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Method for Determining and Reducing Nonresponse Bias

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Nonresponse bias is of continuing concern in participatory surveys of human subjects. It has led frequently to the adoption of expensive interview surveys in place of cheaper self-administered surveys because of relative response rates. Nonresponse bias has been estimated from comparison of early and late returns in self-administered surveys, from comparison of socioeconomic and demographic variables between the survey and census data, from special efforts to contact a sample of nonrespondents, and by assuming extreme values for nonrespondents. None of these methods is totally effective, whereas the relative economy of self-administered surveys has grown and suggests a reexamination of the value of such surveys. A method is outlined by using two survey mechanisms, including a conventional self-administered procedure, where the joint mechanism retains most of the economies but adds information on nonresponse and provides a means to increase response levels of the self-administered segment. Results from two transportation surveys are described and nonresponse biases and response levels are discussed.

One of the first decisions in any survey design is to select the mechanism by which the survey will be performed. Input to this decision includes specification of the purpose of the survey, definition of the sampling frame, determination of desired confidence levels (and thus sample size), labor availability, time and budget constraints, types of questions that need to be asked, likelihood of obtaining accurate answers, length of the survey, and expected response rate (1). Each survey effort is to some extent unique and thus the choice among the face-to-face interview, the mail questionnaire, the telephone interview, and a number of other alternatives must be made for each survey by using a careful balancing procedure that considers the various advantages and disadvantages of each method.

One of the most important of these factors is the expected response rate because of the effects both on costs and on the unknown bias that a low response rate may introduce. More often than not, if respondents are placed in direct contact with an interviewer, the response rate is assumed to be high, generally on the quite strong grounds that refusal is less acceptable to a personal request than it might be to any impersonal approach such as a mail survey. In contrast, significantly lower response rates are assumed to occur when no personal request is involved or when the request is only to accept a survey form and not to answer specific questions. However, as Dillman (1) points out, this supposed significant advantage in response rate may be due, to some extent, to the manner in which response rates are calculated for the mail survey versus the face-to-face interview survey.

Irrespective of the survey mechanism, nonresponse occurs. It can be classified into two forms: genuine and nongenuine nonresponse (2). Genuine nonresponse is not the concern of this paper. This is defined as the nonresponse occasioned by selecting sampling units that are subsequently found to no longer be a part of the survey population (e.g., vacant or demolished houses, addresses that do not exist). In contrast, nongenuine nonresponse is defined as that nonresponse which occurs by the voluntary action of a sampled respondent not to participate in the survey. Genuine nonresponse is not of serious concern because it can be assumed generally to be a random or quasi-random occurrence that adds no significant bias to the survey data and that can be corrected largely by expanding the sample appropriately to cover its expected or encountered level (3). Nongenuine nonresponse is a documented source of bias for a number of reasons (4). It has been shown in a number of instances that those who do not respond to a survey possess generally a characteristic of direct relevance to survey measurements. For example, in surveys of travel habits and needs (an area well known to us), nonrespondents are most likely to be drawn from two segments of the population: those who travel very extensively and who therefore would be subject to much longer questioning on travel habits for a period such as 24 h and those who travel very little or not at all and who doubt the relevance of the survey to them or of themselves to the survey (5,6). This facet alone is a major cause of nonresponse bias. Others, which do not need elaboration here, include educational and income bias to written questionnaires and life-style biases associated with the state of being at home for the survey (1).

As a general rule, it can be assumed that the potential existence of and the extent of nonresponse bias caused by nongenuine nonresponse is correlated with the size of the nonresponse rate. Although it appears that little scientific evidence exists to support this hypothesis (particularly given the paucity of studies of nonresponse itself, let alone the biases and their relationship to rate), this assumption carries a fairly substantial weight of circumstantial common sense. For the purposes of this paper, it will be accepted as a reasonable postulate and not subject to further question.

Given, then, the parallel factors of an expected relationship between nonresponse bias and the common assertion that personally conducted surveys have higher response rates than impersonally conducted ones, it is not surprising that the majority of human surveys have tended to be carried out by means of direct interviewing in preference to most other methods of survey.

