On-Board Bus Surveys: No Questions Asked

PETER R. STOPHER, LAURENCE SHILLITO, DAVID T. GROBER, AND HELEN M. A. STOPHER

In this paper is described an on-board bus survey procedure that allows collection of data about the pattern of use of the bus system within each bus route and limited data on transfer patterns. The procedure is a simple one that involves the passenger accepting a colored, imprinted card when boarding the bus and returning this card on alighting from the bus. The survey therefore obviates the need for passengers to respond to questions, which is of particular value for bus systems the patrons of which may speak a variety of different languages and may be unwilling or unable to respond to a survey in English. The analysis procedures for the survey results are simple and can be executed rapidly, which allows results to be obtained within a matter of days or weeks of survey execution, compared with the months more normally encountered for standard on-board surveys. The survey procedure has also been found to generate a high response rate. In an urban area that had previously shown poor on-board survey responses even with a multilingual instrument, a response rate of between 85 and 98 percent was achieved on a route-by-route basis.

There appears to be a growing interest in conducting bus-rider surveys, particularly on-board bus surveys, as various bus operators find themselves faced with the need to redesign services in an effort to cut costs without too great an impact on transit-dependent patrons. Bus-rider surveys can take a variety of forms *(1-3)* including on and off counts at specific points, farebox sample surveys, self-administered survey forms, on-board interviews, and simple ride checks. The amount of information generally possessed by most bus operators is more variable still than the methods for conducting ridership surveys. The extremes are defined by those operators that conduct on-going monitoring of ridership levels through ride checks and counts, supplemented frequently by interview surveys of bus riders, and those operators that have no on-going information-collection activity apart from farebox counts, from which they derive estimates of ridership for annual reports.

The attitudes of bus operators to ridership information are also varied and depend on their view of the goals and objectives of bus service. Increasingly, the attitudes of operators are changing to a recognition that bus operations provide a service in a competitive market. This change in attitude is bringing with it acceptance that data are needed on the positioning of the product called "transit service" in the market of transportation services. Data are also required to identify the users of transit service and how these users make use of the service.

Ride checks *(2)*, perhaps the commonest form of frequent data collection for bus operations, do not provide adequate information on how the user is consuming the product of transit service. Ride checks provide information on boardings and alightings by stop and the total loads on a bus route at various points along the route, thereby allowing definition of the maximum load point. However, ride checks do not provide information on the travel pattern of individual users of the bus system. However, there is a method for developing route origin-destination (O-D) information from on-off counts, with some major limitations *(4)*.

In general, to determine the patterns of use of the system requires some method for tracking the behavior of the individual user. Many European transit systems have a built-in mechanism for obtaining such data, provided by a ticketing system that records both the boarding and alighting points, to allow a staged fare to be charged. However, in systems with flat fares and no tickets, such as those operating in the United States, passengers do not use any fare mechanism that provides a means of tracking their travel behavior. As a result, U.S. operators, more than their European counterparts, must resort to some type of passenger survey to determine how the system is used.

Passenger surveys are, however, posing more and more difficulty. Apart from the often-encountered resistance to surveys of the bus-riding public, there is a growing language problem that makes it difficult indeed to devise any type of self-administered or interview instrument that can provide data on a representative sample of bus riders.

The specific situation that gave rise to the development of the survey described in the balance of this paper involved language problems that were expected to cut severely into the representativeness of any survey that employed any form of traditional self-administered or interview instrument. In the survey location—Dade County (Miami), Florida—the following conditions existed:

- A bilingual survey conducted in 1980 had achieved only a 20 percent response rate from a self-administered survey form *(5)*.
- A second bilingual survey in 1982, administered simultaneously in five other urban areas in the same state, achieved a response rate of 23 percent compared with an average of 86 percent in the other urban areas *(6)*.
- Data were needed on passenger travel patterns to allow a major redesign of the system to be accomplished without substantial loss of service to existing patrons.
- An ordinance had been passed by referendum since the 1980 survey declaring English the official language of the county and prohibiting use of county funds to translate or print material in any language other than English.

