Sampling Methods for the Collection of Comprehensive Transit Passenger Data

ARTHUR SCHWARTZ, Mass Transportation Planner, Tri-State Transportation Commission

This paper outlines a method of sampling transit service to obtain comprehensive data on passenger usage. Three examples of surveys using this sample design are described—a bus and streetcar survey in the Pittsburgh area, and railroad and bus surveys in the New York area. Differences in the surveys due to refinements in sample design and variations in the data desired are explored. Comparisons of the results of these surveys with complete enumerations at selected points are examined.

A PORTION of comprehensive transportation planning that has been somewhat neglected in the past is the planning for transit facilities and services. Much of this neglect has often been due to the separation of transit planning and the other parts of the comprehensive transportation planning process, with the responsibility for transit planning often being held by a separate agency. More recently, the need for an overall transportation planning process has been seen and transit planning has become an integral part of the program of the comprehensive transportation study.

This broadening of function has required that additional tools of data collection and analysis be developed. It is the purpose of this paper to describe one of these tools—the on-board sample survey method for obtaining transit usage data. Much of the data traditionally collected for a comprehensive transportation study are applicable to transit planning as well as highway planning. The home interview survey provides the same type and level of information about transit trips as it does about highway travel. Land-use surveys are not restricted in use to planning for any one mode of transportation. Although no survey paralleling the cordon line interview survey of highway travel is usually made, it is an extremely rare study area that has a significant number of external transit trips.

The major area in which new survey techniques have had to be developed is the collection of "on the ground" data measuring the actual operation of the transit system. For the purposes of the transportation study, the traditional data collection methods of transit operators are not adequate, and a new approach is necessary. Transit operators have traditionally used two measures of passenger usage, revenue passengers as derived from fare box receipts, and peak load point passengers as observed by field personnel. Each of these measures is seriously deficient as an indication of system usage. Revenue passengers based on fare box receipts can be associated with the geography of the system only in a rough way, as it is almost never reported in greater detail than by route. (Rapid transit systems with station fare collection are an exception.) Thus, the best information that can be derived from this source is the number of passengers by corridor for a largely radial system without through routings. Where a grid of routes or a substantial number of radial routes passing through the central area exists, even this is nearly impossible. In addition, where a zone fare system or any other system

Paper sponsored by Committee on Origin and Destination.

of differential fares is in effect, the adjustment of revenue receipts to reflect patronage is usually made by some overall allocation formula, which is often seriously misleading for a particular route.

Peak load point passenger counts are commonly used for purposes of preparing route schedules. These counts are taken at the highest volume point on a line as determined subjectively, and are analogous to a screenline count for highway traffic. Radial lines will almost always have a peak load point at or near the edge of the central area, so that a cordon around the central area is often available. Nonradial lines will have peak load points at scattered locations, so that usually no pattern of count coverage would be available for a grid system. Again, only partial geographical coverage is possible using this information, while the level of detail concerning the service passing a given point is greater than is needed for system planning work.

After considering the shortcomings of the standard methods of transit data collection, a method of data collection designed specifically for the uses of comprehensive transportation studies was indicated, based on the needs for transit data in such studies. The first need is for a measure of transit usage that can be used to corroborate data collected in a home interview survey. Another principal use of the data is in the development and verification of transit trip distribution and assignment models. The data also have uses in assessing the performance and efficiency of the transit system as currently operated. For all of these purposes, it is necessary to have a measure that is comprehensive, i. e., that permits assertions to be made about the entire transit system or subsystem. This measure should also be designed to be capable of subdivision, both geographically and by time period.

With these needs in mind, a general method of survey procedure has been developed that is not rigid, but can be varied to produce results suited to the problem at hand. The method relies on the fact that a transit system operates a fixed or largely fixed (over the short run) schedule of service. This service has to be specified in complete detail for operating purposes. Such information is sometimes available in the familiar public timetable, but it is usually necessary to obtain operating timetables, equipment assignment lists and other relevant material for sample frame preparation.

The basic procedure requires that the transit service be divided and ordered into units suitable for the selection of a sample. A systematic sample is then drawn, and an observation procedure for determining the desired information is developed and applied to the sample. The results of this procedure are then expanded to a total figure by use of the ratio of sampled service to all service. The ratio used for the expansion need not be based on the same division as that used for selecting the sampling frame. Generally, a more detailed examination of the service is possible for the determination of the expansion ratio.

