SAMPLE BIAS IN TELEPHONE INTERVIEW TRAVEL SURVEYS

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ABSTRACT:

The methodological aspects of travel surveys have been subjected to much recent investigation, with a major emphasis being placed on the biases inherent in a variety of survey instruments. This paper examines the bias in one particular type of survey, the travel survey conducted by telephone interview. More specifically it examines the bias created by the omission of non-telephone households from the sample, but does not address the bias in responses received over the phone.

The study is conducted by examining the characteristics of phone-owning households in the 1978/79 Melbourne Home Interview Survey. In this way, a sample is created which approximates that which would have been obtained had the interview been conducted by telephone. The characteristics of phone-owning and non-phone-owning households are compared with respect to socio-economic characteristics, and areas of potential bias in the survey results are identified. The study then examines differences in travel patterns and suggests ways in which such biases may be corrected.

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INTRODUCTION

The collection of travel pattern data for transport planning purposes has traditionally been performed by means of either home interview surveys or self-administered questionnaire surveys. Each of these methods has been seen to possess inherent advantages and disadvantages. The home interview survey has generally yielded high response rates and allows for a wide variety of question types ranging from factual through to attitudinal questions. It has, however, generally been seen as a high cost survey method. The self-administered questionnaire survey, on the other hand, has been seen as a lower cost method, but one which often has high non-response if not properly designed and which has definite limits as to the types of question which can be asked.

Recently, therefore, interest has been expressed in the use of telephone interview surveys as a means of collecting travel pattern data. The use of telephone interviews has particularly been promoted in the United States where telephone ownership is particularly high (96% of all households in the U.S. have phones), but they have also been used in some Australian studies. Telephone surveys have a number of particular advantages, as noted by Stopher (1983). The geographic coverage of the sample need not be limited by considerations of interviewer travel costs; supervision of interviewers is easier in a central telephone office; costs per interview are lower than for a home interview survey; rare populations can be more easily identified by means of screening questions; and greater use can be made of computerised coding facilities during the course of the interview. On the other hand, telephone interviewing has a number of specific disadvantages. The two primary drawbacks are the limitation on the length of the interview, in order to minimise premature termination of the interview, and the bias resulting from households without telephones being omitted from the sample. As Stopher (1983) notes, "currently, there appear to be no effective solutions to these two problems".

This paper addresses the second of the above problems, i.e. the bias created by the omission of households without telephones. In addressing this problem, it should be noted that not all telephone interview surveys will be affected by this potential bias. For it to be a problem, there needs to be a correlation between the variable of interest and the presence (or absence) of a telephone in the household. At one extreme, a survey of telephone ownership by means of a telephone interview survey will produce an obvious bias; 100% of the respondents will have telephones. Slightly less obvious is the bias in a survey of household car ownership by means of telephone interviewing, or a telephone survey of voting intention. At the other extreme, a survey of transport companies by means of telephone interviewing would probably contain little sample bias because it could be expected that all such companies would have phones. The general point to be made is that telephone surveys will only result in sample bias if the variable of interest is correlated with telephone ownership.

SAMPLE BIAS IN TELEPHONE INTERVIEW TRAVEL SURVEYS

In examining the bias in telephone-interview travel surveys, there are three hypotheses which could be put forward:

(i) That there is a difference in travel patterns between phone-owning and non-phone-owning households;

(ii) That this difference is partly explained by the different socio-demographic characteristics of the households in the two populations; and

(iii) That the residual difference is due to a causal relationship between phone ownership and travel patterns.

This paper will examine each of these hypotheses in turn, using data obtained in the 1978/79 Home Interview Travel Survey conducted in Melbourne by the Victorian Ministry of Transport.

LITERATURE REVIEW

Because telephone interviews have only recently been used in travel surveys, there is little in the transport literature describing such surveys. One must turn to the general market research literature to find articles on telephone interview methodology. Even so, most of the literature refers to the general methodological aspects of telephone interviews, with very few studies concerned with the specifics of sample bias in particular surveys.

Dillman (1978) and Isben and Ballweg (1974) provide good descriptions of the overall methodology of telephone interviews, while Groves and Kahn (1979) provide a comparison between telephone and personal interviews, and Hochstim (1967) compares telephone interviews, personal interviews and questionnaire surveys. Cutler and Sharp (1981) examine a number of the practical aspects of telephone interviewing, while O'Neil (1979) examines the effects of non-response due to refusals in telephone interviews.