The last of these conditions meant that any traditional survey undertaken could be presented only in English. The bus ridership to be surveyed included Spanish speakers and Haitians, as well as others with native languages other than English, most of whom could be expected to be unable or unwilling to read or respond to a survey conducted only in English. Clearly, representativeness could not be expected from any survey that was based on questioning bus riders. Furthermore, it is apparent that bus riders in Dade County are unwilling to respond to on-board surveys, even when multiple languages are used.

After much effort was spent in considering the actual data needs, it was determined that by far the most important elements of data required are the origin and destination bus stops of bus riders and some information on the use of transfers within the bus

P. R. Stopher and H. M. A. Stopher, Schimpeler Corradino Associates, 425 South Main Street, Los Angeles, Calif. 90013. L. Shillito, Schimpeler Corradino Associates, 1429 South 3rd, Louisville, Ky. 40208. D. T. Grober, Metro-Dade Office of Management and Budget, 1050 N.W. 19th Street, Miami, Fla. 33136.

system. Although data on the socioeconomic status of bus riders might be useful, socioeconomic status is not of utmost importance to the redesign of the system. Similarly, data on trip purpose, captivity to transit, actual origins and destinations, and modes of access and egress would all be useful to provide a more complete picture of bus use. However, none of these items was considered to be unequivocally essential for planning and initiating changes in bus routes, frequency of service, and service coverage. All of these desirable but nonessential data items require participation in a survey by the bus riders. In the situation defined here, the expected representativeness of a traditional survey procedure must be considered quite poor. Therefore a survey method was developed that would provide the essential information without involving the active response of bus riders in a question-and-answer survey.

The specific purposes to be served by the data were to provide sufficient information about existing bus users to allow changes to be made in bus routes that would minimize impacts on existing riders. At the same time, it was desired to identify potential changes in bus routes that would improve service or reduce operating budgets without signifiant loss of patronage. The bus system redesign, for which the survey was designed, was a wholesale restructuring of the system to reduce the operating costs significantly while retaining essential services and supporting the recently opened Metrorail system so as to increase rail ridership.

Ride-check data and farebox-based data were considered insufficient for this task. Such data can identify the volumes of boarding and alighting passengers on a route, and at specific bus stops, and can determine the location of the maximum load point, but they do not provide information on how far passengers ride nor on whether or not there are points on the bus route where the bus empties and then commences to fill with a new group of passengers. These are the types of information that it was believed would be helpful in determining how to restructure routes *(4)*. In addition, information was desired that would indicate whether early morning, late night, or weekend service could be curtailed, operated with short turnbacks, or otherwise reduced to save operating costs while losing a minimal number of passengers and amount of revenue.

SURVEY MECHANISM

Ideally, it would desirable to know the bus stop of boarding and the bus stop of alighting for each bus rider. In Dade County, as in many other large cities in the United States, there may be as many as 100 bus stops along a given bus route. Building 100 by 100 matrices for every bus line in the system would provide more detailed information than would ever be likely to be used and would place excessive demands on data processing and storage. It was decided, instead, to segment each bus route into as many as 10 segments and collect information on the segment of boarding and the segment of alighting of each passenger. Also, methods were considered for tracking information on transferring passengers. The ideal would be to know the bus stop for boarding of a transferring passenger and the stop of alighting. As is discussed later in this paper, this did not prove to be possible, although several different methods were attempted in the pilot survey—none with any remote success.

The survey mechanism used colors to identify each route segment. By assigning a different color to each segment of a bus route, color codes could be used to record when a passenger boarded the bus and when the same passenger alighted from the bus. The same sequence of colors was used for each bus route, although the number of segments on any route varied with the length of the route. To simplify execution of the survey, the segments were defined by the timing points used in building schedules for the bus system. These timing points are well known to the bus drivers, are used in all driver schedules, and are generally associated with transfer bus stops. They provide a useful and ready means of identifying route segments. Also, surveyors on the bus can obtain assistance from the driver in identifying the bus stop immediately preceding the timing point or at the street intersection that defines the timing point.