While in theory this sounds extremely simple, there are many pitfalls inherent in the procedure, in both a logical and operational sense. It will thus be of interest to examine three surveys that have been conducted using this method. The first was run by the Pittsburgh Area Transportation Study in the spring of 1959. The information required of this survey was the total number of mass transportation passenger trips by common carrier transportation, excluding suburban railroad passengers. This information was to be used merely as an accuracy check of the PATS home interview survey trip reporting, so that no elaborate data collection procedures were necessary. The procedure used in this project was first to prepare a sampling frame of vehicle trips (bus and streetcar). Transit service was divided into nine expansion areas based on geographic area, vehicle type and CBD orientation as follows:

1. Streetcars, North, Entering CBD;
2. Buses, North, Entering CBD;
3. Streetcars, West and South, Entering CBD;
4. Buses, West and South, Entering CBD;
5. Streetcars, East, Entering CBD;
6. Buses, East, Entering CBD;
7. Buses, North, West and South, Not Entering CBD;

8. Pittsburgh Railways Buses and Streetcars, East, Not Entering CBD; and
9. Other Buses, East, Not Entering CBD.

Within each expansion area, vehicle trips were ordered by company, route number, subroute or branch, direction and time. Each trip was assigned a sequential number based on the above ordering. Thus sequence number 00001 would apply to the first outbound trip on the main route of the route with the lowest number in the first expansion area. In all, 16,603 trips were listed in this fashion, a random start was made and a 1 percent sample, or 166 trips, were selected for data collection.

Since the desired information was passenger origins, each sampled trip was ridden to observe the number of passengers that originated on it. Fieldwork was very straightforward. A form with a heading section describing the trip was prepared including time, route, boarding point (usually at some location near the end of the previous trip if a previous trip was scheduled to be made by the same vehicle), start and end point of the count, and points at which time was to be observed. The field personnel were required to observe passenger origins (defined as all boarding passengers except those presenting transfers), times at terminal and intermediate points and the vehicle number. The last two items were used for assessing the quality of the fieldwork. Times were used for checking adherence of the sampled trip to the scheduled time. If the trip was substantially late due to vehicle breakdown or traffic conditions, the assignment was rescheduled. Vehicle number was intended for use if a question arose as to the actual presence of the enumerator aboard his assigned vehicle. The assignment of a particular vehicle to a trip could be checked with the operating company's records, making it possible to determine, if necessary, whether or not an enumerator had actually been aboard the vehicle with a fair degree of certainty. Although not necessary in this survey, this check has been quite helpful in settling cases of suspected non-performance of duties by enumerators.

Processing of the information was relatively simple. Since the sample selection frame and the expansion frame were identical, it was merely necessary to multiply the observed passenger origins by the ratio of sampled trips to total sequenced trips, by expansion area. Thus a sample count of 3,684 passenger origins was expanded to a total of 369,096 passenger origins. While this number was not verified independently, it appeared to be in reasonably close agreement with home interview passenger trip origins, after corrections for services not included in the survey were made (school buses and inclined planes).

Some major shortcomings were found in the design and operation of this first survey based on service sampling. Most important, the ability of the enumerator to observe passenger movements was seriously underestimated. Thus, in addition to boarding passengers, departing passengers could have been recorded and exact stop locations could have been noted rather than the sequential numbers used. With this information, and some coding work, many measures of transit system behavior could have been derived, including trip length, vehicle occupancy, a total measure of passenger miles, as well as passenger origin and destination location and density patterns.

Other problems were more of an operational nature and did not affect the amount or quality of the data collected. Use of the vehicle trip as a sampling unit posed two such problems. The first was that the enumerator had a difficult time locating the particular trip that he was assigned to ride. Not all terminal locations could be specified exactly, so that in some cases a trip had to be assigned more than once until it could be located. Also, it was often quite difficult to locate the correct trip on routes with frequent service, particularly as small delays were common and buses were at times out of their proper sequence. In such cases it was necessary to stop several buses and obtain from the driver either their run number or scheduled leaving time, whichever was applicable, in order to determine the right vehicle.

