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Nonresponse Problem in Travel Surveys: An Empirical Investigation

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The effects in survey sampling of nonadherence to the assumption that all elements of a selected sample provide the desired information are investigated. On the basis of a thorough survey sample that had four follow-up reminders (77 percent return rate) and a subsequent survey of nonrespondents, it is shown that substantial misrepresentations of mobile households, trip frequencies, mode-choice distributions, and certain trip purposes become evident. A number of precautions and remedies are suggested to deal with this problem in order to improve the quality of the information input used for the analysis of travel behavior. Not only is the nonresponse bias for low response rates substantially greater, but it also affects the trip structure (frequency, choice, purpose, and destination) more than is the case in a more-exhaustive survey sample. It is demonstrated that a systematic bias arises due to the underrepresentation of nonmobile persons. It is therefore essential to take steps that will increase the willingness of the nonmobile persons to respond to such surveys and that will generate more cost-effective methods to accomplish this objective. It is still necessary to aim for as large a response rate as possible, since the systematic nonresponse bias cannot be compensated for by sociodemographic weighting. A reduction in the follow-up reminders cannot be recommended.

In general, empirical surveys are based on the assumption that the survey of a sample will provide sufficiently precise information about the total population from which the sample was drawn. The significance tests used to prove and control the results are based on a further assumption, namely, that every sample point selected provides the desired relevant information. Of course, it is known from experience that this condition is practically never met in survey sampling (1).

In order to be able to make statistically sound statements about the survey population in better-quality surveys, an attempt is made to estimate the effect of this nonresponse factor on the population estimates. This nonresponse factor can seriously distort the results of investigations into travel behavior and can cause inappropriate investments into transportation facilities or services.

BACKGROUND

The research reported in this paper is based on a household travel survey conducted in West Berlin in the spring of 1976. By means of a carefully administered mail-back questionnaire supplemented by four follow-up reminders at one-week intervals, a total return rate of 77 percent was reached. In spite of the excellent return rate, the question remained of what influence the 23 percent nonresponse rate had on the population estimates for that particular investigation of travel behavior.

The existence of any nonresponse component in a survey sample leads to the undesirable, yet often disregarded, fact that the principles of the theory of survey sampling are only applicable with certain limitations. Only when information about every element of the sample is available can the statistical computations of sampling theory be indeed precise.

In general, there are four different approaches used in order to deal with this nonresponse problem. First is the naive approach, in which one simply ignores the problem and proceeds with the computation of statistical significance and population values.

The second approach, the so-called "technocratic approach," compares selected sociodemographic data of the survey sample with corresponding secondary statistics and makes adjustments by means of weighting factors in case of observable deviations. The better strategy in this case is the use of cell adjustments rather than column and row adjustments. The results of the survey can only be improved in cases in which there exists a correlation between the phenomenon under investigation and the sociodemographic variables used.

The scientific approach replicates, by means of substantial effort, the selection principles used for the construction of the original survey sample and combines them into a procedure called "free grossing up" (estimation of population values). It is generally overlooked that nonresponses to survey questions are subject to systematic bias caused by the interrelationships among the survey administrator, the phenomenon under investigation, and the interviewee.

Finally, in the problem-oriented approach, one attempts to gain some basic selection of information for the nonrespondent about the subject under investigation. For that purpose it is generally necessary to conduct so-called "nonresponse investigations." These investigations are guided by the consideration that it might be better to obtain relevant qualitative information for at least a subset of the survey elements than to obtain possibly irrelevant quantitative data from all elements.

Again, the influence of the nonresponse problem can only be estimated.

RESEARCH APPROACH USED

The approach used in the investigation on which this paper is based represents a combination of the technocratic and the problem-oriented approaches. This approach implied that the sociodemographic structure of the nonrespondents was obtained by means of correcting the corresponding variables for the respondents on the basis of secondary statistical information. A second task was to determine the travel behavior (the phenomenon under investigation) of the nonrespondents by a nonresponse investigation. The travel behavior of the remaining hard-core nonrespondents was to be determined by using the response speed of the respondents as a measure of their willingness to participate in the survey.

The stratification of respondents according to their willingness to respond can generally only be performed for mail-back surveys. It should also be noted that it is essential for a meaningful nonresponse investigation that the main survey and the nonresponse survey be performed during the same season in order to avoid the occurrence of seasonal bias in travel behavior.

