are now incurred in monitoring and maintaining statewide vehicle counts. Another approach might entail estimation of the shift factors as functions of socioeconomic variables that take into account gasoline availability and price as well as other indicators of travel.

The initial application of the rank-size rule presented in this paper indicates that further study is warranted. The approach has the potential to greatly ease the very costly and burdensome task of estimating vehicle miles of travel, and its utility in forecasting vehicle miles of travel is yet to be fully explored.

Research is under way to determine effective bellwether sections to be used as a basis for estimating the necessary parameters for this application of the rank-size rule. In addition, the approach has been verified on vehicle miles of travel data for 1976-1979, and the development of a method for determining the shift parameters as functions of gasoline and diesel sales is currently under study.

ACKNOWLEDGMENT

I am grateful to David T. Hartgen for providing the basic idea and inspiration for this research. Special thanks are due to Dave Fifield of the Data Services Section of the New York State Department of Transportation for preparing the initial summaries of the data used in the work. Many thanks to Linda Unangst for her expert typing.

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Publication of this paper sponsored by Committee on Passenger Travel Demand Forecasting.

Consideration of Nonresponse Effects in Large-Scale Mobility Surveys

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This paper continues the line of investigation of nonresponse problems previously presented. After a brief review of the context of the problem, namely the nonresponse effects on measured behavior in spite of demographic weighting, and the results of the previous research on this topic, the paper documents a broadening of the insights gained into the effects of nonresponse. These insights were applied to a large-scale nonresponse analysis of approximately 100 000 trips. The analysis included the nonresponse effects for the number of trips, trip purpose, travel mode, and seasons. Also, nonresponse effects are compared for written and interview surveys. Experience with the characteristics and impacts of nonresponse for intercity travel is presented. The insights gained could be used to clear up and correct past and present survey efforts and also to ensure that future data-collection efforts are conducted at lower costs, since corrections can also be made for smaller rates of return.

In principal, empirical surveys are not capable of providing an exact replication of measured reality: They only provide a picture that deviates more or less from this reality. The size and direction of these deviations are determined significantly by a variety of factors tied to the chosen survey design (see Meyburg and Brög in another paper in this Record).

Strict application of these basic facts shows the limits and possibilities of empirical research:

1. Precise determination of the distortions (biases) induced by the survey method will never be possible and
2. Systematic research into the biases caused by the survey method employed will lead to insights that will permit the estimation of the direction and order of magnitude of these deviations.

The corresponding measurement results will not be exactly correct, but they will be more correct (i.e., closer to reality). In order to reach results closer to reality, systematic research into survey methods is necessary.

Such methods research typically is very expensive. For that reason, these studies will have to be of an exemplary nature. This means that this fundamental research must be designed such that generalizable results (at least within reasonable limits) are obtained. These insights can be that

1. At least the direction of the bias in relation to the chosen survey method can be indicated;
2. Additional correction factors for the elimination of this bias can be provided, whose application would move the measured results closer to reality; and
3. An evaluation method is developed that would make it possible to estimate the relevant influences directly within the survey and to correct the survey data themselves.

The general level of knowledge about relevant factors of influence to survey methods in the determination of activities outside the home is rather limited to date. It has progressed only to a stage where we comprehend that a multitude of factors exists in the survey design that can be of significant influence on the measurement results. Furthermore, we begin to realize that, even in comparatively simple measurements of nonhome mobility, for example, regional and seasonal factors can generate

Table 1. Overall mobility by response increments.

Response Increment	Mobility per Increment	Cumulative Mobility	Index Cumulative Values[a]
First fifth	2.91	2.91	112.8
Second fifth	2.70	2.81	108.9
Third fifth	2.57	2.72	105.4
Fourth fifth[b]	2.41	2.64	102.3
Fifth fifth[c]	2.37	2.58	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Partial nonresponse estimate.
[c]Complete nonresponse estimate.

specific survey situations that stand in the way of generalizing corresponding fundamental research.

For this reason, in the conduct of basic studies of survey-method-specific influence factors, special attention should be paid to the development of an evaluation method that allows the renewed examination of the results in a concrete case and that thereby expands the spectrum of corresponding insights.

THE NONRESPONSE PROBLEM

A significant bias in empirical surveys of nonhome mobility results from the fact that it is not possible to get all households or individuals to respond. This problem exists both in sampling and in total population surveys. In either case conclusions have to be drawn for a larger entity based on a smaller group of respondents. Unfortunately, the severity of the problem increases for the usual sampling situation. In practice, this problem is usually disguised by means of the indication of a significance level based on sampling theory (1). These statistical significance measures are valid only when information about each sampling element is available. This condition cannot be fulfilled in empirical surveys.