This paper raises three parallel concerns that derive from this state of affairs. First, some problems concerned with the calculation of response rates on face-to-face interview surveys versus mail surveys are discussed. Second, given the tremendous differences in unit costs of personal interviews

versus self-administered surveys, it is becoming increasingly worthwhile to seek relatively economical ways to improve self-administered surveys so that better response rates can be obtained and stronger advantages developed for these significantly more economical procedures. We believe that the dual survey mechanism (DSM) described herein is a valuable procedure for improving self-administered surveys. Third, given that nonresponse occurs, some procedure is needed that will provide a means to estimate the extent and shape of nonresponse bias. In this respect, we argue that traditional methods of measuring nonresponse bias (comparison between sample survey and census figures, interviewing by, say, face-to-face interview a subsample of nonrespondents to a mail survey, comparison of early and late returns, and assumption of extreme values for nonrespondents) have significant disadvantages that lead to their not being used in many practical fields of survey research.

The utility of the suggested alternative procedure--the DSM--for determining and reducing nonresponse bias is illustrated by using the results of three travel-behavior surveys, one conducted in Dade County (Miami), Florida, and two in Washtenaw County (Ann Arbor), Michigan.

RESPONSE RATES FOR MAIL AND INTERVIEW SURVEYS

Two options are available for participatory surveys--personal interview or some form of self-administered survey. To a large extent, conventional wisdom in transportation data collection (and in other fields) has been to use face-to-face interviews. This has been based on the notions that response rates are higher, that data are less subject to both error and bias, and that certain items of interest in transportation surveys cannot be collected by using a self-administered survey. The major acknowledged disadvantages of interview surveys are the length of time required to collect the data (particularly for on-board vehicle surveys) and the cost, which currently ranges from about $35 to more than $500 per interview in transportation applications. A major advantage of self-administered surveys is their cost, which may range from as little as $1 for each complete response to a high of about $30.

Recent research in West Germany (2), however, suggests that the response rates claimed for interview surveys may be inflated. Although response rates often are cited as being 90-95 percent or higher, such rates are generally misleading because they are calculated on a different basis than are the response rates of self-administered surveys, which yields an automatically higher figure for the interview survey. For example, for a mail-out, self-administered survey, response rates are calculated as the proportion of those surveys mailed out that were returned as usable responses. Frequently, the proportion of mailed-out surveys not delivered or delivered to an address that was temporarily or permanently vacant will not be known. Conversely, interview-survey response rates usually are based on the total number of completed interviews plus terminations and refusals. Often not computed into such response rates are the number of "no answers," failed requests for calls back, under construction, no such address, and the like, which would be made up from a back-up sample and would be discounted prior to computing a response rate. Therefore, comparable response rates between these two survey types generally have not been reported. Such comparable rates would show interview surveys to achieve a much lower response rate than usually has been reported. As an example, in the 1980 Southeast Michigan Regional Travel Survey, which was an at-home interview survey of 2706 households, the calculated response rate was 85 percent. If "no answers," failed requests for calls back, under construction, no such address, and the like are added in, the response rate drops to 65 percent (7). These ideas are in agreement with Dillman (1, p. 50), who points out that "in face-to-face and telephone interviews a refusal is not considered as such until a contact is made. In mail studies, the opposite is assumed, that is, a nonresponse is a refusal until proven otherwise." Also, researchers often fail to report the way in which the response rate was calculated.

TRADITIONAL SOLUTIONS TO NONRESPONSE BIAS PROBLEM

There exists no solution to the nonresponse bias problem that can guarantee absolutely that [R], the set of respondents, is a random sample of [S], the set of selected individuals in the sample (8). One common procedure is to assume that [S] is a random sample of [P], the population, and then to test for significant differences between [R] and [P] on a set of known variables for [P]. Thus, by using a series of one-sample significance tests, one could, for example, test to see whether the mean income (adjusted for inflation) of [R] is significantly different from the mean income reported for the study area by the census. If no significant differences are found, it would be reasonable to assume that the incomes of [R] and [NR], the set of nonrespondents, are not significantly different and that no response bias exists with respect to income. If, on the other hand, [R] is found to be biased toward upper-income categories (as is likely to be the case), it becomes possible to weight the answers of those of lower income who did respond to produce [R*], the set of respondents with answers weighted to reflect more accurately the distribution of incomes in the study area. This procedure could be performed for various variables and different surveys weighted with different factors to reflect known distributions more accurately.