Survey Instrument

The first part of the survey instrument was designed as a small card, the same size and weight as a standard business card. These cards were imprinted with the bus system logo, to show the association of the survey with the bus operator, and with the route number of each bus route. Two additional numbers, described subsequently, were also printed on the cards. A typical card is shown in Figure 1. Cards were produced for each bus route in each of the colors required to identify all of the segments on the route. Because of limitations in the available card stock and constraints on differentiability of colors, the following color sequence was used on all bus routes: red, grey, yellow, blue, white, green, pink, tan, orange, and gold. If a bus route had only four timing points, defining three segments, the colors allocated to that route were red, grey, and yellow. If a bus route had six timing points, the five segments were coded red, grey, yellow, blue, and white. The same logic was applied to all routes, with the color furthest from red defined by the number of segments.

The second part of the survey instrument was a set of return boxes. These were made out of the boxes used to package business cards stuck to a strip of stiff cardboard (Figure 2). Each of the boxes in the strip was color coded, in the same sequence as the cards. In addition, black cards were cut, slightly smaller than the cross section of the return boxes, to be used as dividers between bus trips.

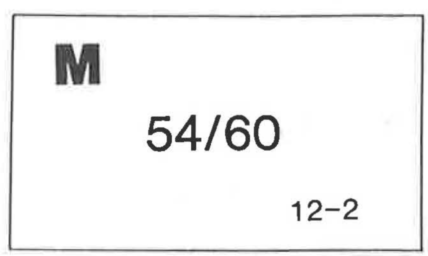

FIGURE 1 Example of the survey instrument.

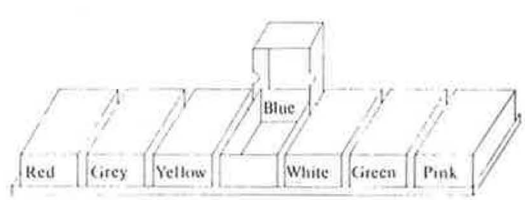

FIGURE 2 Return boxes

Survey Procedure

The survey procedure consisted of handing a colored card to each boarding passenger as the bus rider boarded the bus. The color of the card corresponded to the color coded to the segment of the bus route where the passenger boarded. On alighting, the passenger was asked to return the card, and the card was placed in the return box that corresponded in color to the segment of the bus route on which the passenger alighted. Thus, if a passenger boarded in the red segment of the bus route, he received a red card. If that same passenger alighted in the blue segment, the card was placed in the blue return box. Similarly, a passenger boarding in red and alighting in yellow would have his card placed in the yellow box. Thus, by counting the number of red cards in each return box, it would be possible to deduce the number of passengers that boarded the bus in the red segment and got off in each of the segments of the bus route.

In addition to the survey cards, surveyors collected transfers from the driver at each bus stop and placed these in the return box for the current segment of the bus route. This allowed determination of the number of passengers boarding in a segment who had transferred from another bus. Because the bus route number of the issuing route is recorded on the transfer, the number of transferring passengers by originating bus route was also obtained.

The survey procedure requires passengers to accept the colored card, hold it during the bus ride, and return it when they alight. To effect this, two surveyors rode most buses, one stationed immediately behind the farebox and one near the center exit door. The surveyor at the front of the bus handed out a card to each boarding passenger and also collected cards from those passengers (quite a large proportion in Dade County) who exited by the front door. It is possible for one surveyor to do these two things because the design of U.S. buses is such that passengers cannot both board and alight through the front door at the same time. The surveyor at the center exit has the task of collecting cards from all passengers leaving by that exit door. This procedures does not require any significant communication between surveyor and passenger, beyond the request for the passenger to take a card. This can be translated into several languages, if need be, but it was generally found in practice that there was little time to do more than ask passengers, in English, to take the card. A three-panel pictograph (Figure 3) displayed strategically in the bus communicated the requirement to take a card, hold it, and return it on alighting. This obviated the need to translate instructions into various languages.

