratification by time period and day of the week to reduce the required sample size. Analysis indicated that a simple random sample or a random sample stratified by day would be nearly as accurate. In contrast, the standard Wells sample for Denver did not quite meet the UMTA accuracy requirements. By using the ratio estimate, however, the 10 percent precision level could just be met. Stratification by route type resulted in a further increase in precision.

The second major group of Section 15 data collection procedures, the sample from extensive ride checks, requires the assumption of time stability of average trip length when the extensive ride checks are concentrated in a short period. Ride-check data available from Milwaukee on one route indicated that average trip lengths were reasonably stable over a period of 11 months.

The two-stage estimation approach also uses average trip length to improve accuracy or reduce sample size. In Albany, New York, application of the approach at the route level required only modest sample sizes to achieve a precision of 15 percent for a 90 percent confidence level. The total sample size of more than 700 trips could be reduced substantially if only system-level estimates were of interest.

The last approach is the extensive ride-check program that is of interest for Section 15 purposes when passenger-miles are computed for all ride checks. Full computation of passenger-miles is more likely for APC-based programs than for manual ride-check programs. As shown by the Columbus, Ohio, APC program, a large sample is obtained. A primary concern of the sampling plan for Section 15 purposes should be to give an unbiased estimate of annual passengers, passenger-miles, and other data of interest.

The case studies show that there are many opportunities for improving the accuracy of the standard Section 15 data collection programs. If the only concern is with meeting the minimum accuracy requirements, then improved sampling plans can be used to reduce the sample size. The potential for simple stratification or ratio estimates can be evaluated using the existing Section 15 data base. Use of ratio estimates is possible if an accurate, independent estimate of total passengers is available.

Additional research is needed to determine how Section 15 data collection requirements can best be met with the alternatives to the standard Wells sampling procedure. Identification of the variability in average trip length is a key problem that requires an extensive ride-check data base. Such data bases are currently available in only a few systems.

From a broader perspective the UMTA requirement for estimating annual passenger-miles with a precision of 10 percent needs to be reviewed. If the focus of Section 15 were on developing accurate estimates of total annual passengers, the data could possibly be made more relevant to transit operators. Additional research is needed to explore alternative means of integrating passenger counts obtained from ride checks with other techniques for estimating total passengers.

REFERENCES

1. R.L. Smith, Jr. Innovation and Incremental Improvement in Bus Passenger Data Collection. University of Wisconsin-Madison, Dec. 1983.
2. W.S. Rainville, Jr. Bus Scheduling Manual: Traffic Checking and Schedule Preparation. American Transit Association, Aug. 1947. (Reprinted by the American Public Transit Association and U.S. Department of Transportation, July 1982.)
3. P.C. Box and J.C. Oppenlander. Manual of Traffic Engineering Studies, 4th ed. Institute of Transportation Engineers, Arlington, Va., 1976.
4. J.D. Wells. Technical Basis for Sampling Procedures Used in the Bus Transit and Demand Response System Manuals. Memorandum to A.B. Hallman, UMTA, U.S. Department of Transportation. Wells Research Company, Silver Spring, Md., Nov. 25, 1977.
5. M. Flusberg, J. Kruger, and J. Curry. Bus Transit Monitoring Study: Interim Report 1, Data Requirements and Collection Techniques. Multisystems, Inc., Cambridge, Mass., and ATE Management and Service Co., Cincinnati, Ohio; UMTA, U.S. Department of Transportation, April 1979.
6. J.P. Attanucci, L. Jaeger, and J. Becker. Bus Service Evaluation Procedures: A Review. Massachusetts Bay Transportation Authority and Tide-

water Transportation District Commission; UMTA, U.S. Department of Transportation, March 1979.
7. T.J. Stone, J.A. Austin, R.L. Siegel, and A. Taylor-Harris. Application of Transit Performance Indicators. University of Utah; UMTA, U.S. Department of Transportation, Sept. 1979.
8. J. Attanucci, I. Burns, and N. Wilson. Bus Transit Monitoring Manual: Vol. 1, Data Collection Design. Multisystems Inc., Cambridge, Mass., and ATE Management and Service Co., Cincinnati, Ohio; UMTA, U.S. Department of Transportation, Aug. 1981.
9. S.P. Phifer. Use of Sampling in Bus-Line Data Collection. In Transportation Research Record 877, TRB, National Research Council, Washington, D.C., 1982, pp. 41-44.
10. M.H. Hansen, W.N. Hurwitz, and W.G. Madow. Sample Survey Methods and Theory: Vol. I, Methods and Applications. John Wiley and Sons, Inc., New York, 1956.
11. W.G. Cochran. Sampling Techniques, 3rd ed. John Wiley and Sons, Inc., New York, 1977.
12. D. Vozzolo and J. Attanucci. An Assessment of Automatic Passenger Counters. Multisystems Inc., Cambridge, Mass.; UMTA, U.S. Department of Transportation, Sept. 1982.
13. B. Beuthel. Section 15 Ridership Documentation 1981. Regional Transportation District, Office of Management and Budget, Denver, Colo., Aug. 1982.
14. Transit Route Performance Monitoring Study--Capital District Transportation Authority. Draft of March 1983. Comsis Corporation, Wheaton, Md., 1983.

Transit Operator Performance Evaluation: Study Group Review at Muni

LARRY S. ENGLISHER, MARTIN J. MORGENBESSER, and JOHN P. ATTANUCCI

ABSTRACT

The results of a study group review of employee performance evaluation at the San Francisco Municipal Railway are outlined. The review was undertaken as one step of a demonstration funded by the Urban Mass Transportation Administration, which is aimed at improving the reliability of transit service. Muni is currently implementing study group recommendations as part of the ongoing demonstration. The study group process was used in a previous study of safety issues at Muni and proved quite helpful. By bringing together representatives of other transit properties that have been addressing similar problems, the study group was able to "brainstorm" and exchange ideas. Both Muni staff and the representatives from other properties left the 4-day session with new insights and ideas. The study group addressed several components of a performance standards and motivation program, including measurement of performance, setting targets, establishing incentive and awards programs, ongoing procedures for appraisal and communication, and outlining and operating under a system of discipline. Among the aspects of performance discussed were attendance and punctuality; adherence to schedule; safety; courtesy and appearance; stress and substance abuse; and general conformance to rules, procedures, and directives.

The San Francisco Municipal Railway (Muni) has undertaken a transit service reliability demonstration under a Service and Methods Demonstration grant from the Urban Mass Transportation Administration. The objective of the demonstration is to improve the reliability of service delivered to transit passengers by applying a variety of management and operational strategies. Among the primary strategies are an operator performance evaluation and motivation program, an attendance management program, and on-street supervision and control strategies.

Multisystems initiated the project in December 1983, preparing summary papers to generate discussion on possible demonstration strategies. The papers reviewed Muni's current performance evaluation procedures and the approaches of several other transit authorities, including Metro-Dade, Houston Metro, Seattle Metro, MTC (Twin Cities), Flint MTA, Chittenden County (Vermont), and San Diego Transit. The papers also included summaries of the following approaches to improving productivity and motivation outlined in research performed by the Urban Institute (1): monetary incentives, performance appraisal, performance targeting, job enrichment, and employee assistance programs. Research on the causes of absenteeism among transit employees was also re-