A Method For Measuring Bus Patronage - Who Is Going Where?

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Abstract

Transit operators in all parts of the world seek accurate measures of patronage on their systems to aid in management strategies. These measures have been obtained by methods ranging from curbside estimates to the use of electronic information from automatic ticketing machines. This paper briefly reviews these methods and proposes a simple method of accurately finding who is riding and where they are riding.

A matrix of trip origin-destination stops is obtained, by an on-bus survey procedure, which links them with boarding-alighting times. The journeys are then related to trip purpose, ticket, and socio-economic characteristics of passengers. This is the type of information needed by operators both for marketing and for justification or otherwise of services being subsidized by governments on the basis of social need.

Introduction

Transit operators everywhere seek accurate measures of patronage to aid in management strategies. Passenger kilometers, the distance actually ridden by passengers on the system, has been widely adopted as an appropriate measure. Since 1977, the Urban Mass Transit Administration in the U.S.A. has required American transit systems, receiving federal operating assistance, to provide passenger miles as one of three required measures of service consumption. (U.S. Department of Transportation, Urban Mass Transportation Administration 1977.) A variety of methods has been devised over a period of years to obtain this measure and a considerable body of literature has been built up. Recently technological advances have seen the spread of electronic ticketing devices to a large part of the industry and for both small and large operations. Attention has then been given to obtaining patronage measures from such systems (Zhu,1992).

Often methods are applied to a representative sample of bus journeys, by route, type of service, time of day, and, perhaps, season of the year and expanded up to the total population of bus travellers for the year. Even if data is available from automatic devices, it is common to analyze selected data not the whole body of data. Thus correct sampling strategies and sensible stratification of the sample must be applied for accurate results to be obtained. Conversely good techniques may allow results from relatively small samples. It has been shown that is not necessary to intercept every bus traveller on every day (Stopher, 1983). The corollary of this is that it should also not be necessary to analyze the entire ticket machine output from every service for the whole year.

The primary concern of this paper, however, is with the initial task of finding information for the representative sample. It will be suggested that simple aggregates of passenger kilometers are insufficient. Forward looking management in transit companies today are looking beyond an operational focus, centered upon efficient running of the service, to a market focus, aimed at optimizing the market for their services.

If patronage measures are to provide the information needed to support new market based management strategies, they must address the questions of who the patrons are, when they are travelling, and exactly where they are travelling on the system.

2. Current Methods for Measuring Bus Patronage

2.1. How many riders

Bus passenger kilometers have been calculated using a variety of methods (Attanuci et al, 1982)

- curbside load checks at points on the side of the road
- counters attached to the fare box: Driver is required to log boarding passengers
- ride checkers on board the bus who note boarding and alighting passengers
- automatic passenger counting devices such as light beams and pressure pads
- direct use of fare box receipts and automatic ticketing machine information
- on board passenger surveys

There are some deficiencies in each of the methods, and choice of method is often dictated by the opportunity to simultaneously obtain other information of value to the company.

Curbside counts: Curbside counts or point counts taken as the bus passes a fixed location can be, at best, only estimates of loads and often can't even distinguish between adults and children. However, the checkers can also monitor running to schedule, and give a quick response to the need for another bus to satisfy unexpected demand, and so are both widely used and useful.

Fare box counters: Counting devices attached to the fare box save staff costs as the information is collected by the driver so no extra staff are needed. They have the additional advantage of allowing the counts to make fine distinctions amongst passengers by fare type and/or age. Up to ten buttons can be used by the driver to register boarding passengers in categories such as travel pass, school pass, cash fare. In practice, however, these devices result in an undercounting of passengers as most drivers quite properly see their primary task as driving the bus and serving the passengers rather than counting them (Koffman & Nygaard, 1989).

Ride checkers: Staff riding the bus with the dedicated task of counting passengers will miss fewer passengers but will have greater difficulty distinguishing fare types. The effectiveness of ride checks is also diminished in crowded buses with frequent boardings. The ride checks will be carried out less frequently than point checks but may be economically updated with point check data (Furth, 1988).

Automatic counting devices: Light beams or pressure pads to register boarding and alighting passengers give complete loadings at all points on the bus route and work equally well on a crowded bus within the limits of machine tolerances. If boarding behavior can be controlled sufficiently to prevent passengers boarding exactly at the same time accurate passenger kilometers can be obtained.