A second problem associated with the trip sample was the productivity of the enumerator obtained with this system. Since each trip was sampled independently of all other trips on a route, it was almost impossible to schedule the enumerator's work in such a way that more than half of his time was actually engaged in fieldwork. Thus, for any sampled trip with one end in the CBD, it was necessary to ride a trip not in the sample in the opposite direction, either to get to the starting point or to return. In practice, the productivity was much lower, with an average of only two hours of actual counting possible out of a normal day due to the peaking of sampled trips in the morning and evening, and the large amount of unproductive travel time that was necessary to reach some non-CBD-oriented samples.

The sample of service method of obtaining transit passenger usage information has in addition been used on two surveys in the New York region. Both of these were conducted by the Tri-State Transportation Commission. One was a survey of suburban railroad service, conducted in the summer of 1963. The other covered the regularly scheduled bus operations in the Tri-State region, and was conducted in the period from the spring of 1964 to the winter of 1965. While the principles underlying the method were the same as those of the Pittsburgh survey, many changes were made, both to correct defects in the original design, and to adopt the procedure to produce the desired results.

The purpose of the suburban railroad survey was to obtain the volume of passengers over each segment of a railroad line both for the 24-hour day and for peak periods. To obtain such detailed information a more carefully controlled expansion base as well as a higher sample rate or rates were needed. Thus, it became desirable and readily feasible to use a variable sample rate. Since individual route and segment information was desired, the sample rate should reflect the density of service on the individual routes. Thus a 20 to 50 percent sample was used, depending on the amount of service on the route or group of routes under consideration. In some areas a complete count had to be taken, because there was not sufficient service operated to use a sampling procedure.

To permit a more carefully controlled expansion of the survey findings, it was decided to use a different base for expansion of the survey than was used for sample selection. The expansion base used was the seating capacity of the service operated over each route segment for a given time period. Obviously, this is not a quantity that could be sampled in an operational manner. Although it would be possible to assign an enumerator to count the passengers in every third seat, it would be far simpler and less expensive to take a complete count of a larger segment of service. Thus a method for approximating the seating capacity for sample selection purposes had to be designed. Unlike buses or streetcars, which are single, rather small units, readily enumerated by one man, suburban trains vary widely in size and at best are difficult to observe satisfactorily. Thus, a sample unit had to be devised based on the limitations of the enumeration system. It was decided that a count of passengers taken as the train moved between stations provided sufficient information for the purposes of the study, and required far fewer people than would a count taken of passengers boarding and alighting. This is because an accurate boarding and alighting count requires one man per pair of adjacent vestibules, or the inspection of tickets. Thus a 7-car train would require 6 enumerators, assuming the front vestibule of the lead car and the rear vestibule of the last car are not used. It was determined by some experimental fieldwork that an on-board count can be taken at a rate of slightly over one car per minute. Thus the controlling factor is the time between stops, as well as the train length. The 7-car train in the example would require 1 man, if station stops were 7 minutes or more apart, and more typically two men, if station stops were 3 to 4 minutes apart. While the method of enumeration adopted provided sufficient information for the survey, information on the boarding and alighting points of passengers, and thus station usage, was not obtained. For some applications, this type of information may be desirable and would require a different enumeration procedure.

After the method of enumeration was decided upon, a sample selection scheme compatible with it was laid out. This scheme consisted of dividing all service into sampling units or blocks, a block being defined as the position of a train that could be assigned to one enumerator following the one-car-per-minute rule mentioned. The service to be sampled, i.e., the suburban service on the Long Island, New Haven and New York Central railroads, was first divided into sampling groups by railroad, route and type of service. Trains in each group were then listed in direction and time order and the

RR XYZ

Train No.	Leave	Arrive		Consist	Block No.	Sample No.
201	8:09 AM	9:30 AM	LV	2AC MU	1	0001
203	9:46	10:40	LV	2AC MU	1	0002
17	10:14	11:37	EM	4RSC-1 Grill-1 Parlor	1	0003
209	12:10 PM	1:06 PM	LV	3AC MU	1	0004
451	3:07	4:39	XA	2RSC-1 NRSC	1	0005
211	3:44	5:40	LV	3AC MU	1	0006
213	4:27	5:22	LV	4AC MU	1	0007
453	4:41	6:19	EM	4NRSC-Bar C-5RSC	2	0008-0009
57	4:45	6:04	EM	5RSC-Grill-1 Parlor	1	0010
215	4:52	5:45	LV	6AC MU	2	0011-0012
217	5:16	6:12	LV	8AC MU	3	0013-0014-0015
219	5:41	6:44	LV	9 Old MU	3	0016-0017-0018
499	5:44	6:02	WY	7AC MU	2	0019-0020
23	6:00	7:15	EM	2RSC-Diner-2SL-SL Lge	1	0021
221	6:12	7:07	LV	4AC MU	2	0022-0023

