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Conference on Household Travel Surveys: New Concepts and Research Needs

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Conference on Household Travel Surveys: New Concepts and Research Needs

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Contents

Household Travel Surveys: New Concepts and Research Needs

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At the Conference on Household Travel Surveys: New Concepts and Research Needs, held in Irvine, Calif., March 12–15, 1995, researchers and representatives of federal, state, and local government and private industry gathered to determine research needs and new concepts in household travel surveys. Concurrent workshops were held, in which resource papers and charges were presented. Resource papers were initially presented to the entire conference by appointed discussants, who summarized the papers' contents and commented on the ideas expressed in them. Authors were permitted to reply, to emphasize particular issues and to offer alternative interpretations to those of the discussants.

Resource paper authors and discussants were assigned to the workshops for which they had prepared material. Workshop topics were

- Nonresponse issues,
- Interactive stated-response methods,
- Survey methodologies,
- Data collection issues, and
- New technologies.

Although every attempt was made to keep each workshop focused on a specific area, there were a number of overlapping issues and issues that cut across most areas addressed at the conference.

Background

Household travel surveys have provided data for transportation planning for the past 30 to 40 years. The keynote paper, by Peter Stopher, provides an overview of the history of household travel surveys. There has been a resurgence of interest in household travel surveys within the past few years, fueled in part by requirements of the Clean Air Act Amendments of 1990, rules and regulations stemming from these amendments, and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). Coupled with this resurgence of interest has been rapid change in survey designs, which began in the late 1980s. The formation of the Bureau of Transportation Statistics within the U.S. Department of Transportation as a result of

ISTEA has provided additional impetus to determine the direction of future activities in transportation data collection.

Throughout the brief history of household travel surveys, there has been continuous change in instruments, methods of surveying and sampling, and response rates achieved. In early household travel surveys, conducted through face-to-face interviews in respondents' homes, response rates in the range of 85 to 95 percent were commonly claimed. Response rates for recent telephone contact, mail-out, and telephone retrieval surveys have averaged approximately 40 percent. The decline in response rates, as well as an increasing demand for information, has led to many changes in household travel surveys.

To review existing travel surveys and examine new concepts and research needs, the Federal Highway Administration, Federal Transit Administration, and Bureau of Transportation Statistics asked the Transportation Research Board to develop the Conference on New Concepts in Household Travel Surveys. To organize and conduct this conference, TRB assembled a steering committee, appointed by the National Research Council, composed of individuals actively involved in designing and executing household travel surveys. The committee's focus was the household travel survey, specifically the element of data collection that deals with the travel patterns of people living in households, from the perspective of how that travel satisfies various household and personal needs. Although it was recognized that there are issues in other areas of data collection allied with the household travel survey, it was believed that sufficient issues exist in this area of household travel surveys to convene a conference on the topic. Steering committee members expressed hope that in the near future, other conferences would be organized to deal with other areas of transportation data collection so that issues in related areas could be examined in depth.

The steering committee identified major issues in household travel surveys for which research should be conducted. The committee also performed a postconference function of developing a research agenda, by combining and sorting the research recommendations from the individual workshops. Based on the work of the committee, recommended research topics were identified. These formed the research agenda, which is discussed later in this conference summary.

Conference Objectives

Conference objectives were to bring together nationally and internationally known experts in household travel surveys, with the aim of

- Reviewing existing household travel surveys with respect to recent developments and trends;
- Evaluating the ability of household travel survey data to meet transportation planning and analysis requirements, including the degree of accuracy;
- Analyzing various solutions to problems in household travel surveys, including new and emerging innovative approaches to conducting such surveys;
- Reviewing the implications of new concepts in household travel surveys on the development of national and state transportation systems; and
- Recommending a research program that is responsive to the issues, problems, and needs identified at the conference, which will assist in the further development and implementation of household travel surveys.

Workshops

Nonresponse Issues

Many issues arise in the area of nonresponse, ranging from entire households that do not respond to a survey to nonresponse on specific questions and items within a survey.

In general, surveys are encountering increasingly high levels of nonresponse, perhaps as a result of the number of surveys and marketing contacts made these days. Many recent transportation surveys, therefore, have used incentives to encourage response. There are several issues in the use of incentives, including the efficacy of monetary incentives versus gifts, lotteries, or sweepstakes. There is also an issue of whether incentives generate biases in the completed sample, resulting from a particular type of person or household being influenced by incentives. Other areas to consider are that designs, such as the use of pictographs and color, may affect nonresponse levels and that biases may arise from nonresponse to an entire survey.

Some recent surveys have used various methods to "convert" respondents who refuse to complete a survey. The extent to which conversion of refusals may succeed, its potential to add a new bias, and concerns with the quality of data resulting from a reluctant respondent who has been "converted" are issues to be addressed. At the other end of the spectrum, there are issues of item nonresponse, particularly to questions about income, but also to questions relating to personal characteristics and information on activities and travel. A part of this activity of cleaning data sets has always involved the imputation of missing values. The workshop considered the following issues:

- What is permissible for imputation and whether imputed values should always be flagged in data sets;
- Factors that create nonresponse, such as illiteracy and people whose primary language is not English; and
- The extent to which nonresponse problems can be reduced through design and administration procedures.

Another issue that relates closely to nonresponse is defining what constitutes a complete household. In some surveys, failure to retrieve data from any person in the household is considered sufficient to render the household incomplete, and the data are discarded. In other households, some residents may refuse to provide information, and the household is still counted as being complete. Apart from the budgetary impact of such decisions on the agency executing a survey, there are potential nonresponse biases that may arise from different definitions of what constitutes a complete household. A related issue is collection of data by proxy (i.e., under what circumstances it may be possible to obtain data about one member of a household by questioning another member of the household). Routinely, this is the procedure used for acquiring data from children. The issue here is whether proxy completion for adults and older children will create response and reliability problems. This is an increasingly important issue, given the growing number of surveys using telephone retrieval to collect data from households.

Stated Response

Stated-response surveys attempt to reflect real-world consumer decision making. Respondents are presented with a range of options (e.g., transportation modes they might have for a specific trip) described by a limited set of characteristics. Certain characteristics are selected for variation, and respondents are asked to select their preferred option under each of a number of different scenarios of the values of the characteristics. To do this, respondents must weigh the pros and cons of option characteristics. These sets of trade-off questions typically are administered to specific survey population subgroups.

In the past year, at least six metropolitan planning organizations (MPOs) added stated-response elements to their travel behavior surveys (Portland, Ore.; Vancouver, Wash.; Eugene and Salem, Ore.; Washington, D.C.; and Dallas, Tex.). The purpose of this workshop was to explore issues relating to the use of stated-response surveys. The workshop addressed the following concerns:

- Complexity of the topic;
- Types of issues best addressed through stated-response surveys;

- Process (determining attributes and levels);
- Timing of revealed-preference and stated-response surveys;
- Experimental design, including degree of individualization;
- Sample size and population subgroups;
- Layout of forms (respondent burden); and
- Analysis of results.

Although it was recognized that some background on stated-response surveys had to be presented to provide the framework for discussion, the intent of this workshop was not tutorial. Instead, its goal was to address specific practical issues that MPOs must understand when considering a stated-response element for household travel behavior surveys.

Survey Methodologies

In the area of methodologies, a number of issues were covered. Several sampling and statistical issues have arisen as planners use data that have been collected from travel behavior surveys. Some of these issues involve the initial decisions regarding the sampling frame. For example, in many surveys, the sample had been stratified based on variables usually found in traditional forecasting models, which include number of persons in household, vehicle availability, housing type, and income. Recently, there has been interest in incorporating life-style and other sociodemographic variables as predictors of travel behavior. This approach has led to slightly different sampling schemes in which land use, population density, and access to various transit options are the key sampling strata. Other methodological issues that have arisen include the following:

- Targeting of subgroups of the population, particularly those that use specific (rare) modes or that represent rare or unusual segments;
- Cross-sectional or panel surveys; and
- Use of mail-out forms to collect household and personal data.

Another area of concern of this workshop was data expansion, particularly with respect to determining the universe from which a sample has been drawn and changes that may occur if the decennial census changes to continuous measurement of the variables currently contained in the "long form."

Within the area of methodologies, retrieval methods were discussed. Such methods currently focus on mail-back or telephone retrieval, the latter using computer-assisted telephone interviewing (CATI); however, the possibility of returning to the use of face-to-face in-home interviews should be considered.

Data Collection Instruments and Related Issues

A significant amount of variety exists in the structure and form of instruments to collect household travel data. The past 4 years have seen considerable increases in this variety. Among alternative instruments are travel or activity diaries, 1-day or multiday diaries, and separate or included memory joggers. Older forms of household travel surveys, patterned largely after the interview forms used in the 1950s and 1960s, continue to be used by many agencies. More detailed issues in instrument design include such items as whether to include personal data in diaries; the extent to which a diary is used as a more-detailed memory jogger, with most information requested for the first time in the retrieval interview; use of booklet diaries or single-sheet diaries; and embedding answer categories within questions or using separate lists of categories. In addition to being addressed from the point of view of nonresponse, the issue of literacy was addressed in this workshop, particularly concerning the complexity of concepts, language, and instructions in a data collection instrument.

Finally, this workshop considered issues of content in survey instruments, including collection of personal and household income, vehicle odometer readings, and detailed in-home activities. The workshop resource paper addressed as many of these instrument design issues as possible, providing brief descriptions of each and discussing some of the pros and cons of each type of instrument.

New Technologies

Use of new technologies in the collection and analysis of travel survey data may offer many benefits, such as improved data quality and reduced survey costs. For example, CATI systems permit interviewers to enter data directly into a computer file as the interview proceeds, instead of through a separate step when the interview is complete. Logic and consistency checks built into CATI software minimize data errors and enable survey interviewers to recycle quickly through questions in which initial responses may have been incorrect or ambiguous. Similarly, use of geographic information system (GIS) technology greatly improves the accuracy of coding location data and substantially reduces the time required for postprocessing and expanding survey data. Other new technologies such as vehicle instrumentation, cellular telephones, bar coding, laptop computers, video, aerial photography, and the Global Positioning System (GPS) also are being applied in innovative ways to the collection of travel survey data.

The workshop addressed the following questions:

- How are new computer and other technological innovations being applied to the collection, processing, and analysis of travel survey data?
- What are the advantages of these new technologies, and what new biases or other errors might they introduce?
- What are the costs involved in using these new technologies, and where do they offer the greatest return on investment of time and survey resources?
- What obstacles prevent more widespread use of these new technologies, and how can these obstacles be overcome?

Overarching Themes

Although workshops were focused on specific issues, five primary themes common to two or more of the workshops emerged:

- Concerns about standards and best practice;
- Concerns that quantity of sample and budget are too often the drivers of surveys, because clients do not know what a "good" survey is;
- Nonresponse;
- Expectations of random digit dialing becoming increasingly difficult; and
- Need for research to determine how to perform surveys better.

Standards and Best Practices

There appears to be considerable concern among most transportation survey professionals that no established standards are applied to surveys. This results in much variability in survey quality and harms the credibility of survey data. Among issues that the workshops raised in this area are the wide divergence in methods of calculating response rates, lack of comparability between surveys because of lack of standards on how to assess survey success, and lack of minimum standards that agencies can apply and expect from survey consultants. Although these issues were raised in the context of household travel surveys, they extend to most forms of transportation data collection.

Strategies that could help improve household travel surveys include

- Establishing a consistent method for calculating the response rate and adopting it for all household travel surveys;
- Determining minimum acceptable response rates and best-practice response rates to be used to solicit survey contractors and to assess whether a survey is acceptable; and
- Determining other measures that can be used to assess data quality, including such concepts as minimum acceptable levels of missing and imputed data and required verification processes.

Criteria for "Good" Surveys

A related issue raised at several workshops was concern over what many agencies are currently using as the yardstick by which surveys are judged. Conference participants perceived that the primary measures used by most agencies are the quantity of data (as measured by final sample size) and adherence to budget. In other words, a survey is considered "good" if the desired sample size was met or exceeded, regardless of the response rate, which could vary from 10 or 15 percent to 75 percent or more, and if the survey was completed within budget. This appears to be the case at least in part because the profession has provided no basis to assess the quality of data collected.

Quality of data collected is of primary importance; therefore, the profession needs to

- Develop a means to assess what represents a good survey, in terms of quality and performance measures;
- Educate clients needing transportation surveys about survey quality and the significance of quality measures;
- Make clients aware of the potential dangers of using poor quality data; and
- Adopt quality measures to assess the quality of survey data.

Nonresponse

Although one workshop was devoted entirely to nonresponse issues, concerns about nonresponse arose in all workshops. The declining response rates in recent household travel surveys in the United States have been dealt with either by acceptance of these rates or by diversion of resources to countermeasures such as offering recruited households incentives to respond. There was a marked contrast on this issue between participants whose experience is primarily in the United States and participants from overseas (particularly Europe and Australia), where much higher response rates are still being achieved. It was observed in a number of cases that the decline in response rates is not limited to household travel surveys. Declining response rates even affected the decennial census, in which much greater effort was expended to reach a satisfactory level of response.

Conference participants acknowledged that nonresponse is likely to increase unless steps are taken to reverse the trend. In addition, the levels of nonresponse typically experienced in household travel surveys lead many to believe that significant nonresponse biases are present in all household travel data sets. Despite this, efforts to determine the nature of nonresponse bias are not routinely done. A variety of approaches were suggested to address the issue of nonresponse. Most important were the following:

- Undertake studies to determine the seriousness of nonresponse bias in household travel surveys;
- Conduct research to find methods to reverse the decline in response rates; and
- Make nonresponse surveys a routine part of any household travel survey in which the response rate is below a particular level (to be determined on the basis of the recommended studies).

Random Digit Dialing

Another pervasive theme that emerged in conference discussions was the expectation that, in the United States, it will become increasingly difficult to rely on random digit dialing to draw a sample for a household travel survey. First, it is expected that technology that screens telephone calls will become increasingly more sophisticated, allowing people to avoid sales calls, surveys, and other intrusions into their daily lives. Second, notions of a future in which people are assigned a telephone number, similar to how a social security number is assigned today, and in which that number will move with them wherever they live, suggested to conferees that random digit dialing will become infeasible as a method of sample selection. Although such technology is in the future, rapid technological developments and breakthroughs may make it arrive sooner than expected.

Strategies to overcome the problems of random digit dialing include

- Exploring alternatives to random digit dialing, particularly focusing on the possibility of sampling from GIS data bases of addresses;
- Considering issues of adequacy of sampling frames and providing guidance to the profession; and
- Conducting research on alternatives to initial cold contacts by telephone and testing alternative methods in practice.

Ways To Improve Survey Methods

Most workshops addressed methods for improving surveys. It was noted that most agencies performing surveys are unable to undertake research or experiment with relatively untested survey methods. In recent years, funding has not been available for research on improving household travel surveys. Comparing different ways of performing surveys has largely required comparing two metropolitan areas' procedures; however, problems are created by the variability of many factors, resulting in considerable uncertainty about whether one method is better than another. No series of controlled experiments has been conducted to compare alternative ways in which a wide range of elements of household travel surveys may be designed.

Survey methods could be improved by the following measures:

- Develop a research program that will allow comparative testing under controlled conditions of alternative methods for conducting many aspects of household travel surveys; and
- Allocate funding to undertake comparative tests of alternative methods under carefully controlled situations.

Conclusion

Summaries of each workshop are provided in this document, along with recommendations on research directions that conferees believed deserve priority in the next few years. In a number of cases, there was clear overlap among workshops; other recommendations are specific to the charge of a particular workshop.

Finally, there are many areas in household travel surveys in which little has changed in the past 20 or more years. Perhaps one of the most important of these areas is how the transportation planner views the design of survey instruments. Instruments are generally designed with the needs of the planner, not the respondent, in mind. The result is that there is a tendency for many survey instruments to try to force-fit respondents into the thinking patterns of the profession, and there is a tendency to use jargon that is not used or understood by respondents. It is clear that such problems contribute to nonresponse and are likely to arise in designing stated-response surveys. In addition, these problems are an issue in data collection instruments and probably affect survey design and new technologies.

It is time for the profession to take a hard look at the manner in which surveys are designed and at the quality of data obtained. The necessity of providing respondents with definitions of words or phrases should be taken as a danger signal indicating use of specialized or complex language. Ways other than offering definitions should be sought to solve the problem. Transportation professionals who design household travel surveys must place themselves in the shoes of the respondent. This is likely to bring significant rewards, such as better quality of data, increased response rates, and reduced ambiguity of responses.

It was the hope of all conference participants that conference findings be addressed. Transportation planning depends on sufficient data that are accurate, timely, and of good quality. Planning models are sensitive to the quality of input data. The saying "garbage in, garbage out" is highly applicable to these models, for which the "in" is primarily data from household travel surveys. Even if the primary use of data is to provide descriptive statistics instead of input to models, the saying still applies. The credibility of the transportation planning process rests on the "goodness" of input data, most of which come from household travel surveys. It is worth spending a modest amount of money on research to improve the quality of the data we collect.

Keynote Address

Gloria J. Jeff, *Federal Highway Administration*

I'd like to welcome everyone to sunny Southern California. Despite the rain, it's a lot warmer here than anywhere on the East Coast, so I'm delighted to be here. As Jim Scott mentioned earlier, I worked hard for him and TRB in 1992 and early 1993. One of the conferences in 1992, Transportation Data Needs: Programs for a New Era, focused on many of the issues of interest to this group.

First, let me review what kinds of issues we were discussing in 1992 and then talk about how things have changed since then. In 1992 the manufacturing sector was starting to use the roads for "warehousing," with the development of "just-in-time" production and delivery systems, enabled by better inventory control. The Intermodal Surface Transportation Efficiency Act of 1991 was just getting rolling, and there were major questions about how to define and measure congestion. Some of the primary issues for the TRB data conference were implementation of ISTEA, the role of the National Highway System, the Clean Air Act Amendments, flexible funding, and ISTEA management systems.

Some of the recommendations from that conference were

- Data are collected for decision making, and planners need to learn how to communicate data;
- Avoid duplication of use of limited resources—improve coordination between states and metropolitan planning organizations; and
- A data collection program should have a 5- to 6-year horizon, not 1 year at a time.

Many research needs were identified, including vehicle counting and classification in high-volume, congested areas; better data on goods movement; better understanding of the interaction between land use and the transportation system; and evaluation of TCMs. There also was a widely expressed need for improved travel forecasting models to address air quality, delays, congestion, and quality of life.

Now its 1995. We have a different president, who charged his vice president with the task of reinventing government, and since January 1995, a change in Congress. The Clinton administration has set the direction in reinventing government to make government smaller and more customer-friendly. Government should be less intrusive. The new direction from Congress similarly advocates less government, and particularly, less federal intervention, with a

return of control to states and local governments. This tug-of-war between federal and state control is not a new problem, and conflicts about who is responsible for what are likely to increase. It raises questions about what information states will have and how comparability (or lack thereof) will impact any ability to report on conditions for the nation as a whole.

As part of reinventing government, let me mention some of the Department of Transportation's restructuring efforts. The proposal now is for the 10 administrations within DOT to be merged into three: Coast Guard, FAA, and an Intermodal Transportation Administration. This proposal would have to be approved by Congress. If it is approved, we anticipate it would take 12 to 15 months to put the first phase into place. In addition to combining administrations, the number of program delivery mechanisms, currently at 60, would be reduced to 3, thus considerably reducing the complexity and burdensome nature of grant applications and administration.

So where does this leave transportation planning professionals, especially those of you who have come to this conference to address the issue of household travel surveys? Understanding personal travel behavior remains a critical and recognized component for the larger context of transportation policy and planning, at all levels of government. Personal mobility is considered by many to be a right. In a paper presented at TRB 1995, John Hamburg pondered the question of whether human rights, as affirmed by the Declaration of Independence as the right to "life, liberty, and the pursuit of happiness," include mobility. Should the transportation system in a democracy be designed so that all individuals are ensured mobility?

What do we learn from conducting personal and household travel surveys? We learn how people are traveling today, and we can evaluate how new policies are likely to impact travel choices. We can improve our forecasting and estimation models to predict the outcomes of new or alternative forecasts. Goals for mobility may conflict with environmental concerns. Some programs developed under CAAA and ISTEA, such as TDM efforts, including more carpooling and shared rides and promoting nonmotorized trips, are pushing Americans to "cheat" on their cars.

What are some of the things we have learned from the Nationwide Personal Transportation Survey? On travel by women, we have learned that despite the significant levels of women in the labor force, women continue to make more child-care and family-related trips. Although women make, on average, more trips than men, men still account for a much greater proportion of vehicle miles traveled.

In diverse populations, there is still a lot of room for growth in travel by Hispanic and African American populations. Hispanic and African American women still have substantially lower licensing rates than non-Hispanic whites. These differences have been lessening over time; however, overall, NPTS has not shown "saturation" of travel, particularly in vehicle miles traveled, in these two groups.

As we move toward the 21st century, we need to be concerned with access to data and public participation in decision making via the Information Superhighway. Today, the proportion of households with PCs varies widely by race and ethnicity. Fourteen percent of African American households, compared with 27 percent of white households, have PCs. Equity issues should not be forgotten when data access and public participation via the Internet and other on-line services are raised.

As you look forward to the next 3 days of the conference, I hope you will keep these things in mind:

- We need to do a better job of collecting data.
- We need to do a better job of converting data into meaningful information.
- We need to make data available.
- We need to ask ourselves who has access to the data, statistics, and information we collect and make available.

KEYNOTE PAPER

Household Travel Surveys: Cutting-Edge Concepts for the Next Century

Peter R. Stopher, *Louisiana State University*

This paper focuses on how U.S. household travel surveys are executed and how they will be executed in the future. Many cultural and contextual factors result in marked differences between household travel surveys in the United States and those conducted in other countries. It is not the intent of this paper to deal with these differences nor to provide an overview of household travel surveys in other countries. However, the problems currently experienced in the United States may be a decade or two away for other countries; therefore, the information in this paper may be useful to survey developers abroad.

This paper examines where we are in the development of household travel surveys, what forces have shaped travel surveys being conducted today, and what changes will affect the evolution of household travel surveys. The paper is intended to raise challenges about the concepts that will transport household travel surveys into the next century.

History of Household Travel Surveys

Household travel surveys began in the early 1950s, a mere 40 years ago. Before this, transportation planning, which was rapidly evolving into the regional type of planning performed today, relied principally on roadside surveys that collected origin and destination information from travelers on specific roads. Data about trip-making patterns have always been a mainstay of transportation planning. Surveys of trip making traditionally have provided the basis for formulating transportation policy, developing transportation plans, and making improvements to transportation operations.

Household travel surveys play two primary roles. First, they describe travel trends to facilitate understanding of demands on the transportation system and identify areas in which problems can be expected. Second, surveys provide information for input into travel-forecasting models, which are used to identify potential long-term problems and to provide a means to test the efficacy of proposed solutions.

Household travel surveys are conducted primarily by federal, state, and local governments. The primary impetus for conducting these surveys is for compliance with rules and regulations affecting transportation planning and the need to replace aging data, data that no longer represent the travel patterns and characteristics of an urban area. Household travel surveys usually are conducted in three different cycles. The first is to collect data once a decade.

However, relatively few metropolitan areas in the United States collect household travel data this frequently. The second is to collect data approximately every 20 years, perhaps because 20 years is the typical long-range planning horizon. In addition, data collection every 20 years is consistent with the view that we should check to see how well our forecasts turn out (although if this is done, it is rarely reported). The third is to collect data as often as funds are available, which may range from every 15 to 30 or more years.

Many metropolitan areas collect their data as close as possible to a decennial census to ensure the availability of current information on the entire population from which their samples are drawn. Because the Bureau of the Census requests that jurisdictions avoid collecting data too close to a decennial census, conducted April 1 in each year ending in a zero, household travel surveys usually are undertaken in the 2 years preceding or following the census.

Evolution of Household Travel Surveys

Since their inception, household travel surveys have undergone substantial growth and change. Originally, household travel surveys were conducted almost exclusively by means of face-to-face interviews in respondents' homes, having household members recall the previous day's travel and often involving extensive proxy reporting for most of the household by one family member. Interviews usually were conducted through "cold" contacts because no previous contact had been made with the household to request its cooperation or to arrange interviews. Recent household travel surveys involve recruiting a household by means of the telephone and sending the household a 1- or 2-day activity diary with instructions on which day activities should be recorded. This frequently is followed by retrieving data from the diary by a telephone interview conducted using computer-assisted telephone interviewing (CATI) and involving real-time error checking and data entry.

Another aspect of the evolution of household travel surveys is sampling. Early household travel surveys used either simple random sampling or cluster sampling to reduce interviewer travel. Current household travel surveys usually use a form of random stratified sampling with variable sampling fractions. Strata are typically based on household characteristics determined in the initial recruitment call.

Because the mission of this conference is to consider new concepts and research needs in household travel surveys, it is appropriate to establish what has been driving the evolution of these surveys during the past 40 years. One element of this drive is the desire to improve survey accuracy. Early on, it was recognized that the conventional home-interview survey, which is based on recall, results in a significant level of undercounting of certain trips, particularly trips associated with minor errands and short non-home-based trips. The shift from recall reporting to use of a diary designed to be completed at a subsequent date was one step taken to address the problem of trip underreporting. The hope was that, by reducing proxy reporting (each family member would have a diary in which to record the trips he or she made) and by shifting from recall to real-time recording of a person's travel, the number of short trips reported would increase. Some anecdotal information suggests this may have happened, but it has not been established whether a significant improvement in reporting non-home-based travel actually occurred through this mechanism.

A second driving force has been concern about the confusion that travel surveys often engender in the minds of respondents. Although early diary surveys relied on face-to-face contact with interviewers, the diary required that the respondent complete it. This requirement initially was not recognized as a difficulty, and early surveys used a form that was similar to the type of form previously used by trained interviewers only. Not surprisingly, these survey forms did not perform well. First, response rates dropped because many people were unable to complete the survey form or were intimidated by the amount of information packed into it. Second, responses obtained often showed considerable confusion about how to answer questions correctly; therefore, surveys had to be discarded or major inferential work had to be done to correct them.

A third driving force has been changes in the models and other procedures developed from collected data. Much early work in household travel surveys ignored the survey purist's notion that a survey should be designed carefully with eventual data uses in mind. Data were collected because they were always collected or because someone thought the data would be interesting, even though he or she had only a vague idea of how the data might be used. Recently, significant attention has been given to the concept of measuring only what will be used in descriptive or modeling work with the data. In addition, some data items are included for political reasons, relating to the need to show the types of households included in a sample.

Changes to survey instruments have been made to reflect the fact that more attention is being given to justifying each data item to be included and because parts of the travel-forecasting model system are evolving slowly. General acceptance of disaggregate multinomial logit models for mode-choice modeling made a significant impact on the design of data collection instruments during the 1980s and is reflected in renewed attention given to (*a*) the sequence of use of different travel modes on a single trip, (*b*) auto occupancy, (*c*) parking costs, (*d*) vehicle availability, and (*e*) collection of data on modes of access to and egress from public transportation. Widespread acceptance of disaggregate models also resulted in an interest in collecting data about subjective evaluations of travel options in addition to the standard reporting of objective data. In the 1970s and 1980s, significant interest was sparked in collecting data on attitudes, preferences, and opinions about transportation alternatives. However, little of this information was helpful in travel forecasting, and sufficient doubts were raised about its usefulness even for descriptive purposes; therefore, the late 1980s experienced a significant decline in the collection of such data.