Although the above procedure may be effective in some cases for adjusting for nonresponse bias, a number of significant problems exist:

1. Although many demographic variables are available in the census, many important variables for which one might want to check for nonresponse bias may not be available from a census. Suppose a survey queries attitudes about energy costs in a given county. If a greater percentage of automobile users than bus users answers the survey, one may want to weigh the results from the bus users to reflect modal split in the county more accurately. This is only possible if the number of bus and automobile users in the county is known from the census.
2. Demographic variables may be available in the census but may be significantly dated.
3. The census data may be inaccurate because the census also is likely to suffer nonresponse from the same groups of people as a sample survey.
4. If the population from which the sample is being drawn is a subpopulation (such as the users of a given facility), it is highly unlikely that a census exists of such users.

An excellent example of the application of this first procedure is provided by Young and Willmott (9) in their 1970 study of family sociology in London. Census data for 1971 were available to them only in terms of the sex variable, and no response bias was shown. Age, marital status, and occupation comparisons had to be made with the older Sample

Census 1966. They show their sample to be somewhat underrepresentative of the young and the single. This may have been due to the greater difficulty of finding such people at home, or to an inadequate sampling frame, or to a change in the demographic structure of the population over the four-year period since the census. As expected, comparison of the occupation variable showed some tendency for those in professional and managerial positions to be more responsive to the survey.

A second technique used to judge nonresponse bias is to select a random sample of nonrespondents at the completion of the survey and to make special and persistent efforts to gain some brief information from this sample. Thus, if the original survey mechanism was a mail survey, a brief home interview or telephone survey might be devised on nonrespondents and tests for significant differences between [R] and [NR] performed. This technique also has a number of disadvantages:

1. A significant cost is added to the survey.
2. The amount of time needed to complete the survey is extended because the survey of nonrespondents cannot begin until all nonrespondents are identified.
3. Not all nonrespondents to the first survey will cooperate with the second survey.
4. Suppose one is looking for differences between respondents' attitudes and behavior. If such differences are found, the question arises whether these differences really exist or are caused by the different survey mechnisms used for [R] and [NR].
5. If the follow-up survey occurs after the original survey, it may be that attitudes and/or behavior may have been changed by some outside factor. Thus, it is possible that the original set of respondents [R] completed a survey on energy prior to, say, an oil embargo, whereas those respondents in [NR] are being queried after the oil embargo.

By using this methodology, Goudy (10), in a sample of the general public in rural communities in northern Iowa, raised the response rate from 79 to 93 percent by following a mail survey with a face-to-face interview of nonrespondents to the mail survey. Although the additional interviews resulted in only slight changes in the demographic characteristics of the respondents, the changes were in the expected direction. The proportion of respondents with less than 11 years of school increased from 31 to 33 percent and the proportion with income below $6000 went from 24 to 26 percent.

A third traditional method for dealing with nonresponse bias is to compare early responses with late responses (11). The assumption inherent in such a comparison is that respondents who mail in their questionnaires very late or who answer only after some follow-up effort (such as a reminder postcard) are similar to nonrespondents.

A number of articles have appeared employing this method of comparing early and late respondents to travel surveys. In a travel survey by Wright (12), two reminder letters were mailed to nonrespondents and followed, if necessary, by a personal visit. Significant differences were found between early and late responses in age, sex, occupation, length of residence, and ownership of dwelling unit. No significant differences were found in education, household size, location of the household, and relationship of the respondents to the head of the household.