Therefore, it is important to deal with the nonresponse problem in a systematic fashion in order to be able to estimate how the observed results would change if corresponding information were available for each selected sample element. It is especially important that the information be relevant for the object of the investigation, in this case for nonhome mobility. Information that captures merely the sociodemographic characteristics does not fill this information gap and, therefore, is not sufficient for reliable estimation of the influence of nonresponse.

METHODOLOGICAL EXPERIMENTS

Since the nonresponse effect constitutes a significant bias of empirical results, we have investigated this problem area in several basic research efforts. One of these studies was presented in an earlier paper (2). It constituted the starting point for several additional analyses, including the research reported here.

For a survey of 984 households in West Berlin, the survey design corresponded exactly to the one employed in the national travel survey (KONTIV) and other large surveys in West Germany. The only objective of the West Berlin survey was to obtain as large a response rate as possible and to gather additional qualitative information about late or nonresponding households.

The survey used the mail-back technique with several follow-ups. Although in other large surveys in West Germany the number of reminders was usually limited to four (which normally results in a response rate of 65-75 percent), in this survey it was increased and the response rate increased correspondingly from 74 to 87 percent. Care was taken not to modify the survey design in order to truly measure the influence of the nonresponse effect and not that of a changed survey method.

In order to gain additional insights into the structure and motivation of the group of nonrespondents, interviews were conducted with late respondents and nonrespondents wherever possible. Otherwise, additional investigations were undertaken to obtain certain information about these groups of people.

The most-significant result of this methodological experiment was that the measured mobility (trips per person) decreased with the size of the response rate (see Table 1) and that this effect cannot be corrected sufficiently by means of simple sociodemographic weighting.

The follow-ups and additional investigations clearly indicated that people who had little nonhome mobility (i.e., few trips taken outside the home) did not feel sufficiently concerned and, therefore, did not participate in the survey. On the other hand, it could not be confirmed that late respondents, tired of the numerous follow-ups and reminders, simply report fewer trips than they actually perform.

SUBSEQUENT ANALYSES

The methodological experiment resulted in several important insights for subsequent work on the nonresponse problem:

1. Trend extrapolation on the basis of response speed proved to be a usable method of estimation and an acceptable method of evaluation;
2. Use of the term "mobility per person" (i.e., trips per person) proved to be too imprecise; variables such as "share of mobiles" (i.e., that share of the population surveyed who took a trip on the survey day) and "mobility per mobile" (how many trips the surveyed mobile person took on the survey day; i.e., trip rate per person) should be used instead; and
3. Stratification according to mode and trip purpose did not produce consistent results yet--probably due to relatively small sample size (this suggests further investigations on the basis of larger sample sizes).

In this experiment the specific influence of the survey area and the survey period could not be determined. The present level of knowledge suggested that the nonresponse investigation be repeated on the basis of this evaluation method for the KONTIV survey (3) [i.e., a sample representative of an entire region (in this case, West Germany) and distributed across all seasons].

In its basic version, as it is used in this paper, the KONTIV survey consisted of 105 000 person survey days, and it had a response rate of 72.4 percent. A stratification into five response segments of equal size was performed because the trend extrapolation can be performed most readily when only the last segment has to be estimated completely and the second to last has to be estimated partly. The results presented in the following sections permit a much-more-precise determination of the nonresponse effect. However they are only relevant for surveys of comparable methodological design (i.e., specifically for mail-back surveys).

SELECTED RESULTS

Measures of Nonhome Mobility

The average number of trips for all people surveyed shows the known effect that mobility decreases with increasing response rate. It is almost one-quarter higher for the first respondents than for the (estimated) population average.

The variable "mobility per person" is, however, a quasi-artificial average value that is composed of the "share of mobiles" and the "mobility per mobile." These two measures show modifications already. Although the value of "mobility per mobile" decreases with increasing response rates, the values in each response fifth (stratum) are relatively less exaggerated than they are for the measure "mobility per person" (Table 2). The "share of mobiles" reaches its highest value only in the second fifth, which indicates, among other things, that some people who have low mobility also answer very quickly (Table 2).

NONRESPONSE BY SEASON

The analysis of the nonresponse effect by season shows the importance of subdividing the average mobility into its two constituent components. If we look at the changes in "mobility per person," we also find a rather uniform decrease in values with an increasing response rate (Table 3).