The study which comes closest in spirit to that described in this paper is that of Jones (1981). In that paper, he examines the demographic characteristics of telephone-owning households and non-telephone-owning households using data collected in the Household Expenditure Surveys undertaken by the Australian Bureau of Statistics in 1974-75 and 1975-76. He provides data on the percentage of households with telephones, stratified by many demographic characteristics such as dwelling type and tenure; age, occupation, employment status and income of the head of household; and location of the residence. He then undertakes Automatic Interaction Detection (AID) analysis to find those combinations of demographic variables which best explain the variations in telephone ownership. He concludes that household tenure (owners vs renters), age and occupation of household head are the most significant variables. Whilst Jones (1981) then proceeds to describe some of the implications for telephone interview surveys, he does so only in very general terms and not in the context of a specific survey, such as a travel survey. He also assumes, implicitly, that differences in the variables of interest between phone-owners and non-phone-owners are due entirely to the

demographic differences in the sub-populations, and that phone ownership has no residual causal effect on the variables of interest. He suggests that a post-stratification procedure which ensures that selected characteristics estimated from the sample match those of the population will be sufficient to overcome the effects of sample bias in telephone interview surveys.

THE STUDY METHOD

The study described in this paper is based on data collected in the 1978/79 Melbourne Home Interview Travel Survey. The Melbourne Home Interview Travel Survey was a conventional travel survey conducted by home interview. A final sample size of 11,387 households was obtained, yielding data on 31,948 persons aged 5 years and over, and trip details for 99,953 trips.

In the absence of an actual telephone interview sample, a synthetic sample was created by using only those responses in the Home Interview Survey from households who owned a phone. The responses and characteristics of these respondents were then compared with the responses and characteristics of the 'non-respondents' (i.e. households without phones) to determine the extent of the bias inherent in the telephone sampling method.

It should be realised that the comparison being made in this paper is, in the end, not the most important comparison which needs to be made. For practical purposes one needs to ensure that the sample of phone-owners is similar to the total population, and not the sample of non-phone-owners. Only when there is a significant proportion of non-phone-owners in the population will differences between phone-owners and the total population become significant. This point needs to be borne in mind when interpreting the results in this paper.

STUDY RESULTS

Some Basic Phone-Ownership Statistics

In order to assess the likely magnitude of the problem, it is useful to first examine the degree of phone-ownership in different areas and groups. In this way the significance of the previous paragraph will be highlighted.

As at March 1983, 85% of the five million households in private dwellings in Australia had the telephone connected. In all states, the capital cities had higher connection rates than the rest of the state, with 89% connected in the capital cities and 79% in the rest of the states. In Melbourne, the overall connection rate was 91%. Households consisting of married couples with or without children were most likely to have the phone connected (90% connected) while persons living alone (75%) and one parent families with all children under 15 years of age (72%) were least likely to have the phone connected. Employed persons were more likely to live in a household with a phone (89% connected) than unemployed persons (72%). Of those persons living alone, males were much less likely to have a phone (60%) than females (86%). Males living alone aged between 15 and 24 years of age had an overall low connection rate of 34%, while females living alone aged 60 years and over had an above-average connection rate of 90% (A.B.S., 1984).

The point to emerge from the above summary is that while there may be an overall connection rate of 85%, there are significant variations around this mean. The extent of potential sample bias inherent in telephone interview surveys will therefore depend on the population group at which the survey is aimed. While surveys of capital city, married households may have few problems, surveys of young, unemployed males will have severe sample bias problems in telephone surveys.

To further illustrate this point, consider some of the results of Jones (1981). Using data from 1974/75/76, when the Australia-wide average was only 60% connection, he found some significant variations in telephone connection rate for different household types. For example, 70% of houses had phones connected compared with 39% of flats. This finding was reinforced by the tenure status of the household, where 34% of households paying rent had phones compared with 76% of households buying or owning their property. 81% of households with professional or managerial heads of household had phones, compared with 67% of other white collar households and 53% of manual worker households. The status of the head of household was also reflected in the income of the head of household, where phone ownership ranged from 57% for incomes in the range $2,500 to $7,500 p.a. (1975 values) up to 92% for incomes above $17,500 p.a.

The differential availability of phones is also demonstrated in some of the basic results from an analysis of the 1978/79 Melbourne Home Interview Travel Survey, where the Melbourne overall connection rate was 79%, as shown in Table 1.

TABLE 1. PHONE OWNERSHIP BY SOCIO-DEMOGRAPHIC CHARACTERISTIC.