The basis for this investigation is the Continuous Travel Survey (KONTIV) (2) performed in West Berlin in 1976. The results of that survey were stratified by their different return phases and evaluated according to their return speed. The nonrespondents were the subjects of a special nonresponse investigation.

RESPONSE GROUPS IN MAIN SURVEY

The respondents to the main travel survey and its four follow-up steps can be stratified as follows:

Group 1: Prompt respondents, who answered on the specified survey date;
Group 2: Respondents to the first reminder (a postcard);
Group 3: Respondents to the second reminder (a postcard);
Group 4: Respondents to the third reminder (a second copy of the questionnaire); and
Group 5: Respondents to the fourth reminder (a postcard).

Table 1 gives the results of the main survey by response group. The results of each subsequent follow-up naturally decreased in size. Nevertheless, these reminders contributed substantially to the overall response rate. Each reminder can also be viewed as a separate survey that has a separate gross sample size.

Smaller households tended to show slightly greater willingness to respond to the travel survey. The cumulative average household size increased in the course of the four follow-up actions. Overall, it was found, however, that the distribution of individual household characteristics was virtually identical for these four response phases. This confirms the assertion that the willingness to respond to travel surveys (at least in Germany) has very little relationship to the socioeconomic characteristics of the population. Rather, the personal interest in the phenomenon under investigation is of decisive importance in determining both the willingness and the speed of response.

The trip structure (represented by trip length and duration, trip purpose, and mode choice) showed an equally uniform picture for the groups of respondents as did the sociodemographic structure. If the degree of mobility is considered, however, rather than the trip structure, the results are substantially different. The cumulative average trip frequency decreased by 4 percent between the main survey date and the last response phase after the fourth reminder. The reason for this reduced mobility lies in the fact that completely nonmobile persons are very reluctant and slow to respond, since they tend to assume that their responses are unnecessary for an investigation into travel behavior. These results facilitate the investigation into the nonresponse problem. The relevant problem to be investigated is the question whether the mobility of the nonrespondents differs significantly from that of the respondents.

Table 1. Response groups and response rates in the main survey.

Response Group	Gross Sample Size	Responses	Response Rate per Response Group (%)
1	918	265	29
2	631	148	23
3	470	88	19
4	369	67	18
5	288	30	10

Note: Response groups are defined in the text.

NONRESPONSE INVESTIGATION

In order to solicit responses from nonrespondents, it is often advisable to change the survey method. Of course, different survey methods will also affect the results of the survey. In order to maintain full compatability with the main survey, the mail-back approach was also used in the investigation of nonresponses. The problem is that this method will not lead to a 100 percent return rate. In this project the final hard-core nonrespondents were contacted by specially trained interviewers in order to find out whether and to what degree genuine nonresponses (e.g., change of residence or death) existed among the nonrespondents and whether there were any genuinely nonmobile persons in that last group.

The target group for this nonresponse investigation consisted of 209 households out of a gross total of 984 households (Table 2). This survey of nonresponses consisted of a main survey followed by two written reminder notices. In the course of the survey, 30 households were found to be genuine nonrespondents, whereas 59 completed questionnaires were received. The remaining households were visited by trained interviewers, during which time additional genuine nonrespondents and nonmobile households were identified. Table 2 shows that the nonresponse survey added substantially to the information of this travel survey, which led to the result that statements about travel behavior could be made for 95 percent of the original survey sample. The remaining 5 percent constitute the hard core of project-specific nonrespondents. All percentage values presented in Table 2 represent uncorrected gross values that relate to the original survey sample. Information was obtained about all households; yet this must not be equated with a true response rate. For the true response rate, we started from 984 original sample elements; 178 households were genuine nonrespondents, which left a corrected sample of 806 households, of which 699 were respondents. This represents a return rate of 86.7 percent.

Table 3 represents the cumulative response rates for the six groups of respondents (groups 1-5 were

Table 2. Summary of response rates for main travel survey and nonresponse survey.