This picture is largely reconfirmed in the analysis of the measure "mobility per mobile," but it is relatively different for the "share of mobiles." Two different tendencies become evident: Although the first two response fifths show the highest mobility in winter and spring, this effect only shows in the second and third fifth for summer and fall (i.e., it is delayed). The reason for this phenomenon lies in the fact that people who travel a lot and who belong to the group of fast respondents during winter and spring only answer with a delay during the summer and fall months when they are busy with nonhome activities or when they are more frequently on trips away from home (Table 4).

In connection with the seasonal variation development of the measure "mobility per mobile," we therefore observe quite different nonresponse effects dependent on the time of the survey. In a continuous year-long survey, it is therefore advisable to apply a nonresponse correction separately by time of year.

Nonresponse by Mode

Response or nonresponse behavior has a significant effect on the resulting frequency of modal use. Early respondents often use individual, often nonmotorized, travel modes, and a large number of public transit users apparently decide only relatively late (or not at all) to participate in a survey (Table 5). Also obvious here is that a response rate of, for example, 60 percent still contains tangible fluctuations in the modal split representation, in spite of relatively good representation of the total mobility.

Nonresponse by Trip Purpose

Inconsistencies due to nonresponse are even more pronounced in the analysis by trip purpose. A repeatedly indicated tendency of decrease with increasing response rate is evident for social-recreational and shopping trips, in spite of the fact that the initial values in the first fifths lie substantially above the estimated average value (Table 6). For mandatory trips, however, a substantial de-

Table 2. Share of mobiles and mobility of mobiles.

	Share of Mobiles			Mobility of Mobiles		
Response Increment	Single	Cumulative	Index Cumulative Values[a]	Single	Cumulative	Index Cumulative Values[a]
First fifth	75.7	75.7	102.3	3.84	3.84	110.0
Second fifth	78.4	77.1	104.2	3.45	3.65	104.6
Third fifth	76.8	76.9	103.9	3.34	3.54	101.4
Fourth fifth[b]	71.2	75.2	101.6	3.38	3.51	100.6
Fifth fifth[c]	69.3	74.0	100.0	3.42	3.49	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Partial nonresponse estimate.
[c]Complete nonresponse estimate.

Table 3. Overall mobility by season.

	Cumulative Value				Index Cumulative Value[a]			
Response Increment	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
First fifth	3.00	2.79	2.90	2.98	113.2	106.1	112.8	120.7
Second fifth	2.82	2.73	2.85	2.83	106.4	103.8	110.9	114.6
Third fifth	2.69	2.64	2.80	2.73	101.5	100.4	109.0	110.5
Fourth fifth[b]	2.67	2.63	2.68	2.58	100.8	100.0	104.3	104.5
Fifth fifth[c]	2.65	2.63	2.57	2.47	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Partial nonresponse estimate.
[c]Complete nonresponse estimate.

Table 4. Share of mobiles and mobility of mobiles by season.

	Index of Cumulative Values[a]							
	Share of Mobiles				Mobility of Mobiles			
Response Increment	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
First fifth	104.2	95.4	102.7	108.4	108.5	111.3	109.8	111.5
Second fifth	103.2	99.6	106.1	107.7	102.8	104.2	104.6	106.5
Third fifth	102.1	100.1	105.8	106.9	99.4	100.3	102.9	103.5
Fourth fifth[b]	101.1	100.0	102.7	103.0	99.7	100.0	101.4	101.5
Fifth fifth[c]	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Partial nonresponse estimate.
[c]Complete nonresponse estimate.

Table 5. Mobility of mobiles by principal mode of travel.

Response Increment	Total	Index of Cumulative Values[a] Nonmotorized Modes[b]	Individualized Travel Modes[c]	Public Transit
First fifth	110.0	115.2	107.2	100.0
Second fifth	104.6	107.2	104.8	94.7
Third fifth	101.4	103.6	101.2	97.4
Fourth fifth[d]	100.6	101.4	100.6	100.0
Fifth fifth[e]	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Includes walking, bicycle, and motorized bicycle.
[c]Includes automobile driver, automobile passenger, moped, and motorbike.
[d]Partial nonresponse estimate.
[e]Complete nonresponse estimate.

Table 6. Mobility of mobiles by trip purpose.

Response Increment	Total	Index of Cumulative Values[a] Mandatory Trips[b]	Social-Recreational Trips	Shopping Trips[c]
First fifth	100.0	99.4	114.8	121.4
Second fifth	104.6	98.2	108.6	111.7
Third fifth	101.4	97.6	102.5	105.8
Fourth fifth[d]	100.6	98.8	100.0	102.9
Fifth fifth[e]	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Includes work and school trips.
[c]Includes trips for shopping and personal business.
[d]Partial nonresponse estimate.
[e]Complete nonresponse estimate.