Household Size	1	2	3	4	5	>5
Phone Ownership	67%	77%	77%	85%	85%	84%

Household Income p.a.	<$ 8,000	$8-13,000	$13-20,000	>$ 20,000
Phone Ownership	70%	71%	80%	89%

Car Ownership	0	1	2	> 2
Phone Ownership	60%	76%	90%	91%

It can be seen that phone ownership increased with household size, household income and household car ownership. The relationship of phone ownership with these three variables is of particular importance since these variables are often used as independent variables in various models of travel demand.

Since travel is itself a spatial activity, it is also important to examine the spatial distribution of phone ownership in Melbourne. Using Local Government Areas (LGAs) as the geographic unit of analysis, Figure 1 shows the variation in phone ownership rate with the distance to the Central Business District (CBD). It can be seen that there is a group of LGAs close to the CBD which have much lower phone ownership rates compared to the rest of the city. These well-established older LGAs, including Brunswick, Collingwood (the lowest at 48%), Fitzroy, Footscray, Melbourne, Northcote, Port Melbourne, Richmond, St. Kilda, South Melbourne and Williamstown, would be dramatically under-represented in a telephone interview survey. Merely increasing the sampling rate in these LGAs would not solve the problem, because the households with phones in these LGAs would not be representative of the households without phones in these LGAs.

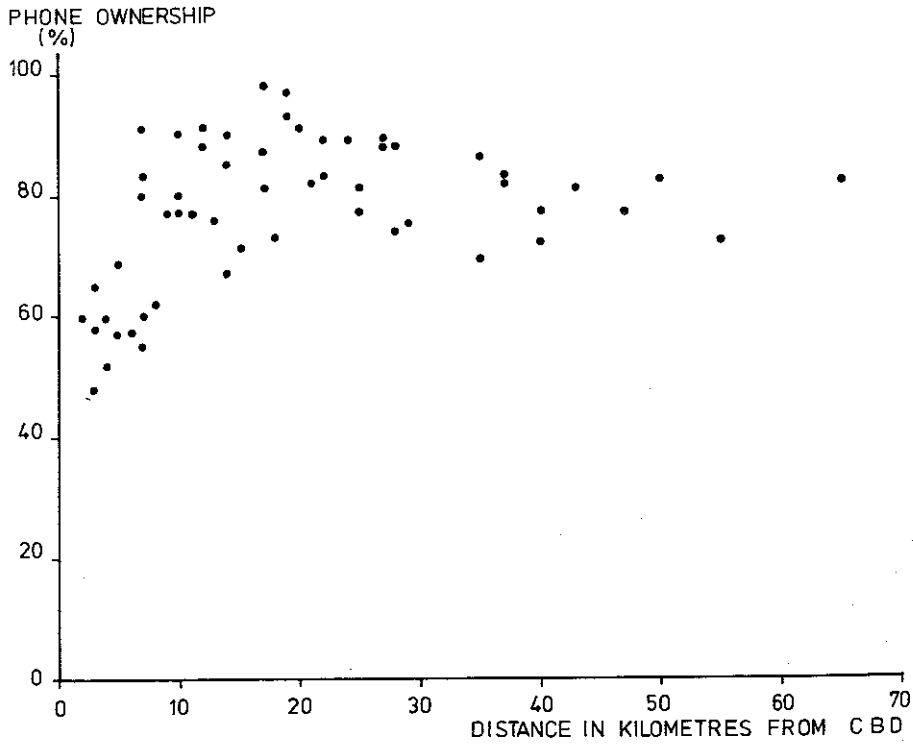

Fig.1. Phone Ownership by Geographic Location

This section of the paper has demonstrated that there is the potential for serious sample bias to occur in telephone surveys, because while the overall phone ownership rate may be quite high, there are social groups and geographic areas with quite low phone ownership rates. The question which remains to be answered is whether in fact there is any significant difference between the travel patterns of phone-owning and non-phone-owning households.

Travel Pattern Comparisons

In examining the travel patterns of phone-owning and non-phone-owning households, the entire samples of households were used (i.e. no geographic stratification was performed). The results obtained for a number of key travel pattern indicators are shown in Table 2.

TABLE 2. KEY TRAVEL PATTERN INDICATORS.