Obtaining More Information on Transfer Passengers

As noted, it was desired to obtain specific information about transfer passengers. Several methods for doing this were considered. Of those considered, three were designated for testing in a pilot survey:

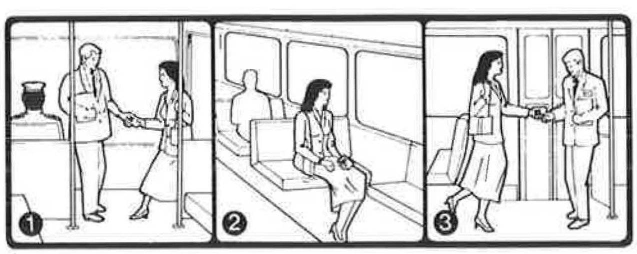

FIGURE 3 Pictograph used to instruct passengers.

- Stapling the colored card to the transfer and handing the two back to the passenger for retrieval when the passenger gets off,
- Marking the colored card with a "T" before handing it to the transfer passenger, and
- Punching a hole in the colored card before handing to the transfer passenger.

None of these methods was found to be workable because there is simply insufficient time to undertake these activities while handing out cards to boarding passengers. Also, it was impossible to watch which passengers used transfers and which did not while also handing out cards to all boarding passengers. Therefore it was decided that the only information to be collected from transfer passengers would be the boarding segment and the information already encoded on the transfer. To facilitate this procedure, bus drivers were asked to hand all transfers to the surveyor at the front of the bus after leaving each bus stop. Transfers were placed in the return box for the current segment color. Because the Dade County bus system does not use the transfers for any further purpose after they are handed to the driver and checked, this was a feasible method. In application to other systems, different procedures may be desirable for transfers, depending on local procedures for transferring passengers and information desired on transferring passengers.

Survey Sample and Execution

The sample was defined by selecting bus runs from each bus route in the system. The Dade County bus system has few lines that are operated interlined, and most of those are designated as dual routes for operation and analysis purposes (e.g., route 54/60). This makes sampling bus runs an easy method of administering the survey because a survey team placed on a selected bus will usually ride a single route for the entire time the bus is in service *(1)*. Bus runs for each route are assigned a unique number, beginning with 1. This bus run number was the second number printed on the survey cards. Thus bus runs are designated on "rotaries," the route operating schedules, and on driver "cards," the individual pieces of work assigned to each driver. Thus both the surveyors and the drivers knew the run number of the current operation. As a check that they were boarding the sampled bus, surveyors were instructed to check the run number with the driver.

The sample size was defined more for political reasons than on the basis of accuracy of the data. Dade County staff desired that a minimum 40 percent sample, covering bus operations for a weekday from start to end of operations and each Saturday and Sunday for the same period, be obtained. To a large extent, this sample size was set with the idea of being able to claim that a large number of riders had been included in the survey.

The sample was comprised of complete bus runs from each bus route. In many instances, this meant that the survey commenced at the bus garage, before the bus went into service. In such cases, the bus often commences service at the timing point nearest the garage, or at some other intermediate point, rather than at one of the end points of the bus route. At other times, survey teams boarded a bus in service, coincident with an operator change and, therefore, a run number change on an in-service bus. Because of the nature of both of these starting locations for a sample run, it was often the case that the survey would commence at some point in the middle of the route, rather than at the ends of the route as defined by the route map and the published schedule.

A team of two surveyors boarded a sampled bus. If a team was the one designated to commence the survey on that bus run, they boarded with survey materials for the entire run. These materials included signs to put up on the bus (requesting passenger assistance with the survey and showing what was expected of passengers) and the survey supplies. Each bus run consists of a number of one-way trips. These trips were numbered from 1 by the survey management for each sampled bus run. The number of trips per run is a function primarily of the length of the bus route, and ranged from 2 to 25 trips. The trip number constituted the third number printed on each survey card, to provide a check on the correct return of cards. To recap, the colored survey cards were imprinted with the bus system logo, the route number, the run number, and the trip number.