Table 7. Mobility of mobiles—mandatory travel by principal modal use.

Response Increment	Total	Index of Cumulative Values for Mandatory Travel[a,b] Nonmotorized Modes[c]	Individualized Travel Modes[d]	Public Transit
First fifth	99.4	104.1	97.6	100.0
Second fifth	98.2	100.0	97.6	92.3
Third fifth	97.6	100.0	97.6	96.2
Fourth fifth[e]	98.8	100.0	98.8	100.0
Fifth fifth[f]	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Includes work and school trips.
[c]Includes walking, bicycle, and motorized bicycle.
[d]Includes automobile driver, automobile passenger, moped, and motorbike.
[e]Partial nonresponse estimate.
[f]Complete nonresponse estimate.

Table 8. Mobility of mobiles for social-recreational travel.

Response Increment	Total	Index of Cumulative Values for Social-Recreational Travel[a] Nonmotorized Modes[b]	Individualized Travel Modes[c]	Public Transit
First fifth	114.8	123.5	109.8	100.0
Second fifth	108.6	111.8	104.9	100.0
Third fifth	102.5	108.8	100.0	100.0
Fourth fifth[d]	100.0	105.9	100.0	100.0
Fifth fifth[e]	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated total value = 100.
[b]Includes walking, bicycle, and motorized bicycle.
[c]Includes automobile driver, automobile passenger, moped, and motorbike.
[d]Partial nonresponse estimate.
[e]Complete nonresponse estimate.

crease can be observed, especially in the middle fifths (Table 7). Evidently, people who have relatively simple activity patterns that do not go significantly beyond trips to and from work tend to belong to the groups of late or nonrespondents.

The indicated effects could be eliminated or, as is more common, enlarged due to the consideration of combined measures. The combination of the measures "trip purpose" and "predominantly used travel mode" illustrates even more clearly the problems of low response rates. For example, a rather good response rate of 60 percent generates a good result only for mandatory trips by nonmotorized modes. For all other modes the results are below average. The situation is exactly opposite for social-recreational travel. For the identical response rate, nonmotorized travel would be overrepresented, but the use of other modes would have been represented correctly (Table 8). For shopping trips only, public transit trips were captured correctly; however, they play a rather insignificant role for that particular trip purpose. The other much-more-important travel modes are substantially overrepresented for a 60 percent response rate (Table 9).

Sociodemographic Weighting

Prior to this nonresponse estimation, the results of the KONTIV survey were subjected to a detailed weighting process. First, an equal distribution of weekdays was performed. This equalization was followed by a reconstruction (replication) and correction of the selection procedures for the formations of the sample in the context of a free estimation of population values. Finally, the results were subjected to sociodemographic weighting on the basis of a cell plan with approximately 200 cells. These weighting efforts were relatively intensive and included all possibilities available on the basis of secondary statistical material.

When the results of the weighting process are compared with those obtained through the nonresponse estimation, it becomes evident that the weighting process does not lead uniformly in the same direction and that it results in substantial deviations from the estimates of the actual values in some cases.

Overall, the weighting procedure results in an overestimate of total mobility by 1.6 percent. This is a difference that looks relatively good compared with other nonresponse investigations (Table 10). A nonuniform picture arises for the individual seasons. In this instance it is particularly noteworthy that sociodemographic weighting is least precise for the winter, when the nonresponse effects are particularly strong. Substantial inaccuracies are also observed for the travel mode and trip purpose categories, where the unweighted results are not changed consistently in the proper direction. Therefore, a correction by means of sociodemographic characterstics does not ensure that the characteristics of the behavior under investigation are improved sufficiently accurately.

CONCLUSIONS ABOUT THE METHODOLOGICAL EXPERIMENTS

These results produce generalizable insights about the direction and the order of magnitude of biases that result from the survey method chosen. They also illustrate an evaluation method on the basis of which corresponding tests of the other empirical surveys can be undertaken. Recognize, however, that such a new nonresponse estimation requires sufficiently high response rates. In the application of the trend-extrapolation method, this rate should not lie below 70 percent if at all possible. Otherwise

Table 9. Mobility of mobiles for shopping and personal business travel.

Response Increment	Total	Index of Cumulative Values for Shopping and Personal Business[a]: Nonmotorized Modes[b]	Individualized Travel Modes[c]	Public Transit
First fifth	121.4	120.0	125.0	128.6
Second fifth	111.7	109.1	120.0	114.3
Third fifth	105.8	103.6	112.5	100.0
Fourth fifth[d]	102.9	101.8	107.5	100.0
Fifth fifth[e]	100.0	100.0	100.0	100.0

Note: KONTIV 1976 had approximately 105 000 person survey days.
[a]Estimated value = 100.
[b]Includes walking, bicycle, and motorized bicycle.
[c]Includes automobile driver, automobile passenger, moped, and motorbike.
[d]Partial nonresponse estimate.
[e]Complete nonresponse estimate.