Waltz and Grecco (13) also compared early and late respondents. Respondents differed significantly by sex, education, occupation, length of residence, and ownership of dwelling unit. No significant differences were found for age, city of residence, marital status, household size, and type of dwelling unit. They also compared respondents and nonrespondents who were shown to differ significantly on length of residence, ownership of dwelling unit, and type of dwelling unit.

Galin (14) also compared both early and late respondents and respondents and nonrespondents as part of a data-collection effort for the Australian Road Research Board. Postcards with eight questions were handed to drivers at a cordon line. The vehicle type (car, truck, van) and the sex of the driver were noted. No significant differences were found for these two variables between those who did mail back the postcard and those who did not. When early and late respondents were compared, no significant differences were found in trip purpose, trip length, vehicle type, age, number of years driving, and sex.

Finally, Kanuk and Berenson (15), in a comprehensive 1975 literature review of mail surveys and response rates, concluded that research efforts to determine the difference between respondents and nonrespondents have focused on demographic, socioeconomic, and, to a lesser extent, personality variables. The only widespread finding is that respondents tend to be better educated than nonrespondents and thus have greater facility in writing.

A variation of this technique for a telephone survey has been suggested by O'Neil (16). He compared those who responded to the survey on first contact with those who answered only after having refused on the first attempt. The "resistor" group, for example, were shown to be more likely from blue-collar occupations and lower in income and education, although O'Neil judges the differences to be unimportant. One very significant drawback to this third traditional procedure, whether for mail or telephone survey use, is that it is based on the unproven and somewhat dubious assumption that those who respond to a survey late or only after some follow-up effort are similar in characteristics to nonrespondents.

Finally, Cochran (17) suggests a procedure that assumes extreme values for nonrespondents. Unfortunately, as shown by Fuller (18) and Wayne (19) under a variety of conditions, the calculated confidence intervals are almost always far too wide to permit meaningful inferences from the data. In sum, all traditional methods for dealing with nonresponse bias have been shown to have significant disadvantages.

DSM AS APPROACH TO NONRESPONSE BIAS

Three goals are implicit in the selection of a survey mechanism, as described in the preceding sections of this paper: lack of bias, economy, and knowledge about the characteristics of inevitable nonrespondents. No single survey mechanism succeeds in achieving all three. Beginning from the premise that the home-based, personal interview is the most effective way to minimize nonresponse and its associated bias but that such a mechanism is rapidly becoming far too uneconomical for many applications, we sought to develop a mechanism that would provide significant economies at a much smaller loss to response and bias.

The mechanism developed is the coupling of a short, relatively inexpensive form of personal contact as a prior approach to a longer, self-administered survey. At least two versions of this mechanism have been developed: (a) an intercept survey in which there is a personal request to complete and hand back a short survey form and a following take-home/mail-back survey and (b) a brief telephone interview followed by a mail-out/mail-back survey. These designs seek several common goals:

1. Through several mechanisms, to increase the response rate to the self-administered survey;
2. To provide the means to execute follow-up on the mail survey (which is often missing in a take-home/mail-back survey) as a means to build the response rate;
3. To provide some useful information on those who respond to the personal contact but refuse to respond to the mail survey, which thus provides a partial measure of nonresponse; and
4. To use the initial contact in several different ways to define more precisely and clearly to potential respondents the situational context for the self-administered survey.

The DSM is much less expensive than home-based personal interviews but is not limited, as are some of its obvious single-mechanism alternatives, in the length of the survey that can be executed nor in the contextural situation. (Clearly, if the survey purposes can be fulfilled by a 5-min intercept or telephone survey, there can be no possible value from a DSM; the use of the DSM is where a longer survey is needed to satisfy the measurement requirements.)

The first and fourth points above merit some elaboration. Increases in response rate should arise from several aspects of the procedure. First, people are generally more likely to respond to a brief intercept survey (e.g., an on-board bus, plane, and train survey) or to a 5- to 10-min telephone interview than to a significantly longer survey of almost any type. For a number of people, this will create a seeming obligation to agree to and to complete the subsequent longer survey--the standard marketing device of compliance with a small request leading to compliance with a subsequent longer request (20). Second, an intercept survey frequently creates circumstances that induce an enhanced response from such effects as peer pressure and the appearance that the survey is neither long nor difficult to do. Similarly, refusal rates for short telephone surveys are usually very low, particularly if the approach is from or on behalf of a public-service agency.