The 1990s have brought a resurgence of interest in collecting conjoint data, now commonly referred to as stated-preference data, or perhaps, more correctly, as interactive stated-response data. This evolutionary change resulted from two coincident issues. First, in the late 1980s, the United States became interested in high-speed rail systems. Because the nation had no intercity service similar to high-speed rail at the time, determining stated preferences for such a service seemed to be the best method for determining potential patronage. The success of this approach resulted in the credibility of using stated-preference measurement to deal with an alternative for which the marketplace had no current equivalent. With current urban policies focusing on new options for handling transportation problems, such as transportation demand management (TDM) strategies and pricing strategies, interest in using stated preference to estimate how the traveling public will respond to such transportation alternatives is increasing rapidly.

Another significant issue in the past 10 to 20 years has been the decrease in survey response rates. There are no hard facts available to explain this decline, but several surveys indicate that it is substantial and continuing. There are a number of contributors to this decline, including the following:

- Increased use of telephone surveys by marketing agencies, which tend to contribute to burnout of the U.S. public with respect to surveys;
- Increased use of marketing surveys as a "foot in the door" to sell a product, as evidenced by the frequent response "I'm not buying anything" when a transportation survey interviewer calls a household;
- The increasing pace of life in the United States, which makes people reluctant to spend time on activities not directly connected to their own busy schedules;
- Increased concern about personal privacy and the potential for outside agencies to know personal details, which represents an invasion of privacy and results in a decreasing willingness to answer questions relating to demographics, activities, and the like;
- The perception of vulnerability to crime through the types of information typically requested in a household transportation survey; and
- The increasing number of immigrant households in which English is not spoken well or not spoken at all.

These and other factors make it difficult to obtain adequate responses to household travel surveys.

In the United States there has been a marked decline in the effectiveness of face-to-face interviewing. First, the crime problem makes it difficult to send interviewers into certain parts of many cities and to guarantee their safety. Second, the perception of vulnerability to crime makes it less likely that a respondent will allow a stranger to enter his or her home. Third, the rapid growth of two-worker households and the increased amount of time spent by household members in out-of-home activities can make it difficult to find a responsible adult at home who can be interviewed. As a result, the costs of performing face-to-face interviews have skyrocketed, while the effectiveness of such interviews and their ability to cover a random sample of households has declined dramatically.

Contextual Changes in Household Travel Surveys

Changes in Transportation Policies

The limitations of previous transportation policies that consider only vehicular travel must be reconsidered. There is an emerging need to consider trips taken by walking and bicycling. Traditionally, data on such trips have not been collected by conventional household travel surveys. Obtaining these data could be a challenge because it is not apparent how households that use these modes with some frequency can be located within the sampling process. Based on recent experiences with adding such travel modes to household travel surveys, problems also arise in reporting and coding such travel. In Southern California, many walk and bicycle trips in the data base report travel distances that are too long to be credible. This suggests that considerable care is needed in the design of survey instruments, to ensure that walk and bicycle are not reported as the only modes for trips in which one of the two modes is used primarily to gain access to or egress from another mode. In addition, it probably will be necessary to introduce other measurements related to walking and bicycling that will allow appropriate values to be developed for the travel times involved.

TDM is another area in which emerging policy changes will dictate significant changes in household travel surveys. Many TDM strategies involve options different from those traditionally featured in household travel surveys, such as use of carpools, vanpools, and high-occupancy vehicle (HOV) lanes and various parking management and parking pricing options. One change in recent surveys is a focus on collecting data about parking locations and prices. However, the level of detail obtained is inadequate for the types of analyses required.

New Paradigms for Travel Forecasting

The Travel Model Improvement Program (*1,2*) and frustration with the inadequacies of current travel forecasting models are likely to result in new paradigms of travel behavior and changes in data collection. To improve the accuracy and completeness of data collected and to respond to likely paradigm shifts, we have already shifted toward collecting data on activity patterns and how they affect travel, as opposed to collecting data on trip patterns. Whether the activity focus or another new paradigm will emerge as the principal new direction of travel forecasting is unclear at the moment. However, these shifts probably will be the most significant contextual changes to occur in the history of household travel surveys.

Another contextual factor that is changing the collection of data on travel patterns is the issue of trip tours or trip chains, which have increased as a proportion of total travel in recent years and which pose serious problems for modeling and measurement. The shift to an activity focus in collecting data on travel patterns stems from the fact that using this approach produces more complete information on trip tours than using the trip focus approach. The trip focus leads to respondents omitting intermediate, less-consequential stops in the trip chain, and thus produces incomplete data.

One reason for the increased focus on trip chains is the existence of households in which all adults are in the work force, making it impossible for them to make trips from home dur-

ing the day. Recognition of this trend has resulted in more interest in microsimulating household life-cycle and life-style changes. This, in turn, is driving a need to collect more complete and more detailed data on household life-styles and lifecycles.

Declining Response Rates

A number of factors of life in the late 20th century are causing response rates to decrease. This decrease is likely to continue, which will put pressure on survey designers to develop new designs. Telemarketing and the ability of households to screen calls through such mechanisms as answering machines and caller identification systems are likely to increase. This will result in greater difficulty in reaching households that do not want to participate and will present a major challenge to any form of telephone-based survey. In the United States, response rates have fallen far below acceptable levels. Typical response rates (depending on how calculated) often run below 40 percent of all eligible households, leaving more than 60 percent of households about which nothing is known. The potential for nonresponse biases in such surveys is enormous.

Literacy and Language

Another contributor to the high nonresponse level in the United States is the drop in literacy and the increasing number of people who are not fluent in English. It appears that as rapidly as demand for information from travel surveys increases, the level of literacy of the population decreases, resulting in an increased disparity between requests for information and the ability of the population to respond. There is no question that an increasing element of the U.S. population is illiterate or has a sufficiently low level of literacy that complex questionnaires traditionally found in transportation surveys are becoming too challenging for people to handle. The design of survey instruments must be simplified, and the level of language used must be adjusted so that it is more readily understood. Use of multisyllabic words, complex ideas, and extensive instructions must be avoided. Perhaps more than ever, it is incumbent on the survey designer to simplify every demand made in a survey.

This trend also raises questions about the long-term validity of surveys that are based on written instruments and that require respondents to write their responses. There is little doubt that the telephone retrieval of data from a written survey provides some increased comfort to those who are "literacy challenged," particularly when they are able to provide verbal responses to questions without having to complete a written survey instrument. However, when a person of low literacy responds by telephone, using recall, questions arise about the validity or completeness of data obtained, compared with data provided by literate respondents who recorded responses at the time the travel or activities took place.

Another aspect of this problem is the increasing number of U.S. households in which languages other than English are spoken or whose members' mastery of English is limited or nonexistent. Although frequent efforts are made to translate survey instruments into other languages, many urban areas in the United States need translations into multiple languages, which results in several problems. First, there is the problem of translating English-language questions and directions into another language so that the meaning is retained. Because many languages exhibit regional differences in dialects and word usage, retaining the precise meaning often can be beyond the capabilities of survey organizations. In addition, the requirements for English-language versions of surveys apply to survey translations, such as the use of simple words and ideas. Second, translations add significantly to the cost of a survey. Third, using multiple languages will, with CATI retrieval of data, require multilingual interviewers and a procedure to identify the language spoken and to assign a respondent to an interviewer who speaks his or her language.

Failure to include the marginally literate, the illiterate, or those who speak only a foreign language will lead to serious biases in survey data, because these population subgroups usu-

ally have different travel patterns and personal characteristics than the literate, English-speaking segment of the population. Literacy and language problems are on the increase and must be taken into account in household travel surveys.

Issues in Household Travel Surveys

Many issues arise in the area of designing household travel surveys. Some of these issues are generated by the contextual factors discussed in the preceding section, whereas others relate to specific design issues that arise in our attempt to make survey instruments more effective and less costly.

Incentives

One way of dealing with declining response rates is to offer people incentives to complete a survey. There are at least three variations in the offering of incentives. First, the incentive could be money, a gift, a combination of a gift and money, or entry into a lottery or drawing. Second, the incentive could be offered before a respondent completes a survey (i.e., as a "bribe" to complete the survey) or after a survey is completed (i.e., as a "thank you" gesture). Third, the incentive could be offered to the individual respondent or to the household as an entity.

Several incentives have been used to encourage people to complete household travel surveys: money (ranging from $1 per person to $10 per household); gifts (such as state highway maps, pens, and refrigerator magnets); combinations of money and gifts (e.g., a pen and money); and entry into a game of chance in which a limited number of major prizes may be won. Little has been done to experiment with different forms of incentives. However, in an experiment in the Seattle area, a limited number of incentives were compared (*3*), and recent pretests in North Central Texas have provided evidence on how alternative incentives affect response rates (*4*).

Little is known in the transportation community about the potential biasing effects of incentives. It is reasonable to conjecture that households that respond to incentives and households that are offended by them may be a biased subset of the population. In both cases, offering incentives may result in a significant bias in the respondent sample.

Beyond the simple issue of whether incentives are useful in raising response rates and whether incentives bias responses, issues relating to the fact that most household travel surveys are conducted by or for public agencies frequently arise. As a result, respondents may question the use of public money for gifts or monetary incentives, and significant questions may be raised about the appropriateness of any type of game of chance (lottery or drawing) in which a public agency is the sponsor and public monies are used to pay for prizes. For example, offering a drawing in which respondents may win free air travel to vacation destinations of varying distances and desirability might come under considerable criticism from the general public as well as the media. Adverse publicity about incentives probably harm survey response more than not offering any incentives at all.

Issues of whether to provide an incentive before or after survey completion are partly tied to the issue of what a public agency is doing with taxpayer dollars and partly tied to costs of administration. There is little debate over the fact that it is much cheaper to send an incentive in every mailed-out survey than to keep track of who responds and then send out, in a second mailing, the incentive to those who complete the survey. In addition, the postcompletion incentive is effective only when it is promised before survey completion. This leads to problems about what type of response qualifies for an incentive and opens the door to controversy over whether a specific person's or household's response is complete enough to merit receipt of the incentive.

The survey administrator has little control over how an incentive is handled, once it has been sent to a household. However, the intent to reward each member of a household can be

made clear when the incentive is attached to each individual's instrument, compared with sending a single incentive to the household. Whether there is any difference in the effectiveness of offering the incentive to each person in the household or to the household as an entity has not been researched in the travel survey context.

Finally, in the event a precompletion incentive is offered, the question should be addressed about whether the incentive should be included in the survey package, which is how it is usually done, or whether the offer of the incentive should be indicated during the recruitment call. Announcing the incentive in the recruitment call may lead to more households indicating a willingness to complete the survey in order to receive the incentive, even though the household has no intention of completing the survey. However, some interesting information could be obtained by ascertaining how much of an incentive must be offered to gain compliance by every household called.

Length and Complexity of Surveys

Survey length refers to the length of the survey instrument and the length of time required to complete it. Complexity refers to the structure of the survey, including such items as conditional skip patterns, multipart questions, and the use of complex ideas and concepts. There is a widespread perception that both length and complexity are negatively correlated with response rates. Yet there is anecdotal information suggesting that length alone may not result in decreased response. Experiences in the 1970s with psychometric questioning on topics of comfort, convenience, and reliability indicate that survey length is not necessarily detrimental to response rate if the survey is interesting and simple to complete (*5*).

More information is needed on a number of issues related to survey length and complexity for the purpose of designing effective household travel surveys.

Form of Survey Document

There are at least two schools of thought with respect to the form of survey instrument. One school believes that a booklet form of diary is appropriate and that surveys whose layouts contain a reasonable amount of white space and whose questions are in a more conversational style are better. The other school believes that the survey instrument should be on as little paper as possible and should be provided on two sides of a single sheet or on as few additional sheets as possible. Whether respondents perceive any difference between these is open to question. Two tests are under way, one as part of the North Central Texas survey (*4*) and one as part of the pretest of the 1995 Nationwide Personal Transportation Study (NPTS) (*6*). At the time of this conference, the results of the Texas survey were unknown, although NPTS results (undocumented as of this writing) indicate that a more complete diary form produces better results than a one-page "memory-jogger" instrument. NPTS did not test a full diary instrument with multiple pages stapled into a booklet form. This form was tested in Texas.

Surprise Questions

Another issue related to survey length and complexity is the completeness of questions asked in a written survey compared with the completeness of questions asked during telephone retrieval. Again, there are two schools of thought, and comparative tests of the alternatives have not been made.

The first school holds that there should be no surprises for respondents; all questions to be asked during retrieval should be asked on the survey form. The exception would be asking probing questions during retrieval to correct incorrect information or to uncover information a respondent forgot to provide, such as information on an unreported activity. Reasons for this school of thought revolve primarily around the notion that respondents (*a*) may forget

key information they were not asked to record on the paper instrument and (*b*) may be unable to recall information or may be annoyed or upset at being asked for details about which they were not asked before the retrieval phase.

The second school holds that it is sufficient for respondents to record only major aspects of travel or activities on which information is being collected so that respondent burden is minimized, while additional data can be collected during the retrieval interview. This position assumes that (*a*) the memory-jogger format is sufficient to allow people to recall other details about their activities and (*b*) respondents are less likely to be negatively affected when asked additional questions during retrieval.

These two positions result in significantly different survey costs, complexity, and length. A controlled comparative study needs to be conducted to ascertain whether there are significant differences in quality and quantity of responses from either approach.

Multiday Surveys

Conventional household travel surveys collect data for a single weekday, usually in the spring or fall. Because of changes that have taken place in the past 2 or 3 decades in the structure and behavior of households and because of an emerging realization that certain dynamics of travel behavior have not been captured by 1-day surveys, there is an emerging trend to collect data for more than 1 day. In addition, planning for air quality improvements has shifted the focus toward winter and summer travel, because winter is when most carbon monoxide violations occur and summer is when most ozone violations occur. One wave of the Puget Sound (Wash.) Panel Survey used a 2-day diary, whereas the Portland, Ore., 1994–1995 Survey is using a 2-day diary. North Central Texas will use a 2-day diary for its household travel survey, to be conducted during the balance of 1995.

Although some decrease in response rates is associated with additional days of diary completion, no controlled comparative studies have been conducted to determine the extent of this drop. (There are anecdotal reports of increases in response on the second day or at least increases in the number of activities reported.) In addition, no studies have been done to determine the gain in total information that might be offered by a 48-hour instrument instead of a 24-hour instrument. The question of repetitiveness of activities over 2 consecutive weekdays has not been addressed adequately; therefore, there is no information available on whether "real" additional data are obtained from a second day or how much additional data are obtained.

In the Portland and Texas cases, households were asked to complete their diaries for 2 consecutive days, and a fraction of the households completed diaries for a combination of a weekday and a weekend day. The importance of collecting data on weekend days has not been established. From a behavioral viewpoint, it can be argued that households trade off activities and travel between weekdays and weekend days and that weekday travel patterns cannot be completely understood unless the relationships between weekday and weekend activities are understood. It also can be argued that peak congestion is moving to the weekend and that a majority of air pollution excesses are occurring then. Both of these phenomena point to an increasing importance for measuring weekend travel.

In-Home Activities

It can be debated that travel occurs as a result of whether a person undertakes activities or satisfies needs at home or at locations outside the home. For this reason, information is needed about in-home activities that may be substituted by or for out-of-home activities. This means that respondents must report all daily activities, whether in or out of the home, with the possible exclusion of in-home activities of a short duration and in-home activities that are too personal or unlikely to be satisfied by an alternative out-of-home activity.

Asking respondents to report in-home activities, however, even with certain restrictions on duration and nature, raises two thorny issues. The first concerns invasions of personal privacy with concomitant impacts on both response rate and the credibility of the public

agency conducting the survey. The second concerns the explosion of information that may result from such questioning, which affects the length of the survey instrument, respondent burden in completing the instrument, and time required to retrieve data from respondents. The Portland survey requested information on in-home activities that took more than 30 min, whereas the North Central Texas survey will not collect data on any in-home activities other than working at home. Comparison of response rates and information content of the two surveys may be a first step in understanding whether significant gains result from collecting in-home activity data and whether there are identifiable costs on response rates and data quality.

Time-Use Surveys

Another issue to resolve in the area of survey length and complexity is determining the amount of detail needed about activities. This can be seen first by considering the additional length incurred in the instrument if each change of travel mode is defined as an activity to be recorded in an activity diary. A change of travel mode theoretically could be defined as occurring any time a person enters or leaves a vehicle. The information provided from such an activity definition is "rich" and valuable. However, respondent burden rapidly increases with the requirement to fill in details about many activities within a 24-hour or 48-hour period.

A further extension of this concept is the time-use diary, in which respondents are asked to fill out information on everything they do throughout the recording period, providing certain characteristics of each activity and treating everything, travel and nontravel, as an activity (*7*). The primary difference between a time-use and an activity diary is that the former does not define travel as an activity and instead collects information about travel involved in getting to an activity, whereas the latter defines travel as simply another activity and collects certain information about travel and nontravel activities. A time-use diary also leads to collecting detailed data on each change of travel mode.

It appears that the time-use diary may involve fewer questions about an activity than an activity diary; however, the time-use diary will lead to reporting more events during the survey period, even if the same restrictions, described in the previous section, are applied about recording in-home activities. In addition, respondent burden of such an instrument, whether its length is acceptable, and whether the time-use diary represents a simplification of the activity diary still need to be determined.

Data Repair

Should data be repaired? To what extent and at what point in the data collection effort should data be repaired? How should we define a complete response so that we know when data repair is necessary? Data repair can take place on at least two levels. First, data can be repaired by recontacting the respondent to correct or complete data. Such repair depends on rapid identification of data damage so that the respondent can be called shortly after the original data collection. Failure to identify damage early will compromise the ability of the respondent to recall correct information, particularly if the damage has to do with reported activities instead of a characteristic of the person or household.

The second level of data repair consists of repairing missing and erroneous information after a significant amount of time has passed since the original data collection. This can be done either by imputation of values from a mathematical procedure, assignment of average values from other data, or another analytical procedure for imputation of missing or erroneous data. The question arises about whether either or both forms of repair—imputation and assignment of average values—should be undertaken routinely. Because of the nature of consultant contracts for data collection, the imputation type of data repair is almost always conducted, because it is cheaper to repair minor problems in data than to collect data from additional households for replacement. Beyond the purely financial aspects, the following issues must be considered: (*a*) potential biases that occur when partially complete households are dropped

from a data set, (*b*) the quality of information that can be obtained from recontacting household members, and (*c*) the rate at which such information degrades over time.

Another data repair issue that must be addressed is determining what constitutes a "complete" household. A survey's purpose will have a significant influence on this question. However, standards would be helpful to the transportation profession so that comparability between data sets is maintained and a certain level of quality is ensured. Trade-offs between adding new households versus completing existing households in the sample need to be explored so that better information is available about the comparative costs and benefits of performing rapid data repair through recall. When data are repaired much later by imputation procedures, the issue to be explored is the extent to which such imputation adds new information and the extent to which modeling efforts and other activities are improved. Because statistical tests of models usually are based on the number of observations contributing to a model, imputed data corrections may be necessary in cases in which the imputed values do not represent new information and should not be counted as observations used in the modeling.

Other Issues

Many other concerns need to be tackled. It is hoped that the conference will raise at least as many issues as have been raised here. Probably the biggest omission in household travel surveys has been the commissioning of thorough comparative studies that allow controlled comparisons among different methods and approaches. Even if the conference does no more than provide pressure to commence such comparative studies, it will advance the state of the practice in household travel surveys more extensively than it has advanced in the past.

Cutting-Edge Concepts

It may seem premature to include a section on cutting-edge concepts in the keynote paper for a conference intended to develop these concepts. However, in this final section of the keynote paper, an attempt is made to speculate on areas in which cutting-edge concepts may be developed and on areas that might represent some of the recommendations of this conference.

Panels

Probably the most underutilized survey device in household travel surveys is the longitudinal panel. Only one panel of significant duration has been undertaken in the United States (*3*), and few such surveys have been undertaken elsewhere in the world. The benefits offered by panels have been discussed in numerous other places—including the First U.S. Conference on Panels for Transportation Planning, held in Lake Arrowhead, Calif., in 1993—and are not elaborated further in this paper. Because of response problems and the size and complexity of the measurement task transportation planners must undertake, such panels probably should be paid and should represent a cross section of the population to eliminate some of the biases perceived to exist in current cross-sectional, telephone-based surveys.

Panels offer advantages by measuring the dynamics of change, measuring seasonal variations in travel behavior, and providing opportunities for more extensive measurement over time, by combining different subsets of stated-preference questions at different waves. Reliance on ongoing, small paid panels is a concept whose time has come. A panel can be benchmarked from time to time by conducting a modest cross-sectional survey to determine the extent to which the panel represents the target population and how panel attrition should be managed. The potential to gain more data from ongoing panels than from large cross-sectional surveys conducted at lengthy time intervals must be explored.

Remote Sensing

A technology that is advancing rapidly is remote sensing. At least two remote sensing advances have potential applications for household travel surveys. First, there is a remote sensing device that can be fitted to an automobile to record various attributes of automobile operation such as starts, stops, acceleration, deceleration, time, and distance (*8*). Coupled with a time-use or activity diary, this device offers great potential for improving collection of data about vehicle use. In the United States, no coupling of remote sensing vehicle devices with multiday diaries has been done, although some work has been done in Canada (*9*).

Another technological advance is the Global Positioning System (GPS), which could be combined in a variety of ways with data collection through diaries. At one extreme, GPS could be connected with the type of automobile sensing device just discussed to provide continuous position information for vehicle routing and to collect data on vehicle function, time, and distance. At the other extreme, if GPS equipment is sufficiently miniaturized and if issues of privacy are resolved, such equipment could be attached to individuals who are completing diaries. This would provide fully geocodable data on where people go during a reporting period.

Nonresponse and Non–Telephone Surveys

Returning to face-to-face interviewing must be given serious consideration, although perhaps this survey method is not a cutting-edge concept. Because of nonresponse to telephone-based surveys discussed earlier in this paper and given the biases that might result from excluding households without telephones, face-to-face interviewing may be the only way to improve response and reduce biases.

New technology, however, does play a role in the return to face-to-face interviewing. Notebook computers offer the opportunity to conduct face-to-face interviews using the computer-assisted personal interviewing (CAPI) process. In addition, the potential exists for allowing respondents to enter data directly into a computer, even through the use of touch screens. As notebook computers increase in power and decrease in weight and cost, the possibilities for this type of face-to-face interviewing are considerable. For example, if paid panels are used, panel members could be given notebook computers, with modem hookup to survey administration, so that they can enter their data directly and have these data transferred to those conducting the survey, without the need for telephone or face-to-face interviewing.

Other Technological Advances

The technological advances that are moving us into an era of two-way television, shopping by television, and other innovative means of communication have enormous potential to change the way in which household travel surveys are conducted. One possibility is using videotapes to conduct surveys or to provide instructions to respondents on how to complete a written survey. Future developments could allow respondents to enter data in real time in response to a videotaped interview.

Similarly, it is possible that computer networks will assist in the conduct of household travel surveys. It is more difficult to determine how this technology could be used, both as a result of issues relating to appropriate uses of networks and because of the undesirability of self-selection. Nevertheless, it is an area worth considering.

Development of a National Sample of Households

It may be time to undertake a national sampling for household travel surveys, which would allow regions to use the data to develop models and plans. Such a sample probably would be

best treated as a panel, but drawn from the entire geographic area of the United States and stratified into a range of household and personal characteristics. Distribution of data on such media as CD-ROM would make these data accessible to most metropolitan planning organizations and state agencies.

This concept goes well beyond that of NPTS by creating a national longitudinal panel designed to provide data for regional modeling and based on differential expansion factors for different regions of the country. Occasional benchmarking surveys at the local level still would be needed to determine how the panel relates to each region of the country. Targeted sampling also may be needed in order to provide data on rare behaviors, such as transit use in areas that have small transit systems, or on low levels of transit use. For such a concept to be embraced, considerable effort would need to be expended to show how the data collected would be transferrable from the national sample to local jurisdictions.

Expanded Sample Coverage

The final area addressed in this paper is expansion of sample coverage in household travel surveys. The time has come to abandon older concepts, such as collecting data only on weekdays in the spring or fall, from households with telephones, and for a 24-hour period. Instead, future data collection must (*a*) include weekend days; (*b*) cover different seasons of the year, including summer (particularly in ozone nonattainment areas) and winter (particularly in carbon monoxide nonattainment areas); and (*c*) be conducted over multiple days for each household included in the sample. Finally, expanded coverage should include non-telephone-owning households, unless it can be established that such households are similar to their telephone-owning counterparts. However, initial anecdotal information from the North Central Texas pilot tests indicates that there may be a disproportionate number of transit riders from non-telephone-owning households, making it likely that this group will need to be part of expanded coverage in future surveys.

Conclusions

It may not be appropriate to draw conclusions in a keynote paper, because such a paper is intended to set the thought processes in motion for the conference and to generate new ideas and concepts. However, the following comments may provide a further impetus for conference deliberations.

First, we should not lose sight of the purposes of data collection. Data are collected primarily to allow us to understand where we are at present and how the system is functioning. Of equal importance, data are usually collected to update models or construct new ones. The principal consideration that should guide which data we collect and the quality we demand of these data are their eventual uses. We also must recognize that data uses change over time. Data that are collected infrequently, such as every decade or two, may not be useful by the time we use it. This demands that more thought be given to which data to collect than to satisfying current policy issues. We must anticipate future issues and problems and future developments in the modeling area.

Second, we need to carefully consider data quality. It is easy to collect data of poor quality and to collect data that contain large biases and errors without realizing it. Many data collection practices in household travel surveys have generated such problems. Reaching total sample requirements by adding more households from the total population to make up for nonresponding households and households that provide only partial data is one way in which data quality and accuracy can be compromised.

Data collection is susceptible to the phenomenon of "garbage in, garbage out." Therefore, we must pay more attention to improving the quality of the data we collect.

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WORKSHOP SUMMARIES AND RESEARCH PROBLEM STATEMENTS

Nonresponse Issues

The objectives of the Nonresponse Issues Workshop were to

- Review existing household travel survey practices;
- Evaluate the ability of survey data to meet planning and analysis requirements, considering the level of nonresponse;
- Analyze and discuss solutions to nonresponse problems; and
- Recommend a research program.

Workshop participants described what is known about the state of the art and the state of the practice of methods to deal with nonresponse issues in household travel surveys and to identify a research program to improve existing techniques.

Definitions for Nonresponse Rates

Techniques for defining and reporting nonresponse for individuals (unit) and for specific questions (item) were discussed.

Unit Nonresponse Calculation and Reporting

Household travel survey practitioners often report response rates, but the use of the term varies. The Council of American Survey Research Organizations (CASRO) defines response rate as the ratio of the number of completed interviews divided by the number of eligible units in the sample.