Category	Main Travel Survey (N = 984)		Mail-Back Nonresponse Survey (N = 209)		Interview Nonresponse Survey (N = 116)		Combined Main and Nonresponse Surveys (N = 984)	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Respondents	598	61	59	28	42	36	699	71
Genuine nonrespondents	128	13	30	14	20	17	178	18
Other nonrespondents	49	5	4	2	2	2	55	6
Total households for which information was obtained	775	79	93	44	64	55	932	95
Households for which no information was obtained[a]	209	21	116	56	52	45	52	5

[a]Basis for computations in the next column.

Table 3. Cumulative response rates and mobility values.

Response Group	Cumulative Return Rates (%)	Average Mobility (trips per person per day)	Cumulative Mobility Values (trips per person per day)
1	32.9	2.72	2.72
2	51.2	2.31	2.57
3	62.2	2.27	2.51
4	70.5	2.22	2.48
5	74.2	2.21	2.46
6	86.7	1.46	2.32

Table 4. Trend extrapolation for computing mobility by response group.

Computed Return Increment	Computed Cumulative Average Mobility (trips per person per day)	Change
First tenth	2.77	
Second tenth	2.73	
Third tenth	2.68	
Fourth tenth	2.65	-0.07
Fifth tenth	2.58	-0.07
Sixth tenth	2.53	-0.05
Seventh tenth	2.47	-0.06
Eighth tenth	2.40	-0.07
Ninth tenth	2.34[a]	-0.06[b]
Tenth tenth	2.29[a]	-0.05[b]

[a]Values computed from the trend estimation. [b]Trend estimate.

defined earlier; group 6 contains respondents in the nonresponse survey). It also depicts the average and cumulative mobility per person per day.

A number of approaches, either intuitively simple or statistically sophisticated, are available to estimate the mobility of the nonresponse group. Examples of the former approaches are trend extrapolation, a minimum-maximum method (averaging procedure), and a qualitative estimation. Simple methods were used here since we are dealing with an estimate of mobility that remained obvious only by means of a simple estimation procedure. Another argument in support of simple approaches is that they are easily tractable by the analyst.

Trend Extrapolation

In the trend extrapolation of the cumulative mobility values, the return rates were subdivided into 10 equal increments and values were estimated for the last 1.5 tenths. Table 4 shows the values computed for this procedure. By using this method, an average trip frequency of 2.29 for the total population was obtained.

Minimum-Maximum Method

In the minimum-maximum method, we ignored response group 1, since persons in this group are particularly interested in the subject of the investigation (i.e., travel), and it can be assumed that they almost all will have answered. This leaves 2.21 (group 5) as the lowest and 2.31 (group 2) as the highest mobility values among response groups 2-5; this results in a weighted average of 2.29 trips per person per day. Computing the highest and lowest mobility alternately for the nonresponse group, averaging the two values, and inserting that value into the cumulative analysis results in a mobility value of 2.32 trips per person per day.

Qualitative Estimation

In the qualitative-estimation approach, the individual response groups were subjected to a qualitative analysis and the mobility value was used of that group most similar to the nonresponse group. After the characteristics of all response groups (in terms of their socioeconomic characteristics) had been investigated, it was concluded that the structure of the nonresponse group (group 6) was most similar to the last two groups of the main survey (groups 4 and 5), whose average mobility was 2.22 and 2.21 trips per person per day, respectively. On the other hand, the values derived from the nonresponse survey seemed to stabilize at about 1.46 trips per person per day. It seemed reasonable to conclude that the mobility of the remaining nonrespondents would tend to be lower than that of the comparison group.

The average value of the comparison group lies at 2.22 trips per person per day and would have to be adjusted downward to an average trip frequency of 1.83 trips per person per day. Inserting this value into the cumulative computation results in an estimated average value of 2.26 trips per person per day.

The results of the three simple estimation methods differed only insignificantly. The final value would have to lie somewhere between 2.26 and 2.32 trips per person per day, namely, an estimated trip frequency value of 2.29.

ANALYSIS OF RESULTS OF NONRESPONSE ANALYSIS

In general, the ultimate objective of an investigation into nonresponse is not the detailed analysis of the nonrespondents; rather, it is the determination of the changes that would have occurred in the survey results had the opportunity existed of securing a response from every element of the survey sample. Since survey results are generally weighted, we can reformulate this objective as investigating whether such weighting will have already provided sufficiently corrected results for the phenomenon under investigation.