The context-setting capability of the initial contact is also extremely valuable. In an intercept survey with subsequent self-administered survey, the self-administered survey may ask questions about the activity that was intercepted. If the self-administered survey is completed some time after the activity occurred, recall may be a problem. The occurrence of the intercept survey, however, may serve to help fix the specific occasion in the minds of respondents. When the initial mechanism is a telephone survey, the telephone contact can be used to specify a particular day or activity that should be the subject of the self-administered section. This provides a control of situational context that is usually lacking in self-administered surveys.

The remainder of this paper discusses two case studies of the use of the DSM and its benefits in specific contexts. Case Study 1 is the Dade County On-Board Transit Survey (21), which was an intercept-and-mail DSM. Case Study 2 is a similar survey for Washtenaw County, Michigan, which included both an intercept-and-mail DSM and a telephone-and-mail DSM.

CASE STUDY 1: DADE COUNTY ON-BOARD TRANSIT SURVEY

Dade County, Florida, is involved currently in the construction of a rail rapid transit system, a downtown people mover, and a revised and expanded bus network expected to cost a total of about $1 billion and all scheduled for completion by 1984. The Dade County Transit Development Program, 1980-1985, calls for survey work to elicit information concerning the manner in which the bus system is being used currently. Such information is to be employed in adjusting the bus system to user needs as new vehicles are purchased, in designing the feeder bus network into the rapid transit stations, and in updating available modal-split models (22).

Because the desire was to sample only those individuals who ride the bus and such individuals comprise a small percentage of the county's population, the only possible cost-effective means of reaching bus riders was an intercept survey. The short length of time for which many riders are on a bus, the obvious difficulties of conducting an interview under such circumstances, and the fact that an interviewer needs to select respondents dictated the use of a self-administered form.

Four competing forces presented themselves: (a) the volume of information needed from each rider was extensive and filled 10 pages of legal-size paper; (b) the longer the form, the lower the response rate is likely to be; (c) persons on short bus rides could not be asked to fill out long forms while riding; and (d) some respondents (particularly the large number of elderly in Dade County) would experience physical discomfort from trying to read and write on a moving bus.

Thus, a DSM was developed that contained five parts:

1. An instruction page;
2. Form a, designed to be completed and returned on board the bus, although designed so that it could be mailed back instead if the respondent so desired (the on-board form);
3. Form b, designed to be completed at home and mailed back (the take-home form);
4. An envelope for the return of the take-home form; and
5. A cover letter from the Dade County Transportation Coordinator, designed to lend credibility and encourage response.

The Dade County intercept-and-mail DSM was designed specifically to accomplish the following:

1. The on-board form was designed to gain response from the type of person who would give 3-5 min but would certainly not go to the trouble of carrying home a survey form, spending 45 min to fill it out, and then remembering to mail it back.
2. The on-board form also could take advantage of people's feelings about being good citizens by way of a "demonstration effect." That is, suppose forms are handed to 30 persons on board a bus. If even some minimum number sit down and begin to fill out the form, the chances are good that others will follow the lead to avoid feeling guilty and being viewed by fellow passengers in a negative way for not cooperating. Persons who would be reluctant respondents also will be encouraged to cooperate when they see that the survey does in fact take only a few minutes.
3. The fact that respondents were handed the form while boarding the bus and were thus a captive audience also helped to encourage response. Unlike a personal interview at home or a telephone interview, where the interviewer may be interrupting the interviewee involved in some activity, most bus riders usually do little with the time they are on the bus. The survey could thus act as an interesting diversion.
4. As mentioned above, certain questions are best answered while a respondent is performing a given activity because loss of information can be

expected if time is permitted to lapse. For example, "How long did you wait at the bus stop for this bus?" is answered most accurately (in terms of the respondent's perception of waiting time) immediately following the wait. Thus, a major problem of travel surveys, that respondents have difficulty remembering trip details or even that a trip was made, is averted.