	Phone-owning Households	Non-Phone-owning Households
Trips/household/day	9.37	7.09
Trip Distance (km.)	10.21	8.94
Trip Duration (min.)	25	25
% Trips by Car	71	58
% Trips by Public Transport	11	16
% Trips by Walk	13	21
% Trips with Choice Available	8	8

It can be seen that there are significant differences in a number of key indicators. Phone-owning households make 32% more trips than non-phone-owning households and each of these trips is 14% longer in distance. Interestingly, however, the average duration of trips for the two samples is the same, indicating a lower average trip speed for the non-phone-owning group. This difference in average trip speed is reflected in the mode usage of the two groups, with phone-owning households using cars more often and non-phone-owning households using public transport and walking more often. The final indicator in Table 2 shows that phone and non-phone households have the same probability of having a choice available for any trip. For both groups, this probability is very low and reflects that fact that the question sought to obtain the perceived availability of alternative modes. While public transport users may not have a car (physically) available for a trip, car users often perceive that public transport is not available simply because it is, to a greater or lesser extent, inconvenient.

The differences shown in Table 2 indicate that the respondents in a telephone interview survey would not be representative of the non-respondents. The question remains, however, as to what is the cause of these differences, and how can one attempt to correct for the non-response effect in telephone surveys.

Socio-Demographic Corrections

The first step in correcting for the non-response effect is to determine to what extent the differences in observed travel patterns are caused by the different socio-demographic composition of the two populations. Already in Table 1, it has been shown that phone-owning households tend to be larger, wealthier and with higher car ownership, and this would tend to explain the higher trip rates and the higher car usage in phone-owning households. The method used to determine the effects of these socio-demographic variables is to stratify both populations according to these variables and then to compare the travel pattern indicator within each of the cells for each population. If the differences in travel patterns between the phone and non-phone households are due to the differences in socio-demographic characteristics, then the travel pattern indicator should be the same in the corresponding cells for each population. In this initial analysis, the travel pattern indicator being considered is the household trip rate.

Trip rate comparisons

Initially, one-dimensional stratifications were conducted on the variables of household size, household income and household car ownership. The results of these stratifications are shown in Figures 2,3 and 4.

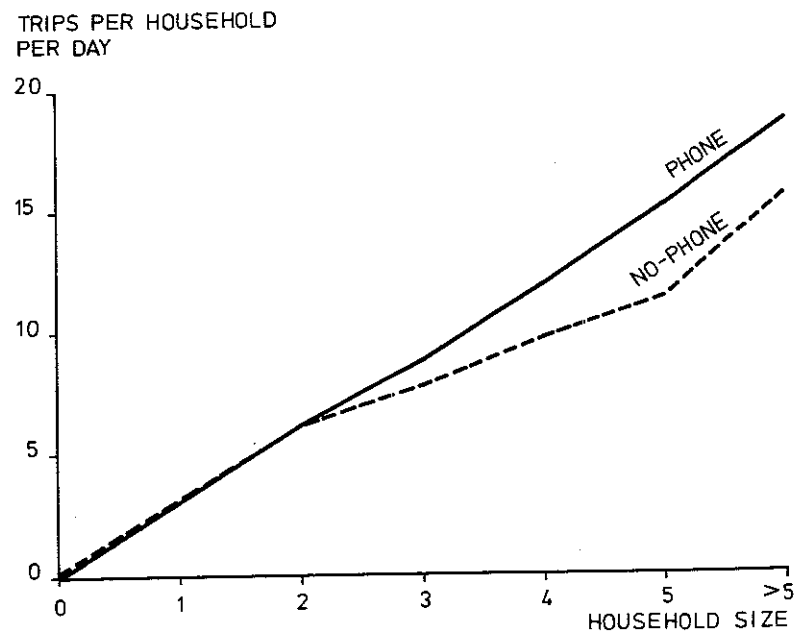

Fig. 2. Trip Rate as a Function of Household Size

It can be seen that although each variable is able to explain some of the difference between phone and non-phone household trip rates, non-phone households still make less trips even after correction for each of these variables. Thus, although there is no difference in trip rate for one- and two-person households in each of the groups, it can be seen from Figure 2 that whereas the trip rate in phone-owning households continues to increase linearly at a rate of 3 trips per day per additional household member, the trip rate for non-phone-owning households falls below that for phone-owning households at larger household sizes.

The household income stratification was performed using four income strata, where the stratum boundaries were based on the quartiles of the household income distribution for the entire population of households. As household income increases, the marginal trip rate falls for both phone-owning and non-phone-owning households, as shown in Figure 3. However, at all household income levels the trip rate of non-phone-owning households is consistently below that of phone-owning households.