The survey materials for each bus run consisted of

- A "tailored" trip box for each trip on the sampled run;
- A supply of black divider cards equal to the number of trips multiplied by the number of trip segments;
- A supply of spare, blank red cards;
- The tray of return boxes; and
- Clipboards and color-coded maps of the bus route

The tailored trip boxes included one card box for each trip that the bus was scheduled to make on a sampled run and contained 60 cards banded together for each color of the route. The tailoring consisted of ordering the colors to correspond to the order in which the segments would be met on each trip and removing any colors that would not be needed on a trip. For example, the first trip, on a route with seven colors, might begin in blue and proceed to pink, so that only the colors blue, white, green, and pink in that order would be in the trip box for trip one. The cards in that trip box would be imprinted with the route number, the run number, and Trip 1. Trip 2 might then proceed from pink back to red, and all colors would appear in that trip box, but ordered from pink to red. On the third trip, the bus might make a short turn at the end of the white segment, so the colored cards would be ordered red to white. This system, although time-consuming to set up, was found to be essential to minimizing surveyor confusion when buses made short turns or began in midroute. Also, it ensured that the trip colors were always handed out in the correct order.

The black divider cards were provided to be placed in the return boxes at the end of each trip. This was necessary to be able to record the data on a trip-by-trip basis for analysis. Also, because passengers do not use the bus the same way that the schedule of the bus is designed, it is not sufficient to depend on the trip numbers to identify the trip from which the cards are received. On a number of bus routes, it was found that passengers stayed on the bus over the turn-around at the end of the line and then got off at some point further along the line, past the place that the passenger boarded. This was particularly the case where the bus had no layover at one end of the trip, or a minimal layover, and where the frequency of service was low.

The color coding was designed so that any route that began or ended in the Miami central business district (CBD) was coded red in the CBD. On routes that did not have an end in the CBD, a rule of coding colors from east to west and south to north was applied to maintain consistency. Because of the high concentration of routes in the CBD, the CBD-red rule meant that there were times when the bus would fill up in the red segment, and surveyors could run out of red cards. It was not reasonable to tailor the number of cards by color or by trip. For the survey in Dade County, 4 runs on average were selected from each of 89 routes for weekdays and 4 runs for each of Saturday and Sunday were selected from each of the 46 routes operating on those days. This involved the printer in setting up approximately 4,500 different masters for the route, run, and trip number combinations. A determination was made to print 60 cards for between three and ten colors according to the route number. Blank red cards were provided to be used as spares, in the event that the printed supply was exhausted. The blank red cards could also be used if the supply of some other color was exhausted. However, the surveyors were required to write the color on the cards before handing them out; this was a rare occurrence.

The remaining element of the survey execution that warrants some explanation is the procedure for changing the cards and return boxes at the end of each segment. Surveyors were instructed to ask the driver to tell them when they were approaching a timing point that corresponded to the boundary between two segments. The first action taken was that the surveyor at the front of the bus put away the remaining unused cards of the current color segment and picked up the next color for the new segment, before starting to hand out cards to boarding passengers. Thus passengers boarding at the stop closest to the timing point would receive cards of the color appropriate for the next segment, into which they would travel immediately. After leaving the stop, all cards retrieved from alighting passengers were placed in the box colored for the segment through which the bus had just passed. Then, a black divider card was placed in the return box, and the box was closed. Finally, the next return box was opened and the transfers obtained from the driver at that stop were placed in the newly opened return box. That meant that the returns from the stop closest to the segment end stayed with the color segment that was in use up to the timing point.

There are two reasons for this process. First, spreading these activities out over the segment transition stop made it easier for the surveyors to undertake the required actions, without confusion and without compromising the other activities required at the stop. Second, it was deemed to be more logical to associate boarding passengers with the just-beginning segment color and alighting passengers with the just-ending segment color, in order to reflect the loading of the route.