2.2 Who are the riders

There would be no need to look for any other method if bus passengers could be viewed as equivalent interchangeable units. However this is not true, different passengers have different revenue implications. In the simplest example, children are carried at half fare in many countries. For marketing purposes, as advertising strategies move towards targeting specific groups, companies want to distinguish between

passengers. Moreover governments frequently will require information on specific groups, such as elderly passengers, for social costs estimation in considering subsidies.

Similarly specific journey information may be required. One passengers alights, did he/she board at the previous stop or at the beginning of the trip? It may be useful to understand common origin destination choices for proper transit planning. Perhaps the crowding on one section of a route might be alleviated by diverting a bus to cover that section, but that solution would only work if a significant number of passengers had journeys confined to that section.

Fare box and Automatic ticket machine information: If everyone paid a distance related cash fare or used a form of ticket that was registered in some way on boarding, this information could be obtained from the fare box and ticketing machines. However, some cities have area wide flat fares, and, in others, there has been a spread of pre-paid (off-bus) ticketing. Off-bus ticketing introduced to streamline boarding, by even avoiding a need to register a ticket in a machine in busy transit operations, has increased the need for survey work (Savage, 1989). Alternative strategies such as boarding tubes at stops, which allow ticket registration prior to boarding, are an interesting concept but are not yet viable on a broad scale.

2.3 On-board bus surveys

There are two possible alternative mechanisms, either an on-board interview or a self administered survey form. Interviews are difficult on crowded buses, so self administered forms are more often used. The form is either completed on the bus or mailed back or in some cases both. Two part forms combine a short on-bus form with a longer form for reply by prepaid mail. Obviously, the amount of information that can be obtained during a short bus ride will be limited. However, a two-sided A4 card can provide a wealth of data if clear questions are combined with careful form design. For instance, it is easier for the passenger to check boxes than write answers.

The advantage of the form being completed during the journey is that it is much more easily retrieved and elicits a better response rate. This is important because one of the major criticisms of surveys as a means of collecting transit information is that they produce biased estimates due to non-response. Brog and Meyburg (1981) have shown that response rates as high as 90 percent can still result in biased estimates. To more easily measure non-response it is better that all passengers on any surveyed trip are offered forms. This also saves the practical problems of keeping mental counts to sample each fifth passenger or needing to answer the complaints of "why me , not him?" (Stopher, 1983).

Obviously, surveys have and can be used to obtain a wide variety of information of interest to the bus companies, but this paper concentrates on obtaining passenger origin and destination data and relating this information to the passengers socio-economic status. The origin and destination in this context relates merely to the transit section of the trip. Thus, the origin is the place where the traveller boards the bus, and the destination the place where the traveller alights. This is much more limited OD definition than one which describes the place where the traveller's trip begins, the production site, and the place where the trip purpose is satisfied, the attraction site. If this type information is required in detail, for instance for activity modelling, the only way to get it is via a survey that asks the passenger.

However, very often such detail is not really needed. To know that the passenger is going to work in the CBD of a city may be sufficient. Or the transit operator may be more interested in the finding the bus stops, where passengers board and alight, rather than their initial origin and final destination. In theory, this bus stop information might be obtained by ride checkers monitoring each passengers boarding and alighting, but, in practice, this proves impossible on busy bus routes.

Seeking bus origin-destination information from passengers on routes with many bus stops is difficult. Most bus stops do not have unique identities like train stations. Even if we exclude the type of passenger who gets on "near home" and gets off "near my mothers house", those who do their best to name nearest cross streets often choose a different one to that marked on the transit operators bus stop location sheet. Perhaps they walk east from the stop and name the next street east, whereas the list quotes the nearest street to the west. Thus, to translate this survey response information into a form suitable for computer analysis considerable hand editing of survey forms using maps is needed.

Another approach uses numbered survey forms handed out in sequence order. The survey officer notes on a log form the sequence number of the first survey form handed out at each stop. This method works well when the bus is not crowded and the stops are well defined and infrequent. However, in a bus stopping every 200 meters with passengers boarding frequently, the logistics of the exercise requires the survey officer to combine wonderful concentration with the skills of a juggler, writing sequence numbers whilst simultaneously handing out forms and pens. To apply a similar logging system to alighting, survey forms are collected upon exit and bundled in some manner according to the stop.