Figure 1. Sample train listing sheet.

number of blocks determined for each train. Each block was then given a sequential number. Figure 1 shows a sample train listing sheet. Note that the number of blocks per train will vary with respect to the train length quite noticeably. This example is designed to show a mixed type of service, with local suburban trains and medium distance trains carrying suburban passengers intermixed. Information on normal train lengths and consists was provided by the railroads.

The sequential numbers chosen to be sampled were based on a series of random starts in a group of 10 numbers. Thus, if a 40 percent sample was to be chosen, 4 random starts were taken, and the final digits thus determined were selected from each group of 10 sequence numbers. Each block was then included in a work assignment for an enumerator. Work assignments were laid out so as to maximize utilization of personnel, but due to the highly peaked nature of railroad service only 3 to 4 hours of fieldwork per man day was possible. Field work was straightforward, with each enumerator making a count of his assigned block between all station stops. In addition, each enumerator was to record a complete count of the train at the point where it crossed the river boundaries of Manhattan. A list of car numbers on the train was also made, to verify, if necessary, the presence of the enumerator on the train as well as to provide a more exact record of seating capacities for use in establishing the expansion ratio. Trains with substantial observed deviations from normal train length were reassigned, as well as trains that were significantly behind schedule.

In order to expand the sample, a complete record of seating capacity was needed for the universe of service. An approximation of capacity could be obtained from the equipment assignment lists used to prepare the sampling frame, but it was desired to make a more accurate estimate. Therefore capacity was established based on the trains actually observed in the counting process. As has been noted before, car numbers were observed for all trains, along with a notation as to whether or not the car was open to passengers. Capacity of each car was obtained from equipment rosters supplied by the railroads, or from the "Official Register of Passenger Train Equipment." All trains not falling in the sample were also observed. Those trains that crossed into Manhattan had complete counts taken at the crossing point, while the unsampled trains that did not enter Manhattan were inspected only for car numbers at a major terminal.

Capacity was defined as the total number of seats in cars open to passengers at the inner terminal. In a few cases where cars were added or removed at intermediate points, trains are assigned different capacity values over several parts of the system. Capacity of the sampled blocks was handled in the same manner as described for system capacity. Volumes were calculated by means of the expansion ratio described for the previous survey:

$$\text{Passenger volume} = \frac{\text{Observed passengers}}{\text{Sampled capacity}} \times \frac{\text{Total capacity}}{\text{Sampled capacity}}$$

The expansion was performed based on the sum of each value for the route segment and time period of interest.

Two tests of the accuracy level of this survey were designed into the procedure. The first was a comparison of the complete count made at the Manhattan boundary with the expanded sample count taken at that point. Table 1 shows the results of this comparison. The general comparison is very good, with the largest difference in the 9 groups being 3.6 percent. Note, however, a slight tendency for the expanded sample to be slightly biased upward from the complete count. An overall comparison of +2.0 percent for all service was obtained, and 6 of the 9 subgroups compared had expanded sample volumes higher than the complete count volumes recorded.

A more detailed comparison of the results of the sample counting process was obtained for the Port Washington branch of the Long Island Rail Road. A complete count was taken of passengers on the branch in a way that made it possible to divide the count into five subsamples of 20 percent each. A comparison of the expanded volume derived from each subsample with the complete count showed that the expansion of subsample 1 produced almost the same number of passenger-miles as the complete count. Subsamples 2, 3 and 4 were respectively 9, 2 and 1 percent higher than the complete count, and subsample 5 was 10 percent lower. The counts entering Manhattan followed a similar pattern, with the expansion of subsample 1 being almost the same as the complete count, subsamples 2, 3 and 4 being 6, 1 and 3 percent higher, and subsample 5 being 9 percent lower. It appears that variations in both passenger-miles and the Manhattan entry count parallel each other. All samples varied in the same direction in both quantities, and remain within 3 percent of each other at all times. Also, looking at the detailed results of the comparison (Table 2), descrepancies remain in the same range throughout the length of a line, except for the low-volume outermost links where a greater dispersion can be observed.