Nonresponse should be distinguished from "no answers" in random digit dialing surveys. Standard research practice as defined by CASRO suggests that the percentage of no answers that are considered nonresponses is equal to the percentage of in-scope households for the calls for which answers are received. Workshop participants pointed out that this method has

consistency problems compared with mail surveys in which all households in a sample have been identified as in-scope.

Participants endorsed the idea of reporting more than one nonresponse measure and of providing detailed disposition information at each step of the survey process. If consistently collected and reported, this type of information will allow practitioners to understand how well various strategies to increase response rates work. Transaction logs should be used by all survey contractors and should be identified in contract specifications.

Item Nonresponse Reporting

Workshop members endorsed the idea of reporting nonresponse rates for each survey variable. This information can be used by the analyst to determine whether individual variables should be used for planning and forecasting purposes. Currently there is no standard regarding how many responses are necessary in order to use a data item.

Nonresponse and Special Population Groups

Workshop participants agreed that not enough is known about the characteristics of survey nonrespondents. Low response rates are often obtained when dealing with particular groups, such as residents of group quarters, immigrants, non-English speakers, and the illiterate and functionally illiterate.

Factors Contributing to Nonresponse

Workshop participants identified a number of factors that affect response rates, including respondent burden, respondent interest, interviewer quality, and the number of survey research efforts to which respondents are exposed. Recent innovations in household surveys, such as stated-preference questions, activity inquiries, and panels, are also increasing the burden on respondents.

A key factor in the length of household travel surveys is the amount of information collected in travel and activity diaries. As analysis needs have expanded, surveys have had to become more detailed in terms of trip information collection. In addition, some practitioners offer multiday diaries rather than single-day diaries. There is some evidence that overall response rates decrease as a result of greater respondent burden and that trip reporting varies for multiple travel days.

Workshop participants recommended that if multiday diaries are used, retrieval calls be made each day, as opposed to at the end of the survey. In addition, because many trips reported in multiday diaries are the same from day to day, collection of weekend and weekday data is less repetitive.

Household travel surveys tend to be much longer than standard market research surveys. Some workshop participants believed that household travel surveys have reached or surpassed their most cost-effective length. Shorter surveys with larger samples may prove to be cost-effective.

Interviewer Quality

Workshop participants pointed out that interviewers in telephone and in-person surveys have a great effect on nonresponse rates. To minimize nonresponse problems, interviewers need to be well trained and experienced. Interviewers must be knowledgeable about the entire survey process, able to convey enthusiasm to respondents, and flexible enough in their questioning to build rapport with respondents without introducing bias into the survey.

Participants believed that these traits are not common, particularly among lower-paid and less well-trained interviewers, and that there is a correlation between response rates and levels of interviewer training and pay. This hypothesis should be tested in a controlled experiment.

Competing Survey Research Efforts

Workshop participants noted that surveys have become so common that potential respondents are burned out. Participants predicted that in the not-so-distant future, computer-assisted telephone interviewing (CATI) will no longer be a viable survey approach because of decreasing cooperation levels. Future surveys may need to rely on a combination of survey approaches to achieve acceptable response levels.

Nonresponse By Survey Type

Nonresponse is commonly related to the type of survey used. In the United States, mail survey response rates are considerably lower than response rates for telephone and in-person surveys. Workshop participants believed that the differences in response rates may have resulted from surveys of unequal quality. Because the quality of design for any type of survey has a greater effect on nonresponse than the choice of survey type, participants proposed that a controlled test be developed. The best possible surveys of each type should be compared to determine whether inadequate response rates achieved in the past were due to survey choice or to survey design decisions after the survey type was chosen.

Techniques to Reduce Nonresponse

Reducing Unit Nonresponse

Workshop participants discussed a number of techniques for reducing the amount of unit nonresponse in household travel surveys. These include the use of incentives, prior contacts, and letters of introduction and endorsement. Attitudinal or opinion questions that build respondent interest and develop rapport also have decreased nonresponse rates. Most important, the questions must be understandable and the responses easy to provide. Follow-ups are generally required.

Reducing Item Nonresponse

Workshop participants identified the following key factors for combatting item nonresponse: (*a*) high-quality survey layout, including clear skip patterns and effective use of color and shading; (*b*) improved interviewer training; and (*c*) careful pretesting.

Nonresponse to Particular Survey Questions

Two questions in which item nonresponse has been a significant issue are income questions and travel (or activity) diary questions.

Income Nonresponse

Workshop participants expressed concern that income data from household travel surveys were being misused in model development, because modelers failed to recognize the

debilitating effect of high rates of nonresponse, potential inaccuracies in the data, and difficulties in forecasting income. Participants believed that the goal of measuring income in household travel surveys to the level of accuracy that will allow data to be used directly in mode choice models is unattainable. However, participants believed that aggregate measures of income (such as at the quartile level) are useful for stratification purposes and descriptive research.

Workshop participants noted a few approaches for decreasing income question nonresponse. In the United Kingdom and Australia, the use of show cards in personal interview settings has produced nonresponse rates far lower than commonly observed in U.S. telephone surveys. In the U.K., the increased use of computer-assisted personal interviewing also is an effective tool in minimizing this type of item nonresponse.

Participants discussed two techniques to increase reliability of telephone surveys. First, the income question can be asked through a series of higher-lower questions until a respondent is classified to the degree of detail desired. Second, income can be requested in both the recruitment and retrieval surveys, thus providing some information if the survey is not completed.

Participants also discussed the importance of household definition in understanding the most relevant income measure. Most unrelated household members, and some related ones, maintain separate spending profiles; therefore, they are more appropriately analyzed with a personal income measure instead of a household measure. Participants discussed the benefits and potential problems of collecting both personal and household income as some surveys do now.

The discussion of problems with the use of income data led to a proposal for a research project to learn more about the levels of uncertainty related to individual household travel survey variables.

Underreporting of Trips in Travel Diaries

The following techniques for reducing the instances of trip underreporting were raised: (*a*) activity reporting, instead of trip reporting; and (*b*) CATI use, with the interviewer probing for intermediate trip destinations.

Workshop participants discussed some U.K. evidence that trip underreporting may be related to the diary period. Continuous surveying was proposed as a means to test this hypothesis.

Imputation techniques for missing trip data were discussed. In some cases, specific missing trips (e.g., trips home at the end of the day) can be identified by those who conduct the survey. In these cases, some trip imputation may be possible. It was pointed out, however, that clarification with a respondent usually is the better approach. Imputing trips usually directly is not possible.

Trip rates are estimated using corrective weighting procedures based on location and family structure characteristics. Workshop participants expressed some concern over imputing data for missing people within households, but others defended the practice, particularly when one member had traveled with the missing member. If households are excluded because of a missing person, larger households will be underrepresented. Because it is likely that larger households have different travel patterns, the bias could be substantial.

Imputation and Weighting

Discussion of weighting techniques for trip rate corrections led to a discussion of weighting in general and of using late response information to weight nonresponses more accurately. Workshop participants disagreed on whether nonrespondents are similar enough to respondents, even late-return respondents, to use their information to correct for nonresponse.

The resource paper by Richardson, Ampt, and Meyburg underscores the relationship between trip making, nonresponse, and late responses. Even after correcting the demographic differences and nonreporting differences, late respondents and nonrespondents had significantly lower trip rates.

Workshop participants identified weighting as a research issue. When and how data should be weighted and how weighted data should be analyzed need to be studied. Though participants recognized that not all practitioners are comfortable with imputing missing data, no one objected to its use, provided that it is done carefully and is well documented.

Single imputation causes reduced estimate variance; therefore, it is problematic in model development. Workshop participants agreed that multiple imputation techniques, particularly "hot decking," were more appropriate and that stochastic techniques hold the most promise. There are questions, however, about whether stochastic variable estimates are worth the additional effort.

Participants agreed that any imputation of variables as well as any other changes to a survey data base should be carefully documented. They endorsed the metadata concept now being applied to U.S. Geological Survey spatial data sets, which provides on-line documentation of all data.

Workshop participants suggested that an important research topic is to determine when and how to best impute missing data and to determine when nonresponse is too high to allow imputation.

Workshop Recommendations

Workshop participants classified the issues along the following dimensions.

- Current level of understanding of the topic:
  - –Topics for which there are reasonable guidelines based on what we know; and
  - –Topics for which further research is needed before meaningful guidance will be available to practitioners.
- Relationship of the topic to nonresponse:
  - –Topics that deal with efforts to reduce nonresponse; and
  - –Topics that deal with efforts to better use data with nonresponse problems and efforts to mitigate the effects of nonresponse.

This categorization produced two sets of recommendations: those dealing with guidelines for the field and those related to research needs.

Workshop participants believed that it is imperative that all aspects of survey design and implementation be reported in a standard format. This way, information on the effectiveness of various techniques can be obtained and compared. In addition, the analyst can judge whether and how best to use data elements in modeling.

It was also deemed important that the field promote standards for household travel surveys. There are correct and incorrect ways to perform surveys, and it was believed that these guidelines need to be provided to practitioners. Even in evaluating contract proposals, the practitioner needs to know how to calculate a response rate, what it means, and how it can be improved. There are agreed-on methods to increase the response rate, which should be available to anyone considering conducting a household survey.

A second area of recommendations involves the need to train practitioners on the standards and best practices in the field. This traditionally has been a role for the federal government. Workshop participants proposed increased funding and attention to this essential function.

A related recommendation involves the use of peer-review panels. Because the best way to increase response rates is to provide a quality survey, the use of peer-review panels in the initial phase of survey design was strongly recommended.

Development of Research Problem Statements

Based on the categorization of nonresponse issues, workshop participants developed an integrated set of research proposals in the area of nonresponse.

Problem Statements

Workshop participants identified seven research proposals, some of which were combined with topics in other workshops. This group identified the need for the following:

- Development of guidelines to reduce nonresponse;
- A controlled comparison of different survey methods to determine nonresponse rates;
- A study of travel survey nonrespondents;
- Research on techniques for reducing nonresponse, integrated into other research statements;
- Guidelines for reporting nonresponse;
- Guidelines and best practices for mitigating nonresponse; and
- Research on nonresponse mitigation techniques.

Phasing of Research on Nonresponse

Workshop participants believed that research on nonresponse should be phased to take advantage of results from other efforts. Figure 1 shows the proposed phasing of and interrelationships among the research projects. Three proposed research efforts—development of guidelines to reduce nonresponse, the best practices manual for reporting nonresponse, and the best practices manual for mitigating nonresponse—should be implemented immediately. These efforts rely on the analysis of existing travel survey practices and current survey research techniques. The output of these efforts could be used in implementing the controlled comparison of survey methods, which will involve fielding different types of new best practice surveys and carefully monitoring survey response. These surveys would be ideal data sources for the three remaining proposed research efforts—research on nonresponse mitigating techniques, the study of travel survey nonrespondents, and research on techniques for reducing nonresponse.

Research Problem Statements

A Controlled Comparison of Travel Survey Methods

Three major methods for conducting travel surveys have been used in the past: personal interviews, telephone interviews, and self-completion mail-back questionnaires. Each method has advantages and disadvantages, including costs, response rates, and quality of data collected. Decision makers need better knowledge of the trade-offs involved in using these different survey methods. Although much has been written about the strengths and weaknesses of each survey method as applied to various travel surveys, there is a need to compare the performance of each method, under controlled conditions. The results of this research should enable decision makers and practitioners to select the most appropriate method for different circumstances.

Proposed Research

The proposed research would compare the performance of personal interviews, telephone interviews, and self-completion mail-back questionnaires when used to conduct a travel survey

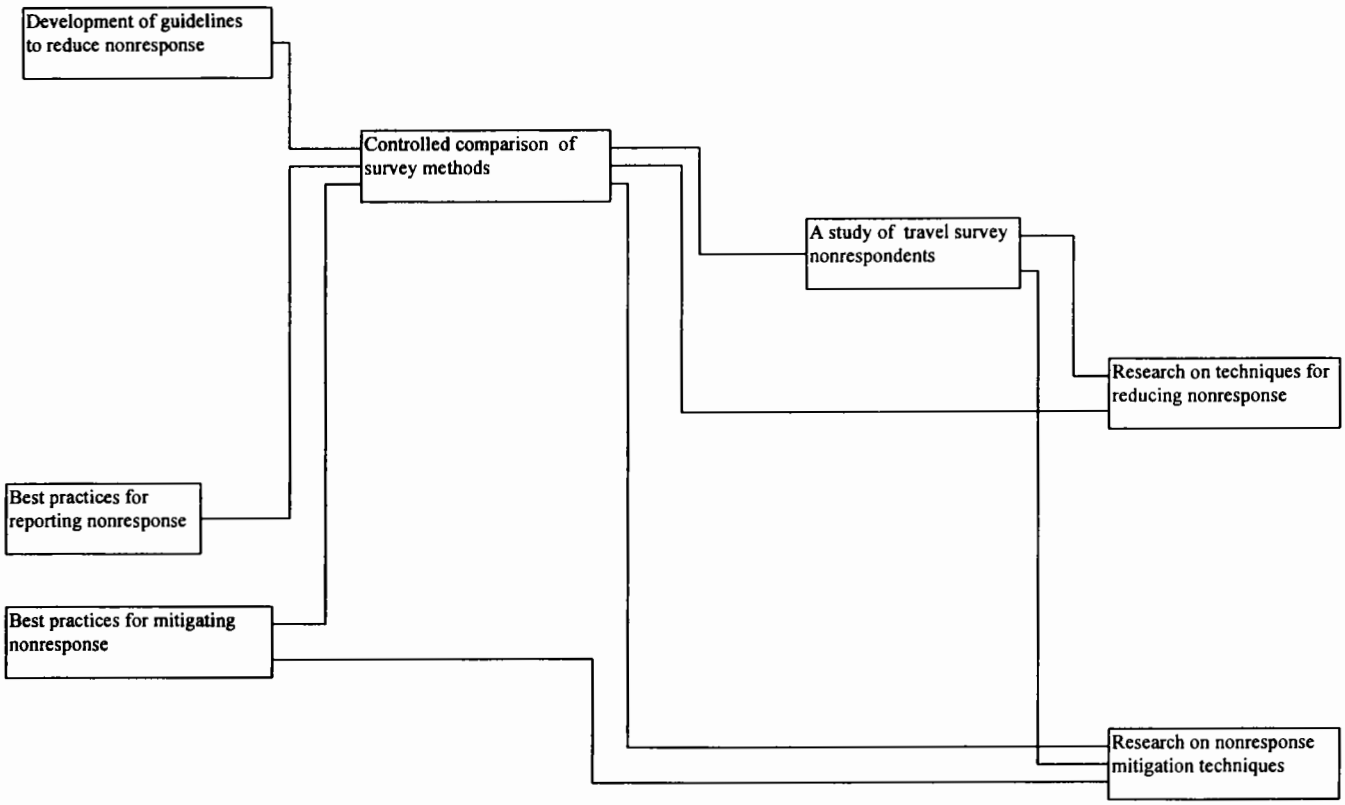

FIGURE 1 Proposed phasing of and interrelationships among nonresponse research projects.

with specific objectives in a given study area. Each survey would be conducted with state-of-the-art procedures and by a survey organization recognized as a leader in travel surveys. Each survey would collect specific information from a specified population, as determined by a management committee for the project. The surveys would cover all aspects of survey design, but would enable the evaluation of individual aspects of the survey, such as response rates, accuracy of data, biases introduced, results for different population groups, and survey costs. Special attention also would be focused on coverage bias caused by the inability to interview certain types of households [e.g., households without telephones (in random digit dialing surveys) and households that refuse to respond to mail and personal interview surveys].

Some aspects of the design of each survey would be specified. For example

- The survey would be restricted to 24-hour periods but would be spread over all days of the week;
- All trip origin and trip destination information would be geocoded, but the method of geocoding would be left to the survey designer's discretion to take advantage of the characteristics of the survey method; and
- Categories for closed questions would be specified, but the exact wording would be left to the discretion of the survey designer.

The final designs would need to be approved by the management committee to ensure that the surveys are comparable.

The study area selected would require that a range of typical conditions (e.g., different income groups, residential densities, ethnicities, transit usage, etc.) is encountered by all methods. The size of the initial sample would be specified by the management committee. The selection of the units of this initial sample would be performed in a comparable manner across each method to ensure comparability of calculated response rates and sample coverage. Each survey would include a pilot survey, the size of which would be included in the

total sample size for the overall study. The design, conduct, and performance of each survey would be fully documented in a manner specified by the management committee.

The objectives of the research would be to provide comparative information on the performance of the three survey methods to help clients and contractors make informed decisions on the selection of a travel survey method under different conditions. The results of this research would be widely disseminated in a form useful to practitioners and others in planning and conducting different types of travel surveys.

Recommended Funding

The cost of this project would depend primarily on the size of the sample selected and the unit costs of each survey. Assuming a total sample size (including pilot survey) of approximately 1000 households for each survey method, the total project cost should be about $500,000, including the cost of overall project design and administration.

Urgency, Payoff Potential, and Implementation

The conduct of this project is an important step in facilitating informed decisions on selection of survey methods for particular travel studies. This is especially the case as demographic changes and technological advances are making it increasingly difficult to achieve acceptable response rates through traditional survey methods.

The comparative survey effort should be completed in about 12 months. However, other projects compiling documents that detail the state of the art for the different survey methods, especially for dealing with nonresponse issues and for specifying the required definitions and levels of documentation for the different methods, will need to be completed in advance.

Describing and Reaching Nonresponding Populations

The problem of nonresponding households increases the costs of household travel surveys and introduces biases in the data collected. The implicit but incorrect assumption is that nonrespondents' demographic characteristics and travel behaviors are similar to those of responding households. However, experience indicates that this is not true. There are many populations that may not be fully represented in current household travel surveys. These include non-English speakers, persons of various ethnic origins, households without telephones, low-income households, and individuals with disabilities. If such populations are underrepresented in household travel surveys, research findings and the policy decisions that result from them will not represent the full population. This is particularly important because future increases in trip making may be concentrated among these underrepresented groups.

A related issue is that the complexity of our questions and concepts is increasing while the general education level of the population is decreasing. To what degree does this situation affect nonresponse?

Proposed Research

The objectives of this research are to identify reasons for nonresponse and the characteristics of nonresponders; to determine how effective the use of multiple data collection methods can be in reducing nonresponse; and to identify what specific actions researchers can take to reduce the incidence of nonresponse.

The proposed research would include

- Developing a synthesis of previous research on nonresponding populations, including analyzing data from previous travel surveys and reviewing literature from other fields;
- Testing and comparing alternative recruitment methods, such as community groups, door-to-door, intercepts, and other non-telephone-based recruiting;

- Customizing survey instruments in terms of age, disabilities, languages, literacy, and so on;
- Using various survey research methods, such as in-person, in-home, mail-back, and computer-assisted telephone interviewing (CATI), to determine how they affect response rates of hard-to-reach populations and quality of data collected from them; and
- Developing ways to expand and use data collected from nonresponding populations.

One approach proposed is to select several household travel surveys—ones that are ready to be conducted and that will be administered using different methods—and add a nonresponse investigation component to them. The nonresponse investigation would consist of

- Identifying nonresponding households;
- Getting nonresponding households to respond to the survey using an alternative method;
- Obtaining information about converted households, including why they did not respond to the first method, but did to the second, and compiling characteristics of these households; and
- Obtaining information from unconverted households, including why they did not respond, and compiling characteristics of these households.

Information on waves of respondents, including hard core, should include at least two focus groups: one with converted households and one with unconverted households.

To clarify, the term "nonresponding households" can encompass a number of groups, including low-income groups, recent immigrants, non-English-speaking groups, disabled persons, illiterate persons, and households without telephones. At the other end of the spectrum, nonresponding households may include the wealthy and people who routinely have their calls screened. For purposes of this research, we are concerned more about the low end of the socioeconomic scale than the high end. The reason is that the high- and middle-income households that do not respond to travel surveys probably have a much better chance of having their mobility needs met than low-income households.

Recommended Funding

- Synthesis, $100,000; and
- Nonresponse component, $560,000 (1600 interviews and six focus groups).

Urgency, Payoff Potential, and Implementation

Given the number of surveys that will be conducted in the immediate and distant future, coupled with the potential for cost savings and an increase in data accuracy, this research should be considered urgent. In addition, travel surveys are currently suffering from a serious and steady decline in response rates, which could be mitigated by this research.

Alternatives for Mitigating the Effects of Nonresponse Bias

Well-designed surveys include provisions for reducing nonresponse, such as carefully designing the data collection instrument and thoroughly training interviewers. Despite the effectiveness of these measures, survey planners and methodologists must accept the inevitability of some nonresponse and the challenge to produce, from the data that are collected, "good" estimates in an efficient manner.

Unbiased or nearly unbiased estimates can be derived if there is full or nearly full participation from the targeted sample units of a survey. However, if such cooperation is not achieved, the validity of subsequent survey inferences become contingent on the ability of es-

timators to ensure that nonresponse bias is within reasonable limits. Ostensibly adjusting for nonresponse is not a widely accepted practice for travel surveys. Yet the biases associated with discarding partially completed households and neglecting to assess and adjust for the impact of nonresponding households can seriously reduce the quality of data reported in these surveys. As a research issue, studying the effectiveness of estimation techniques in the presence of unit, person, and item nonresponse is warranted for these surveys.

Proposed Research

The proposed research is assessment of the effectiveness of selected methods of compensating for nonresponse biases in household travel surveys.

The principal techniques for dealing with survey nonresponse are weighting adjustment and imputation. The compensatory procedures selected for study include design and model-assisted weighting for unit and person nonresponse and several main imputation techniques for item nonresponse, including the mean, "hot-deck," regression, and multiple imputation procedures. Stochastic procedures need to be evaluated as well.

The proposed study is expected to provide useful information on the effectiveness of selected weighting and imputation approaches to nonresponse, insight into developing guidelines for the selection and application of nonresponse adjustment alternatives, and suggestions for further research on nonresponse issues in travel surveys.

Recommended Funding

One and a half person years.

Urgency, Payoff Potential, and Implementation

This project is important because it can provide assistance to practitioners who are faced with incomplete data and who have little guidance on how to mitigate the effects of nonresponse. The transportation field has done little work in the use of imputation techniques, and the implications of alternative actions are not clear.

Best Practices for Adjusting for Nonresponse

The conduct of sample surveys always results in some level of nonresponse. Individuals who refuse to respond to travel surveys have different travel characteristics than the overall population. Because of these differences, biases in survey estimates may result. This can negatively affect decision making on transportation issues.

In addition, not everyone who responds to a survey instrument will answer all questions. This, too, can bias estimates of trip making and household descriptors. Another nonresponse issue is the definition of what makes a complete household. This is particularly important in cases in which a household is the sampling unit. Failure to obtain data from all persons in a household results in an inability to classify a household as a complete unit. Discarding information due to within-household undercoverage biases the results because larger households are not represented accurately.

The literature suggests ways to adjust collected data to reduce these biases; however, these methods are not universally applied in the transportation arena.

Proposed Research

Data from travel surveys must be compared with other data (e.g., data from the census and previous surveys), and an appropriate weighting scheme needs to be developed. It is the objective of this effort to describe the methods that can be employed to bring the final estimates of population parameters closer to real values.

Adjustments for items that have not been reported can be accomplished in several ways. Single and multiple imputation techniques can be employed, including hot decking. The project must address the implications of each type of adjustment. For example, simple adjustments such as averages affect the variance of estimates and usually should not be used.

Adjustments for unit nonresponse can be based on the same methods or can be derived from models of nonresponse. One method of computing nonresponse adjustment factors involves grouping interviews and noninterviews into various cells based on known characteristics of both, computing an adjustment factor unique to each cell, and applying this factor to the weight of the interviews in each cell. This increases the weight of interviews in a given cell to represent noninterviews. The success of this method depends on the ability to define cells using characteristics that are common to interviews and noninterviews and that are related to the items the survey is trying to measure. This type of adjustment can be done separately for missing households and for missing persons within the household.

This research effort will describe these methods and discuss how they can best be used for household travel surveys. Examples from transportation experience also will be provided. Discussion should take place in cases in which the survey method results in different weighting requirements.

Recommended Funding

One person year.

Urgency, Payoff Potential, and Implementation

This project is extremely important. It a low-cost project (i.e., it basically is a synthesis document) with a high payoff. There are accepted statistical ways to adjust for nonresponse in surveys, and it is necessary for transportation practitioners to understand them and use them appropriately.

Standards for Describing Travel Survey Nonresponse

Users need to be aware of the level of nonresponse in surveys in order to assess the value of a data set. The quality of survey methodology, determined in part by the response rates for a survey and for specific questions, determines data uses and interpretations. Standard reporting of nonresponse also allows users to evaluate different techniques for implementing surveys, thus building a coherent body of knowledge on methods for travel surveys.

Proposed Research

The first objective of the research is to discuss alternative definitions and to describe the state of the art in survey methods. Materials from the Council of American Survey Research Organizations should be reviewed and discussed for their applicability to transportation surveys. Information requirements should be documented and explained and should be identified by means of practitioners as well as sponsoring bodies. The other objective is to produce recommendations on how nonresponse data should be shown in technical and other reports. Areas to be examined follow.

Descriptive Information

- Details of sample design: the population, sample design, sampling frame, number of eligible units in the sample, and how the type of survey affects the design; and
- Details of the contact: number of reminders/callbacks, time of interview, disposition of each household, and information on the particular interviewer.

Numerical Information

- Sampling frame and an estimate of the households/persons not included on the sampling frame;
- Losses from out-of-scope sources (e.g., telephone number);
- Losses due to refusals;
- Losses due to noncontacts;
- Numbers of fully cooperating households with no proxy interviews;
- Numbers of fully cooperating households with proxy interviews;
- Numbers of partly cooperating households with an indication of the extent to which the user was willing to use the data of cooperating members of the household; and
- Data provided separately for inner city areas and possibly other areas of interest.

For continuous surveys, data should be supplied for the four quarters of the year.

Comparative Information

Comparisons with basic demographic data for the sampled areas should be given.

Recommended Funding

One-half person year.

Urgency, Payoff Potential, and Implementation

The project is essential; it has a high payoff and a low cost. For the field to grow, this type of information must become standard. A great deal of information has been accumulated in other fields on how to ensure high-quality surveys, and the transportation field cannot continue to ignore this information and tolerate poor-quality survey work. This is one step toward high-quality surveys in transportation.

Development of Guidelines to Reduce Nonresponse

A number of techniques are available for reducing the levels of unit and item nonresponse in household travel surveys, but there is an absence of uniformity in the application of these measures. Offering incentives to survey participants may be one means of mitigating poor response rates; however, there is concern that incentives themselves may introduce response bias. Incentives and other mechanisms are available to reduce nonresponse, and an overview of the state of the art in travel surveys must be made available to the practitioner.

This project seeks to create a uniform understanding of the best practices currently being employed to reduce nonresponse and the costs and implementation issues related to these practices. The effort will make the best practices information easily accessible to all travel survey practitioners. In addition, this research will serve as the basis for larger, long-term research efforts recommended by the nonresponse workshop.