3. An Alternative Survey Design

3.1. The setting requiring a design

The initial study of was of passenger travel system-wide on the bus routes of a public bus operator running 410 buses out of five depots over 52 routes in 24 route clusters, where a cluster was defined as a set of very similar routes, often identical except for minor diversions. The routes were to be surveyed from terminus to terminus to monitor travel behavior in all parts of the routes. On board surveys needed to allow for special characteristics of both the buses routes and the population in the region:

Frequent stops and crowded buses: In parts of the region, bus stops are located only 100 meters apart, and the peak buses are frequently crowded with standees making filling in log forms difficult.

Limited English: In addition, the region has a significant concentration of bus travellers with limited English. Providing each with a form in their own language is impractical.

Elderly: There is also a greater number of elderly people in the region compared with Sydney as a whole. These passengers often have difficulty reading a printed form.

High passenger turnover: Many routes in the area carry passengers on short trips, and there is a high incidence of complete load renewal on the buses as the bus fills with passengers to alight at the first railway station on the route and then refills with passengers for a second station. This makes survey conditions far more difficult than on commuter buses that bring passengers from outlying suburbs to the city center. The classic dilemma facing on-board bus surveys — of trading off the need to obtain as much information as possible against the passengers ability to fill in the form during the bus journey — is exacerbated.

A design was sought that addressed all these difficulties. It uses the times that the passengers get on and off the bus.

3.2. The survey method

One survey officer hands forms and pencils to boarding passengers sympathetically encouraging response. The forms are sequentially numbered, but, instead of writing down the sequence of the first form given

out at each stop, the number on the form is circled for noting at data entry. The sequence number of the first form handed out at the stop was then retrieved in the analysis stage. The officer is also required to immediately set aside any forms refused in keeping with proper sampling practice.

A second survey officer collects the forms as the people get off the bus. They are put into a snugly fitting box. After the last form from each stop is collected, a divider form is inserted with the time, section, and the bus stop location. At data analysis, the time and section and stop can be attached to the survey records which follow them. The first question on the survey form is "what time did you get on this bus?" Knowledge of the (actual not timetable) time the bus was at each bus stop from the divider sheets allows deduction of where each passenger got on from when they got on.

This method was very successful if carried out by dedicated survey officers who take particular care that:

- that the forms must be collected at the stop where the passenger gets off. This sounds simple but in practice many passengers need to be cajoled into retaining their completed forms until they alight. If they cannot be deterred from handing the form back early, their destination data is lost.

- that they are handed out in sequence order so that if the passenger with form number 1429 doesn't give a boarding time but the people with forms 1428 and 1430 both said they got on the bus at 8.25am we can assume that time for 1429.

A by-product of the method is a set of stop arrival times, which can also be used as an indicator of service reliability.

3.3. Conduct of the Surveys

Surveys using the methodology described were carried out for two regions of the State Transit Authority inner suburban bus operation in Sydney, Australia during 1990 and 1991. The first involved a survey of 11,000 passengers riding on 50 routes and the second 9,500 passengers over 66 routes. The survey officers were newly appointed revenue inspectors from the bus companies, who volunteered for the task, under the supervision of a survey research firm National Surveys Research. The officers' training consisted of a thorough explanation of theory behind the method as well as instruction and practice in the physical requirements.

They understood they were linking time to place in the survey and carried their task out very diligently, despite finding the work demanding. They worked in a similar shift pattern to their normal duties, either in seven hour straight shifts with a meal break or in split morning/evening shifts, riding buses on selected routes terminus to terminus. Services were surveyed in both journey directions, usually inwards and outwards to and from the CBD in seven periods:

Monday to Friday: (1) Morning: Until 9.00, (2) Day: 9.00 to 15.00, (3) Evening: 15.00 to 18.30, (4) Night: After 18.30
Saturday: (5) Day: Until 17.00, (6) Night:After: 17.00 (7) Sunday: Day

A combination of the authority carried by an inspectors badge as the officers handed out the surveys and their efforts to encourage respondents resulted in an amazing 100 percent response on some routes. Those unable to fill in the form due to language difficulties were either helped to provide the most vital information or minimally asked to hold the form until they alighted, so that their origin destination information could be obtained.