For this investigation the weighting of the main survey sample (taken as 100) resulted in a reduction

Table 5. Mobility and trip-frequency indices.

Item	Cumulative Share of Mobile Persons in Survey	Cumulative Trip Frequency for All Survey Elements	Cumulative Trip Frequency for Mobile Persons
Response group			
1	107	111	103
2	103	104	101
3	101	102	101
4	101	101	100
5[a]	100	100	100
6	95	94	100
Weighted values for main survey	96	96	99
Final estimates	92	93	100

[a]The unweighted overall results of the main survey were set to 100.

Table 6. Comparison of indices from low-response survey sample with those of main survey sample.

Variable	Group 1 Respondents (unweighted)	Main Survey		Final Estimated Values[a]
		Unweighted	Weighted	
Mobile persons				
Share	116	109	104	100
Overall	119	107	103	100
Mobility	103	100	99	100
Mode choice				
Walk	103	100	103	100
Bicycle or motorized bicycle	100	100	75	100
Automobile driver	100	101	97	100
Automobile passenger	114	103	100	100
Public transit	89	94	104	100
Trip purpose				
Work	97	97	100	100
School	92	100	85	100
Shopping	116	104	112	100
Social or recreation	100	100	100	100
Other	88	100	100	100
Trip length				
Average duration	100	100	100	100
Average distance	100	100	100	100

[a]The final estimated values were set to 100 for the index computation.

of the average mobility, as shown below:

Item	Average Mobility (trips per person per day)	Index
Main survey		
Unweighted	2.46	104
Weighted	2.36	100
Final estimated value	2.29	97

It turned out that the direction of the correction (which included nonresponse considerations) performed through the weighting process was correct but not pronounced enough. If we set the typical result of a household survey (weighted according to sociodemographic characteristics) equal to 100, we have to suspect that nearly 50 percent of the actually required correction is not accomplished by such a weighting. This result confirms the fact that the correlation between sociodemographic characteristics and travel behavior is not sufficiently strong to provide a corrected picture of travel behavior that can be obtained by means of weighting through demographic characteristics.

TRAVEL CHARACTERISTICS OF MOBILE VERSUS NONMOBILE RESPONDENTS

It is significant to determine how many of the survey respondents participated in an activity outside the home during the survey date and what the trip frequency of this mobile group was. As is evident from an inspection of Table 5, the portion of mobile persons was too high in the early phases of the survey compared with the share of mobile persons in the whole survey population. The degree of representativeness of the mobile persons (those who participated in an activity outside the home) improved within subsequent response groups. Nevertheless, at the end of the survey there remained a discrepancy between the expected share in the total population and the share evident in the survey sample.

On the other hand, it was found that the average trip frequency of the mobile persons was almost independent of the return rate. The value was a little too high with the first response group, but it reached the final results of the survey very quickly. Furthermore, this result is not affected by the results of the nonresponse survey. The observed reduction in overall mobility in later response groups can therefore be attributed exclusively to the underrepresentation of nonmobile persons in early response groups. A further investigation of the relationship among response speed and choice of mode, trip purpose or destination, and trip length (time and distance) revealed that the nonresponse investigation did not result in any changes from the unweighted values of the main survey. In most cases, the results were already stable after the first response phase; i.e., they were free from any nonresponse influences. On the other hand, the results obtained by weighting according to socioeconomic characteristics do not show this homogeneous picture. The sociodemographic weighting procedure did not lead to any improvements in the results, since the relatively small portion of mobile persons in the nonresponse group cannot lead to such a change in the trip structure. On the contrary, sociodemographic weighting in part led to deterioration of the survey sample results.

IMPLICATIONS FOR SURVEY PRACTICE

It is not uncommon for survey analysts and administrators to work with return rates of about 30 percent without attempting to obtain any additional information about the remainder of the sample. This research has shown what consequences such a strategy has on the quality of the collected travel data. The data of such a survey correspond to the 32.9 percent of group 1 respondents identified in the main survey in this paper. Table 6 permits a comparison of survey results for that group (response rate of 32.9 percent) with those of the main (complete) survey (response rate of 74.2 percent). The major results of using such a low response rate are likely to be as follows:

1. Overestimation of mobile persons (those who pursue activities outside the home on the survey day),
2. Overestimation of trip frequencies per person per day,
3. Poor representation of the mode-choice distribution, and
4. Serious overestimation of shopping trips (although social and recreational trips are represented correctly).