Table 10. Influence of sociodemographic weighting on the measurement of nonhome mobility.

Stratification	Characteristic	Original Values: Sociodemographic Weighting	Nonresponse Estimation	Index
Total year	Mobility per person	2.62	2.58	101.6
	Share of mobiles	74.8	74.0	101.1
	Mobility per mobile	3.50	3.49	100.3
Spring	Share of mobiles	76.2	75.4	101.1
	Mobility per mobile	3.49	3.52	99.2
Summer	Share of mobiles	72.6	74.1	98.0
	Mobility per mobile	3.60	3.55	101.4
Fall	Share of mobiles	74.8	73.8	101.4
	Mobility per mobile	3.53	3.48	101.4
Winter	Share of mobiles	75.7	72.8	104.0
	Mobility per mobile	3.53	3.39	104.1
Travel mode	Nonmotorized	1.44	1.38	104.4
	Individualized	1.64	1.66	98.8
	Public transit	0.35	0.38	92.1
	Other	0.07	0.07	100.0
Trip purpurpose	Mandatory	1.54	1.65	93.3
	Social-recreational	0.85	0.81	104.9
	Shopping and personal business	1.11	1.03	107.8

Note: KONTIV 1976 had approximately 105 000 person survey days.

Table 11. Influence of response rate on the measurement of nonhome mobility.

Stratification	Characteristic	Original Values for a Response Rate of 33 Percent: Sociodemographic Weighting	Nonresponse Estimation	Index
Total year	Mobility per person	2.82	2.58	109.3
	Share of mobiles	76.7	74.0	103.6
	Mobility per mobile	3.68	3.49	105.4
Spring	Share of mobiles	77.9	75.4	103.3
	Mobility per mobile	3.66	3.52	104.0
Summer	Share of mobiles	72.7	74.1	98.1
	Mobility per mobile	3.75	3.55	105.6
Fall	Share of mobiles	77.2	73.8	104.6
	Mobility per mobile	3.68	3.48	105.7
Winter	Share of mobiles	78.4	72.8	107.7
	Mobility per mobile	3.64	3.39	107.4
Travel mode	Nonmotorized	1.50	1.38	108.7
	Individualized	1.74	1.66	104.8
	Public transit	0.37	0.38	97.4
	Other	0.07	0.07	100.0
Trip purpose	Mandatory	1.63	1.65	98.8
	Social-recreational	0.88	0.81	108.6
	Shopping and personal business	1.17	1.03	113.6

Note: KONTIV 1976 had approximately 105 000 person survey days.

a uniform trend might not be detected and, as a consequence, the final value will be estimated incorrectly.

In cases where a new nonresponse estimation cannot or should not be performed, corresponding values from the KONTIV survey are available. For a new empirical survey that has a comparable time frame, size of urban area, and response rate, corresponding correction factors (with or without sociodemographic weighting) can be computed and inserted. We have already tested such a procedure successfully.

Significance of Nonresponse Effects in Mail-Back Surveys

In the example presented earlier, the measurement error due to incomplete participation by the sample elements might appear comparatively small. To a large degree this is due to the high response rate of 72.4 percent achieved in the KONTIV survey.

Such high response rates will probably not be achievable in the future due to tightened data protection problems and due to the general public apathy (at least in Germany) toward the increasing number of poorly designed surveys. The measurement error will therefore increase substantially for lower response rates.

This problem can be illustrated by applying sociodemographic weighting only to the first third of the respondents and by comparing the results with the population estimates. The 33 percent response rate in Table 11 was selected because many travel surveys do not exceed that rate.

Such a response rate, although somewhat normal in general research practice, yet too low to produce reliable results, leads, for example, to an overestimation of the mobility of the average population of almost 10 percent (Table 11). The determining factors for this are the overrepresentation of the "share of mobiles" (by about 4 percent) and of the "mobility per mobile" (by about 5 percent). Accordingly, the mobility values by season, travel mode, and trip purpose are overrepresented with few exceptions. Low response rates in the absence of knowledge about effects induced by them constitute a substantial source of error in surveys of nonhome mobility.