5. As mentioned above, most intercept surveys that involve only a take-home, mail-back form have no possibility of a follow-up, because the addresses of those taking the forms are unknown. The Dade County DSM, by asking for the address of the respondent on the on-board form (for the purpose of sending them a free bus pass incentive), permitted a follow-up to proceed for those not returning the take-home form.

6. The Dade County DSM also took advantage of the idea that compliance with a small request can be effective in encouraging compliance with a longer request. It is also more likely that respondents will remember to fill out the take-home form given that they have already spent some time that day on the survey. Also, some people have an aversion to leaving a job only half done.

7. An effective device used in the Dade County DSM was to promise respondents to both the on-board and the take-home forms that a free bus pass would be forthcoming.

8. An additional advantage of the on-board form is that, although the form was designed to be self-administered, those who had trouble filling out the form could seek assistance from fellow passengers or from the survey worker.

9. One rather unexpected benefit of the take-home form was that in addition to the 181 persons who returned both the on-board and the take-home forms, 120 persons who did not complete the on-board form did fill out the take-home form. A number of factors may have contributed to this outcome: (a) some persons are discomforted by reading and writing in a moving vehicle; (b) some respondents were on the bus for too short a time to fill out the on-board form; and (c) survey workers reported that many elderly persons did not bring their reading glasses. In all cases, these nonrespondents perceived the take-home form as more important or, in spite of a business-reply panel on the on-board form, might have assumed that the on-board form could not be mailed in.

10. Perhaps the most important benefit of the on-board form is that it permits the evaluation of possible response biases in the take-home form. For the pilot survey in Dade County, 632 persons answered the on-board form, whereas only 181 of these (29 percent) answered the take-home form. Thus, if the on-board form did not exist, the response rate would have been about one third. More important, dividing the 632 persons into the [R] and [NR] groups depending on whether or not they had responded to the mail-back permits the identification of age, sex, driver's license, transit captivity, and geographical location (via zip code) bias.

As Table 1 shows, such biases were apparently not significant in this survey. For both the [R] and [NR] groups, about 48 percent are female, about 60 percent have driver's licenses, and about 43 percent are captive to transit. The percentages of respondents in each of the age categories are strikingly similar; there are two exceptions. Those less than 12 years old did not return the take-home form and those older than 70 were more likely to complete the take-home form.

An interesting but not unexpected observation is that, in all cases, item nonresponse on the on-board form is significantly higher for the [NR] group than for the [R] group. For example, 6.7 percent of the [R] group did not answer the question about sex, whereas 12.2 percent of the [NR] group left this question blank.

Other variables that appear on the on-board survey may also be used to check for possible biases in the attitude questions on the take-home form. If attitudes toward transit are influenced by the way one uses (or is forced to use) the system (a reasonable assumption), then if a disproportionate share of the [R] group are forced to use transfers, wait longer for the bus, etc., than those in the [NR] group and if these negative service aspects are reflected in a more negative response to attitude questions on the take-home form, the results from the attitude questions would be more negative than would be the case if everyone completed the take-home form. No significant difference between [R] and [NR] for average waiting time and the need to transfer was found, as shown in Table 2.

Although it can be argued successfully that not all nonresponse bias on either the take-home (mail) or the on-board (intercept) survey form can be identified because there are people who will not respond to either form, a successful argument has been made that the nonresponse rate is decreased considerably by the on-board form.

CASE STUDY 2: WASHTENAW COUNTY ON-BOARD TRANSIT SURVEY AND TELEPHONE MAIL SURVEY

Washtenaw County, Michigan, has been considering expansion of its bus system into more rural areas as well as various funding options for the system. To garner information on the feasibility of various plans, a survey similar in structure to that used in Dade County was designed that contained both an on-board and a take-home form and accrued all the same types of benefits described for the Dade County survey. The response rate on the on-board form was 88 percent; on the take-home, 38 percent.