Proposed Research

The proposed research has three tasks:

- Review available literature, and document best practices to the extent possible;
- Organize a formal panel of travel survey researchers to review and revise the best practices document; and
- Widely disseminate this information to practitioners and clients.

The researchers will create a concise document that describes current best practices based on recent and ongoing survey research guidance, including the following:

- Ongoing NCHRP household travel survey research;
- Updated *FHWA Travel Survey Manual*;
- *Survey Methods for Transport Planning*, by Richardson, Ampt, and Meyburg;
- Nonresponse Issues in Household Travel Surveys, by Richardson, Ampt, and Meyburg;
- Current practices in the survey research field; and
- Findings of this conference workshop.

These data sources will provide detailed information about the different techniques for reducing travel survey nonresponse and will concentrate on identifying the most successful techniques for personal, mail, and telephone methods.

The statement of best practices will discuss the importance of the following:

- Effects of nonresponse on anticipated use and purpose of survey results
- How interviewers affect nonresponse
- Policies regarding the use and reporting of proxy interviews
- Use of incentives, including
  - –Types of incentives (monetary, motivational materials, drawings, and gifts)
  - –Whether incentives should be offered to households or to individual household members
  - –Whether incentives should be offered as inducements or rewards
  - –Circumstances in which incentives are the most and least effective
- Inclusion of other mechanisms in the survey design, such as
  - –A cover letter signed by a high-ranking individual
  - –Personalization of survey materials for each respondent
  - –Using postage stamps on packages sent to respondents, instead of using prepaid or machine-stamped mailings, to make the mailing stand out from direct mail
  - –Sending materials in distinctive envelopes
  - –Providing a toll-free telephone number for respondents to call in case they have questions or complaints
  - –Giving a return address that is within the region under study
  - –Giving a return address for the agency or another public organization, instead of for a private firm
  - –Giving respondents a deadline
  - –Using interviewers who have local or no accents
  - –Ensuring respondents' anonymity
  - –Selecting interviewers of the same age groups, races, ethnic backgrounds, and social classes of potential respondents for personal interviews
- Questionnaire design issues, including
  - –Layout
  - –Level of language
  - –Use of technical terms
  - –Inclusion of language describing the importance of the survey and the respondent's role in it
  - –Inclusion of questions that build respondent interest in the survey

Once a draft best practices statement is prepared, the researchers will share it with a small group of travel survey practitioners to ensure that there is some consensus that the recommended practices represent the best approaches. The researchers will revise the document as directed.

Recommended Funding

The research will require approximately 1 person year.

Urgency, Payoff Potential, and Implementation

This research is considered essential. The effort requires only the compilation of existing information; therefore, it is a relatively low-risk exercise. The potential rewards of the effort, however, are great. Disseminating the information assembled in this effort to practitioners currently engaging in or planning survey efforts may help prevent the collection of flawed data and the resulting flawed analyses and policy decisions. In addition, the outcome of this research is essential to research efforts on testing methods to reduce nonresponse and comparing personal, mail, and telephone surveys that employ best practices.

Stated Response

During the past year, several metropolitan planning organizations (MPOs) added stated-preference elements to their travel behavior surveys, including the MPOs in Dallas, Tex.; Washington, D.C.; and Portland, Eugene, and Salem, Ore. Given the expectation that other MPOs might be considering doing this as well, one purpose of this workshop was to explore issues related to the use of stated-preference surveys in household travel surveys. A second purpose was to discuss the use of stated-preference surveys for transportation planning.

The intent of the workshop was to address specific practical issues that MPOs need to understand when considering the use of stated-preference surveys in their household travel surveys. The workshop was not intended to be a tutorial on how to conduct such surveys.

Participants took part in several sequential activities during the workshop, including (*a*) identifying participant expectations of what to accomplish and what to avoid, (*b*) assessing the state of the practice, (*c*) identifying issues, (*d*) specifying potential research topics relative to identified issues, (*e*) selecting the most important research needs and topics, (*f*) developing research problem statements for these topics, and (*g*) determining research priorities.

Nearly all 16 workshop participants had some direct experience with stated-preference survey methods; many had a considerable amount of experience. Participants were almost evenly divided among the categories of academic researchers, MPO staff members, consultants, and federal staff members and others.

The following summarizes workshop results in terms of the state of the practice, basic issues, and topics that may not have been incorporated into the research problem statements.

State of the Practice

Stated-preference surveys attempt to reflect real-world consumer decision-making tasks and behaviors. Respondents are given a range of behavior, or choice options, they would be expected to use and from which to select. The options are described by a limited number of attributes, such as the transportation modes respondents might use for specific trips. Respondents also are given certain characteristics or constraints selected by survey developers for variation.

Respondents are then asked to select or give their stated preference for an option under a number of scenarios that express these variations, often through a series of trade-off questions. The use of such scenarios, choices, and trade-off questions distinguish stated-preference household travel surveys from more traditional ones, which ask respondents to answer questions about how they traveled (i.e., to give their revealed preference of their travel patterns).

Workshop participants concluded that stated-preference techniques are one component of a broader class of stated-response techniques. This conclusion was based on information presented in Lee-Gosselin's resource paper. He presented a "taxonomy of stated-response approaches," which he uses to distinguish among a wide range of existing and potential techniques typically included under the subject of stated-preference surveys. Participants found that this taxonomy gives a much broader, yet focused, means of characterizing the state of the practice. An adaptation of Lee-Gosselin's taxonomy appears in Figure 1, which was developed by participants during the workshop.

This classification is based on variations along two dimensions, each shown as an axis in Figure 1. Each axis is represents the relationship between and the activities of those who conduct surveys and respondents for the travel behavior and the constraints characterizing the options. There is a full spectrum of variations along each axis, but the axes are described here in terms of their extremes.

On the travel behavior axis, the extremes range from (*a*) giving respondents a specific set of behavior options from which to select to (*b*) eliciting specific behavior options from respondents. Similarly, for the other axis, which is related to the constraints of the travel mode or the traveler, the extremes range from (*a*) giving respondents a specific set of constraints from which to select to (*b*) eliciting specific travel constraints from respondents.

Figure 1 illustrates that the state of the practice of stated-preference surveys can be viewed as part of a broader set of stated-response techniques, which vary with the interaction between respondents and those who conduct transportation behavior surveys. As discussed during the workshop and as illustrated by the linkages among the survey applications shown in each quadrant of Figure 1, different types of stated-response surveys might be used in different circumstances and in particular sequences to help researchers better understand people's travel behavior and their reactions to constraints. For example, in surveys on congestion pricing, two survey instruments might be used. The first might be a typical stated-preference survey in which behaviors and constraints are given. The second might be a "stated-adaptation" survey, structured to elicit from respondents how they would adapt their behavior under different congestion pricing scenarios. This would be done without prompting respondents to any particular way of adapting.

The validity and usefulness of stated-response approaches was accepted by all workshop participants, with the recognition that further improvements to the taxonomy are possible.

Basic Issues

Workshop participants identified stated-response survey issues that they thought were important and require research. More than 40 issues were identified. Participants identified similar or related issues that could be grouped for purposes of further discussion. Participants identified eight issue groups:

- Relationships (linkages) between revealed-preference/stated-response surveys;
- Validity of various survey techniques;
- Selection of techniques within stated response;
- Transportation program issues (policy) best tested by stated-response techniques;
- Respondents coping with survey response tasks;
- Instruments for stated-response surveys and/or experiments;
- Sampling procedures needed to obtain adequate responses; and
- Analysis approaches to which stated-response techniques are applied.

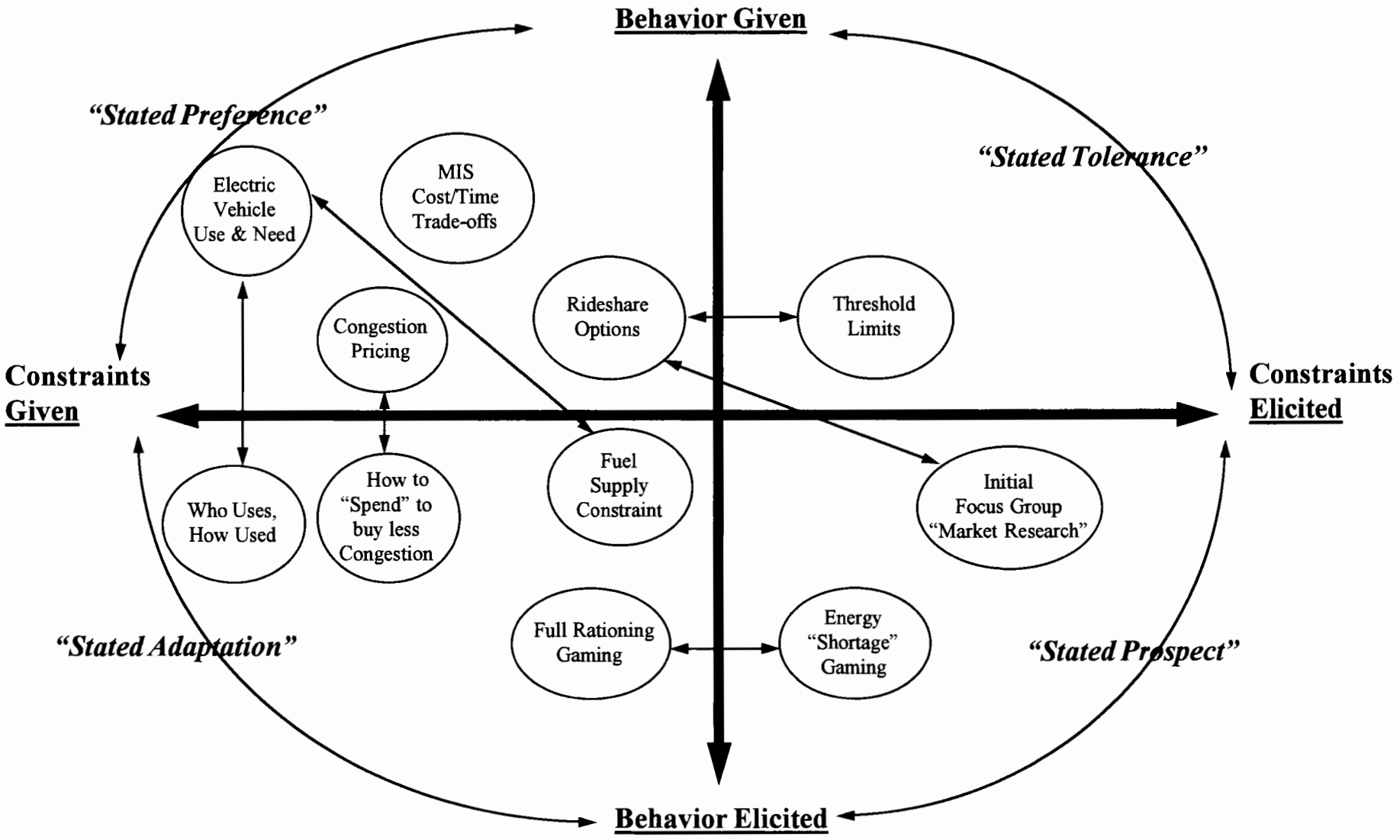

FIGURE 1 Stated-response techniques: classification of content.

For each issue group, participants identified specific topics for research problem statements, which are discussed later.

Topics Incorporated Into Other Research Problem Statements

The steering committee combined two of the most important stated-response research topics with appropriate topics and statements from other workshops:

Approaches and Survey Instruments to Improve the Relevance and Presentation of Transportation Alternative Attributes in Household Travel Surveys Using Stated-Response Techniques

This was integrated into a New Technologies Research Problem Statement, Approaches to Improve the Presentation and Understanding of Transportation Alternatives in Stated-Response (Stated-Preference) Surveys. Some concerns of the Nonresponse Issues Workshop also were appropriate to work into a research statement.

The Use of Stated-Response Techniques to Determine Ways to Lessen Respondent Burden in Household Travel Surveys

This was integrated into a Nonresponse Issues Workshop Research Problem Statement, Development of Guidelines to Reduce Nonresponse.

Topics Not Incorporated Into Research Problem Statements

Workshop participants identified about 3 dozen research topics related to stated response. Workshop participants agreed that seven of the topics, about 20 percent of the total, were important. Another four research ideas or topics were ranked as important by workshop participants but were not incorporated into research statements. These topics include the following:

- Attenuating survey fatigue and reducing complexity in household travel surveys by using stated-response techniques and alternate designs;
- Using stated-response techniques in basic travel behavior research versus using the techniques to collect data on how travelers are likely to respond in the future;
- Creating a synthesis of applied and basic research in travel behavior using stated-response techniques; and
- Creating a synthesis of the linkages between revealed-preference and stated-response survey techniques.

Research Problem Statements

The Potential for Using Stated-Response Methods to Improve Transportation Demand Models

Urban and regional travel demand models are based on revealed-preference data, typically collected by means of household travel surveys. It is now recognized that stated-response methods can provide more accurate estimates of model parameters for a wider range of variables and scenarios. As yet, however, no systematic research has been done on (*a*) optimal

ways of incorporating stated-response experiments in household travel surveys and (*b*) using stated-response data together with revealed-preference data in estimating travel demand models.

Proposed Research

1. Create a theoretical framework. There are fundamental differences in the choice/response processes underlying revealed-preference and stated-preference/stated-response data. These differences are discussed in both the psychological/descriptive literature and the statistical/quantitative literature. This literature should be reviewed and synthesized, specifically as it relates to urban and regional travel behavior.
2. Review previous evidence. Practical methods for designing stated-response experiments around revealed behavior (actual trips) in travel-related surveys were developed during the late 1980s. Modeling approaches for combining revealed-preference and stated-response data in estimation have been developed and applied in the 1990s. Although some of this work has been performed in the United States, the majority has been done in Europe, Australia, and Japan—often in the context of predicting demand for major new intercity modes or routes. Existing experience should be synthesized and related to the intraurban travel context of households. In particular, a range of typical modeling calibration variables need to be identified that (*a*) most likely would have meaningful differences in their estimated values, due to the differences between revealed-preference and stated-response data; and (*b*) most likely would provide sufficient sensitivity and differences in the results of travel demand model structure and/or calibration.
3. Design a recommended approach and research strategy. Based on the syntheses in steps 1 and 2, it should be possible to describe a few recommended methodologies for including stated response in household travel surveys and analyzing the resulting data. A number of options/decision points will need to be included in order to relate to various research and policy contexts. It is expected that it will not be practical or possible to recommend a single best approach. For many aspects of the methodology, alternative approaches can be described as well as a research strategy for testing and recommending more general approaches that move toward an optimal approach.
4. Conduct a controlled, comparative study of revealed-preference/stated-response approaches. Depending on the success of steps 2 and 3 in developing promising research strategies, a carefully controlled, comparative study of alternative revealed-preference/stated-response approaches for household travel surveys can be conducted. The comparative study ideally should include some way to assess the validity of data collected, such as with an appropriately designed before and after study, so that the alternative approaches can be compared in practical, meaningful, and perhaps statistical ways. Another option would be to collect sufficient data so that the approaches can be independently followed to calibrate alternative travel demand model structures. At a minimum, the comparative study should determine incremental changes in differences of various aspects of improved travel demand modeling results, based on the addition of stated-response-based data and information.

Recommended Funding

$800,000 consisting of 3 person years and 2,000 household travel surveys.

Urgency, Payoff Potential, and Implementation

This is viewed as high-priority exploratory research to determine the value and effectiveness of stated-response approaches. The ability of travel demand modeling to effectively deal with a broad range of variables, at a finer level of detail, may depend on the development and application of stated-response household travel survey techniques.

Using Combinations of Stated-Response Techniques in Different Transportation Planning Contexts

There is a need to investigate how different stated-response approaches can be applied to tasks and needs typically found in different transportation planning contexts. There appears to be few practitioners who know that different approaches can be tailored to fit different applications and that "one size does not have to fit all." A need exists for a state-of-the-practice guidebook, targeted to a general audience of practitioners, that illustrates how such stated-response combinations can include linkages to the more familiar revealed-preference techniques. A detailed state-of-the-practice manual is needed to aid the smaller audience of practitioners that wants to become actively involved in developing and/or applying stated-response techniques to different transportation planning contexts.

Proposed Research

1. Conduct a literature review and develop stated-response classifications. Conduct a literature review and provide short annotated bibliographies that are grouped to distinguish among various quantitative and qualitative stated-response approaches, particularly those that have been specifically developed and applied to transportation-related concerns. Develop in conjunction with this grouping a taxonomy or schema to clarify differences among classes of data and stated-response approaches. Specify a framework that uses this schema to assess how different combinations of stated-response techniques can be used in different analytical or behavioral understanding contexts in transportation planning and decision making.
2. Assess the applicability of combinations of stated-response techniques to different transportation planning contexts. Conduct an assessment of the strengths, weaknesses, benefits, and costs of specified combinations of stated-response techniques as applied to different transportation planning and decision-making contexts. To the extent possible, references should be made to appropriate materials from the literature search. It is recognized, however, that much of this assessment will be speculative because some or most of the specified combinations may not have been used in actual practice or previous research. The combinations may include linkages to the revealed-preference techniques that typically have been used in transportation planning applications.
3. Prepare a guidebook for practitioners. Develop targeted informational materials that will sensitize a more general audience of practitioners to the approach, paying particular attention to the inclusion of linkages to revealed-preference methods.
4. Produce a techniques manual for practitioners. Produce a state-of-the-practice manual that is a compilation of information and approaches to aid practitioners who are actively involved in developing and/or applying these techniques to different transportation planning contexts.

Recommended Funding

$200,000 consisting of 1 person year and provision for publication and distribution of the guidebook and manual.

Urgency, Payoff Potential, and Implementation

Many new surveys will be conducted by metropolitan planning organizations, states, and transportation authorities in the next several years. The availability of a guidebook for key staff and managers of these agencies will sensitize them to the possibility and value of including stated-response techniques in their survey budgets. The manual will enable technical staff members who will perform this work to do it on a consistent basis from a national perspective, which can aid in subsequent research to assess more of the actual experiences with different combinations of stated-response techniques.

The Validity of Stated-Response Techniques in Forecasting Individual Travel Behavior Changes and Information Needs of Decision Makers

There is a need for fundamental research on the validity of stated-response techniques in forecasting individual travel behavior changes. Validity is seen as the ability of different travel demand models, which are derived from stated-response techniques, to predict how individuals choose to travel under different circumstances. Validity is also viewed from a qualitative appropriateness context: Do the stated-response techniques satisfy the information needs of planners and decision makers?

Proposed Research

1. Establish an evaluation framework. The research should first establish an evaluation framework that is based in part on the existence of different types and degrees of validity. For example, quantitative validity deals with how well a forecast measure or indicator of travel behavior matches a corresponding observed or measured indicator. However, the observed or measured indicator has margins of errors associated with it, which should be accounted for in an evaluation framework.

In addition, there is a common sense validity, which often is used by decision makers to determine which courses of action to consider. This type of validity is based on broader qualitative and comparative information derived from their experiences. For example, a technique may be valid to decision makers only if it provides accurate, reliable, and understandable information about the future that relates to their perceptions of similar information about current conditions.

2. Identify appropriate test locations and data needs. Appropriate test locations that will facilitate the conduct of the research will be identified. Such locations should have (*a*) one or more stated-response-based travel demand models already functioning and (*b*) a significant project or change in the transportation system about to occur. Ideally this research should be combined with a before and after study of an actual significant improvement, as opposed to a conceptual experimental design. Estimates will be made of additional data required to supplement any already planned or programmed so that the full data set will be effective in testing different aspects of the evaluation framework. One or more locations will be proposed to test the validity of the models in replicating observed behavior of individuals, monitoring how people actually behave versus what they say they will do, and the validity of results for decision makers.

3. Conduct the research and analysis. For the selected locations, the following will be determined: specific measures or indicators related to individual travel behavior that have been forecasted based on stated-response models and that can be observed or measured before, during, and after the significant improvement. New forecasts will be made, if necessary, to produce as complete a set of measures as possible that will respond to the established evaluation framework. Data will be collected to measure or observe individual behavior before, during, and after improvement with revealed-preference and stated-response techniques. The focus of the research will be on obtaining observed behavior data as well as having a sample of people who have responded to stated-response questions about the improvement about to be implemented. There may be advantages to collecting stated-response data from a common sample of participants. A data analysis will be performed that estimates the different types and degrees of validity and the contribution of stated-response techniques toward achieving that validity.

4. Prepare an assessment report. Prepare an assessment report that focuses on the results of the evaluation and that incorporates the technical papers and memorandums associated with the earlier tasks of the research.

Recommended Funding

$500,000 consisting of 3 person years and a sample of 300 households.

Urgency, Payoff Potential, and Implementation

This is seen as important research to improve the confidence of planners in using stated-response techniques and to provide them and decision makers with information on the value of such techniques.

Explorations of the Validity of Aggregate Short-Term Forecasts Based on Stated-Response Methods by Using Before, During, and After Surveys

Transportation planning has been moving away from focusing on major infrastructure investments to focusing on operational and short-term policy matters. Forecasting the aggregate or net response to such short-term initiatives provides an opportunity to highlight stated-response methods to increase awareness in the transportation planning community as well as to explore how well such methods perform. The research approach should be designed so that the behavioral response to short-term improvements provides opportunities to validate stated-response-based forecasts.

Proposed Research

There are three approaches for exploring the validity of stated-response methods:

- Comparison of stated-response-derived values with revealed-preference-derived values when they attempt to measure the same entity (e.g., marginal valuation of travel time savings for a particular population);
- "Face validity" investigations of stated-response-derived values as they vary across different market segments; and
- Comparison of stated-response-derived forecasts with experience with an innovative policy over a sufficiently short period of time so that external effects can be identified and discounted.

The program of U.S. Department of Transportation-funded operational tests of ITS products and services and/or of congestion pricing initiatives should provide a number of opportunities for the third type of investigation. Short-term congestion management initiatives can provide other opportunities.

For selected operational tests, a program of data collection that includes stated-response surveys before, during, and after the operational tests will be designed. This stated-response program might be integrated with the revealed-preference data collection planned for the purpose of evaluating the operational test. There may be advantages to collecting the revealed-preference and stated-response data from a common sample of participants.

An experimental design that pools time-series and cross-sectional revealed-preference and stated-response data will help identify stated-response models that, using only pretest data, best predict observed outcomes. These models will be compared with the "best" models based only on pretested revealed-preference data.

Recommended Funding

Will vary with the number of operational tests chosen and the details/complexity of the operational test. Minimum worthwhile effort would be $200,000 to $250,000; a better funded program would be $500,000 to $750,000. This would use several locales to see the degree to which the results are replicable across several areas.

Urgency, Payoff Potential, and Implementation

High, given the relatively rare opportunities that such operational tests provide.

Approaches and Instruments to Improve the Relevance and Presentation of Transportation Alternative Attributes in Household Travel Surveys Using Stated-Response Techniques

This statement was combined with a New Technologies Research Problem Statement, Approaches to Improve the Presentation and Understanding of Transportation Alternatives in Stated-Response (Stated-Preference) Surveys. New technologies present an opportunity to more realistically present attributes that influence travel behavior choices and to decrease respondent burden by customizing and personalizing survey/experimental tasks. However, the interaction of information presented and its format can be easily separated.

Research is necessary to investigate appropriate attributes that influence travel choice in combination with new presentation and interview techniques. The goal is to present respondents with a sufficient number of relevant tasks in a context that reduces response burden. The research also should provide an opportunity to test several unconventional approaches to (*a*) survey instrument design and (*b*) the presentation of features or characteristics of alternative existing and/or future transportation improvements.

Proposed Research

Two phases of the research are proposed:

1. Use response-elicited-type stated response in traditional presentation methods to identify critical dimensions of choice/acceptance; and
2. Design and test response-given-type stated-response tasks using new/alternative technologies (video, interactive media, etc.) to evaluate interactions with presented attributes in Phase 1.

In addition, previous work will be exploited, possibly yielding syntheses requested elsewhere.

Developing a Diagnostic Approach to Selecting Appropriate Stated-Response Program Combinations for Different Transportation Planning Applications

Metropolitan planning organizations and departments of transportation are faced with an increasing number of policy issues of a much broader range and variety. A variety of stated-response techniques are being used in different locations and contexts, but are not widely known. Guidelines are needed on how to select appropriate stated-response program combinations for different transportation planning applications.

Proposed Research

1. Establish a framework of relevant dimensions or policy questions. A framework must be developed that is relevant and sensitive to how travel-related survey data are used in transportation planning and analysis and that depends on key distinctions between stated-response and revealed-preference survey approaches and among different stated-response survey approaches. The framework could be based on basic differences in the survey methods and/or the planning or policy questions to which the survey results are usually applied.
2. Describe available stated-response approaches and how they fit into the framework. A thorough identification of all stated-response approaches needs to be done based on a literature review and non-site visits with a sample of practitioners. The emphasis will be on approaches that have been or might be considered primarily for transportation planning or policy applications. However, consideration also could be given to approaches used in other fields of study that may have some applicability to transportation. Summary characteristics will be specified, and linkages will be made to the framework being developed in the preceding task.

3. Establish guidelines for a diagnostic approach to selecting stated-response combinations for different transportation planning applications. A methodology will be developed that will enable various practitioners and researchers to (*a*) perform a self-diagnosis of the underlying dimensions of the transportation planning application or policy issue being addressed and (*b*) then select the appropriate combinations of different approaches to cost-effectively address the application or policy issue. A sample of practitioners will be selected to test the understandability and practicality of the methodology. After any necessary refinements, appropriate guideline documentation will be prepared as part of the final report.

Recommended Funding

$225,000 consisting of 1.5 person years.

Urgency, Payoff Potential, and Implementation

This research needs to be performed shortly in order to be most beneficial to practitioners who are contemplating conducting household travel surveys to coincide with the year 2000. The work could be performed within a relatively short time frame. There are many potential benefits for other travel survey studies that may be under consideration with major investment studies or major intercity initiatives.

Designing Low-Respondent-Burden Stated-Response Techniques for Use in Household Travel Surveys

Respondent burden is a concern in designing household travel surveys. Adding stated-response questions may increase respondent burden, with the danger that quality of data obtained will decrease. It is expected that data obtained using stated-response approaches will be more effective and useful in various transportation planning analyses and that using such approaches will be cost-effective even with lower response rates caused by perceived increases in respondent burden. Choosing the appropriate level of respondent burden, therefore, will be the subject of the research.

In addition, the potential to specify different approaches for designing, linking, and administering stated-response questions may help alleviate this problem to varying degrees. The research will investigate ways to minimize respondent burden and to decrease such burden from what it would be without a stated-response approach.

Proposed Research

The research would consist of controlled experiments to compare alternative approaches, including the use of stated-response techniques, to traditional household travel surveys. Presentation format, complexity of design, method of linking with revealed-preference behavior, and other factors that influence respondent fatigue would be studied.

Survey Methodologies

Survey Design Issues

Traditionally, household travel surveys have focused on travel (trip data). The state of the practice now includes trip-based, activity-based, and time-use surveys. Workshop participants were unclear about the distinguishing characteristics of each of these survey types. Consensus was that the field would benefit from standard conceptual and operational definitions of each type, along with a listing of the type of questions each can address. Participants were asked a key question for which there was no definitive answer: Which one is better? Several participants answered, "It depends on the goals of the research."