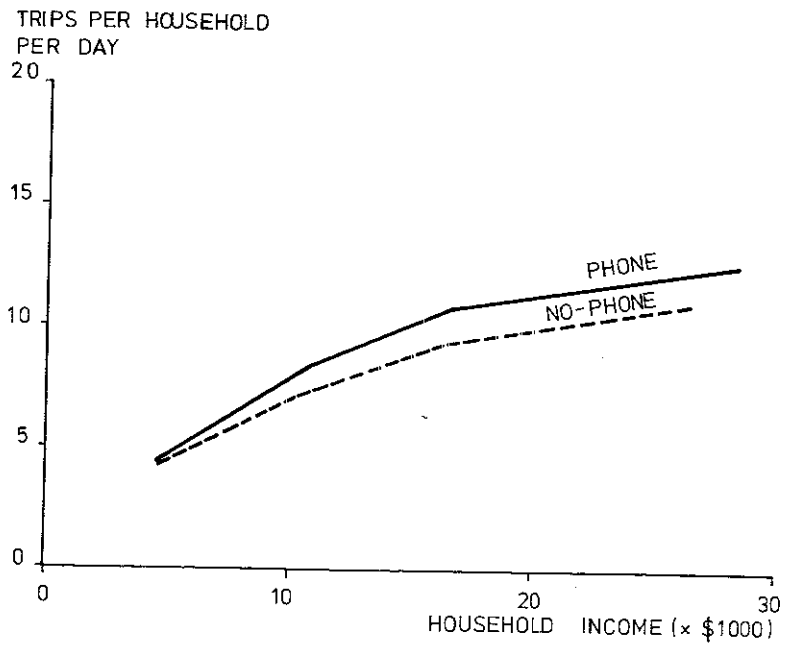

Fig. 3. Trip Rate as a Function of Household Income.

The stratification on the basis of car ownership shows an interesting result. For zero-car households, the non-phone-owning households have a higher trip rate than the phone-owning households (significant at the 0.1% level). This demonstrates that for some subgroups the general trend of higher trip rates for phone-owning households can be reversed. In this case,

the higher trip rate for zero-car, no-phone households may be dependent on other socio-demographic differences (such as age, life-style or residence location), or it may be a causal phenomenon whereby the lack of a phone, compounded by the lack of a car, causes people in non-phone households to make more trips in order to overcome their isolation at home. For all other car ownership levels, the trip rate returns to its normal trend of being lower for non-phone households than for phone-owning households.

From the above results, it appears that a simple one-dimensional stratification is insufficient to correct for the differences in trip rate between phone-owning and non-phone-owning households. The difference in trip rate has been reduced however from 32% for the overall samples to 16% for a weighted average across all of the cells in the one-way stratifications.

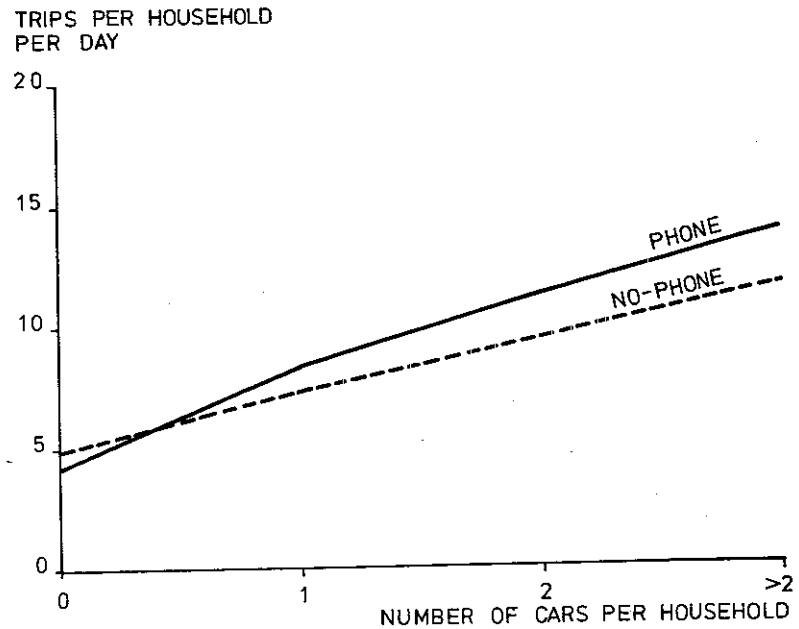

Fig. 4. Trip Rate as a Function of Household Car Ownership.