TABLE 1

ENTRY COMPARISON FOR EXPANDED SAMPLE VS 100 PERCENT COUNT

Terminal	Complete Count	Expanded Sample	Percent Difference
Penn Station (LIRR)			
8-9 AM Inbound	31,651	32,002	+1.11
7-10 AM Inbound	52,782	53,305	+0.99
24 Hour-2 Direction	136,943	140,049	+2.27
Grand Central (NHRR)			
8-9 AM Inbound	14,674	14,882	+1.42
7-10 AM Inbound	22,286	22,198	-0.39
24 Hour-2 Direction	62,394	64,670	+3.65
Grand Central (NYCRR)			
8-9 AM Inbound	19,139	19,110	-0.15
7-10 AM Inbound	27,776	28,206	+1.58
24 Hour-2 Direction	69,923	69,855	-0.97

TABLE 2

PORT WASHINGTON BRANCH SUBSAMPLE COMPARISON

Station	Sample 1			Sample 2			Sample 3		
	100% Volume Count	Expanded Volume Count	Exp/100% Ratio	100% Volume Count	Expanded Volume Count	Exp/100% Ratio	100% Volume Count	Expanded Volume Count	Exp/100% Ratio
Penn Station-Woodside	30651.0	30718.9	1.0022	30651.0	32561.5	1.0623	30651.0	31055.3	1.0132
Woodside-Elmhurst	31833.0	31829.1	0.9999	31833.0	34637.1	1.0881	31833.0	31896.8	1.0020
Elmhurst-Corona	31905.0	32109.3	1.0064	31905.0	34668.2	1.0866	31905.0	31889.8	0.9995
Corona-World's Fair	31900.0	32104.4	1.0064	31900.0	34658.5	1.0865	31900.0	31889.8	0.9997
World's Fair-Flushing	31655.0	32316.1	1.0209	31655.0	34644.6	1.0944	31655.0	31826.5	1.0054
Flushing-Murray Hill	32962.0	33488.0	1.0160	32962.0	35976.5	1.0914	32962.0	32678.2	0.9914
Murray Hill-Broadway	32098.0	32767.7	1.0209	32098.0	34654.4	1.0796	32098.0	31903.1	0.9939
Broadway-Auburndale	30596.0	31401.4	1.0263	30596.0	33448.4	1.0932	30596.0	30624.4	1.0009
Auburndale-Bayside	29524.0	30320.6	1.0270	29524.0	32207.9	1.0909	29524.0	29297.6	0.9923
Bayside-Douglaston	26439.0	26976.3	1.0203	26439.0	28646.7	1.0835	26439.0	26814.2	1.0142
Douglaston-Little Neck	24678.0	24814.9	1.0055	24678.0	27483.5	1.1137	24678.0	25615.1	1.0380
Little Neck-Great Neck	22777.0	22339.1	0.9808	22777.0	25716.2	1.1290	22777.0	25710.8	1.1288
Great Neck-Manhasset	13055.0	12044.8	0.9226	13055.0	14579.6	1.1168	13055.0	15307.0	1.1725
Manhasset-Plandome	7029.0	6598.5	0.9388	7029.0	8523.1	1.2126	7029.0	7844.6	1.1160
Plandome-Port Washington	5529.0	4974.9	0.8998	5529.0	6891.2	1.2464	5529.0	6376.6	1.1533