ANALYSIS OF RESULTS

The results of the survey are essentially counts of color cards and transfers by the segment color in which each is received. It might be possible to computerize the counting process, but such a procedure was not devised for the Dade County survey effort. Two issues are important to keep in mind in determining how to take the contents of the return boxes and obtain count data from them:

- The returned cards are in reverse order of the trips surveyed (i.e., the top layer of returned cards is from the last trip surveyed and the returned cards in the bottom of the boxes are from the first trip surveyed).
- The returned cards on any given layer in one color box do not necessarily come from the same trip as that layer in a different color box. For example, if the first trip starts midway along the route, the bottom layer of half the boxes will be from Trip 1, while the bottom layer of the other half of the boxes will be from Trip 2.

The procedure developed for analyzing the results was based on a two-step process: first, the trip pattern of the surveyed bus run

METRO-DADE COUNTY ON-BOARD BUS SURVEY: ORIGIN-DESTINATION MATRIX

Route No. 1 Run No. 1 No. of Trips 8

Segment Colors: Red through Yellow Day Thursday1 Weather ___________

RUN DESCRIPTION:

TRIP NO.										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

LAYER 1 (TOP) Route No. 1 Run No. 1 Day Thursday1

E N V E L O P E C O L O R (TO SEGMENT)

		RED	GREY	YEL	BLUE	WHITE	GREEN	PINK	TAN	ORANGE	GOLD
C	RED										
A	GY										
R	YEL										
D	BLU										
	WHT										
C	GRN										
O	PNK										
L	TAN										
O	ORN										
R	GLD										

LAYER 2 E N V E L O P E C O L O R (TO SEGMENT)

		RED	GREY	YEL	BLUE	WHITE	GREEN	PINK	TAN	ORANGE	GOLD
C	RED										
A	GY										
R	YEL										
D	BLU										
	WHT										
C	GRN										
O	PNK										
L	TAN										
O	ORN										

FIGURE 4 Example of the counting record form.

was recorded; second, the cards found in each layer in each return box were counted and recorded. An example of the forms used for this is shown in Figure 4. After these forms were filled out, the trip pattern was used to define the trip number of each layer in each color box. Using this key, a matrix was filled out for each trip, as shown in Figure 5. The resulting matrices can be keyed into a microcomputer or mainframe computer for further analysis and for aggregation by time period or other analysis.

The analysis is not instantaneous because of the incidence of potential errors by surveyors, particularly as found by the authors in the case study. These errors lengthen the process of analyzing the results, which must be done by only one or two trained people who will make consistent judgments about the rectification of errors. However, even in the case described here, in which the incidence of error could be expected to be significantly higher than in most cases, it was possible to develop results within about 10 days of execution of the survey for a given route. This represents a quite rapid turn-around of processed data compared with more traditional survey methods.

CASE STUDY

The survey procedure described in the preceding sections of this paper was used in Dade County, Florida, in the early summer of 1985. The purpose was to provide information on the bus system that could be used to plan substantial changes in the bus system while minimizing the potential loss of existing bus users. As noted earlier, Dade County had previously proved a difficult location to survey, partly because of the multiple languages used by the population and partly because bus riders there appear to be little inclined to cooperate in an on-bus survey.

A large sample was selected to provide extensive data on the various time periods. Of particular concern was collection of data on the low-patronage periods, such as the early morning, the late evening, and weekends. This concern dictated a large sample, although good information on the remaining service periods was also desired. The sample selected was generally four bus runs from each route for a weekday, four runs for a Saturday, and four runs for a Sunday. The number of runs operated on bus routes in Miami

METRO-DADE COUNTY ON-BOARD BUS SURVEY: ORIGIN-DESTINATION MATRIX

Route No. ________ Run No. ________ Trip ________

Date ________ Weather ________ Direction ________

B O X   C O L O R (TO SEGMENT)

CARD COLOR (FROM)	RED	GREY	YEL	BLUE	WHT	GRN	PINK	TAN	ORN	GOLD	Sub-Total	Not Dist.	Diff-erence
RED													
GREY													
YEL													
BLUE													
WHT													
GRN													
PINK													
TAN													
ORN													
GOLD													
TOTAL													

FIGURE 5 Example of the segment-to-segment trip matrix.

ranges from 1 to more than 25. For bus routes with large numbers of runs, more than four runs were sampled. For routes with four or fewer runs, all operated runs were included in the sample.