To further reduce the effects of socio-demographic differences, two-way stratifications were performed. The choice of which two-way stratification to select was confounded by the fact that the three stratifying variables are not independent. The three possible two-way stratifications were performed, but because household size and income are the more basic socio-demographic variables only the results from this two-way stratification are presented in this paper. Using the same categories as in the one-way stratifications, the results are shown in Table 3 and Figure 5.

TABLE 3. TRIP RATES FOR PHONE-OWNING AND NON-PHONE-OWNING HOUSEHOLDS STRATIFIED BY HOUSEHOLD INCOME AND SIZE.

Household Size	Household Income (x $1000)			
	8	8-13	13-20	20
1	2.09(a) 2.37(b) 0.88(c)	4.21 4.34 0.97	5.06 3.84 1.32	4.74 5.70 0.83
2	4.20 4.34 0.97	5.72 6.70 0.84*	7.68 8.25 0.93	8.59 8.72 0.99
3	7.95 6.24 1.27	7.76 7.38 1.05	8.94 8.95 1.00	11.27 9.50 1.19*
4	9.87 9.55 1.03	10.49 8.84 1.19*	12.44 10.69 1.16*	13.75 12.67 1.09
5	13.90 6.99 1.99*	14.26 10.14 1.41*	14.83 14.82 1.00	17.25 15.72 1.10
75	14.19 12.37 1.15	16.97 14.96 1.13	20.24 14.63 1.38*	20.35 18.60 1.09

Notes:
(a) Trip Rate for phone-owning households
(b) Trip Rate for non-phone-owning households
(c) Trip Rate Ratio
* Significant at 5% Level.

It can be seen that in fifteen of the twenty-four cells there is no significant difference (at the 5% level) in trip rate between the phone-owning and the non-phone-owning households. The weighted average difference in trip rates across all cells is 11.6%. Two-way stratification has therefore been successful in further reducing the differences in trip rates for phone and non-phone households.

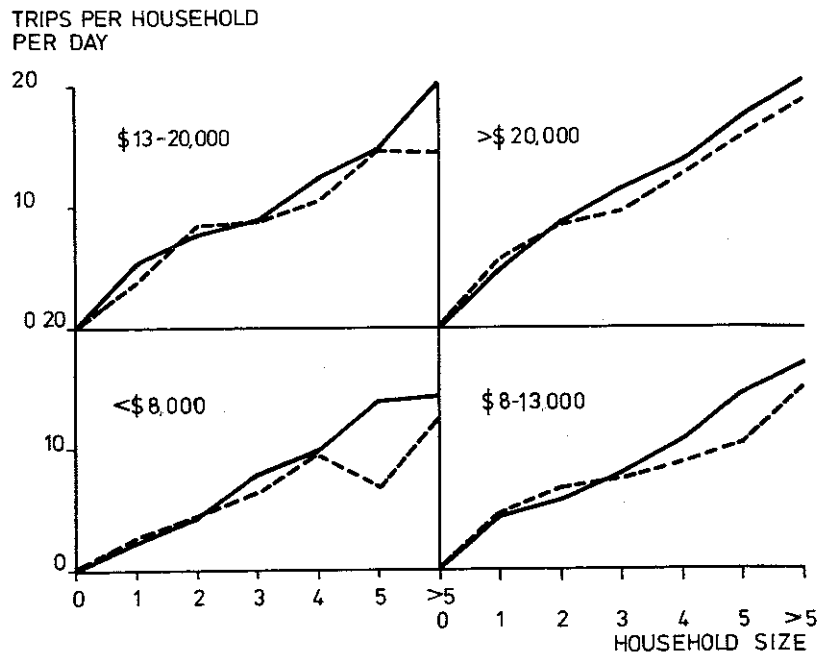

Fig. 5. Trip Rate as a Function of Household Income and Size.

To avoid the problem of small sample sizes in cells, the data in Table 3 can be re-combined into a one-way stratification by standardising the trip rate by household size, resulting in a new dependent variable of average number of trips per day per household member. The relationship between household income and this variable for both populations is shown in Figure 6.

Person trip rates for all income categories show no significant difference between phone-owning and non-phone-owning households. Overall, the average difference in trip rates is only 1% (compared to 32% for the unstratified samples of phone-owning and non-phone-owning households). It therefore appears that differences in person trip rates between phone and no-phone households can be explained entirely on terms of differences in household income and household size in the two sub-populations.