Station	Sample 4			Sample 5		
	100% Volume Count	Expanded Volume Count	Exp/100% Ratio	100% Volume Count	Expanded Volume Count	Exp/100% Ratio
Penn Station-Woodside	30651.0	31693.5	1.0340	30651.0	27868.5	0.9092
Woodside-Elmhurst	31833.0	32504.7	1.0211	31833.0	28783.7	0.9042
Elmhurst-Corona	31905.0	32524.0	1.0194	31905.0	28672.2	0.8987
Corona-World's Fair	31900.0	32524.0	1.0196	31900.0	28662.3	0.8985
World's Fair-Flushing	31655.0	32461.7	1.0255	31655.0	28805.3	0.9100
Flushing-Murray Hill	32962.0	32837.8	0.9962	32962.0	29720.1	0.9016
Murray Hill-Broadway	32098.0	31792.0	0.9905	32098.0	28847.1	0.8987
Broadway-Auburndale	30596.0	30508.6	0.9971	30596.0	27430.1	0.8965
Auburndale-Bayside	29524.0	29573.1	1.0017	29524.0	26148.0	0.8856
Bayside-Douglaston	26439.0	25583.0	0.9676	26439.0	23280.2	0.8805
Douglaston-Little Neck	24678.0	23556.5	0.9546	24678.0	21629.8	0.8765
Little Neck-Great Neck	22777.0	22062.8	0.9686	22777.0	19301.1	0.8474
Great Neck-Manhasset	13055.0	13045.8	0.9993	13055.0	11662.3	0.8933
Manhasset-Plandome	7029.0	7159.0	1.0185	7029.0	5990.6	0.8523
Plandome-Port Washington	5529.0	5486.2	0.9922	5529.0	4643.9	0.8399

The two tests indicate that the results of surveys using this method can be used with a considerable degree of confidence. In general, it appears that the results obtained are well within the normal (day-to-day) variability level of the information sought. In the one area where excessive variation was observed—the outer end of the Port Washington branch—it was accounted for by the low total volume observed and the low sample rate (20 percent) used. The lesson to be drawn is that the sample rate used in this test (the lowest used in the survey) was too small to provide a high level of accuracy on the lowest volume segments of this service. However, the estimated and actual volumes in this area did not vary by more than around 1, 500 persons per day, which for many purposes would be a sufficiently accurate estimate.

The second survey using the sample of service method was the bus passenger survey taken by Tri-State in 1964. Here the information desired was bus passenger-miles of travel by geographic area. Although this survey is not yet completely analyzed, a description of the methods used is possible.

Looking back to the 1959 Pittsburgh work, it was apparent that a vehicle trip sample would present almost insurmountable selection problems, as well as requiring a large amount of geographic coding of both sample and universe data to produce the desired geographic breakdown. Since the geographic coding appeared inevitable, a sample frame was sought that approximated the distribution of bus movements, yet was operationally simple to use. The sample unit decided upon was the active vehicle. This is a somewhat arbitrary concept. It is defined as a bus in service at the time when the maximum number of buses are in service that are based at the facility under consideration.

Perhaps working through the preparation of the sample frame will be helpful. First the bus service is ordered by major geographic area (state, county, etc.) based on the garaging location of the vehicles. Within this order, bus service is separated by company and division or garage. The garage thus becomes the primary subdivision of service within which the sample is drawn. For each garage, the maximum number of buses required to operate the service is determined. This number represents the total sample frame for the garage. The detailed sample frame is determined as follows. The number of buses on each route at the time of day when the maximum number of buses is required from the garage is computed and is used to determine the number of lines in the sample listing. Buses are then listed by route in order of their first departure from the garage until the number of lines indicated is reached. The return time to the garage is listed for each of the departures. The remaining buses departing from the garage are tied to previously listed departures on a first-in, first-out basis, within route if possible. A 30-minute minimum time between arrival and departure at the garage is required. Generally, the final arrival cannot be more than 23 hours 30

Sample No.	ON AM	OFF AM	ON PM	OFF PM	ON EX	OFF EX
8243	5:25	7:50 PM	→	→		
8244	5:45	8:30 PM	→	→		
8245	6:05	9:00 PM	→	→		
8246	6:20	10:20 AM	4:30	6:25		
8248	6:25	12:50 AM	→	→	→	→
*8248	6:35	11:10 AM	(Route 23)		(4:35 PM	7:15 PM)
8249	6:55	10:00 AM	2:30	9:10		
8250	7:05	9:10	1:55	8:10		
8251	7:20	9:20	2:15	12:15 AM		

Figure 2. Master sample list.

minutes later than the initial departure. When it is impossible to remain within the route structure and follow the above rules, the remaining portions of the service on a route may be listed with another route in the same garage. For example, this would occur when a route using its maximum number of buses in the afternoon peak operates from a garage having a maximum bus requirement during the morning peak. In some cases, buses are not specifically assigned by route, so that a whole garage may be treated as one route. The result of this procedure is a listing for each garage by route showing the departure and return times of each active vehicle. A sample of this listing is shown in Figure 2. Sample vehicles to be used in a count program can be selected by numbering the list of active vehicles sequentially and selecting a sample using every nth sample number. In 1964 a 5 percent sequential sample was selected using every 20th line starting with sample number 0008.