Workshop participants raised the issue of trade-offs to determine the appropriate type of travel survey design. For instance, trip-based is the least burdensome for respondents and costs the least, whereas time use gathers the "richest" data but costs the most. However, much of the discussion was anecdotal. It was determined that full documentation of previous studies is needed to determine what constitutes a well-conducted study of each type and to assess the cost-benefit of each type. The guiding question was "How do you balance funding with what you need to do?"

Several workshop participants were aware of household travel surveys being conducted or surveys that were conducted in comparable areas using one of the design formats that could form the basis of comparative case studies:

- California Case—A trip-based survey in the state of California and an activity-based survey in Los Angeles; and
- North Carolina Case—A trip-based survey in Greensboro and a time-use survey in the Research Triangle.

Several participants felt strongly that a comparison of outcome variables from these case studies might help answer the question "Which design format is better?" The outcome variables singled out for comparison were

- Trip rates by purpose by mode,
- Mobility rates,

- Item nonresponse rates, and
- Response rates (overall, recruitment, and retrieval).

Each of the three design formats requires slightly different survey instrument designs. The information processing burden on respondents increases as one moves from a trip-based to an activity-based survey and to the time-use format. For this reason, it was agreed that cognitive research to assess the level of burden and ways of correcting for it is necessary.

Time-Related Issues

Participants discussed several time elements related to household travel surveys. The issue that consumed the most discussion time was longitudinal research or panel designs. Traditional household travel surveys are cross-sectional surveys. A few projects (e.g., Puget Sound, Dallas/Fort Worth, and San Francisco Bay Area) are using panel designs. The discussion highlighted the need for standard definitions of "panel" and "wave."

The necessity of long-term planning for panel surveys was underscored by the workshop members who have undertaken this type of research. It was pointed out that the care and feeding of panels costs money and that panel designs should not be an afterthought. Several participants suggested that basic information was needed:

- For what reasons should panel designs be considered?
- What are the advantages and disadvantages of panels?
- What are the basic design issues that someone considering a panel needs to address and consider?

Many workshop members acknowledged that panels have been used in industries other than transportation and that a rich literature exists on their use. There is no need to reinvent the wheel; however, there is a need for standard rules on transportation panel maintenance, replacement, tracking, and weighting procedures. In addition, participants believed that there is inadequate information on how best to apply panel design to a household survey project. In frugal times, people need ways to determine the optimum panel size, length of panel life, gap between waves, and level acceptable of attrition. The notion of a national panel was raised; however, there was no clear sense of how best to approach a national panel, what questions it would answer, or what value it would add to local areas.

Discussion also focused on two other time-related issues. First, traditionally, respondents in household travel surveys reported travel behavior for a 24-hour (1-day) period. The state of the practice now includes 1 or more days. Even though successful multiday surveys have been undertaken, empirical evidence of the benefits is lacking. The marginal costs of reporting behavior for 1 or more days need to be systematically validated against the increased information gained. In addition, participants believed that research is needed to determine the optimum number and best combination of days. Again, much of the evidence of multiday surveys is anecdotal.

Second, the state of the practice includes collecting household travel data during spring and fall. Policy needs (e.g., air quality) and changing life-styles (e.g., year-round schools and telecommuting) drive the need to collect data at other times of the year. Several participants felt the need to identify the subsets of information that require data to be collected at times other than spring and fall and to determine the optimum sample size for addressing such questions.

Sampling Issues

Sampling issues took up a large part of workshop discussion. Participants focused on the issue of the increase in bias associated with random digit dialing samples and the need to

examine and document the level of bias and to develop correction strategies for it. Correction strategies mentioned included multiframe samples, multimode surveys, and statistical techniques.

The discussion also focused on the frugality with which travel surveys often need to be completed. Participants believed that guidance is needed to answer the question "What is an efficient sample size?" Consensus was that a decision framework that outlines the standards and criteria for estimating sample size, given model estimation requirements, is needed.

Lawton and Pas, the authors of the resource paper on survey methodology, raised the issue of the need for a framework to determine the best methodology mix or the best optimal allocation of a data collection budget. This framework would provide decision support in calculating key household travel survey methodology components: number of households, travel days, and panel waves and years of panel life.

Research Problem Statements

Comparative Study of Trip, Activity, and Time-Use Formats

Agencies that commission and/or conduct household travel surveys have questions about the relative benefits versus costs of using trip-based, activity-based, and time-use methods. Reliable information is needed on the following:

- Conditions under which each method should be undertaken;
- Trade-offs (trip rates, response rates, costs, and data quality) that are associated with each type;
- Strengths and weaknesses of each type; and
- Cost and time implications.

The fundamental question that the research would answer is "How do results obtained by the three methods differ?"

Proposed Research

A two-phase research project is proposed:

Phase 1—Qualitative

- Synthesis of documentation and outcome from existing projects with a comparative case study approach;
- Cognitive research (focus groups) to assess the information processing burden of each format on respondents; and
- Comprehensive documentation.

Phase 2—Quantitative

This phase calls for an extended pilot study for a "split panel" test in one metropolitan area. The sample size will be 1200 households, 400 per format. This project would result in standard conceptual and operational definitions of each format with a listing of the type of questions each can address. It also would provide a decision-making framework for assessing and comparing the costs versus benefits of each format. A comparative case study will be used [e.g., California Case—trip-based (CALTRANS) and activity-based (Los Angeles); North Carolina Case—trip-based (Greensboro) and time use (Research Triangle)]. Finally, it would produce a guidance document on how best to conduct each type.

Recommended Funding

- Phase 1, $150,000; and
- Phase 2, $250,000 to $500,000.

Panel Surveys in Transportation Planning

Much is known about panel surveys in industries other than transportation; however, within the transportation research ranks, knowledge and understanding levels vary. Experience with using panels in transportation surveys is limited. A key measure for transportation planners is change, which is effectively measured with panels. Research questions pertaining to the topic include how to conduct panel surveys efficiently, who should be selected, and how to select the sample.

Proposed Research

A qualitative project that includes the following is proposed:

- Review of the literature (nontransportation and transportation);
- Preparation of a primer or how-to on why panels should be used, operational considerations (design and maintenance), and cost implications; and
- Development of a recommended strategy for use of panels nationwide and in metropolitan areas.

The primer or guidance document would describe the basic design issues that someone considering a panel must address and consider. It would contain standard definitions of "panel" and "wave" and set standards and means to determine the optimum

- Panel size,
- Length of panel life,
- Gap between waves,
- Acceptable level of attrition,
- Amount of instrument modification across waves,
- Way to contract field work,
- Strategies for maintenance (care and feeding),
- Tracking rules (split households), and
- Weighting procedures.

The project also would assess the need for a national panel. The following questions would guide the inquiry:

- What questions would a national panel answer?
- What value would it add to local areas?
- How would it support transportation planning in small metro areas?
- How would it deal with responses that are influenced by where a respondent lives?

Recommended Funding

$120,000.

Metropolitan Transportation Survey Evaluation Project (MTSEP)

The shifting travel demand modeling and transportation planning paradigms that have flowed from the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Clean Air

Act Amendments (CAAA), coupled with recent direction supplied by the federally sponsored Travel Model Improvement Program (TMIP), emphasize the need for a comprehensive research program for the following:

- Systematic methods for collecting activity-based travel data;
- Data and analytic methods that support policy development and transportation system investments; and
- Travel models that are based on a more comprehensive understanding of the dynamic nature of household decision making.

Little applied research or experience exists concerning the methods necessary to design, collect, maintain, and analyze longitudinal data about travel behavior or to explain the changing nature of travel behavior caused by life-cycle effects, changes in workplace or residential location, and changes in travel choices available to individual trip makers. Longitudinal, repeated sampling of the same analysis unit (panel data) is the only way to systematically address these issues.

The objective of this research proposal is to develop methods, procedures, and guidelines for activity-based models and a body of applied research into methods of collecting panel data that (*a*) support these models and ISTEA and CAAA mandates and (*b*) significantly contribute to an understanding of the dynamics of household-based travel behavior and decision making.

Proposed Research

A comprehensive program of concurrent household travel surveys in several metropolitan areas is proposed. The sites for the proposed project would consist of carefully selected metropolitan areas with varied populations, transportation systems, and geographic characteristics. These sites also would have ongoing data collection programs and staffing that could support and contribute to the project.

The research program would be centrally coordinated to ensure that panel study designs are comparable and fully integrated with the overall project design. The research design would be carefully controlled to secure adequate and proper data. The model for the research design would address research issues that emerged from the conference, including the following:

- Multiday sample administration;
- Efficient sampling design, strategies, recruitment, administration, and follow-up;
- Seasonality effects and variation; and
- Clustering/stratification and parsimonious sampling methodologies.

A coordinated, multisite study would be a more cost-effective way to address these issues than separate, individual studies focused on one issue and one site.

Several important outcomes could accrue as a result of this comprehensive research project:

- Better understanding of and well-documented methods for longitudinal data collection;
- Research-level data that support development of activity-based travel demand models;
- Scientific, systematic evaluation of methods of data collection and survey administration that addresses conference objectives; and
- Documentation of methods and maintenance of a data repository for metropolitan-level travel data.

Recommended Funding

The estimated cost of program development and design, field testing of alternate panel designs, recruitment of panels, fielding of panel instruments for six metropolitan areas for a

minimum of 5 consecutive years, and overall program administration (not including the cost of publications, conferences, etc.) is estimated to be $15.75 million over the 5-year life of the project. The project could be funded in phases, beginning with design and feasibility ($75,000). Funding for this project is based on the following:

- Implementation in six diverse metropolitan areas;
- Five successive years of longitudinal survey administration; and
- A sample design that delivers continuous, multiyear samples with approximately 2000 households remaining in each survey by the fifth year.

Funding Sources

The project would fulfill several research and policy data needs; therefore, funding could come from several sources, including TMIP (Track D), the U.S. Census Bureau, Bureau of Transportation Statistics, Department of Housing and Urban Development (for locational data), and Environmental Protection Agency (long-term air quality issues). In addition, contributions from the six participating metropolitan planning organizations could help fund the project.

Guidelines for Gathering and Using Data on Small Areas

Primary data on midsize and large areas are prevalent. Data on small areas, or clusters of small areas such as "rest of state," are scarce. Many individuals charged with collecting and/or using data on small areas do not have the money or expertise to conduct complex survey projects. They often borrow data (e.g., demographic and trip rate) from other areas. However, the industry lacks standards by which data can and should be transferred from one context to another or on how data could be pooled from multiple sources (primary and secondary) and used effectively. State transportation departments, small metropolitan planning organizations, and other agencies could benefit from guidance on how to conduct these surveys in the most effective and cost-efficient manner.

Proposed Research

The proposed research would answer these questions:

- Which techniques are best to use for small-area estimation of population parameters? How do each affect model estimation?
- Which variables lend themselves to transfer from one area to another? Which do not? How does one make this decision?
- What is the best way to combine primary data collected at the local level with borrowed data?

The research would be conducted in three phases:

1. Review of the literature
2. Field testing
   - –Select case sites
   - –Collect primary data or use existing data
   - –Estimate models
3. Evaluation
   - –Apply transfer techniques
   - –Evaluate

Recommended Funding

- Phase 1: $ 15,000;
- Phase 2: $250,000; and
- Phase 3: $ 75,000.

Household Travel Survey Coverage Bias Project

Coverage loss from the use of random digit dialing (RDD) telephone interviews is likely to increase during the next few years. Coverage loss is the inability of a survey conductor to contact respondents in an RDD survey sample frame. Noncontact can result from the following: non-telephone-owning households and telephone-owning households unable to be contacted (e.g., households that screen incoming calls, households in which members are not home, and households that use "call waiting" screening).

This sample frame coverage loss may cause a coverage bias, which may distort household parameters, travel characteristics, and activity patterns obtained from an RDD telephone survey. It is important for travel behavior researchers, state departments of transportation, and metropolitan planning organizations to understand the nature and magnitude of coverage bias in RDD telephone surveys in order to plan for the necessary adaptations and corrections to survey methodology, survey design and conduct, and potential post-factor adjustment of population parameters.

Proposed Research

The purpose of this project is to design and conduct an extended pilot study in several metropolitan areas and states to augment RDD telephone survey design with split panel or post-enumeration-survey designs to analyze the characteristics of survey frame coverage bias. These non-RDD surveys may take several forms, including mail-out/mail-back surveys and in-home face-to-face interviews.

These pilot studies will be needed in metropolitan areas and states of various sizes to determine what warrants the use of alternative sampling frames and alternative survey methodologies to augment or replace RDD survey design. A related extension of this research is to design and conduct validation interviews to determine levels of underreporting and item nonresponse bias.

Recommended Funding

$400,000.

Guidelines for Total Design or Optimal Mix

Research design is as much an art as it is a science, and several alternative approaches may satisfy the objectives of a study. To assess research design is to compare alternative approaches to determine whether the approach selected is sufficient, given the constraints of time, budget, potential value of results, and potential risk of incorrect information. Given this situation, it would be useful to develop a framework (standards, criteria, and questions, etc.) that could be used to determine the most efficient mix of design elements:

- Sample size,
- Number and type of days targeted,
- Efficient sampling strategies and frames,
- Seasonality,
- Mode of administration,
- Use of panel (number of waves and length),

- Long-term data collection stream of costs, and
- Stated-preference/revealed-preference mix.

Proposed Research

Meta-analysis of results of several projects, along with a cost-benefit analysis is proposed. The outcome would be a decision support system for determining the optimal mix for a given area.

Recommended Funding

$75,000 to $125,000.

Transportation Planning Data Archive

A key issue in advancing transportation research is access to transportation planning data collected at the national, statewide, and metropolitan area levels. Transportation researchers need convenient access to well-documented data files to conduct their research. The establishment of a national archive, depository, or clearinghouse for transportation planning data is critical to achieve this goal of advancing the state of transportation planning research.

Proposed Research

The proposal involves the establishment of a permanent national archive for storage of national, statewide, and metropolitan area transportation planning data, including but not limited to the following:

- Household travel survey files;
- Transit and highway networks and network levels-of-service files;
- Demographic data bases including recent decennial census data;
- Travel model calibration files;
- Comprehensive documentation of all data items including data dictionaries, methodology reports, and reports showing analysis of results.

National archives containing transportation planning data bases have been established in other countries, including at the University of Essex in the United Kingdom, the Steinmetz Archives at the University of Amsterdam (the Netherlands), and Laval University in Canada. This research project would review the experience of other national archives in obtaining, documenting, and disseminating transportation planning data and would incorporate this information into the U.S. archive.

Recommended Funding

Recommended funding is approximately $100,000 per year. The U.S. Department of Transportation's Bureau of Transportation Statistics may be the most suitable government agency to support a national transportation planning data archive.

Data Collection Instruments and Related Issues

Data Collection Methods and Issues

Data Collection Methods

Research on response variation in attitudinal surveys indicates that interview methods affect response. For example, in one study, socially acceptable answers were given more often during home interviews than during telephone interviews. Four methods of data collection were addressed by workshop participants: mail-back, telephone, in-person, and home.

Mail-back combined with telephone follow-up is the primary data collection method used outside the United States. In the United States, the census is the ultimate mail-back data collection effort. For the census in the year 2000, the Census Bureau will send prenotification letters, followed by questionnaires. A few days later, reminder cards will be sent, with instructions to households to send back the completed instruments; a telephone number will be provided for households that do not receive questionnaires. If questionnaires are not returned in a specified time frame, replacement questionnaires will be sent. If replacement questionnaires are not returned, telephone follow-ups will be conducted. Each step should result in an incremental improvement in response rate.

Administration of a telephone survey can be done using paper and pencil or through the use of computer-assisted telephone interviewing (CATI). Discussions of telephone survey methods led workshop participants to the issue of the inclusion of non-telephone-owning households and the resulting bias on study results. In Sweden, households without telephones are a small part of the population. Once identified, these households are sent a letter and a respondent package, resulting in the inclusion of some non-telephone-owning households in the data. Another option is to conduct home interviews, which are costly. Conducting in-person interviews is another, less costly alternative.

Several research questions were raised by participants:

- What trade-offs and biases are inherent in each data collection method? Metropolitan planning organizations (MPOs) planning to conduct travel surveys need to know more about the consequences of data collection decisions. MPOs can make better-educated decisions if common sense information on all methods, including biases and how to deal with them, and their affects on response rates are available.

- Does the data collection method matter to respondents? Has anyone asked respondents what method they prefer? Does respondent preference matter, or should the method be determined based on obtaining better data? What level of accuracy is needed? Is all this effort worthwhile? For data collectors the issue is data accuracy and the ability to probe each question. Telephone surveys are useful because people do not always complete mail-back forms accurately.
- With telephone surveys, how should fax machines and answering machines be handled?
- Does precontact with respondents (advance letter or telephone call) matter?

Data Collection Stages

Workshop participants discussed the implications of each stage of data collection:

1. Pretest and pilot test,
2. Monitoring data quality during collection, and
3. Post-test and postenumeration validation of results.

Pretest and Pilot Test

A pretest compares methodologies, whereas a pilot test is a dress rehearsal. A pretest to compare methods should be conducted, followed by a pilot test to rehearse the chosen method. The best pilot test is one in which both these procedures are undertaken.

In a perfect world, one would pretest alternatives, choose the best one and pilot test it, create a budget, and conduct the survey. There is, however, the ideal situation and the real world. The ideal situation includes focus groups and cognitive research, yet in the real world, one can still test everything in a focus group that is made up of people not related to the survey design. It is extremely important to have representative focus groups. In addition, focus groups are for interacting. What must be tested in a survey is one person's ability to conduct it.

Many problems can be discovered and resolved during the pilot test. The staff of the Washington Council of Government (WCOG) discovered a CATI programming error—a skip preventing the collection of income data—in its pilot survey. Most problems in a survey are not discovered until people begin using it. This issue can be compared to editing a report—it requires an iterative process to debug it. In Sweden, agencies hold internal discussions, test the forms on a few people, and conduct a pretest followed by a pilot test and, finally, the survey.

Should the concept of peer review be considered a best practices element? There are varying degrees of peer review, and although the input is valuable, a review can take forever. A particular agency had data users from nearby agencies review its forms. Another option is to have a survey undergo review using the Transportation Research Board process. Sometimes reviews are done for political purposes only—even though specific questions may not be included, it is still necessary to have others look at the forms.

Workshop participants saw this process as a linear one—conduct a pretest, conduct a pilot test, and run the survey. Perhaps the process should be one of continuous quality improvement in real-time, making changes to a survey as it is conducted, as WCOG did. Sometimes a change occurred in interviewer instructions (repeating addresses back to respondents), whereas at other times, entire questions were changed or added. Regardless, it is extremely important to keep track of who answers a survey and which version a respondent used. In addition, before making any changes, decisions about whether or how to combine data must be considered.

Monitoring Data Quality During Collection

The use of real-time review during data collection was discussed in other workshops as a way to identify item nonresponse and to improve it as a survey progresses. The purpose is to monitor data quality. Some look specifically for zero trip households or zero trip persons—replacing households when responses appear to be fraudulent.

Research topics for monitoring data quality during collection include the following:

- Types of data quality checks. For example, is a respondent reporting using two vehicles at the same time? Is an unemployed person reporting trips to work? It would be useful to synthesize all data quality checks used by agencies.
- Criteria to guide decisions concerning data that are out of range, including zero trip persons, zero trip households, low trip rates, and identical trip rates for all household members.

Post-Test and Postenumeration Validation of Data

Post-test and postenumeration validation was used by workshop participants to describe the process in which consultants recontact a sample of households to confirm that the data collected are correct. Households are asked about their original travel days a second time. If budget permits, the ideal validation is to reinterview a sample of respondents to confirm their responses (postenumeration survey). This stage of validation is often excluded from studies because of financial constraints. But what is the impact if such validation is not conducted?

Another way of asking this question is "What would be gained by conducting a postenumeration survey?" In a postenumeration survey, travel data are not collected for 2 new days; only original travel days are included. A workshop participant raised a good point: If it is difficult to obtain response in the first place, it will be difficult to conduct postenumeration surveys. An alternative is to conduct a reinterview, shortly after the first interview, to measure response consistency. As always, cost is a big issue—many agencies have difficulty obtaining resources for the travel survey itself, much less for reinterviewing or postenumeration surveys. This problem was raised in Richardson, Ampt, and Meyburg's resource paper on nonresponse. We are getting at what quality is all about. People will still make decisions constrained by budget and the need for quantity.

Research issues raised at the workshop include the following:

- NCHRP needs to fund studies to demonstrate the value of this type of research. In this way, MPOs could understand the value of additional surveys and what trade-offs they make when they do not conduct them.
- Should the household or a person within the household be selected as the sampling unit? If a person is used as the sampling unit, how should an individual be selected within the household? How do you factor the variability in travel by gender? This is an important issue when dealing with stated-preference surveys, because such surveys are based on the person.

Data Validation

The discussion of data validation began with the topic of control totals. It is important to recognize that uncertainty is associated with survey data and the data source for validation. To some extent, validation has ties to expansion of data. However, there is disagreement on whether expanded data should be used in modeling or if they are needed at all. One solution is to compare both weighted and unweighted results. Data expansion must be done with care and must reflect the sampling scheme.

Geocoding Issues

For geocoding to be successful, it must take place shortly after data collection, because respondents may need to be recontacted. The Baltimore Travel Survey used on-line geocoding, which required data bases that reflect local familiarity because respondents do not always know exact addresses or cross streets and may give landmarks instead. If we move to a continuous census, there will be a need for continuous updating of files of common, local addresses such as workplaces and major activity centers. The Census Bureau will depend highly on the MPOs, recognizing that it will be a give-and-take relationship.

Data Items

Income

Are income data necessary for household travel surveys? Alternatives to collecting information on income include collecting information on home values, auto ownership, and labor force participation. However, these too have problems. Most workshop participants believed that income is a needed data item, to allow comparison with other data sources. For states with income taxes, consulting state tax records may be an alternative to asking respondents directly about their income.

Practitioners need direction on when, how, and why to ask about income. Such questions can be open ended or midpoint, with ranges or a combination thereof. With a mail-out survey, close-ended questions work best. The definition of income should be conveyed to respondents (i.e., gross pay, including or excluding dividends). In addition, the order of questions is important; if a question about income is asked first, respondents may refuse to disclose this information.

Vehicle Information

Vehicle information is gathered for emissions analysis in the modeling process. Most air quality nonattainment areas need these data. Although state vehicle registry data seem to be a good secondary data source, those who have used this source have been dissatisfied with the results.

Parking Costs

There were mixed reactions from workshop participants on the need for data on parking costs. On the surface, parking cost data seem to be useful in large metropolitan areas. The 1970 Chicago survey collected these data; however, no one used them. These data were dropped from the 1990 survey, and people are now asking for them. A secondary issue is whether respondents understand the concept of subsidized costs.

Ethnicity

Ethnicity is not asked in all household travel surveys. Recent surveys in Chicago, Detroit, Los Angeles, and San Diego omitted this item. However, the Boston, Oregon, and Houston surveys collected this information, and the Census Bureau and Nationwide Personal Transportation Survey collect it.

Recruitment Issues

Specific segments of the population tend to be underrepresented in large-scale household travel surveys. To make contact with and recruit hard-to-reach populations, several research issues arise:

- What methods do non-transportation survey professionals use to recruit these groups? Possibilities include intercept recruitment at schools, churches, social service agencies, workplaces (including employees and visitors), and major activity sites.
- Is oversampling the target population the answer for recruiting the hard to reach?
- Does the language used on forms affect recruitment of these subgroups?

Respondent Materials

Complexity of Surveys

Have travel surveys been used to collect information that is better collected in supplemental surveys? Where do we draw the line in determining how much data to collect? It is important to recognize that each metropolitan area has its own objectives. From a national perspective, commonality of questions for comparability is important. Perhaps there should be a core set of questions for all locations, to which local representatives can add questions to meet their objectives.

- Is there a relationship between survey length and response rates? What is a "long" survey? Does dividing data collection into stages (phasing) affect response rates?
- Do our questions collect the data we want?
- When should one survey collect all data, and when should supplemental surveys be conducted? What about the use of panel surveys versus cross-sectional surveys?

Activities Versus Trips

The theory behind using activities instead of trips is that using activities captures more walk-based trips. Trip purpose is defined from activities reported. Recent studies show that (*a*) activity diaries capture more gaps in time and higher trip generation rates (Salt Lake), (*b*) activity diaries are not necessarily more expensive, and (*c*) interviewers can probe by asking "What did you do next?" However, anomalies can result in the data; for example, home-to-home trips when people leave their houses and return when they forget something. In addition, in Boston these diaries capture people moving their cars to avoid parking violations.

Layout and Design

Layout and design of data collection instruments are important, especially with increased complexity. Understandable instructions and user-friendly forms are vital to respondent participation. Respondent packets must look different from junk mail. Research issues include the following:

- Should we use booklets or large pages?
- How should we handle people who travel for a living? (Sweden and Oakland/San Francisco collect everything from the person.)
- Does type of postage matter?

Incentives

As pointed out in the nonresponse resource paper, there is not enough research on incentives. No experiments have been conducted to prove whether expensive incentives work (e.g., offering $100 or $1000 in exchange for a detailed activity diary), although lotteries have been done. A 1990 Brownsville, Tex., study found that using incentives made no difference in response, whereas in Puget Sound, $1 worked better than $10. The Salt Lake and Oregon/Southwest Washington surveys did not use any incentives at all.

There is a difference between incentives and gifts or tokens such as pens and magnets. Motivational inserts such as brochures about a region's transportation or area maps could be used. The cover letter should be written to convey relevance and civic duty. However, attitudes and income vary in urban areas. What works in one area may not work in another.

Research questions, which could be covered with a synthesis of current practice, are

- When are incentives needed?
- What form should an incentive take?
- What are you trying to measure—if you have a survey with no incentive, and one with an incentive, what is the measure? Response rate? Or are there other things you are trying to work on?
- Does using incentives set a bad precedent for government?
- Who will respond to an incentive? Is it going to affect nonresponse bias?

Respondent Materials

Discussion on respondent materials centered on techniques to improve response rates, including designing materials based on the age, literacy level, and language of respondents and whether respondents have disabilities. Avoiding the use of jargon will improve response, as will providing definitions and limiting ambiguity. Research questions include

- How would customizing affect response bias? Would it make any difference in response rates, item response rates, response biases, trip rates, and data quality?
- How should data collected through special efforts be used? Do such data introduce problems in expansion?

Materials Used

Most travel studies include a cover letter, household form, and some type of diary or recording device in respondent packets. No conclusion has been drawn on whether including a memory jogger is beneficial. In the Oregon/Southwest Washington survey, respondents tended to use the memory jogger or the diary, but not both. This raises the question of whether all questions should appear in the diary or on the recording device. If all questions are not included, proxy reporting cannot be allowed, which results in an increase in partially completed households. This leads to these research questions: What are the trade-offs? Is there a difference in response rates?