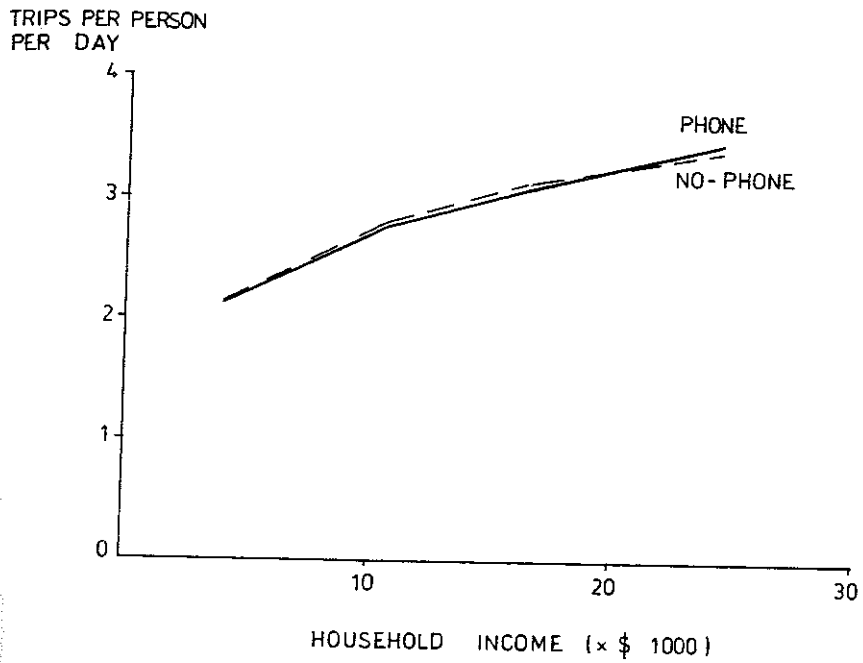

Fig. 6. Person Trip Rate as a Function of Household Income.

Mode use comparisons

To test the generality of the effect of the above stratification method, the analysis was repeated using mode usage as the travel pattern indicator. From Table 2, it can be seen that phone-owning households use cars 22% more often than non-phone-owning households, public transport 31% less often and walking 38% less often. Using stratifications on the basis of household size and household income, little improvement in agreement in mode usage was observed. When stratification was performed on the basis of household income per household member, the percentage differences were still high with phone-owning households making 21% more car trips, 31% less public transport trips and 30% less walking trips, as shown in Table 4.

TABLE 4. MODE USE FOR PHONE-OWNING AND NON-PHONE-OWNING HOUSEHOLDS STRATIFIED BY HOUSEHOLD INCOME PER HOUSEHOLD MEMBER

	Household Income per Household Member (x $1,000)			
Mode	< 2.5	2.5 - 4.5	4.5 - 7.5	> 7.5
Car	61.4(a)	67.5	74.2	80.7
	47.3(b)	55.5	61.4	69.3
	1.30(c)	1.22	1.21	1.16
Public Transport	11.6	10.6	11.7	11.0
	14.9	14.0	18.1	18.0
	0.78	0.76	0.65	0.61
Walk	22.3	18.0	10.2	5.8
	33.8	24.9	14.9	7.6
	0.66	0.72	0.69	0.76

Notes: (a) Percent Use for Phone-Owning Households
(b) Percent Use for Non-Phone-Owning Households
(c) Mode Use Ratio.

It would appear therefore that while socio-demographic weighting would correct for differences in trip rates, they would, alone, be insufficient to account for differences in patterns of mode usage. Even after allowing for socio-demographic differences, phone-owning households make more trips by car and less by public transport and walking.

Part of this remaining difference in mode usage may be attributable to the differing accessibilities of the two groups to components of the transport system. It will be remembered from Figure 1, that areas close to the CBD had the lowest phone ownership rates. These areas also have the highest accessibility to the public transport system, which would explain their higher public transport usage, and the highest land-use density, which would explain the higher frequency of walking trips.

To test the effect of geographical location, the samples were split into two sub-groups; an inner urban area comprising those inner LGAs with low phone ownership as shown in Figure 1, and an outer urban area comprising the rest of the LGAs. When these sub-groups were stratified on the basis of household income per household member, the weighted average percent differences in mode usage between phone-owning and non-phone-owning households showed a moderate decrease to 17% for car usage, 19% for public transport usage and 19% for walking. There still appears, however, to be a substantial amount of unexplained difference between the two groups.