In summary, it can be stated that the nonresponse bias for low response rates not only is substantially greater but also affects the trip structure (frequency, choice, purpose, and destination) more than is the case in a more-exhaustive survey sample. As a consequence, the nonresponse error certainly cannot be compensated for by a correction of the share of mobile versus nonmobile persons.

The survey procedure (which includes the main survey and the nonresponse survey) was obviously quite cost-intensive, mainly because of the various follow-up phases. The question arises how these costs can be reduced while essentially the same data quality is maintained. The insights into the response behavior provided by this research might provide the prerequisite for meeting such a goal. It was demonstrated that a systematic bias arises due to the underrepresentation of nonmobile persons. It is therefore essential to take steps that increase the willingness of the nonmobile persons to respond to such surveys and that generate more cost-effective methods to accomplish this objective. It is still necessary to aim for as large a response rate as possible, since the systematic nonresponse bias cannot be compensated for by sociodemographic weighting. A reduction in the follow-up reminders cannot be recommended. At the moment, cost savings might be suggested (assuming that the results of this research are transferrable) by means of correcting the portion of mobile persons on the basis of the research results presented in this paper prior to the sociodemographic weighting of results. Another procedure would be to determine the ratio of mobile to nonmobile persons on the basis of a subsample of nonrespondents. This approach would be justifiable on the basis of this research, since the trip structure is practically unaltered by the nonrespondents.

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Assessment of Land-Use and Socioeconomic Forecasts in the Baltimore Region

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Accuracy of forecasts for population, labor force, employment, and car ownership from 1962 to 1975 in the Baltimore area are examined. Comparisons are made at three levels of zonal aggregation—city and suburbs, traffic districts, and traffic zones. The lack of information about household size and household income made inferences from the results incomplete. The results show that regionwide forecasts were accurate for all the variables except population. However, allocation of these forecasts between city and suburbs, to traffic districts, and to traffic zones was quite inaccurate. The correlation coefficient between predicted and actual changes varied from 0.93 to 0.17 for the city zones and from 0.28 to 0.02 for the suburban zones. The corresponding ranges at the traffic-district level were from 0.86 to 0.61 and from 0.36 to 0.30, respectively. The results in the paper point toward large errors and uncertainties in the independent variables of traditional travel-demand models.

The importance of socioeconomic and land-use variables to travel forecasts requires no elaboration. Forecasts of population, labor force, employment, car ownership, income, and other such variables are routinely made for 15-20 years into the future.

In spite of the popularity of hindsight, the accuracy of forecasts of land-use and socioeconomic variables is rarely examined. In fact, we know of no other study that has reported on the matter.

In this paper, forecasts of Baltimore-area population, labor force, employment, and car ownership by traffic zone made in 1962 for 1980 are interpolated for 1975 and compared with the actual 1975 figures as given by the Baltimore Regional Planning Council.

The comparison is made at three levels of zonal aggregation--city and suburbs, traffic districts (68), and traffic zones (484). These levels of aggregation were chosen to pinpoint the location of inaccuracy in forecasts. It is noted that 14 zones or 2 districts were eliminated from the analysis because of lack of 1962 data. These areas were on the very outskirts of Baltimore.

DATA AND METHOD

Three things need to be said about the data and method. First, the data pertain to the Baltimore area. In the 1962 study, this area was divided into 796 traffic zones. Some time later, the traffic zones were redefined, which resulted in 498 traffic zones. Equivalency between the old and the new traffic zones is achieved by means of a zone-equivalency table that assigns certain percentages of the old zones to new zones. This introduces a source of error. Percentage allocations of old zones to new zones cannot be done in a faultless manner. This problem will be examined briefly later in the paper.

Second, the 1980 forecasts were interpolated for 1975 by using both linear and logarithmic mathematical forms. The former provided better agreement for areawide figures for population, labor force, and employment (jobs). The latter provided a better match for car ownership [Table 1 (1)]. Thus, the linearly interpolated figures are chosen as the basis of comparison for population, labor force, and