On the other hand, more precise knowledge of the nonresponse effects in such surveys can also lead to substantial savings when such knowledge is implemented. A precise calculation of the funds required for such a survey indicates that the lowest survey cost per returned questionnaire is reached when two follow-up reminders are used. By applying the correction factors presented earlier, the bias introduced due to response losses can largely be compensated for and a substantially more advantageous cost-result (performance) ratio can be reached. The table below, from the West Berlin survey of approximately 45 000 persons for the transportation development plan, shows the relation of response rate and survey costs (4):

Survey Method	Reponse Rate (%)	Index of Cost/Usable Response
Mail-back questionnaire without follow-up action	30	100.0
Mail-back questionnaire with two reminder notices	60	88.5
Mail-back questionnaire with four reminders, including one additional questionnaire mailing	77	96.4

Significance of Nonresponse Effects in Interview Surveys

The trend-extrapolation method for estimating biases introduced due to nonrespondents by means of the response speed is based on the notion that, in a mail-back survey, a significant stimulus for participation (voluntarily, as a rule) lies in the object of the investigation. This insight has been documented through several research projects (5).

Interest in a survey on nonhome mobility is large when such nonhome mobility is practiced to a large degree, and it is small when such mobility is small or nonexistent. For this reason, it is only natural that, in a mail-back survey of nonhome mobility, many mobile people respond relatively faster and in larger numbers than do the immobile ones. This relationship holds only for this particular survey method, as we have stressed repeatedly.

The main reason for participation in an interview survey, on the other hand, is that the target person is reachable at home and can be convinced by the interviewer to participate. For relatively well-trained interviewers, the accessibility factor (meeting the interviewee) is the more important one here. Less-mobile people can be contacted more easily, and people who have a wide range of nonhome mobility are a definite problem group for interview surveys. They are hard to reach and often very busy--which means that they are potential interview refusers. For this reason, the nonresponse effect acts in precisely the opposite direction from that observed in mail-back surveys, where the respondents tend to provide too low a representation of their actual mobility.

These interrelationships were illustrated in a methodological experiment performed by Moolman (6). In the course of an interview survey about nonhome mobility the selected households were contacted until an interview actually was conducted. A response rate of 98.5 percent was attained by this method. When the respondents are stratified according to response speed into those who respond at the first, the second, or only at the third contact effort, it becomes evident that the mobility per person is substantially higher for the nonrespondents (6):

	Index for Number of Trips per Person	
Response Speed	Respondents	Nonrespondents
After one contact attempt	100.0	127.5
After two contact attempts	100.0	109.8
After three contact attempts	100.0	109.6

From that observation, we can conclude that, even with very good response rates (after three or four contact efforts), the observed mobility per person is 4-5 percent too low in interview surveys due to the nonresponse effect alone.

A further stratification of the unreported trips also shows that the largest underrepresentation occurs for the non-home-based trips (i.e., people who follow complicated trip chains are more likely to be nonrespondents). Expressed differently, we can state: Aside from those people who have little or no mobility, those people who have simple activity patterns are the primary respondents, and these are the groups that are relatively difficult to reach through mail-back surveys.

These substantial differences of nonresponse effect by survey method do not only belong to the absolutely necessary prerequisite basic knowledge in the area of nonresponse estimation, but they are also impressive proof of the fact that each survey method produces its own specific types of measurement errors. Therefore, discussion and comparison of empirical measurement results is practically not possible without knowledge of the survey method employed.

This also implies that identical numerical results that were achieved with different survey designs do not necessarily mean that the corresponding phenomena are represented identically. If, for example, in country X the mobility per inhabitant observed by means of an interview survey (with two contact efforts) is quantitatively identical to that obtained by means of a mail-back questionnaire (with a 30 percent response rate) in country Y, this implies that, on the basis of different nonresponse effects alone, without consideration of numerous other influencing factors, the mobility in country Y has to be set at 15 percent below that in country X. This insight could, for example, throw a different light on the recent discussion of international comparisons of non-home-activity time budgets.

APPLICATION TO INTERCITY PASSENGER TRAVEL

After an evaluation method, such as the one postulated in the first section of this paper, has been developed and tested successfully, it can be applied in general to other similar problem contexts. For the case of the problem of nonresponse, this means that in measurements of nonhome mobility we can typically expect that, on the basis of nonresponse effects, the mobility indices will be too high for mail-back questionnaires and too low for interview surveys. (Other influential factors exit, but they are not considered in this paper.) For an estimate of this nonresponse effect, the method of trend extrapolation on the basis of response speed presents itself. A distinction has to be made between mobiles and immobiles, and stratification according to trip purpose and travel mode are advisable.