Since the geographic (or public transport accessibility) stratification appeared to have greater effect than the socio-demographic stratifications, it was decided to replace the income and household size stratification with a one-way stratification on the basis of household car ownership. As noted earlier, car ownership captures the effects of both household income and household size and also reflects the household's accessibility to private transport. It may therefore have more power in explaining differences in mode usage.

Using the stratifications of inner and outer urban areas and car ownership, the mode usage patterns for phone-owning and non-phone-owning households are shown in Tables 5 and 6. For the inner area, car ownership levels of two and greater than two were collapsed into a single category of car ownership greater than one (because of sample size problems). As can be seen, stratification in this way produced significant reductions in the percentage differences in mode use between phone-owning and non-phone-owning households, with 4% difference in car use, 9% difference in public transport use and 10% difference in walking (weighted over all stratification cells).

TABLE 5. MODE USAGE FOR PHONE-OWNING AND NON-PHONE-OWNING HOUSEHOLDS IN INNER AREA STRATIFIED BY HOUSEHOLD CAR OWNERSHIP.

	Car Ownership		
Mode	0	1	> 1
Car	12.7(a) 12.2(b) 1.04(c)	59.7 58.8 1.02	73.6 70.0 1.05
Public Transport	37.2 40.3 0.92	17.1 16.7 1.02	11.4 12.6 0.90
Walk	43.2 41.3 1.05	19.1 20.6 0.93	9.7 10.1 0.96

Notes: (a) Percent Use for Phone-Owning Households
(b) Percent Use for Non-Phone-Owning Households
(c) Mode Use Ratio

TABLE 6. MODE USAGE FOR PHONE-OWNING AND NON-PHONE-OWNING HOUSEHOLDS IN OUTER AREA STRATIFIED BY HOUSEHOLD CAR OWNERSHIP.

	Car Ownership			
Mode	0	1	2	> 2
Car	21.8(a) 17.6(b) 1.24(c)	67.8 65.9 1.03	79.2 77.5 1.02	78.4 71.6 1.09
Public Transport	34.1 28.3 1.20	12.6 11.2 1.13	7.3 7.5 0.97	8.1 8.5 0.95
Walk	37.8 47.6 0.79	16.1 19.5 0.83	9.8 9.4 1.04	7.1 9.1 0.78

Notes: (a) Percent Use for Phone-Owning Households
(b) Percent Use for Non-Phone-Owning Households
(c) Mode Use Ratio

CONCLUSION

This paper has examined the nature of sample bias in telephone interview travel surveys. Using data from the 1978/79 Melbourne Home Interview Travel Survey, it has been shown that the socio-demographic characteristics of phone-owning and non-phone-owning households have distinctive differences, with phone-owning households being larger, higher income and with more cars. These differences are in accord with findings from previous studies of phone ownership. The travel patterns of the two types of household are also different with phone-owning households making more trips, longer trips, more trips by car and less by public transport and walking.

It has been shown however that a large proportion of this variation in trip patterns can be explained by reference to the different characteristics of the households. By appropriate stratification of the population, the differences in trip making between phone-owning and non-phone-owning households can be dramatically reduced. For example, stratification of households on the basis of household income reduced the difference in trip rate per person per day to 1%, while stratification on the basis of residential location and car ownership reduced the differences in mode usage to an average of 5%. This implies that the differences are largely due to household characteristics with little, if any, causal relationship between phone ownership and trip making. This latter proposition has, however, not been fully tested in this study because of the limited degree of stratification employed. The differences in trip rates and mode usage after stratification may be explained by differences in other socio-demographic variables such as dwelling type, tenure status and occupation.

In interpreting the results of this study, it should be remembered that the analysis method used has exaggerated the differences which would be found in practice. There the problem is to estimate the characteristics of the total population from knowledge of the phone-owning households (which are part of the total population). The differences between phone-owning and non-phone-owning households will be diluted according to the proportion of the population owning phones. Higher phone ownership will mean less potential for sample bias. Where it is expected that the target population in question will have a low phone-ownership rate, then telephone inteviews should be used with extreme caution unless adequate provisions are made, before the survey is conducted, for correction of the sample.

In conclusion, it would appear that sample bias in telephone interview travel surveys can be corrected by socio-demographic weighting techniques of the type suggested by Jones (1981) and described by Heathcote (1985) using variables such as household size, household income, car ownership, residential location and dwelling type. What this paper has not addressed, however, and what may be a more serious problem is the bias in responses received due to the nature of the telephone interview itself.

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