The information needs minimal hand preparation for data entry, and an accurate matrix of trip origin destination stops is obtained, which means that the viability of options, such as express services and interchanges, can be examined. This level of information was obtained for nearly 100 percent of passengers. The overall response rate was 99 percent on the first survey and 95 percent on the second. In addition, there was a high level of response to questions of type of fare, adult, concession or child and type of ticket or travel pass. This information was of particular interest to the operators involved since they carried a large proportion of passengers on weekly or monthly travel passes, some intermodal, which were not subject to any validation per journey procedure, and the aim of these surveys was to monitor their usage patterns. Information about gender, age, journey purpose, work pattern and home post code allowed us to build up a picture of who goes where on the buses in the regions.

4. Survey Results

4.1 Passenger Revenue by Route

The primary motivation of the surveys from the viewpoint of the operators who commissioned them was estimates of route revenue by time of day. A breakdown of distance travelled by ticket type on their various routes was used to work out the proportion of overall off-bus ticket revenue attributable to the various routes in the system and in addition the amount of travel by people using such tickets. This was part of a larger project which also involved estimation of cost per route with the aim of finding out which routes were viable in the commercial sense of revenue covering costs.

For each route or each route cluster (essentially the same routes with minor differences in diversion patterns), passenger origins and destinations were linked to find the number of sections travelled for each route cluster broken into seven time periods. As the data come from samples, it was necessary to expand the data for to the total bus population. Curbside count loading figures were used for this purpose. Revenue estimates were thus made by ticket type. Table 1 shows the estimates for a sample route.

The passenger section and ticket type information has been used to calculate the expected return from the cash sales, the amount of off-bus ticket revenue due to this route from the pool of MetroTen, Travel pass and pensioner ticket sales income and the amount of reimbursement money from government subsidies to pensioners and other concession fare holders, partial reimbursement of fare plus government payment for the free carriage of school children. Some school children ride regular route buses; the majority take specially provided services.

Whilst the revenue from off-bus tickets was not known at the route level, it is a balance sheet number system wide. It was, therefore, encouraging that the sum total of the figures derived at route level showed excellent agreement with the known system wide figures. Percentage non validated ticket use: travel pass, school bus passes, pensioner excursion tickets combined ranged up to 70 percent for some services in peak periods. In contrast, on some Sunday services, 50 percent of fares were cash fares.

4.2 Profile of the Riders

It was envisaged by the managers in both of the surveyed regions that it would be necessary to look at the net social benefit of loss making services, and, hence, the profile of users by socio-economic status at route level was welcomed. In addition, the management of the second region wanted to gain as much market information as possible in conjunction with the revenue study. This extended to the use of subsidiary questions about journeys that passengers would have liked to make by bus.

Tables 2, 3, 4, and 5 give a profile of respondents: their age, gender, where they work, and the purpose

Table 1: Estimated Annual Revenue by Ticket Source for a Sample Route

REVENUE (Revenue in $1000)	Mon-Fri until 9.00	Mon-Fri 9.00-15.00	Mon-Fri 15.00-18.30	Mon-Fri 18.30 on	Sat until 17.00	Sunday	TOTAL
Cash Tickets	118	233	168	83	24	16	642
MetroTen	112	109	81	33	17	1	352
Travelpass	121	144	61	51	21	5	403
Pensioner excursion	19	52	18	2	7	3	101
Total Fare Box	**370**	**538**	**328**	**168**	**69**	**24**	**1498**
Pensioner reimburse	106	284	100	9	39	16	554
Concession reimburse	71	36	62	36	13	2	220
School children	32	11	43	0	0	0	86
Total Reimbursement	**209**	**332**	**205**	**45**	**51**	**18**	**860**
TOTAL Revenue	**579**	**870**	**532**	**213**	**120**	**42**	**2358**

for their trip. Their home post code was also obtained to see if passengers were from within the bus companies' operating region. These results are from the second survey, but both surveys show that public transit use is not confined to the stereotypes of those either to young or too old to drive; the majority of passengers are in their middle years, and there are still a considerable number of men riding the bus.

These profiles when further broken down by time of day and route showed school and work trips in peak hours make up 70 percent of trips. However, the remaining 30 percent of trips are less repetitive, often non-repeat, and when examined at route level, yielded information about routes and times attractive for recreation and shopping.