Equipped with this knowledge and experience we can attempt to determine the biases in surveys of intercity travel generation caused by nonresponses. For this purpose, two continuous surveys are available that measure annual intercity vacation travel in the Federal Republic of Germany. One survey was performed by the Federal Statistics Office (Statistisches Bundesamt) in the context of the Microcensus. The second one was a privately conducted travel analysis (8). The two surveys are not exactly comparable with respect to the samples used, but both have been criticized for alleged underestimation of vacation travel volume.

The mere knowledge of the direction of valid nonresponse effects already indicates one possible cause for deviations of the estimates from reality. However, in this case at least two other significant influences have to be recognized in addition to the nonresponse effect that must result in the underestimation of travel, given that the interview survey technique was applied. Respondents are asked to report vacation trips performed during the preceding 12 months. Memory gaps are known to show in this retroactive technique. These gaps have proved to be greatest for interview surveys, largely due to the required instant recall. The mail-back method gives the respondent more time to recall past travel. In addition, the interview method typically requires that a household member also report the behavior of other members, which again will lead to underreporting of trips.

These three influences suggest that it is advisable to survey intercity travel behavior by means of the mail-back questionnaire technique. We need to be aware that, initially, the travel volume will be overrepresented. It will have to be scaled down

Table 12. Vacation travel behavior.

Response Increment	Index of Cumulatives Values		
	Average No. of Vacation Trips per Person	Share of People with Vacation Trips	Average No. of Vacation Trips per Vacation Traveler
First fifth	132.0	118.9	111.5
Second fifth	116.5	110.2	105.5
Third fifth	108.2	104.9	103.0
Fourth fifth	103.1	102.0	101.2
Fifth fifth	100.0	100.0	100.0

Note: Index of estimated total travel = 100.

Table 13. Modal choice for vacation travel.

Response Increment	Index of Cumulative Values for Principally Used Travel Mode			
	Automobile	Train	Airplane	Other
First fifth	112.7	116.7	105.0	100.0
Second fifth	105.5	112.5	100.0	100.0
Third fifth	102.7	108.3	100.0	100.0
Fourth fifth	100.9	104.2	100.0	100.0
Fifth fifth	100.0	100.0	100.0	100.0

Note: Index of estimated total travel = 100.

Table 14. Intercity travel behavior.

Response Increment	Index of Cumulative Values for Share of People			
	Who Did Not Make Intercity Trips	Who Had Vacation Travel Only	Who Made Other Private Intercity Trips Only	Who Made Vacation and Other Private Intercity Trips
First fifth	64.4	100.0	108.6	150.9
Second fifth	80.1	99.7	107.4	128.0
Third fifth	89.7	99.2	106.2	114.7
Fourth fifth	95.8	99.7	102.5	106.0
Fifth fifth	100.0	100.0	100.0	100.0
Index[a]	94.9	97.3	109.9	108.3

Note: Estimated total value of index of sociodemographically weighted values = 100.
[a]Response rate was 67 percent.

(corrected) in the course of a nonresponse analysis. This method was applied in a large survey of intercity travel behavior in the Federal Republic of Germany (7).

When we look, for example, at the number of vacation trips per person by response segments (fifths), the familiar nonresponse influence is very pronounced, especially among early respondents to a 1979 intercity travel survey of approximately 60 000 people (Table 12). This effect is mainly due to the fact that people who have not made vacation trips apparently can only be enticed very late, if at all, to respond to the survey. Among the people who have made vacation trips, those people who made more than one vacation trip are more likely to respond.

A stratification, from the same survey, of vacation trips by primary mode of travel shows that the nonresponse effect varies by mode. Particularly overreported are train trips in the case of low response rates. Automobile trips develop largely analogous to the total distribution, due to their dominant share of all vacation trips (70 percent) (Table 13).

The nonresponse effect is even more significant in the stratification according to trip purposes. In this case, observe how late respondents answer a mail-back questionnaire if they did not undertake any intercity trips (Table 14). Equally obvious is that people who have a particularly high intensity of intercity travel respond to this type of survey. The share of people who engage in private intercity trips other than for vacation purposes develops in a relatively moderate fashion. People whose intercity travel consists of their annual vacation trip are represented equally (i.e., largely correctly) in all response increments.

Therefore, the special problem groups with respect to the nonresponse influence in measuring vacation travel are again composed of those people who do not, or who rarely, undertake the activity under investigation. In light of the present level of understanding, these groups are overestimated in mail-back surveys and underestimated in interview surveys, which results in too high a volume for mail-back responses and too low a volume for interview surveys. Again, sociodemographic correction can only provide limited compensation for these deviations.