Of the 1171 respondents to the on-board form, 44 percent (510) sent in a mail survey. Thus, [NR] constituted 661 individuals (56 percent). Variables of age, automobile ownership, transit captivity, length of residence, sex, and driver's license were available for checking for nonresponse bias.

A result that confirmed the Dade County results was that in all cases those who had not returned the mail survey were also less likely to complete the questions on the on-board form fully. In the [NR] group, 7.1 percent left the age question blank (versus 2.4 percent for the [R] group); 7.6 percent of the [NR] group omitted automobile ownership (2.2 percent of the [R] group); 9 percent of the [NR] group omitted transit captivity (2.2 percent); 5.3 percent of the [NR] group left the length-of-residence question blank (3.5 percent); 7 percent omitted the question about sex (2.6 percent); and 6.0 percent omitted the driver's-license question (1.2 percent).

By using either chi-square or Kolmogorov-Smirnov tests (as appropriate), no significant differences were found between [R] and [NR] for age, automobile ownership, transit captivity, and length of residence. On the other hand, respondents to the mail survey were more likely to be female (chi-square = 16.4) and to not have a driver's license (chi-square = 39.7). Thus, analysis of the mail-back survey might be weighted to reflect more accurately the characteristics of the bus-riding public as revealed by the on-board survey, on which the response rate was more than twice that on the mail-back survey.

As a second part to this overall survey effort,

another DSM was used, which consisted of a brief (5-min) telephone interview of a random, stratified sample (by using random-digit dialing), followed by a mail-out, mail-back survey. From eligible telephone contacts, a response rate of 80 percent was obtained, whereas the mail-back survey achieved a 56 percent response rate.

The results bear considerable similarity in the existence of nonresponse bias to the results of the on-board bus sample. A total of 2468 usable responses was obtained from the mail-back survey. As before, nonrespondents to the mail-back survey had a significantly higher rate of nonresponse to telephone survey questions on all questions. Some significant differences were found in the stratum response rates, although not in the major urbanized areas of the county. Apart from that, respondents to the mail-back survey were more likely to hold a driver's license and consequently to use cars as driver or passenger on a frequent basis and were more likely to have lived in the area for a long time, to own one or more automobiles, to be female, and to be older than the nonrespondent. Of particular importance here is that nonresponse bias appears related (as for the on-board survey) to variables related to the survey issues (i.e., transportation and mobility) and the funding of transportation investment. Again, this suggests the need to weight the survey results to reflect population characteristics more accurately if results are to be used to represent the county population.

Table 1. Response bias in mail-back survey revealed by on-board survey, Dade County.

Variable	Mail-Back Respondents [R]		Mail-Back Nonrespondents [NR]	
	Frequency	Percentage	Frequency	Percentage
Sex ($\chi^2 = 4.05$)[a]				
Male	88	48.6	186	41.3
Female	81	44.7	209	46.4
No response	12	6.7	55	12.2
Total	181		450	
Age (D = 0.075)[a]				
<12	0	0.0	10	2.2
12-17	20	11.0	50	11.1
18-34	54	29.8	139	30.9
35-54	57	31.5	140	31.1
55-69	18	9.9	46	10.2
>70	18	9.9	13	2.9
No response	14	7.7	52	11.6
Total	181		450	
Driver's license ($\chi^2 = 1.56$)[a]				
No	61	33.7	152	33.8
Yes	103	56.9	223	49.6
No response	17	9.4	75	16.7
Total	181		450	
Captivity status ($\chi^2 = 0.019$)[a]				
Could be driver or passenger	41	22.7	102	16.9
Could be passenger	20	11.0	49	16.2
Could be driver	33	18.2	81	15.8
Could not go by car	69	38.1	171	36.0
No response	18	9.9	44	15.1
Total	181		450	

Notes: Raw chi-square values are reported. D = Kolmogorov-Smirnov statistic.
[a]Not significantly greater than 0 at the 0.001 confidence level.