To a large extent, run numbers are assigned in chronological order beginning with the time at which the bus route first goes into service. Thus low-numbered runs are generally those commencing service early in the morning, and high-numbered runs commence in the late afternoon. Trippers (runs that are operated for only one or two trips) are generally interspersed in the run numbering on the same chronological basis. It was decided therefore to use systematic sampling. The size of the interval for systematic sampling was varied by route, according to the number of runs operated on the route and the desired sample. For example, if a route had 12 runs and a sample of 4 was desired, every third run was picked, with a starting point that was systematically varied between Run 1 and Run 3. The sample generated by this procedure for each route was found to contain trippers and base runs in approximately the same proportions as for the entire route and to have a reasonable distribution of runs by time of day.

It was desired by Dade County that county employees be trained to undertake the on-bus survey work with supervision provided by the consultants who designed the survey. Because the use of county employees involved taking employees away from their normal duties during the survey, a limit of eight 5-hr (approximately) shifts was established. This required that a total of more than 450 employees be trained to conduct the survey. With such a large number of surveyors, there was great difficulty in identifying and correcting surveyors who did not perform correctly and a lack of ability to impose disciplinary action against nonperforming surveyors. It could be expected that this scenario would result in much greater potential for problems than would be the case when the surveyors are hired and trained specifically for the survey, a smaller number of surveyors are used, and retraining and dismissal of surveyors not working correctly are possible.

In execution, a number of mistakes were made by surveyors. However, it was found that many of these mistakes did not compromise survey results, if care was taken in the counting and analysis work. Four of the most common errors made are listed next.

- Surveyors did not change to a new trip box at the end of each trip, so the number of the trip on returned cards did not correspond to the trip on the surveyed run. Provided that the black divider cards were always placed correctly, this generally had no effect on the final data—the trip numbers were simply ignored.
- Surveyors did not always place a black divider card in the return boxes at the end of each segment throughout the trip. If the correct trip boxes had been used, this could generally be corrected by checking the trip numbers printed on the cards.
- Surveyors did not always change trip boxes and did not place black divider cards correctly to identify completion of each segment during each trip. About 50 percent of these cases were recoverable by examining the transfers placed with returned cards (indicating route and time of issue) in conjuntion with the color pattern of the cards. The transfers revealed the trip number and the color pattern revealed whether it was an outward trip or an inward trip (i.e., which half of the matrix was represented).
- Surveyors failed to change survey materials from one run number to the next when the sample included two consecutive runs on the same bus. In such cases, surveyors often continued handing out cards from the earlier run on the new run, going back and using unused cards out of earlier trip boxes. In virtually all such cases, the data could be recovered, provided that cards were at least used in consecutive trip order, and more easily if divider cards were used correctly.

On the basis of the total number of cards of each color that was returned and the number unused for trips on which no errors were made, it appears that the response rate from passengers who accepted cards was generally between 95 and 100 percent. On the basis of an earlier survey that provided on-off counts and some spot checks of the surveyors, it was found that between 90 and 98 percent of passengers accepted cards. Therefore, the overall response rate from this survey was between 85 and 98 percent.

The success of the survey methodology can also be seen in Table 1, which gives the disposition of the final sample in summary form. As can be seen from the table, only four weekday runs and two weekend runs that were surveyed could not be processed into trip matrices. Included in the count of runs cancelled are runs that were sampled but for which it turned out not to be possible to schedule a survey team; runs that were cancelled by the bus operator on the survey day; runs on which the bus broke down and the run did not continue in service; and runs where an error was made in the survey scheduling, which resulted in an inability to get a survey team on the bus in time to do the survey. Overall, completed runs, for which the data could be analyzed and used, represent 86.6 percent of the originally selected weekday sample

TABLE 1 SUMMARY OF FINAL DISPOSITIONS OF SURVEY CASE STUDY

Day of Week	Runs Sampled	Runs Completed	Runs Cancelled	Incomplete Runs
Weekday	344	298	42[a]	4
Weekend	349	291	56	2

Source: Schimpeler Corradino Associates.