New Technologies

Workshop participants identified three populations that are critical players in the household travel survey arena:

- Respondents: New technology must be used to reduce respondent burden, with the goal of reducing nonresponse. In addition, individual needs for privacy must be respected.
- Data collectors: The interviewer is the first line of contact with respondents. Life must be made as easy and comfortable as possible for interviewers.
- Data users: Data must be useful to analysts and forecasters. Technology should be used to improve accuracy of data, timeliness of data delivery, and travel demand models and resulting forecasts. Unless variables obtained from the interview process are capable of being forecast with an acceptable degree of accuracy, they should not be collected. Collection of household travel and activity data must be flexible to adjust to needs of new models. In addition, data collection costs and the likelihood of them increasing must be kept in mind.

State of the Art

Workshop participants made several assumptions about the state of the art and decided not to address the state of the practice. These assumptions are

- Random digit dialing (RDD) has replaced the housing unit sampling frame in most household travel surveys.
- Computer-assisted telephone interviewing (CATI) is used regularly, replacing paper-and-pencil interviews.
- Graphical user interfaces (GUIs) can improve CATI systems, particularly for trip rostering, in which trips reported by one household member can be replicated when household members travel together.
- Geocoding of trip ends uses geographic information system (GIS) technology and relies on maintained geographic street reference files. Geocoding has occurred in real time (during the interview) and, more often, in batch processing.

- Data loggers have been used to measure engine performance but have not been tied to traditional travel demand measures such as trips and trip purpose.
- The Global Positioning System (GPS) has been used for in-vehicle route navigation; however, it does not save information on path/route, travel start and end times, trip purpose, or vehicle occupancy.

Computer-Assisted Telephone and Personal Interviewing

Telephone interviews have become the primary data collection method for household travel surveys because of the high cost of in-home personal surveys and poor response to mail-out/mail-back surveys (i.e., those without telephone recruiting). Despite the increase in answering machines, caller ID used to screen calls, and avoidance of unsolicited phone calls, telephone interviewing is still likely to be the primary method used. Response rates to telephone surveys are likely to drop even further; however, in-person and mail-back surveys are not viable replacements. Personal telephone numbers (i.e., phone numbers that follow individuals instead of being tied to a specific location) are in testing stages. This will have a large impact on sampling design of telephone surveys. The time frame for or public acceptance of this concept is unknown.

We probably will move toward using combined methods so that specific target populations will be surveyed with appropriate methods. Some subpopulations may be best surveyed using computer-assisted personal interviewing (CAPI) and in-home interviewing. Alternative methods to reduce sample bias in telephone surveys must be developed. We need to understand the differences between travel needs and demands of households with and without telephones. The proportion of households without telephones varies widely by state and by household poverty status. Using 1990 Public Use Microdata Sample (PUMS) data, Cohen, in his 1993 report to FHWA, showed that 12 percent of households in New Mexico had no phone, whereas only 2 percent of households in Massachusetts had no phone. For the United States as a whole, households with incomes below $10,000 account for 16 percent of all households but more than 45 percent of households without telephones. Households without telephones also are more likely to be without a vehicle.

Most surveys use RDD instead of a housing unit sampling frame. Computer-assisted interviewing now includes CATI, CAPI, and self-interviewing (CASI). These interviewing technologies have proven beneficial in many ways. For one, the interviewer does not have to remember, or read, skip patterns or instructions. This permits him or her to concentrate on getting respondents to cooperate and answer questions. CATI and CAPI improve the accuracy and detail of data collected because responses to earlier questions can be used to tailor later questions closely to respondents' actual experiences. In addition, comparing responses for inconsistencies can be done "on the fly" during the interview. Other benefits include access to data, such as longitudinal data, from other sources; the ability to bring these data into the current survey; on-the-fly sampling; and easy randomization of the presentation of questions.

GUIs are becoming more common in CATI and CAPI, which will make things easier for the interviewer. GUIs have been used in household travel surveys to access vehicle make and model data bases so that checks for valid vehicle make, model, and model year can be made in real time. In addition, GUIs have been used for trip rostering, in which trips reported by one household member can be replicated when household members travel together, thus reducing respondent fatigue.

Workshop participants believed that the survey industry should pursue GUI development and that transportation surveys do not have specific needs except for the need for integrated CATI/GIS.

GIS Technology

A synthesis project is needed to document GIS uses in travel surveys. This project should cover GIS technology's role and the costs and benefits of using this type of software in travel surveys.

On-line geocoding of addresses, or coding of trip destinations during telephone interviews, has been implemented in the Baltimore, Md., area by the Baltimore Metropolitan Council. For this project to be successful, a geographic base file with individual addresses or address ranges for street segments and a list of landmarks incorporating colloquialisms or nicknames must be maintained. These geocoding programs have at their origins a GIS, but have been translated into data base files for integration with CATI. In the state of the art, CATI has integrated a GIS only after the GIS data base has been converted into a relational data-base structure that loses much of its connectivity to geography. As documented by Ng and Sargeant in *Transportation Research Record 1412*, Toronto used extensive "monument" and landmark files and street address directories during CATI and to correct spelling and check feasible addresses. Detailed transit route choice information also was collected during interviews using on-line files of transit route information, including feasible transfers between routes. Actual geocoding was done in batch mode after the interviews.

Workshop participants would like to see the development of an integrated CATI/GIS in which connectivity is maintained so that as one address is located, a map pops up, and when a second address is located, the map appears with perhaps a computer calculated shortest path. This would facilitate the correct coding of complicated trips, especially those made on transit. Similarly, if a respondent does not know the address of a business and refers to a business name, the CATI/GIS could locate the business within the stated estimated distance and present it as an alternative choice to the respondent.

The travel demand modeling field is moving toward integrated land use and transportation models. This can best be accomplished by using GISs. The transportation profession needs to work more closely with geographers and urban economists to develop a standard urban form typology so that comparisons across areas can be made more easily and thus can make these models functional for different areas. Once a useable typology has been established, a GIS can be used for sample selection in household travel surveys. Some regional surveys, such as the one in Raleigh-Durham, N.C., have defined land use types for sample selection; however, because no standard has been established, comparisons are nearly impossible.

Other Computer Technologies

Other computer technologies discussed by workshop participants include pen-based systems and computer-based self-interviews conducted by sending diskettes to people or by sending data via modem or the Internet.

The pen-based system most familiar to participants was signing for UPS packages and for traffic violations/ticketing; however, participants were not aware of its use in transportation surveys. There are two kinds of systems: one in which a stylus and a screen replace pen and paper and another in which pen and paper are used but an electronic clipboard underneath the paper serves as the data collection point. This technology might be appropriate in conjunction with having travel survey respondents mark their routes on a map shown on a CAPI screen. This technology could be used in areas where people can choose toll or non-toll facilities and freeways or arterials. In a London Transport Study conducted in the 1960s, people were able to trace their routes on paper maps satisfactorily.

In Europe, particularly the Netherlands and France (with mini-tels), survey respondents have been provided computers and/or data-link hookups with which to respond to transportation surveys. Providing these instruments to respondents would be particularly effective in longitudinal surveys, in which the same respondents are surveyed over time.

Workshop participants had three primary concerns about using this approach: sample bias, computer viruses, and appropriate use of the Internet. Many subpopulations, such as the elderly and low-income and less-educated households, are not likely to have access to the Internet. Some surveys of businesses and professionals have used diskettes to send surveys and receive responses; however, this is dangerous because new viruses may be transmitted—viruses of which virus checking programs are unaware. In addition, the Internet is not supposed to be used for commercial applications, and it would be impossible to define a

population universe or to control access to any survey form. As in telemarketing, some sales pitches are structured to appear as surveys, and a similar problem could arise if surveys were allowed on the Internet.

GPS and Intelligent Transportation Systems

Workshop participants believed that GPS and intelligent transportation systems (ITS) can improve household travel data by improving accuracy. However, there could be large roadblocks ahead if the public believes these research techniques and travel management methods are invasive and that "big brother is watching."

Workshop participants wanted to compare self-reported travel with machine-recorded travel using GPS. Machine-recorded travel is likely to be more accurate in measuring travel distance and time, and subsequently, speed, and in counting vehicle starts and restarts. Although participants did not envision a time when all household travel survey respondents are asked to attach a GPS unit to their vehicles, they did believe that a sample could provide rates with which to adjust self-reported travel data. Using GPS may be more expensive per respondent, and researchers may want to explore the use of GPS with longitudinal surveys so that GPS units would go to fewer respondents, but data would be collected for a longer period of time. Once an actual path is recorded, it could be compared with the shortest path as calculated by a computer travel model. This would permit hypotheses on travel behavior as reflected in the model to be reviewed.

Vehicle travel is only one form of personal travel. Participants discussed the potential of using "body packs" to track individual movements. Research in the health sciences has included such projects for environmental monitoring and measuring exposure to harmful materials. Usually, monetary incentives are provided to encourage participation in this kind of research. Any work in this area would have to be reviewed carefully for privacy issues.

There are three basic aspects of ITS: advanced traffic management systems (ATMS), advanced traveler information systems (ATIS), and advanced vehicle control systems, such as automated highway and safety systems. The ITS area most relevant to household travel surveys is ATIS, in which current travel conditions are available either in the home, on a personal digital assistant, or at various locations. ATIS could provide information such as travel times on specific paths or at different departure times. An individual receiving this information might select an alternate destination or omit a trip, if it is perceived as discretionary.

Using an ATMS and GPS, one could collect transportation system operation characteristics with the GPS-recorded travel. For example, if a trip is recorded by GPS at 20 mph on an interstate, the congestion levels and system-reported travel speed matched by time and date could be attached to the trip record.

Vehicle instrumentation projects include work on vehicle emissions for the Environmental Protection Agency (EPA) and for ITS. So far, no project has integrated household travel with GPS-measured vehicular travel. EPA data-logger projects have focused on engine performance and vehicular emissions and have omitted the connection to trip purpose, number of persons in a vehicle, and other variables that may be needed in travel demand models. The EPA project at Georgia Tech is just beginning to include GPS in its vehicle instrumentation, and researchers would like to incorporate a travel diary into their data collection effort. ITS projects, primarily in-vehicle navigation systems, generally are used to direct a driver to a specific route by showing him or her the shortest path and ways to avoid congestion. These systems could save information that could be used in transportation planning, such as trip start and end times and path selection.

Video, Multimedia, and Virtual Reality

Video has been used for interviewer training; however, workshop participants were not aware of instances in which video or other multimedia were used to help respondents complete

survey forms. Using these not-so-new technologies might increase response rate and improve data reliability.

Participants suspected that respondents often do not read the directions accompanying survey forms. Illiteracy and immigrants, for whom English is a second language or a language they do not speak at all, also limit response. Because our society relies so much on television, perhaps a short video would encourage more people to spend 5 to 10 min (*a*) to help them understand how the data being collected will be used and (*b*) to show them how to complete survey forms.

Video and multimedia also could be used in the area of stated response/stated preference. Workshop participants believed that use of simulations with CAPI and video/multimedia on computer screen holds promise. Currently, when people are presented alternatives for stated response, descriptions of these alternatives are given over the phone, in person, or on a card. Video and multimedia—or with great expense, virtual reality—could provide visual and more experiential versions of such choices as walking to a rail station, paying a fare with a "smart" card, waiting for a train, and riding a train. In addition, a simulation of congested driving conditions with recommendations for alternate routes could be provided. Finally, conditions that would make people change their behavior would be evaluated.

Topics for Research Problem Statements

Workshop participants cited the following as high-priority items:

- Using GIS technology for sampling, including development of typology of urban form;
- Using GPS to improve accuracy of travel behavior information; and
- Integrating GIS into CATI for on-line geocoding.

The following are medium-priority items:

- Using CAPI for stated-preference research;
- Using CAPI for multimedia-assisted interviewing; and
- Creating a research synthesis on using GIS technology in household travel surveys.

These items were given medium to low priority:

- Route coding using GIS technology in personal interviews; and
- Using multimedia instructions in household travel surveys.

Workshop participants identified these items as having low priority:

- Monitoring personal travel with GPS body pack units; and
- Monitoring the effect of personal telephone numbers on household sampling.

Research Problem Statements

Using GIS for Developing Standard Land Use Types and for Drawing Spatial/Geographic-Based Samples

GIS technology adds a dimension to samples drawn for household surveys. Typical samples are stratified by household demographic characteristics, such as number of people in and number of autos owned by a household, or by income, as a variable of wealth. Only recently have metropolitan planning organizations (MPOs) considered drawing samples by specific area and/or area type.

Because of insufficient attention given to land use issues, no current survey data have the capability of producing travel data that can ascertain the effect of land use patterns with the

desired level of reliability. GIS technology allows the location of sampled households to be addressed and analyzed in a reliable way.

Proposed Research

No current definitions of area types exist. Designations such as central business district (CBD), suburban, and rural denote area types; however, there is no stable, quantifiable definition of what constitutes a CBD. In Phase 1 of this research, standard definitions of urban forms, with quantifiable area type designations for use in Phases 2 and 3, will be established. Terms familiar to transportation planners—CBD, fringe, suburban, and rural—should be grounded in theory and demonstrably affect travel patterns. These terms should include transportation accessibility measures and should be applicable across the U.S. landscape (i.e., the definition of suburban area type should be the same whether the term is used in San Francisco, Calif., or in Duluth, Minn.).

In Phase I, geographically coded travel data from cities representing a range of geographic aspects and sizes will be collected. Data from a minimum of 30 areas should be collected and used. Trip rates, travel times, auto occupancy, and other pertinent characteristics will be compared to ascertain what densities and land use types affect these variables. A definition of what constitutes an area type will be developed. This definition should be transferable (i.e., useful from urban area to urban area) and differentiated (i.e., suburban should be demonstrably separable from fringe).

Some available geographic location data that might separate household travel behavior are distance from the center, distance from subway or bus station, and single versus mixed use areas. Some comparative data are trip length, mode use, trip time, average speed, and vehicle miles of travel (VMT) per household.

Phase 2 of this research will develop sampling and weighting procedures based on area type. This phase will include the use of statistically different travel characteristics to develop urban typology to calculate the coefficients of variation and sample sizes needed to accurately represent travel of households—not only by household demographics and trip characteristics, but by land use patterns and area type. This phase will include development of a sample design methodology based on urban typology, in addition to the demographic characteristics commonly used, and a set of weighting procedures to expand sample data to reflect total area.

In Phase 3, alleged land use types and sample/expansion procedures will be tested. The use of a sample drawn by area type may affect the descriptive statistics that result from a travel survey. For the testing phase, it is proposed that a researcher take a household sample survey selected from a typical demographic matrix (e.g., number of persons in the household and autos owned) and reallocate the households based on the newly developed area types. The confidence and error by area type will be calculated from the number of households that fall into each area. The household survey data will then be reexpanded based on geographic characteristics and weighting procedures developed in Phase 2. Descriptive results of the reexpanded data will be compared with the data expanded on demographic characteristics, and any significant differences will be documented.

Recommended Funding

$250,000 to $500,000.

Urgency, Payoff Potential, and Implementation

This project is urgent because samples based on area types with little theoretical foundation are being drawn. The payoff potential is great because a quantitative measure of the effect of urban form, including accessibility and availability of modal options, on transportation is vital to future policy. Phase 1 should include cities of all sizes from across the country; Phase 2 should be conducted by a trained statistician (but written for us simpletons); and Phase 3

should use a recent survey with a larger sample size (2,500 or more) to ensure coverage for possible area types.

Improving Accuracy of Travel Behavior Information Using GPS

Analysts are placing increasing demands on data obtained from household travel surveys, and greater data accuracy is desired. Current data collection efforts consist of collecting self-reported trip and activity information; however, this practice is suspect because of omissions (missing short trips or missing stops in trip chains) and errors caused by rounding minutes and miles. In addition, the information collected does not include speed data by link and road classification or VMT by road classification. Because a majority of trips are made by private vehicle, a vehicle-based GPS project will provide many trips for comparison with self-reported trips.

Proposed Research

Researchers will work with a state department of transportation and an MPO to test the use of vehicle-based GPS for household travel surveys. Conventional household travel survey data, including appending network data on distance and speed, will be collected simultaneously. The components of this research follow:

- Develop and test units that can be sent to randomly selected households for attachment to household vehicles, without requiring skilled technicians to attach the machinery. These units may be a combination of GPS components, personal digital assistants, and data storage devices.
- Conduct a pilot test, including the processing of collected GPS data into travel links that are matched to a GIS base file and can be analyzed for road classification, speed, VMT, time of day of travel, trips, and trip chains. Household travel data comparable to self-reported data collected by conventional household travel surveys also will be collected.
- Compare results from conventional methods with results from GPS methods.
- Develop factors that allow conventional household surveys to represent real-world conditions more accurately.
- Analyze actual travel as collected by GPS with network choice of shortest path. Are people really optimizing their travel by using the same criteria as the model? Or are other factors heavily influencing their decisions (e.g., a dislike of driving on freeways, avoidance of tolls, a dislike of rural roads, and so on)?
- Append transportation system performance characteristics from ATMS to trip records. GPS will tell which links were used, and ATMS will describe conditions such as travel speed. Heavy congestion can make a 10-mi trip on an interstate take 30 min; therefore, a record should not be deemed unreasonable and discarded during quality control.

Recommended Funding

$250,000 to $500,000.

Urgency, Payoff Potential, and Implementation

Self-reported behavior needs to be compared with actual behavior, especially if accurate emissions and other data are to be computed and forecasted. Self-reported data needs to be validated, and if necessary, adjusted to produce better analyses and forecasts.

Integrated CATI and GIS

Household travel surveys usually ask respondents to report addresses of places they visited on their assigned travel days. This information, however, may be unknown because people

travel to many places out of habit and locate them by using landmarks instead of a specific street name and number. Analysts want great detail and accurate information about each trip and want each trip destination to have an accurate x,y coordinate.

By integrating GIS with CATI, respondent burden can be reduced by helping respondents locate destinations, often without requiring them to supply a specific street address. Instead, business names, landmark files, and cross-street references can be used. The use of GIS with CATI may make on-line geocoding faster and easier, reducing both respondent and interviewer burden, and can increase accuracy of results.

In postcollection geocoding, many anomalies are corrected by the analyst or not corrected at all. Even with a 70 percent "hit" rate, a travel survey can produce many trip ends that need to be corrected. On-line coding can reduce respondent burden, increase the reliability of the coded trip end, increase the hit rate, and lower the cost of geocoding. In addition, it can decrease the amount of time required between collection and completion.

Proposed Research

It is proposed that researchers, in cooperation with an MPO-sponsored travel survey, develop a prototype system that integrates GIS and CATI. The CATI program should provide various mechanisms to help the interviewer capture trip origins and destinations and to correctly geocode records to x,y coordinates, using data-base and geographic base files. Two mechanisms could be used: one that is similar to current on-line geocoding efforts that look for similar street names and then check for valid address ranges and another that provides an on-screen map that begins with the residence location and traverses to each destination using search techniques for business names, distance from last location, and travel time. Results should be compared with results from similar travel data collection efforts without GIS integration, including interview time (to ensure the added component does not add to respondent burden) and the geocoding hit rate (with on-line and postprocessing compared).

Recommended Funding

$100,000 to $250,000.

Approaches To Improve the Presentation and Understanding of Transportation Alternatives in Stated-Response (Stated-Preference) Surveys

When presenting new travel options in interviews or surveys to gauge future patronage, market researchers have had to depend on uncontrolled elements. Traditional techniques of providing options for respondents to consider or rank in importance increase respondent burden and decrease confidence in results. That is, using descriptions alone makes those who conduct surveys depend on a respondent's imagination to envision a new scenario or option and ability to judge small differences in time and cost. New technologies allow attributes influencing travel behavior choices to be represented more realistically, while decreasing respondent burden by customizing and personalizing survey/experimental tasks.

Proposed Research

Research is needed to investigate attributes that influence travel choices in combination with new presentation and interviewing techniques. This study would document the use of CAPI in developing an interview environment that simulates new travel options for the respondent. The goal of this research is to present the respondent with a context for stated response, which reduces respondent burden and more evenly and fully represents a new scenario or future transportation alternative.

It is proposed that researchers, in cooperation with an MPO-sponsored travel survey, design and integrate stated-response techniques using new and alternate technologies to evaluate the respondent's interaction with presented attributes. For example, CAPI, which uses a notebook computer to assist the interviewer during face-to-face interviews, could use the new

tools and the power of the notebook computer to include sophisticated graphics, multimedia, interactive questioning, and so on.

Simulation would be part of the interviewing package to familiarize the respondent with unfamiliar concepts and collect response data at intervals. For instance, the simulation could walk the respondent through a new transit station, including through escalators, fare-paying procedures, turnstiles, platforms, and boarding with detailed stated-response questions on each phase of the walk-through.

CAPI would be conducted at households identified through traditional household interviews or focus groups to test the critical dimensions of respondents' choice/acceptance patterns. CAPI could be compared with more traditional interviewing (either computer-assisted or paper-and-pencil) to test the interview environment and results. The results would present conclusions on what simulation method offers better respondent perception, better comparison of results between respondents, and the like.

Recommended Funding

$100,000 to $250,000.

Urgency, Payoff Potential, and Implementation

This research has medium urgency. The payoff potential is high where private/public partnerships are being considered for new transportation alternatives, especially transit (this may be more likely overseas). The most likely implementation would be in areas in which patronage forecasts are critical to policy makers and funding agencies; for instance, where a private entity builds the infrastructure for a portion of the fares for a set number of years.

Multimedia-Assisted Interview

The traditional CAPI instrument is intended only for the use of interviewers. The proposed research will investigate the value of including multimedia presentations in CAPI to help interviewers obtain more accurate answers from respondents.

Proposed Research

The proposed research is to use a subsample from a proposed CAPI household travel survey to determine the effectiveness of employing multimedia presentations in personal interviews. At predetermined points, multimedia presentations will be available for interviewers to present to respondents so that interviewers can (*a*) clarify questions, (*b*) offer respondents graphic and audio presentations that explain the intent of questions, and (*c*) prompt respondents for more accurate responses. Multimedia presentations will be available in a variety of languages so that the interviewer can use a presentation in the primary language of the respondent.

The research will compare responses from respondents who received a text-only-based CAPI with those who received a multimedia-based CAPI. The additional cost to prepare the multimedia presentation will be compared with the quality responses and any time differences (interviewer costs) between the two instruments. A benefit/cost analysis will be part of research results.

Recommended Funding

$50,000 to $100,000.

Urgency, Payoff Potential, and Implementation

If the research proves that providing this supplemental material raises the quality of responses and reduces CAPI interviewing time, the benefits should outweigh the marginal costs of preparing the multimedia material in a variety of languages.

Research Synthesis on Using GIS Technology in Household Travel Surveys

GISs offer many benefits in the conduct of household travel surveys. These benefits include more effective and efficient data collection, improved data quality, and reduced survey costs. In addition, GISs provide a platform for data integration and provide more flexible output products to better interpret survey results. The purpose of this research is to develop a comprehensive synthesis on the use of GIS technology in household travel surveys.

Proposed Research

The objectives of the proposed research are to

- Perform a comprehensive review of potential uses of GISs in household travel surveys;
- Develop guidelines and methodologies for using GISs in household travel surveys;
- Identify critical issues regarding data needs in terms of types of data (e.g., base map and land use), accuracy/precision of data, and temporal considerations;
- Identify costs and benefits of using GISs in household travel surveys; and
- Establish criteria for selecting hardware and software.

The proposed activities for performing this research include (*a*) performing a comprehensive literature review, (*b*) conducting pilot projects, and (*c*) reporting results/technology transfer.

Recommended Funding

$100,000 to $250,000.

Urgency, Payoff Potential, and Implementation

This effort should be conducted within the next 2 years to encourage regional agencies to progress into GIS activities not limited to survey research. The technology is changing rapidly; therefore, it may be appropriate to make this effort now—and again in 4 to 5 years.

Path-Coding with Pen-Based Technology in CAPI

A potential application of GIS technology in household travel surveys is to use pen-based technology to ask respondents to identify paths and routes during CAPI surveys. By including GIS components in a CAPI program, respondents can mark paths and verify that origins and destinations have been geocoded properly. The purpose of this research is to determine the benefits of using a GIS for CAPI surveys and to weigh these benefits against costs.

Proposed Research

The objectives of this proposed research are to

- Develop guidelines and methodologies for using pen-based technology with CAPI;
- Identify costs and benefits of using a pen-based technology for route coding in household travel surveys; and
- Develop prototype software and test it on a functional CAPI system.

The proposed activities for performing this research include designing and conducting a GIS-based CAPI and reporting results/technology transfer.

Recommended Funding

$100,000 to $250,000.

Urgency, Payoff Potential, and Implementation

This research has medium priority. Questions about route choice and whether people choose the shortest path, as assumed by current models, must be answered.

Multimedia Respondent Training

Respondents to CAPI and CATI household interviews often have trouble answering questionnaires because of language or other difficulties. The purpose of this research is to determine the benefits and costs of preparing specialized videos to enhance response rates and response accuracy.

Proposed Research

The proposed research project will develop VHS videotapes that explain the purpose of a household travel survey and educate respondents on how to answer questions. Once a respondent views the videotape and does any accompanying exercises that show how to answer questions more fully, he or she will be asked to call an 800 number for a reverse CATI operation or be provided detailed instructions on how to prepare travel diaries.

The VHS tapes will be developed in several languages and mailed to qualified respondents. Depending on the language used in the videotape, the 800 number will connect a respondent to an interviewer who speaks his or her language. The research will compare the quality of answers between respondents who receive the video and those who do not. This will help determine how the videos affect the quality of answers and responsiveness of respondents.

Recommended Funding

$50,000 to $100,000.

Urgency, Payoff Potential, and Implementation

If the research proves that providing this supplemental material raises the quality of responses and reduces CATI interview time, the benefits should outweigh the marginal costs of preparing the videotapes.

Monitoring Personal Travel with Body-Pack Units

There is an increasing need for accuracy in data from household travel surveys. Current practice is to use self-reported trip and activity information, but this practice can create omissions (missing short trips or stops in trip chains) and errors caused by rounding minutes and miles. In addition, the information collected does not include speed data by link or road classification or VMT by road classification. A project that uses vehicles equipped with GPS misses trips not made in private household vehicles, such as walking, bike, and transit trips.

Proposed Research

To evaluate the feasibility of this project, researchers will look for examples of research in which people were asked to attach a machine to their bodies (e.g., research into personal

exposure to environmental hazards). A focus group or a few face-to-face interviews will be conducted to determine whether asking respondents to attach a unit to their bodies for travel behavior research would fly and to determine medical/health implications. Appropriate hardware and software will be developed, units will be tested on a small number of persons, and results will be compared with the recall or diary method of trip/activity reporting.

Recommended Funding

Less than $100,000.

Urgency, Payoff Potential, and Implementation

Because current technology requires bulky instruments instead of wristwatch-sized units, this research is less urgent than vehicle-based GPS research. Body-pack units have the potential for reducing respondent burden; however, the trade-off would be a reduction in privacy.