The use of the active vehicle as a sample unit was decided upon primarily for operational reasons. A sample of bus trips would more closely approximate the desired sampling quantity of bus miles, since only variations in route length would cause the two quantities to differ. With the active vehicle sample, differences occur due to extent of utilization during the day, as well as due to variations in route length. In addition, the use of a trip sample would permit stratification by direction and time of day as well as by route, which was not possible in the vehicle sample.

However, a bus trip sample would be very difficult to handle in an operational sense. The work required in stratifying and delineating the sample would be increased by a very substantial amount, as there would have been at least 10 times the number of units in the sampling universe. More important, the fieldwork involved in a trip sample would be much more time-consuming and difficult to organize. Deadheading time and time between assignments would be increased from about 10 percent of total paid time for field personnel to over half of the total, based on Pittsburgh experience, thus doubling the cost of fieldwork for a given sample size. In addition, it was much simpler for enumerators to locate buses at the beginning of a day's run at the garage than it would be to have to locate a particular trip at the end of a line, four or five times during the day, especially during rush hours and at crowded locations such as subway transfer points, where it might be necessary to go down a line of buses and inquire of the driver as to the run number or leaving time of each bus until the correct one is located. It would be expected that a substantial number of assignments would not have been completed due to the enumerator's inability to located the correct trip, thus adding even more to the costs of the survey.

While final results of the bus survey have not yet been completed, the question of the degree to which the sampling device, using the active vehicle as the sampling and

TABLE 3

COMPARISON OF EXPANDED SAMPLE COUNT WITH COMPLETE COUNT ON BRONX-MANHATTAN, AND BROOKLYN AND QUEENS-MANHATTAN SCREENLINES

Category	Bronx-Manhattan Screenline	Brooklyn and Queens-Manhattan Screenline	Combined Screenline
Number of routes	12	7	19
Number of buses crossing screenline	4362	1630	5998
Buses sampled	212	70	282
Percent of buses sampled	4.86	4.29	4.70
Passengers counted in sample	3206	1682	4888
Average passengers per bus	15.12	24.03	17.33
Total passengers (expanded from sample counts)	65,965	39,167	103,965*
Total passengers (from screenline count)	67,038	35,184	102,222
Percent difference	-1.60	+11.32	+1.27

*Computed based on total sample count and number of buses, not sum of estimates for individual screenlines.

enumeration unit, succeeded in representing the total universe of bus miles has to some extent been solved. In the Tri-State bus survey, 391 sample buses were observed. These buses traveled a total of 38,653 miles. The total bus movement (excluding school and charter buses) in the region was 799,037 miles, divided into 7824 active buses. Thus the sampled bus miles represent 4.84 percent of the total bus miles as compared with an intended 5 percent sample. When data are available, the stability of this ratio will be examined for smaller areas.

Due to the size of the survey, no comparison of sample results with a complete enumeration was possible. However, two tests of the accuracy of the results are available. For test purposes, two 5 percent samples were taken in Staten Island. When results are available for both of these samples, they will be compared to get some idea of the stability of the results. Another test possibility is to compare the results of the sample survey at a screenline with independent complete counts taken at this screenline. A series of counts taken in the fall of 1963 at the crossings between Manhattan and Brooklyn, Queens and the Bronx were available for this purpose. The results of this comparison are shown in Table 3. The comparison is almost too good to believe, except for the Manhattan-Queens and Brooklyn screenline, where as a result of the small size of the sample, substantial deviation might be expected. Results on this screenline are still good, particularly considering that only 4 of the 7 routes fell into the sample and 3 of 6 samples were on one route. Additional comparisons of this type will be made for other screenlines as data become available.

It appears that the sample of service method can be used to satisfactorily obtain data on the usage of transit systems, and that the level of detail and accuracy desired can be achieved by control of the sample size and method of observation. However, it must be cautioned that no exhaustive test of the accuracy of this sampling method has been made using an entire service area as a base, and all evaluations made up to this time have been based on partial data.