[a]Includes one run on which there were insufficient data to process—may have been spoilt by the surveyor.

and 83.4 percent of the weekend sample. Spoilt runs constitute less than 1/2 percent of either weekday or weekend samples.

Expansion factors for this survey by time of day ranged between 1.000 and 12.000. Average expansion factors by time of day are given in Table 2. The aim of the survey originally was a 40 percent sample, which would give an average expansion factor of 2.500. Given cancelled runs, the final sample was around 34 percent, which would give an average expansion factor of 2.9. The figures in Table 2 are based on a count of the trips within each run for which data were usable and is, therefore, based on more precise numbers than route-by-route. Also, the disaggregation by time of day adds precision to the data. It is clear that each period of the day averaged a quite similar expansion factor, with only the early morning and morning peak exceeding the average 2.9 factor. More important, the late evening (6 p.m. to 2 a.m.) has one of the lowest expansion factors, at 2.692, with a low standard error of 1.815. Assuming that expansion factors are t-distributed, 95 percent of expansion factors by period of the day lie between 1.000 and 7.30 for any period. For most periods, the range is much narrower than this. The average of these expansion factors is lower than the expected 2.9, largely because runs that were cancelled for lack of surveyors were chosen as far as possible to be runs with the fewest trips from the sample for each route. Also, it is apparent that

TABLE 2 AVERAGE OF ROUTE-BY-ROUTE EXPANSION FACTORS BY TIME OF DAY

Factor	Time of Weekday 4 a.m.–7 a.m.	7 a.m.–9 a.m.	9 a.m.–4 p.m.	4 p.m.–6 p.m.	6.p.m.–2 a.m.	Saturday	Sunday
Average	3.166	3.096	2.422	2.897	2.692	2.247	2.261
Minimum	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Maximum	11.500	11.000	8.000	12.000	9.000	5.455	5.526
Standard error	2.100	2.332	1.526	2.012	1.815	1.540	1.460

Source: Schimpeler Corradino Associates.

approximately the same level of accuracy was achieved, in terms of sampling rate of bus trips, for each time period of interest. Overall, Tables 1 and 2 point to a successful survey that achieved the desired sampling accuracy.

CONCLUSIONS

An on-board bus survey procedure is described that allows collection of data about the origin-destination pattern of use of each bus route in a system, together with limited data on transfer patterns. These data, typically only available by questioning bus passengers, can be obtained through this on-board bus survey procedure without requiring passengers to respond to questions. The survey is of particular value in locations where significant numbers of bus patrons may be unable to speak English or are insufficiently fluent in English to be able to deal with an interview or self-administered form. The procedure is a simple one that requires the passenger to accept a colored, imprinted card when boarding the bus, hold the card during his trip, and return the card on alighting from the bus. The potential response rate is quite high, with the case study presented in this paper indicating an achievable response of from 85 to 98 percent on a route-by-route basis in a location that had previously proved to be highly resistant to on-board bus surveys. The survey execution is sufficiently simple that a large number of surveyors could be trained to conduct the survey and do so with a quite low error rate.

The analysis procedures for the survey results are simple and can be executed rapidly, which allows results to be obtained within a matter of days or weeks of survey execution compared with the months more normally encountered in traditional on-board surveys. Although the initial recording activities for the survey results are manual and comparatively time consuming, the rate of obtaining survey results compares favorably with most surveys, and the counted data are readily analyzed on either a microcomputer or a mainframe computer.

ACKNOWLEDGMENTS

The authors would like to thank Merritt R. Steirheim, County Manager, and Joseph Fletcher, Director Metro-Dade Transportation Administration, for permission to use the results described in this paper and for their active support of the presentation of this paper. The opinions expressed are those of the authors and do not necessarily reflect the position or policies of Metro–Dade County. The authors are solely responsible for any errors or omissions in the paper.

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Publication of this paper sponsored by Committee on Traveler Behavior and Values.