Although in this mail-back survey this effect was compensated for by appropriate nonresponse factors, such corrections were absent in the other two intercity travel surveys mentioned earlier. As a consequence of this uneven treatment, the results for the three surveys are substantially different. A comparison of our results with those of the travel analysis conducted during the same year (8) shows that the share of people who made vacation trips (travel intensity) was underestimated by 4-5 percent and the number of trips per vacation traveler (trip frequency) by more than 20 percent. This underestimation is not only due to the nonresponse factor but is also a consequence of the distortions that result from memory gaps and from reporting by a household member about activities of other members. The latter sources of errors could have been controlled in a systematic analysis of response behavior. In any event, the documents currently in use concerning intercity vacation travel in the Federal Republic of Germany understate that travel category by about 25 percent. A substantial part of this underestimation can be tied directly to the fact that nonresponse effects were not taken into account.

SUMMARY

This paper reports on an ongoing investigation into the effects of nonresponse on the accuracy of empirical survey results. A number of examples were presented to show the types and magnitude of distortions that result from ignoring nonresponse effects. The different impacts of stratification by season, mode, and trip purposes were demonstrated. Also, the varying results generated by the mail-back versus interview method were analyzed.

Given the limited experience with nonresponse effects, a useful procedure was developed and presented by means of which the relevant influences can be reestimated and corrected for each survey. Aside from these methodological experiments, applications of their results to the study of intercity passenger travel behavior were shown.

The paper concludes that fundamental methodological survey research must be designed so that generalizable results can be obtained. Through systematic research into the distortions caused by nonresponse, at least the direction of the bias in relation to the chosen survey method can be determined, and additional correction factors for the elimination of this bias can be generated. Sociodemographic weighting is shown not to be a satisfactory remedy for the effects of nonresponse.

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Publication of this paper sponsored by Committee on Passenger Travel Demand Forecasting.

Validity Problems in Empirical Analyses of Non-Home-Activity Patterns

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Validity problems of empirical data have been neglected to a large extent in the transportation planning field. This paper illustrates the impact that choice of survey method has on the validity of the data. It shows that the recorded data depend directly on the method selected for obtaining them. An uncritical application of survey methods is not justifiable and, in fact, can lead to incorrect survey results. Basic research in the area of empirical survey methods is long overdue. An international exchange of experiences in this regard is considered most beneficial, as illustrated by this paper. The exchange of information and insights is often hampered because the survey methods used for specific investigations tend to be inadequately documented. This deficiency makes subsequent assessment of data validity very difficult, if not impossible. Furthermore, the use of such data without consideration of the underlying survey method is dangerous. The paper cites examples where the results of analyses can be manipulated by means of different survey methods. Greater efforts should be made to integrate data collection with the research effort performed on the basis of these data.

Many transportation planners, engineers, and modelers have, for all too long, ignored the quality of the basic input to their research efforts, namely the data. Since much of this research is of an empirical nature, the data are obtained through empirical surveys. This paper is intended to add to the efforts concerned with survey methodology for empirical analyses of travel activities. It presents a number of examples that show how the survey method and design can influence the results of an investigation.

We recognize that only a limited set of examples can be shown in the context of a paper of this nature. Further, the basis of comparison is yet another survey, albeit one that is generally recognized as representative of the state of the art in survey methodology [e.g., the national travel survey (KONTIV) (1)]. We need to accept the quality of that survey and the validity of its results in order to believe in the results of the research presented in this paper.

Even if the argument is made that the different survey results obtained through two surveys do not prove the correctness (or lack thereof) of one or the other survey results, the disturbing fact remains that different results about mobility were obtained when the study objectives were identical and only the survey method differed. This result alone is worth keeping in mind. The transportation planner or modeler is well advised to pay careful attention to the procedure used to generate the inputs that are used in any modeling effort or in the generation of simple mobility statistics. The validity (correctness) of the data will also determine the validity of any model or statistical results, which in turn might be used as the basis for policy and investment decisions.

VALIDITY VERSUS REPRESENTATIVENESS

The paper concentrates on the validity aspects of survey results because problems of validity of empirical data have been neglected to a large extent in the transportation planning field. The issue of validity of survey data transcends that of representativeness. Representativeness addresses the question of whether we have enough data points for each of our strata or cells. The concept of validity is aimed at questions of whether the data obtained are valid (correct or relevant) or whether they are an accident ascribable to a particular method of data collection. We attempt to show in this paper that empirical results based on survey data typically contain substantial errors that result in severe misrepresentation of reality.

The error sources addressed in this research lie exclusively in the survey method and design employed to generate these data. A fair assessment of pres-