Use of Personal Telephone Numbers for Travel Surveys

With new technology upon us, everyone will have a personal telephone number wherever he or she goes. To better determine travel behavior and to use this information to develop travel demand models, personal trips will replace those generated at households. Personal trips could be monitored to provide data on daily travel patterns and trip purposes, time-of-day and mode decisions, and trip chaining decisions.

Proposed Research

The proposed research would determine whether trips should be recorded per person instead of by household. Because there is no geographic basis to determine these trips, researchers must discover whether sampling by personal phone numbers instead of by stratifications by household and vehicles owned can be done adequately. Sampling techniques need to be examined. A possible use of personal telephone numbers may be to call people who have these numbers and ask what they are doing at a particular moment.

Recommended Funding

Less than $100,000.

Urgency, Payoff Potential, and Implementation

Will this technique replace the typical household survey? What are the implications of this technology? What changes would it cause? This research proposal has low priority because the technology will not be available for about 5 to 10 years.

RESOURCE PAPERS

Nonresponse Issues in Household Travel Surveys

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Sample surveys in transport are invariably associated with some level of nonresponse. The issue of nonresponse is fundamentally connected with the questions of reducing survey bias and increasing the accuracy of sample estimates. This is because nonrespondents are from segments of the population having characteristics significantly different from those of respondents. The differences are in sociodemographic characteristics and, more important, in travel behavior characteristics. Some of the background concepts of transport surveys within which nonresponse should be considered are described. In particular, the distinction between sampling error and survey bias and the trade-offs between quantity, quality, and cost of survey data are described. Ways of reducing nonresponse and the impacts of nonresponse are discussed. The need to consider all sources of nonresponse in different types of survey and the importance of using consistent methods of calculating nonresponse are stressed. The use of population expansion factors, nonreporting weights, and nonresponse weights as ways of allowing for the remaining extent of nonresponse is described. The use of these methods is demonstrated by reference to a mailback questionnaire survey.

Sample surveys in transport are invariably associated with some level of nonresponse. The issue of nonresponse is fundamentally connected with the questions of reducing survey bias and increasing the accuracy of sample estimates. This is because nonrespondents are from segments of the population having characteristics significantly different from those of respondents. The differences are in sociodemographic characteristics and, more important, in travel behavior characteristics. For example, nonrespondents to postal questionnaires tend to travel less than respondents to such questionnaires. If allowance is not made for this known difference, estimates of total travel and travel distance will be overestimated from such surveys. This will result in overestimates of emissions and fuel consumption in the survey area. Other types of nonresponse bias are associated with other survey methods.

Some of the background concepts of transport surveys within which nonresponse should be considered are described. In particular, the distinction between sampling error and survey bias and the trade-offs between quantity, quality, and cost of survey data are described. Ways of reducing nonresponse and the impacts of nonresponse are discussed. The need to consider all sources of nonresponse in different types of survey and the importance of using consistent methods of calculating nonresponse are stressed. The use of population expansion factors,

nonreporting weights, and nonresponse weights as ways of allowing for the remaining extent of nonresponse is described. The use of these methods is demonstrated by reference to a mailback questionnaire survey.

Transport Survey Process

The conduct of a household travel survey is not an informal procedure. It should follow a series of logical, interconnected steps that progress toward the end product of the survey. The stages in a typical sample survey are shown in Figure 1 (*1*). They include preliminary planning, selection and design of a survey method, and design and selection of a sample. An important but often neglected component is the pilot survey, which gives a chance to correct the inevitable errors in the original design. After the survey, the data are coded, edited, and made ready for analysis. It is important at this stage to correct biases in the data and to apply expansion factors to obtain estimates of parameters for the original population from which the sample was drawn. Finally, the results of the analysis are presented to the client, and the survey process is tidied up by the production of documentation and the storage of the data.

In the survey process just outlined, there are three types of linkages between activities: forward, feedback, and backward linkages. The forward linkages are relatively obvious. For example, the questionnaire design cannot begin until the survey method has been selected. The feedback linkages indicate that two or more activities must be performed sequentially in a closed loop. For example, after the pilot survey has been performed, it may be necessary to redesign the questionnaire and then pilot test the new questionnaire. Backward linkages indicate that information must be transferred from an activity occurring later in the process to one occurring early in the process. For example, the design of the questionnaire will be affected by the coding procedure to be used later, whereas the coding procedure will depend on the type of analysis to be performed on the data. Whereas such backward linkages may not be highly visible, it is important that consideration be given to them so that decisions made early in the process will not proscribe options for later data analysis. This is particularly the case for the treatment of nonresponse issues; it is too late to discover that there is a problem with nonresponse after the conduct of the survey. Nonresponse issues must be recognized before the survey is begun, and plans must be made to reduce the nonresponse and to account for nonresponse in the overall survey design.

Trade-Offs in Transport Survey Design

Good survey design demands making trade-offs between the competing requirements of good design practice in several areas (such as sample design, survey instrument design, conduct of surveys, and data weighting and expansion) to arrive at the most cost-effective, high-quality survey meeting the needs of the client within budget constraints. The overall nature of these trade-offs is shown in Figure 2.

The underlying nature of the trade-off process is the "Architect's Triangle," in which quantity and quality are traded off against cost. A trade-off occurs because it is impossible to control all three of the major elements in Figure 2. At best, only two of the three can be controlled by the survey designer. Given a fixed budget, as is normally the case, the decision to obtain data of a specified quality will control the quantity of data that can be collected. Alternatively, within a fixed budget, specification of the quantity of data to be collected will dictate the quality of the data that can be collected. That is, we can collect a greater quantity of low-quality data or a limited amount of higher-quality data within a given budget. Generally, the latter course of action is preferred.

The quality of data to be collected is a function of the survey method selected and the quality of the sample (insofar as the sample is free of bias). The quality of data obtained from any survey method will, in turn, be a function of the quality of the survey instrument design (i.e.,

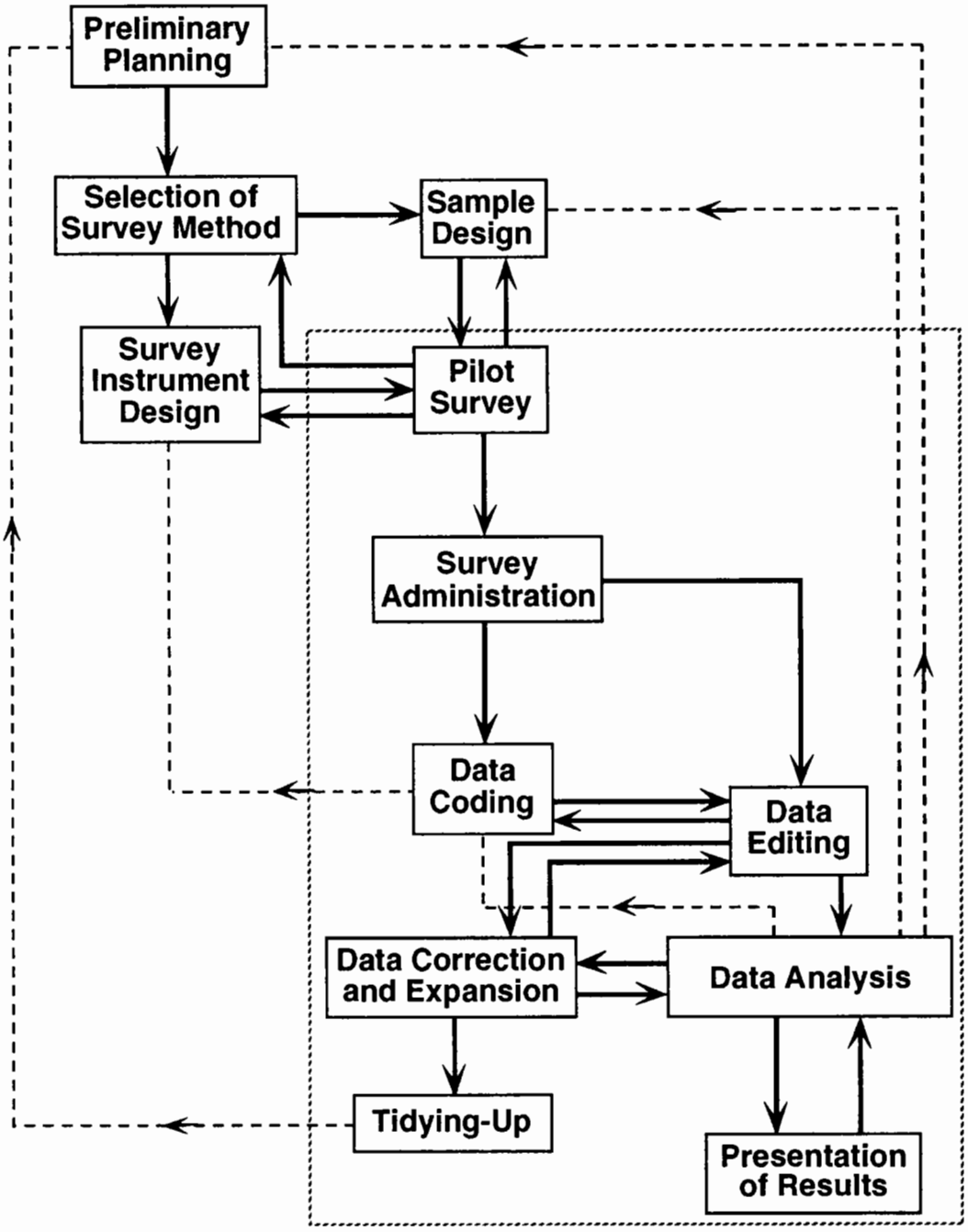

FIGURE 1 Transport survey process.

whether it collects information on the variables of interest in an unbiased way) and the quality control procedures put in place for the implementation of that survey method (i.e., the follow-up procedures to be used to verify the quality of the data collected). The quality of the sample will depend on the ability of the sampling frame to truly represent the population and the extent to which the sample selection procedures result in a random selection from the sampling frame.

The quantity of data collected will be a function of the number of respondents in the final data set and the amount of information obtained from each respondent. This, in itself, presents a trade-off situation, because any attempt to collect more information from each respondent (beyond a threshold level of information) may result in fewer responses. The total

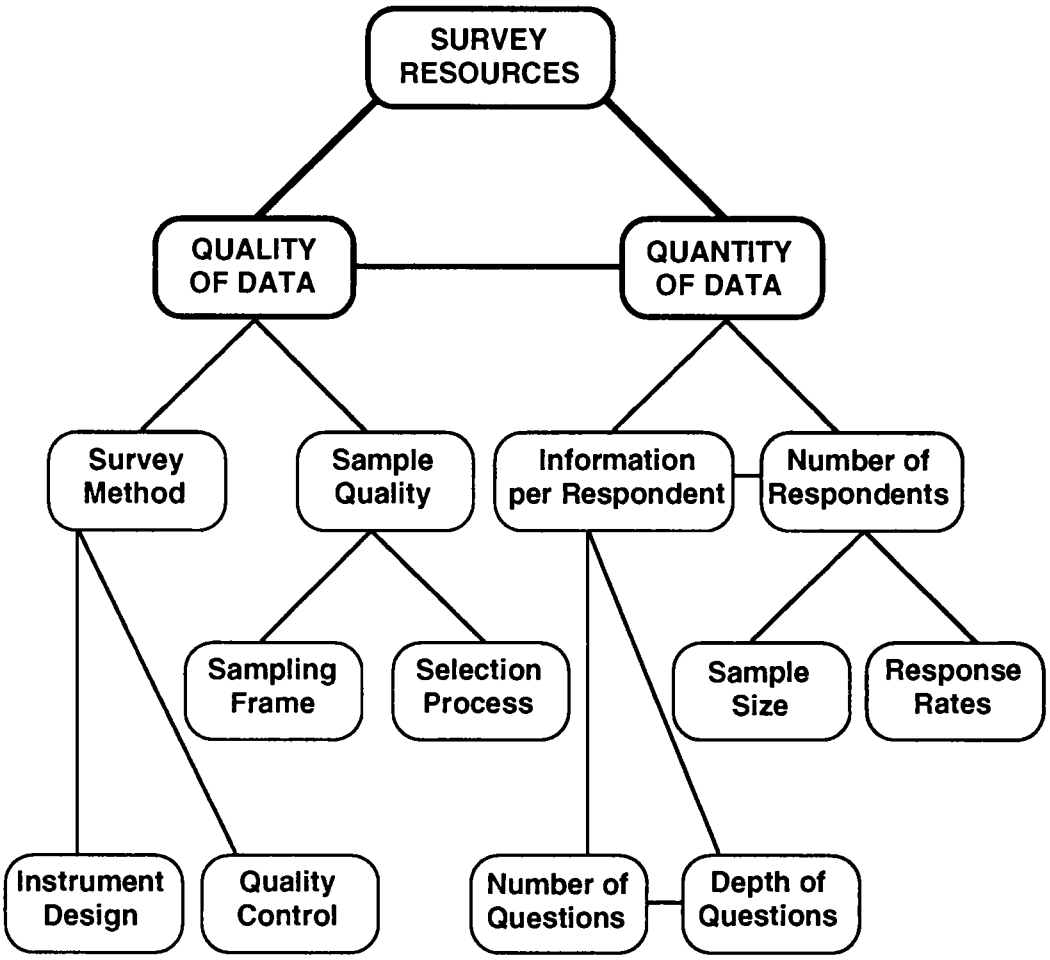

FIGURE 2 Trade-offs in the transport survey process.

number of respondents will obviously depend on the size of the sample drawn and the response rate obtained from that sample. The amount of information obtained from each respondent will depend on the number of questions asked and the depth of the questions asked. Thus some surveys can be effective with only a large number of highly directed questions, whereas others need to explore a few topics in depth. The extent of this trade-off is therefore a specific decision of the survey designer. The trade-off will also be partly determined by the respondents themselves. As the length of the survey increases, the response rate will generally decrease (the rate of decrease will depend on such factors as the interest level of the survey topic to the respondents and the overall quality of the survey instrument design). There will be a point at which an increase in the number of questions asked will result in the collection of fewer data in total because of the more than proportional decrease in the response rate. The survey designer should recognize this interaction when making the trade-off between the number of respondents and the information obtained per respondent.

In considering the trade-off between quantity, quality, and cost of data, it is unfortunate that more attention has been focused on the quantity of data that can be collected for a given cost than on the quality of the data so collected. It is important to realize the implications of concentrating on data quantity rather than data quality.

Sampling Error and Survey Bias

Despite all our best intentions in sample and survey design, the parameter estimates made from sample survey data will always be just that: estimates. There are two distinct types of

error occurring in survey sampling and design, which, combined, contribute to measurement error in sampled data.

The first is termed sampling error and is the error arising simply because we are dealing with a sample and not with the total population. No matter how well designed our sample is, sampling error will be present because of chance occurrences. However, sampling error should not affect the expected values of parameter averages; it merely affects the variability around these averages and determines the confidence that one can place in the average values. Sampling error is primarily a function of the sample size and the inherent variability of the parameter under investigation.

The second type of error is termed survey bias. It is a completely different concept from sampling error and arises because of mistakes made in choosing the sampling frame, the sampling technique, the choice and design of questions, the nonreporting of information by respondents, nonresponse from elements of the sample, or many other aspects of the survey design. Survey bias is different from sampling error in two major respects. First, whereas sampling error only affects the variability around the estimated parameter average, survey bias affects the value of the average itself and hence more severely distorts the survey results. Second, whereas sampling error can never be eliminated and can only be minimized by increasing the sample size, survey bias can be virtually eliminated by careful attention to various aspects of sample survey design. Small sampling error gives rise to precise estimates, whereas small survey bias gives rise to accurate estimates.

The difference between these two sources of error is sometimes confused, with attention being paid to reducing sampling error while relatively little attention is paid to minimizing survey bias. To understand the difference between the two concepts, consider an analogy with rifle marksmanship as shown in Figure 3.

Figure 3 shows four essentially different ways in which rifle shooters may hit the target. The marksman firing at the top left target consistently hits the bull's-eye. The marksman firing at the bottom left target centers his shots on the bull's-eye but tends to spray his shots; he seems to aim at the right point but to suffer from a slight movement of the rifle at the last moment so that his shots are not consistent. The top right target shows the results of a marksman who consistently misses the bull's-eye; he holds the rifle rock-steady but is aiming at the wrong point, maybe because the telescopic sights on the rifle are out of adjustment. The

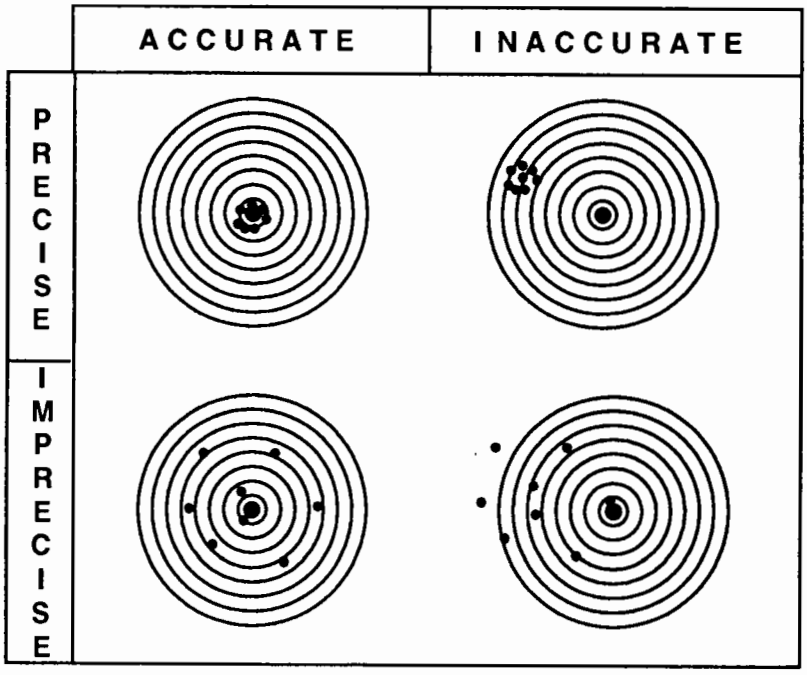

FIGURE 3 Distinction between accuracy and precision.

marksman firing at the bottom right target appears to be aiming at the wrong point, but because he also suffers from nervous jitters he sometimes hits the bull's-eye even though he is not aiming at it. These four situations may be categorized in terms of the precision and the accuracy of the shots; precise shooters always hit the same spot, whereas accurate shooters aim at the right point on the target.

It is clear which of the four shooters would be regarded as the best; the top left shooter shoots with both accuracy and precision in that he consistently hits the bull's-eye. It is also probably safe to say that the bottom left shooter is the second best in that he is at least on target (on the average). However, it is not quite so clear which of the remaining two is the worse. Is it better to be consistently off target or inconsistently off target (where at least you have some chance of hitting the bull's-eye)?

The judgment of the quality of marksmanship is made more difficult when the bull's-eyes are removed to leave only the holes left by the rifle shots, as shown in Figure 4. In this case, it is difficult to say whether the top left or the top right group of shots came from the better marksman. Indeed, one may argue that the two groups are equally good. In the absence of knowledge about where the marksmen were aiming, one is more readily swayed by the precision of the shots in judging the quality of the shooter. Without this knowledge, the top right group of shots might be considered the best, whereas in Figure 3 it might have been considered the worst.

The preceding description of the marksman is analogous to the design and use of sample surveys. A precise survey displays repeatability; that is, if it is repeated under similar conditions it will yield the same answers (whether the answers are right or wrong). On the other hand, an accurate survey displays validity in that the survey asks the correct questions in the correct way and gets responses from a correct sample of the correct target population. The precision of a sample survey can be increased by increasing the sample size to reduce the possibility of unobserved members of the population having, by pure chance, characteristics different from those observed. The accuracy of a sample survey can be increased by ensuring that (*a*) the sampling frame does not systematically eliminate some members of the population, (*b*) the sample is obtained from the sampling frame in a truly random fashion, (*c*) the correct questions are asked in the correct way, and (*d*) responses are obtained from a representative selection of the original sample.

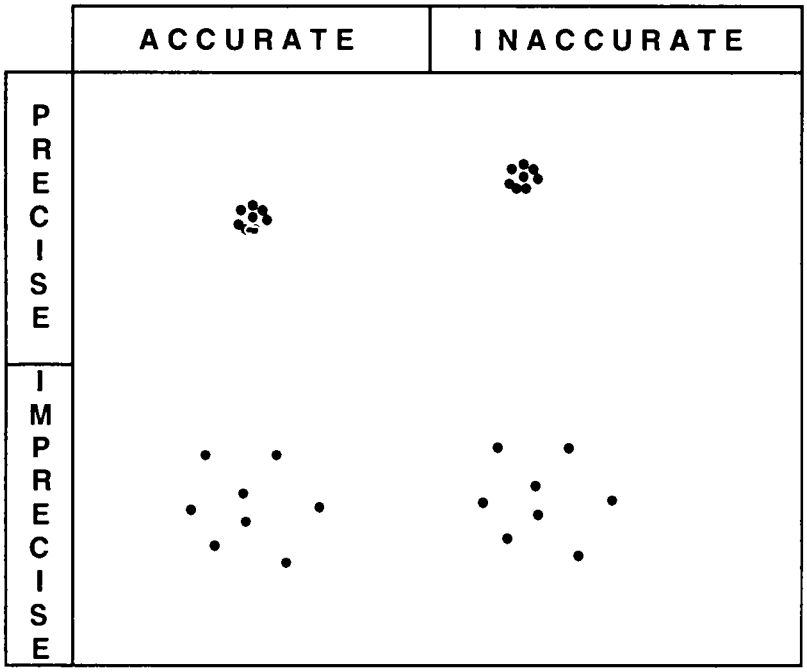

FIGURE 4 Confusion between accuracy and precision.

Much attention is often paid to reducing sampling error (i.e., increasing precision) by means of elaborate sampling designs and large sample sizes. Relatively little attention, however, is generally paid to increasing accuracy by means of reducing survey bias to ensure that the representative responses are received to the right questions asked of the right people. We are often guilty of "Type III Errors," described by Armstrong (*2*) as "good solutions to the wrong problems." By simply increasing sample sizes and not paying attention to the quality of the sample, the survey instrument, or the survey procedure, we can always ensure that we will be able to spend enough money to get precisely wrong answers! Indeed, by analogy with Figure 4, when we do not know much about the population we are surveying, we assume that a precise answer is better than an imprecise answer, whether or not it is accurate.

The issues of nonresponse are fundamentally connected to the questions of reducing survey bias and increasing the accuracy of sample estimates. This is because nonrespondents in sample surveys have been shown to be from segments of the population having characteristics significantly different from those of the respondents. These differences are in the sociodemographic characteristics and, more important, in their travel behavior characteristics. For example, nonrespondents to postal questionnaires tend to travel less than respondents to such questionnaires. If allowance is not made for this known difference, total travel and travel distance will be overestimated from such surveys. This will result in overestimates of emissions and fuel consumption in the survey area.

Types and Sources of Nonresponse

A number of factors will interfere with obtaining the exact information, both in quality and quantity, from the survey data despite the analyst's efforts to choose the appropriate survey method, develop the best possible instrument, and administer and execute the survey meticulously. Why will we not quite get the information we want, and why should any corrections, adjustments, and weightings be necessary?

The answers to these questions fall into a number of categories. After the survey instrument was distributed, many of the analyst's conceptual, theoretical, and logical considerations were tested against the behavioral characteristics of the human beings from whom the survey information was to be obtained. These human beings do not necessarily respond to our request in line with our wishes, expectations, and theories. Some of them were not able to respond to our requests, others did not want to cooperate, others responded only partially, and others misunderstood some questions on the survey instrument.

Despite the less than perfect response that is likely to have occurred, the investigator still must use the data to obtain information that is relevant for the survey population and not just for the subsample of people who responded "perfectly." The original intent was to develop population estimates on the basis of a carefully selected sample of that population. Unfortunately, in virtually all surveys, the population estimates have to be derived on the basis of a response of less than 100 percent, in most instances substantially less.

The purpose of this section is to make the analyst aware of the likely reasons for and the consequences of having to deal with only a subset of the desired sample. An awareness of these reasons and, in particular, of the effects of an imperfect response rate can help in understanding the limitations of the survey results and the likely magnitude, direction, and implications of any biases resulting from them. Such an awareness can also help in developing adjustments and compensating measures.

Unfortunately, there are many examples in the literature of researchers concentrating their efforts on the more challenging exercise of developing sophisticated mathematical models without proper attention to the quality of the data that they use to validate these models. However, there is a trade-off between data quality and sophistication of the modeling process. Without a knowledge of the characteristics of the data set used, it is almost impossible to draw proper conclusions about the quality of such models, since the source of the problem could lie in the data base or the model itself.

Apart from the use of sample survey data in modeling, the improper use of survey subsample information can lead to disastrous results in simple statistical information and in the conclusions derived from sample information. Given the multitude of surveys conducted every day, this area is probably the more serious one, since such statistical information is used daily at all levels of government and in the private sector for short- and long-term decision making, investments, and projections.

There are three major sources of systematic error (bias, distortion) in a typical sample survey data set: inaccurate reporting, nonreporting, and nonresponse. Inaccurate reporting describes the cases in which the analyst has determined that some of the responses provided on the survey instrument are objectively incorrect, inaccurate, or incomplete. Nonreporting refers to receipt of a survey form on which certain questions have not been answered, or at least not answered in full. Nonresponse pertains to the failure of a household or individual to provide any response (i.e., no survey form was filled out).

Strategies to Reduce the Impact of Nonresponse

To minimize the impact of these various forms of systematic error in the typical sample survey data set, a number of strategies can be pursued:

- Improvements in the design and administration of the survey: A number of techniques can be adopted to minimize the incidence of systematic errors. The techniques include selection of a suitable sampling frame, careful design of the survey instrument, use of incentives, and adoption of follow-up procedures involving call-backs, reminder notices, and reinterviewing.
- Office editing: The standard process of "repairing" the survey responses simply eliminates obvious omissions, errors, and so forth. Editing obviously will not address the problem of nonresponse and in most cases will not contribute to overcoming nonreporting.
- Computer coding and edit checks: The computer coding process eliminates additional errors and omissions created in the transfer of information from the survey form to the computer data base. Edit checking identifies out-of-range errors for individual variables and inconsistencies among the answers given by the respondent. This process does not address the nonresponse problem (obviously, coding and editing can only take place if the questionnaire was returned).
- Imputation: Where the respondent fails to answer a specific question, it is sometimes possible to impute the answer on the basis of the respondent's answers to other questions. In the simplest case, this may entail imputing the answer to a question on whether the individual holds a driver's license from observing whether the respondent reports driving a car in the travel behavior questions. A more complex imputation concerns the estimation of missing incomes from a range of other sociodemographic responses (*3,4*).
- Weighting factors: There are a number of sociodemographic and statistical adjustments to account for nonobserved information, such as sociodemographic expansion factors, nonreporting correction weights, and nonresponse correction weights.