Table 2: Main Purpose of the Trip

Trip Type	Number of Respondents
Work	47.0
School/Uni/Technical college	20.5
Shopping	13.9
Sport/recreation	6.2
Visiting friends/relatives	8.0
Other	4.3
TOTAL	100.0

The rich data base obtained here points to the continuing advantage of being able to relate travel patterns and ticket type to socio-economic factors. This sort of data can be utilized to market the bus services on under-utilized clusters and in under-utilized time periods.

4.3 Bus Stop Usage Data

The complete origin destination matrix of passengers at bus stop level was considered useful for consideration of bus stop rationalization, and for consideration of express services in some time periods. On some routes surveyed, bus stops were spaced only 100 meters apart. In congested traffic conditions, frequent

stopping makes running an efficient service extremely difficult. However, whenever bus stop rationalization is suggested, the bus company takes complaints from people who claim disadvantage from loss of "their" bus stop. A system wide matrix that allows seldom used stops to be identified by time of day can support rationalization strategies.

In addition, knowledge of heavily and lightly used bus stops is valuable in scheduling express services. Typical numbers using stops may also be used in soliciting advertising revenue to help pay for bus shelters.

The bus stop usage matrix may be aggregated to give a distribution of long and short journeys also of value to transit planners. Table 6 shows such an aggregation for a selection of the routes checked in the first survey. As can be seen from these results the bus services are mainly used for short to medium distance journeys. The longer journeys in the area under consideration are predominantly by train with the bus services feeding the rail line.

Table 3: Work Pattern of Respondents

Work Pattern Type	Number of Respondents
Work full-time	49.2
Work part-time	10.2
Looking for work	3.6
Retired/pensioner	10.8
Keep house	2.4
Attend school/Uni/TAFE	23.9
TOTAL	100.0

Table 4: Gender of Respondents

Gender	Number of Respondents
Male	46.3
Female	53.7
TOTAL	100.0

Table 5: Age Groups of Respondents

Age Group	Number of Respondents
17 years and under	10.0
18 to 24 years	29.3
25 to 44 years	38.4
45 to 64 years	14.7
65 years and over	7.6
TOTAL	100.0

5. Conclusions

Technology for automatically counting passengers is now widely available and it can be expected to decrease in price and spread throughout the bus industry. However, at the same time, corresponding rise in off-bus ticketing can be expected for at least two reasons.

1. Together with frequency of service, reliability has an important influence on passengers satisfaction with a bus service. The use of travel passes limits the boarding delays which result in buses running behind schedule. As factors outside the control of bus operators such as automobile traffic congestion increase they may be expected to streamline the parts of the operation still under their control so expediting boarding will become even more important.

2. Due to concerns about the environment both at the local level : air quality and at the global level: greenhouse warming governments are seeking to stem the growth in private automobile traffic. The effort to attract some mode switch to public transit must be aided by making the journey as easy as

Table 6: Percentage of Passengers by Sections Travelled within Sample Route Clusters

CLUSTER	1 section	2 sections	3-9 sections	More than 9
Lidcombe	100	0	0	0
Rockdale-Ramsgate	25.1	46.1	28.8	0
Town Hall-Strathfield	14.1	30.8	53.3	1.5
Canterbury-Bankstown	19.8	27.2	53	0
Drummoyne-Rockdale	15.1	31	53.5	0.51
Ryde	7.6	16	76.3	0.11
Drummoyne	9.1	10.4	80.5	0
Meadowbank	85.4	14.6	0	0

possible by multi-modal fares and off-bus ticketing.

Thus until validation equipment is universally available to check passes at minimum inconvenience to the user on-board surveys will still be required to estimate patronage. It is fortunate that surveys will continue for calculating passenger kilometers because they can be used to link the passenger with the journey. This gives a much more useful description of patronage, which will allow companies to consider market segments, in line with new management practices. The information will also allow governments to address questions of social needs.

The design for obtaining passenger origin-destination data proposed here is eminently suited to the conditions on buses in Australian cities in the near future, at least. We can expect a multi-cultural population with difficulties with the English language. The percentage of elderly people is expected to increase. And, as the cities grow, crowding on peak bus services can be expected. The growing desire for information to be obtained without delay can be satisfied, as the simple method eliminates time consuming coding of origin-destination data on each survey form. On all public transport modes in the future we can expect to see a greater recognition of the needs of individual passengers, or groups of passengers, in response to market demands. The survey method presented here can provide the disaggregate bus patronage data that will be required.

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