CONCLUSION

This paper has first made the point that the response rates on interview surveys have often been overestimated, whereas the rates for mail surveys are often underestimated. Given the enormous cost savings of a self-administered mail survey, it would seem worthwhile to develop methods to improve such procedures. Certainly, Dillman's (1) total design method deserves significant attention in this respect. The DSM procedure described above has been shown to have significant advantages. The idea can be extended to virtually any survey effort. Researchers need not always think of a mail survey or a telephone survey or a face-to-face survey but rather the proper mix of these methods, which allows the researcher to take advantage of the benefits of each survey mechanism and to avoid as many disadvantages as possible.

One of the most important benefits of the DSM is its ability to increase response rates and thus decrease nonresponse bias. More important, the DSM facilitates the determination of the existence of nonresponse bias and provides a procedure for correcting for it. The traditional solutions to the nonresponse bias problem--to perform one-sample statistical tests on variables available in the census, to make a special effort to gain cooperation of a sample of those who have refused to cooperate, to compare early and late returns, or to assume extreme values for nonrespondents--although useful, have been shown to have some significant drawbacks. As an alternative, the DSM employed in the Dade County and Washtenaw County on-board transit surveys has been shown to be beneficial in ameliorating nonresponse bias somewhat by improving response rates and eliciting some information from those who will only take the time to respond to a brief survey form.

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Table 2. Response bias in service variables from Dade County on-board survey.

Service Variable	Take-Home Respondents [R]			Take-Home Nonrespondents [NR]		
	Min	Frequency	Percentage	Min	Frequency	Percentage
Waiting time	χ = 18.20 S = 15.25 Median = 15[a]			χ = 17.32 S = 14.96 Median = 15[a]		
Need to transfer ($\chi^2 = 0.0003$)						
Yes		66	36.5		164	33.3
No		107	59.1		266	56.4
No response		8	4.4		19	10.2
Total		181			450	

[a]Both distributions are highly skewed to the right because zero is a lower bound on waiting time. The rather high standard deviations are due, then, to a number of reasonably high waiting times experienced by a reasonably small number of persons.

Transportation Study Committee, under whose auspices this work was executed. We are responsible, however, for the facts and accuracy of the data presented here. The contents reflect our views and are not necessarily those of any of the participating agencies.

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Small-Sample Home-Interview Travel Surveys: Application and Suggested Modifications

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A method was put forward three years ago for estimating the sample sizes needed for travel surveys from information contained in earlier household surveys. The method showed that very small samples (of the order of 1000-3000 households) could be used to update trip rates and the succeeding steps of travel forecasting by using the information on standard deviations contained in 1950 and 1960 data. Despite the potentially far-reaching impacts of this method, little use appears to have been made of it. An application of the method is described that shows that, in a region of more than 1.6 million households, a sample of 2600 households was estimated as being sufficient to achieve measurement of trip rates to within ±5 percent sampling error with 90 percent confidence. After the survey had been executed, measured trip-rate variances and sample distribution were compared with those used for sample-size estimation from 1965 data. Although variances and distributions were found to have changed quite substantially, the sample was found to have produced trip-rate estimates that were within or no more than ±1.5 percent beyond the specified design sampling error. Second, it was found that the method originally put forward does not provide efficient or intuitively appealing samples for the common case of stratified trip-generation relationships. For this case, a procedure is put forward to specify the required levels of error in each stratum in such a way that account is taken of the magnitude of the trip rate and the size of the stratum. It is shown that this procedure is more efficient and that it yields more intuitively appealing sample distributions than the assumption implied by the earlier procedure of an identical percentage error for each stratum.

Many of the large urban areas of the United States are continuing in the 1980s to do transportation planning by using forecasting procedures calibrated on data collected in the 1960s. These data were generally collected by means of a random or systematic sample of households; the sampling rate was from 1 to 5 percent of the regional population. In urban areas of 100 000 population and more, this might have involved anywhere from a few thousand to 20 000 or 30 000 households in the sample. Because of the high cost of such surveys, few have been conducted since about 1972, and it is unlikely that funding will exist in the foreseeable future for such major surveys. Currently, the cost of a house-