Calculation of Response Rates

Every survey has a response rate associated with it, and this response rate must be calculated and reported correctly. Unfortunately, the results of sample surveys are often quoted without giving the response rate. Since a low response rate is cause for concern about the representativeness of the sample data, one should always be wary of sample survey data used without any indication of the response rate of the survey. However, even when response rates are quoted, one needs to be sure how the response rates were calculated. Because of the association of low response rates with lack of representativeness, there is often a tendency to inflate the response rate achieved from a survey, and hence dubious means of calculating response rates have sometimes been used.

The response rate measures the extent to which the sample of the population responds to the survey instrument. The objective is to obtain a high response rate such that the set of respondents more closely represents the target population. Response rates, in principle, are calculated in the following way. From the gross sample size is subtracted those members of the sample from whom a response could not possibly be obtained, because they do not in fact exist. These forms of sample loss (such as vacant or demolished dwellings) do not affect the quality of the sample because they do not contain people who are systematically different from the rest of the population and are sometimes said to be quality neutral. The resultant number is the net sample size. The number of total responses is then taken as a percentage of this net sample size.

The following example is useful: given 100 households in the gross sample, 5 vacant dwellings, and 64 full responses, the response rate would be 64 divided by 95 (net sample size = 100 − 5 = 95), or 67.4 percent.

One problem in the calculation of response rates is that different survey methods can give rise to different methods of calculating response rates. Most of the differences involve various definitions of sample loss and nonresponse that are possible in these types of survey because of the procedures and stages of the survey process. For example, Figures 5, 6, and 7 show the sampling and response processes associated with a typical mailback questionnaire survey, a personal interview survey, and a telephone interview survey, respectively.

In the mailback survey of Figure 5, it is assumed that the sampling frame is something like a list of addresses obtained from a utility company, such as an electricity supply company. To the extent that some households in the study area are not contained on that list (either because they are not connected to electricity or because they are part of a block of apartments that is billed, and hence listed, as one entity), there will be nonresponse from this cause.

Once the sample is drawn randomly from the sampling frame, there are a number of possible response mechanisms. Outright refusals could be received, either by having the questionnaire mailed back with a refusal message written on it by the respondent or by the respondent calling the phone number provided for inquiries and refusing verbally. (One should not forget that many people who phone to refuse can often be persuaded to become

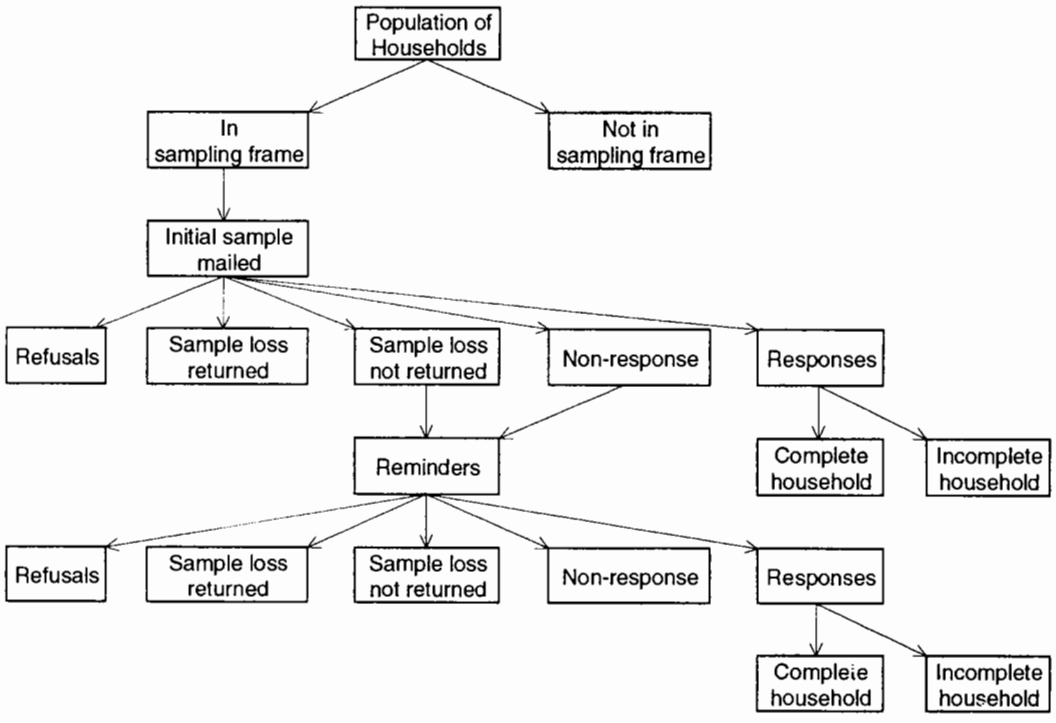

FIGURE 5 Sampling and response processes with mailback survey.

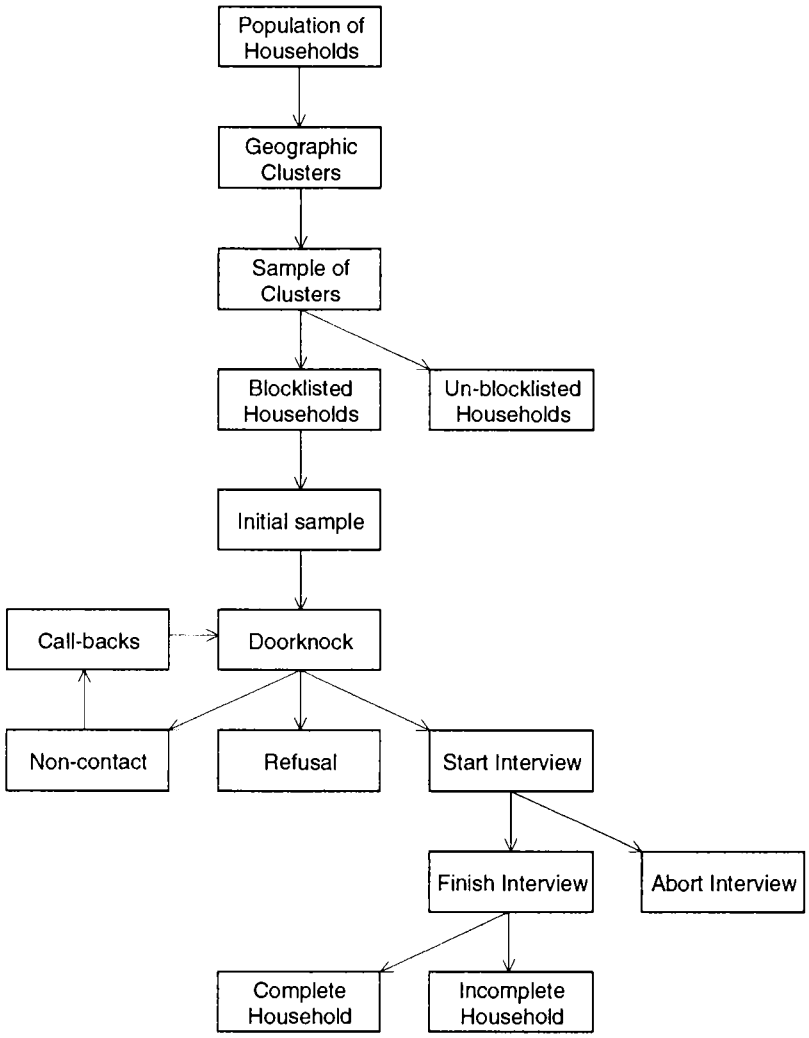

FIGURE 6 Sampling and response processes with personal interview survey.

respondents by staff who are sympathetic and knowledgeable in answering the legitimate problems raised by the callers.) Other questionnaires could be returned by the postal authorities indicating that the address to which the survey has been sent does not exist. This may be because the address is vacant land, the building has been demolished, or the address on the envelope does not exist (perhaps because of a clerical error in the sampling frame list). Any of these reasons indicates a genuine case of sample loss. A second type of sample loss may occur when the postal authority does not return the letter to the sender. This may be because the dwelling at the address is temporarily vacant or because the building at the address is not a residential property. These types of sample loss are normally not discovered and are simply assumed to be nonresponses. However, in a recent survey in Brisbane, Australia (*5*), where personal interviews were conducted with nonresponding households, it was found that 29 percent of the nonresponding addresses were in fact sample loss. The remainder of the addresses from which no reply was received are nonresponses, at least to the first mailing. However, by a series of reminders it is possible to convert many of these nonresponses into responses, as will be described later in this paper. Finally, from the total set of responding households it is possible to obtain completed questionnaires from the entire household or from only some of the household members.

The extent to which a household with missing respondents is counted as a responding household depends on the purpose of the analysis. Some analyses treat each person individually, and hence a partially responding large household can provide just as much data as a

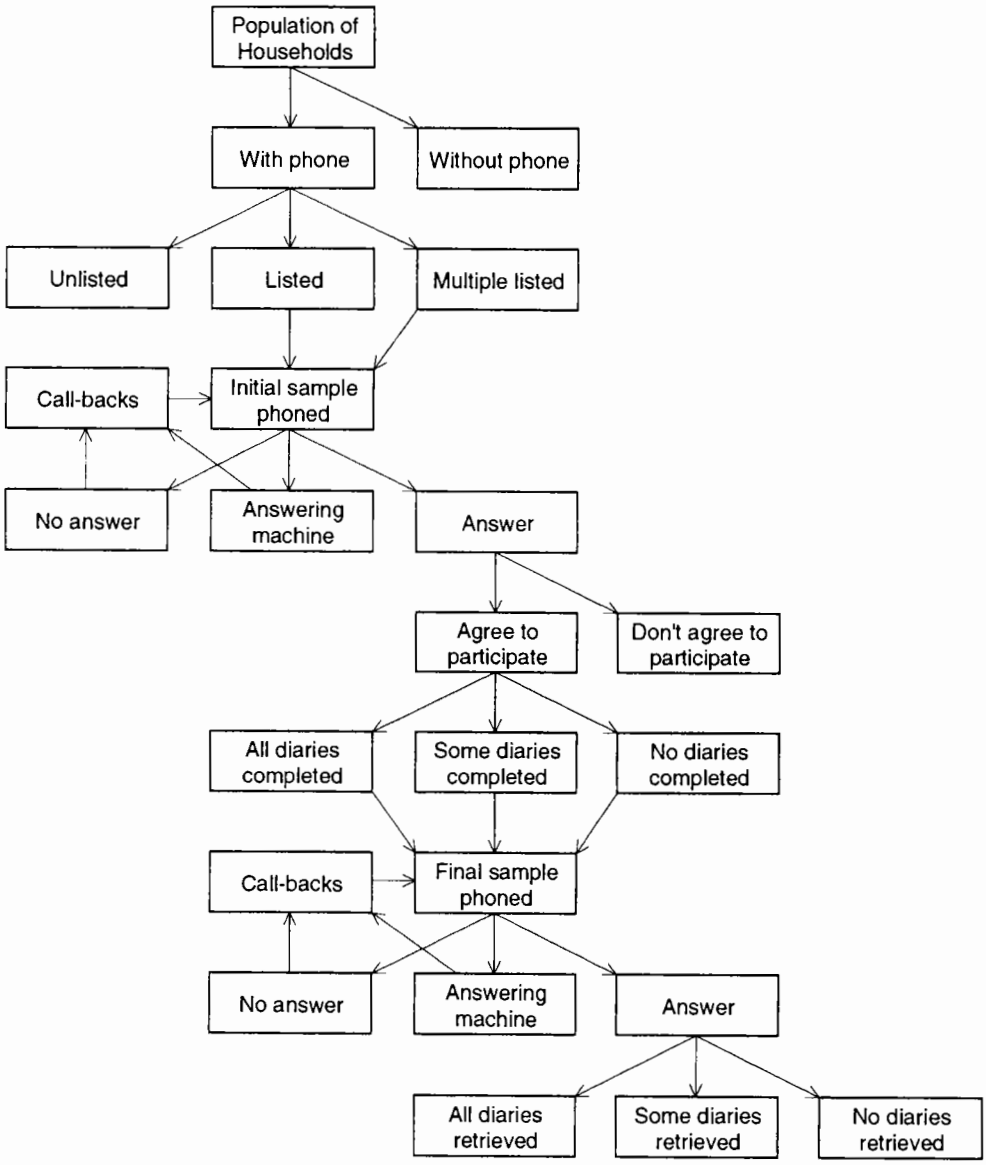

FIGURE 7 Sampling and response processes with telephone interview survey.

fully responding small household. Other analyses are conducted at the household level, and a nonresponding household member can invalidate such analyses. Clearly, it is an overestimate of the response rate to count partially responding households as full respondents. Equally clearly, it is an underestimate to exclude partially responding households from the response rate. A useful compromise is simply to count the proportion of household members who respond as contributing toward the response rate; for example, a household of four people, of whom three respond fully, would be counted as 0.75 of a household in calculating the response rate.

In the calculation of the response rate for mailback surveys, the nonresponses should include households not in the sampling frame, those that refuse or do not reply after the series of reminders, and fractions of responding households that do not respond. The sample loss should include those questionnaires returned by the postal authorities and the sample loss discovered in the group of households not replying to the survey.

The sampling and response process for personal interviews is significantly different, as shown in Figure 6. In this case, the nature of the interviewing process often results in a clustered sample being chosen for logistical and financial efficiency. Thus, the area covered by the

population of households is first divided into geographical clusters (perhaps at the level of the census tract), and then a sample of these clusters is chosen. The chosen clusters are then blocklisted to obtain a list of household addresses in these clusters. At this stage, it is possible that some households will be missed and not included in the blocklists. This is particularly the case for so-called "granny flats," where a second household exists at what appears to be a single address. Such omissions should be counted as nonrespondents, since they are members of the target population who are not included in the sampling frame.

From the blocklisted households, a sample is drawn for interviewing. Interviewers are then sent to these households to perform an interview (it is assumed in this example that the interview will be performed "cold," rather than leaving a diary to be used as the basis for an interview at a later date). The possible outcomes are as follows: a noncontact because no one is home, an outright refusal, or an acceptance to begin the interview.

Noncontacts should be counted as nonresponses, since there is good reason to believe that the members of such households are systematically different from those who are home (i.e., since they are out of the home, they are more likely to participate in more out-of-home activities and hence travel more than people who are home). To reduce this source of nonresponse, a series of call-backs should be used, whereby the interviewer repeats the attempt at this household to at least make contact. To maximize the chance of a successful contact, the call-backs should be made at different times of day and on different days of the week. Households remaining uncontacted after three to five call-backs should be counted as nonresponses.

An interesting approach to dealing with the not-at-home problem in personal interview surveys was developed by Politz and Simmons (6). The survey population is grouped into strata according to the probability of the interviewer finding people at home on the first call. All calls are assumed to be made during the same time of the day (for example, in the evening). On the basis of the respondent's answer to the question of how many of the previous five evenings he or she spent at home, the probability of each respondent being at home on any random evening could be calculated. To derive population estimates, the interview results for each stratum should be weighted with the reciprocal of the probability of being at home. Of course, a slight bias is introduced because those people who are never at home will not be considered in this procedure. Whereas the Politz-Simmons method makes one-call interviews a palatable survey procedure, it is not clear whether this reweighting procedure is more efficient in terms of cost and quality of results than the more conventional approach of multiple calls until a successful contact and interview are made. Also, it is not clear that people are necessarily willing to disclose to the interviewer their typical behavior concerning presence at or absence from home (because of fears about security).

The interview at those households at which an interview begins can terminate in a number of ways. First, the interview may be aborted by the respondent after a relatively short time, without any significant information being obtained by the interviewer. These households should be counted as nonresponses. Second, the interview may be carried out to completion with all members of the household, and these should be counted as full responses. Third, the interview may be completed with only some members of the household, either because the others were not home at the time of the interview or because they simply did not want to participate. Such partially responding households should be counted as partial responses, as described previously.

The sampling and response process for telephone interviews can be much more complex, as shown in Figure 7. In this example, it is assumed that phone numbers are selected from a telephone directory (probably a reverse-entry electronic directory to enable geographic stratification, if necessary), and that households are initially phoned to solicit their participation in the survey. Households agreeing to participate are then sent travel diaries to complete, and the information entered into the diaries is retrieved by phone at a later date.

Throughout this process, there are many ways in which households or people can drop out of the survey. Some households do not have a phone. Since they are known to be systematically different from households with a phone, they must be classified as nonresponses. If phone numbers are obtained from phone books, households with unlisted numbers cannot be contacted, and since they are likely to be socioeconomically different they too must be clas-

sified as nonresponses. A secondary problem is households with multiple listings, perhaps with different names or numbers, or both, at the same address, which would have an increased chance of selection in the sample. Appropriate sorting and deduplication techniques can reduce the extent of this problem.

A sample of households with listed numbers is then phoned to solicit participation in the survey. If no answer is obtained, then, as in a personal interview survey, a system of call-backs should be implemented to attempt to make contact. As in a personal interview survey, the remaining noncontacts should be counted as nonresponses, since there is good reason to believe that the members of such households are systematically different from those who are at home.

Answering machines pose a different, but related, problem. For households who use the answering machine when they are away from home, the situation is the same as phoning and getting no answer. A growing number of households, however, use the answering machine as a filtering device even when they are home. From the viewpoint of the caller, it is impossible to detect which way the answering machine is being used. Therefore, they should all be treated as noncontacts and subjected to call-backs.

Of households who answer the phone, a proportion will agree to participate in the actual survey, and travel diaries will then be mailed to them. It is possible that all members of the household will complete these diaries, that only some members will complete them, or that no one in the household will complete them. At a later date, the participating households are phoned to retrieve the travel diary data. The same problems may occur at this stage with noncontacts and answering machines, necessitating a further series of call-backs. When an answer is obtained, it is possible that all, some, or none of the diaries will be retrieved from the household members.

The calculation of the response rate for telephone surveys should take account of all the stages shown in Figure 7 (a similar process exists for variations such as random-digit dialing). Thus the nonrespondents should include households without a phone, those with unlisted numbers, those not contacted at the first phoning, those refusing to participate, those not contacted at the retrieval phoning, those from whom nothing is retrieved, and a proportion of the households from whom only some of the diaries are retrieved. Unfortunately, response rates for telephone surveys often only give the response rate to the final stages of the survey; for example, of those who are sent travel diaries because they agree to participate, the proportion finally providing full travel diary information. This may yield relatively high response rates (70 to 80 percent). However, if one accounts for all the sources of nonresponse at the various stages of the survey, the actual response rate may be much lower (20 to 40 percent). The latter range is the one that should be used for comparison with equivalent response rates for mailback and personal interview surveys.

The lesson from the preceding descriptions of the sampling and response processes for mailback, personal interview, and telephone interview surveys is that one needs to be consistent in calculating the response rate for the various types of survey method. A nonrespondent is any member of the original population who fails to provide a valid response to the survey, for whatever reason. Different survey methods have different sources of nonresponse, and all of these must be accounted for in calculating the response rate. The effect of nonresponse on the results of the survey will depend on whether the nonrespondents are a random sample of the population or are systematically different from the respondents. These differences can be inferred logically, but they should always be tested empirically. If nonresponse bias is deemed to exist, steps should be taken to reduce nonresponse (without introducing further bias) and to correct for the effects of any remaining nonresponse.

Strategies to Reduce Nonresponse

The first step in controlling for nonresponse is to implement procedures in the design and conduct of the survey to reduce the extent of nonresponse (without introducing further biases). A range of possible procedures that could, for example, be implemented with a mailback survey is described here.

Sponsorship of Survey

Obtaining official sponsorship of the survey from a well-known and respected group or individual is likely to increase the response rate and therefore should be given particular attention in self-completion survey design. Noncontroversial government authorities, research institutions, universities, and public figures are useful sponsors whose name or letterhead paper can be used in the cover letter. As noted earlier, if there is any doubt about the impact of these sponsors, it is important to check the effect of these sponsors during a pilot survey.

An interesting example occurred in New Zealand, where (at the time of the survey) the Ministry of Transport was not only a policy and planning body, but also the policing authority for all traffic offenses. Although it appeared as if the prestige of the ministry was a positive aspect of the survey design, people who received a letter in the mail with a potential offense notice did not react positively to the survey—and the sponsoring authority was changed after the pilot survey!

Cover Letter

Since there is no opportunity to personally introduce and explain the questionnaire to the respondent, the use of a cover letter is essential in all self-completion surveys to increase the response rate and the understanding of the questions. The letter need not be overly personalized but should be clear, friendly, and not officious. Handwritten notes urging reply in reminder cover letters have been found to be effective. In addition, it is sometimes useful to enclose a brochure explaining the survey in a more informal and colorful manner than is generally possible in a letter.

Consideration of Nature of Respondents

In general, self-completion surveys have most success where the population under study is literate and concerned with the subject under study. For surveys of the general public, there is evidence to suggest that nonresponse is highest among the lower socioeconomic groups. Such evidence reinforces the need for special measures to be introduced to ensure participation by all groups, if this is required by the objectives of the survey, and to carry out follow-up surveys to give information on nonrespondents.

Use of Incentives

One method that is frequently mentioned as a way to increase response rate is to use incentives. Opinions vary, however, as to whether incentives actually increase or decrease response rates. Intuitively, the use of a small payment or gift would appear appropriate as a way to increase response rates. However, there is some evidence to suggest that this is not always the case (*7,8*). Even if incentives increase response rates, there is the question of whether they also introduce a bias of their own. For example, the offering of a small cash incentive may disproportionately encourage respondents of lower income; offering a lottery ticket may encourage the risk-seeking (as opposed to risk averse) section of the population; offering transit tickets would encourage those who already use transit services. Unfortunately, there is little evidence in the literature (especially the transport literature) about the effectiveness of incentives; most evidence is anecdotal with very little controlled experimentation.

We would argue that designing a survey whose purpose and layout are easily understood and that makes it easy to contact someone if questions need to be asked provides the best incentive.

Special Postage

One technique that has been recommended by Brög (*9*) is the use of stamped return envelopes in mailback surveys. This involves placing a normal stamp on the return envelope before the questionnaire is sent out. On receiving this envelope the respondent has, according to Brög, three options:

1. Throw the envelope and the stamp away with the questionnaire,
2. Throw the questionnaire away but steam the stamp off the envelope, or
3. Return the completed questionnaire in the envelope.

Option 1 leaves the respondent with the feeling of having wasted a resource—a perfectly good stamp. Option 2 leaves some respondents with a guilt feeling of having gone to a lot of trouble to get a stamp. The only way to overcome both of these guilt feelings is to adopt Option 3. Whereas this method appears to obtain better response rates when the questionnaire is small, the cost of individually affixing stamps to each envelope needs to be compared with simply getting reply-paid envelopes printed. In addition, when the value of the stamp is large, there is an added incentive to steam the stamp off the envelope. The value of stamped return envelopes versus reply-paid envelopes has recently been compared systematically in the Victorian Activity & Travel Survey (*10*). In this case, the value of the return stamp was $2.00. In a sample of approximately 10,000 households, half received stamped return envelopes, and the other half received reply-paid envelopes. No significant difference was discernible in either the overall response rate or the speed of response.

Use of Comments Section

The use of a comments section at the end of the questionnaire can often improve response rates by giving respondents an opportunity to air their own views on the subject, independent of the formal questions that may have been asked in the main part of the questionnaire. These comments may or may not be coded and used in the analysis.

Provision of Phone-In Service

A key element in a self-completion survey is the provision of a phone-in service for respondents. Since there is often no other personal contact with survey investigators, it is necessary that this service be available (free, if possible) for as many hours of the day as practicable. Given that most people are away from home during the day and are likely to be completing the forms at nights and on weekends, it is not at all practical to limit the hours of operation to conventional business hours. This may mean having someone on duty during nonwork times, or switching the phone through to the private homes of the survey administrators. To be fully effective, all people who answer the phone need to have comprehensive training in the survey objectives as well as the questionnaire content.

Language Assistance

In areas where there is expected to be a significant number of respondents of different ethnic backgrounds or with different languages, there is a need to cater to these differences. Ideally, self-completion questionnaires should be produced in each of the significant languages in the area, and this is done routinely in several multilingual societies (e.g., Canada and Singapore). Care should be taken to ensure that the same meaning is conveyed for each of the questions in each language. In areas where there is one dominant language and a large number of minority languages (e.g., Australia), it is generally impractical to produce multilingual ques-

tionnaires, and other techniques must be adopted. In the Victorian Activity & Travel Survey (*10*), the precontact letter contained a message in seven foreign languages inviting respondents with language difficulties to ring the survey office for assistance. By various means, such as having bilingual interviewers assisting respondents over the phone or conducting the interview at their home, the proportion of respondents from non-English-speaking backgrounds was approximately the same as the proportion of people in the population from non-English-speaking backgrounds (about 20 percent).

Use of Reminders and Follow-Up Regimes

The most effective method of reducing nonresponse in mailback surveys and obtaining data for the calculation of correction factors is by the use of a series of reminders and follow-up interviews. The use of reminders in the 1992 South-East Queensland Household Travel Survey (SEQHTS) (*5*) and the 1994 Victorian Activity & Travel Survey (VATS) (*10*) is illustrative. The procedure is based on the well-tested KONTIV method, originating in Germany (*11*). The method described here has been widely used [for example, in the United States and Europe (*12*)] for a household travel survey in which all people in the household are asked to report travel for a specified travel day. The principles could be used for any self-completion survey.

- Initial contact: This stage is to introduce the respondents to the fact that they have been selected to participate in the survey and to legitimize the survey in some way. This is done with an introductory letter and an informational brochure, which are sent just over 1 week prior to the travel day allocated to the household (each household is asked to provide complete travel and activity data for one specified travel day).
- First mailing: The first mailing includes a follow-up covering letter, a household and person form, six trip forms (to cover the maximum expected number of persons in the household), a trip form with a preprinted completed example, and a postage-paid return envelope. This mailing is sent in an envelope with a postage stamp to make the letter seem more personal. The letters are sent so that they arrive 2 working days before the travel day.
- First reminder: This takes the form of a postcard either to thank respondents who have already returned their forms or to remind respondents to return the questionnaire and to allocate them a new travel date (1 week after the initial date) in case the forms have not yet been filled in.
- Second reminder: The second reminder is a letter sent in an ordinary business envelope, again signed by the survey director. Once again, a new travel date is suggested for those people who have not yet filled in the forms.
- Third reminder: By this time it is possible that nonresponding households have either lost the survey forms or perhaps never received them in the first instance. Therefore, this reminder contains all the items sent in the first mailing with the addition of a cover letter from the survey director stressing the importance of obtaining as complete a response as possible from all segments of the population. It seeks the cooperation of all respondents in completing and returning the forms. Again, a new travel date is proposed.
- Fourth reminder: For this (final) reminder a postcard is again used—but in a different color. A new travel date is again proposed.

Each of these reminders raises the response rate, but at a marginally diminishing rate. The effect of the reminders on response rates is shown in Figure 8 for the SEQHTS survey (*5*).

Approximately 60 percent of all valid responses are received in response to the first mailing, with the remaining 40 percent being generated as a result of the reminders. About 30 percent of all sample loss is known before the first questionnaire mailing is performed because of the precontact letter being returned by the postal authorities. As well as increasing the response rate, each reminder produces a wave of responses that provide useful information to calculate a set of correction factors for nonresponse, as will be demonstrated later.

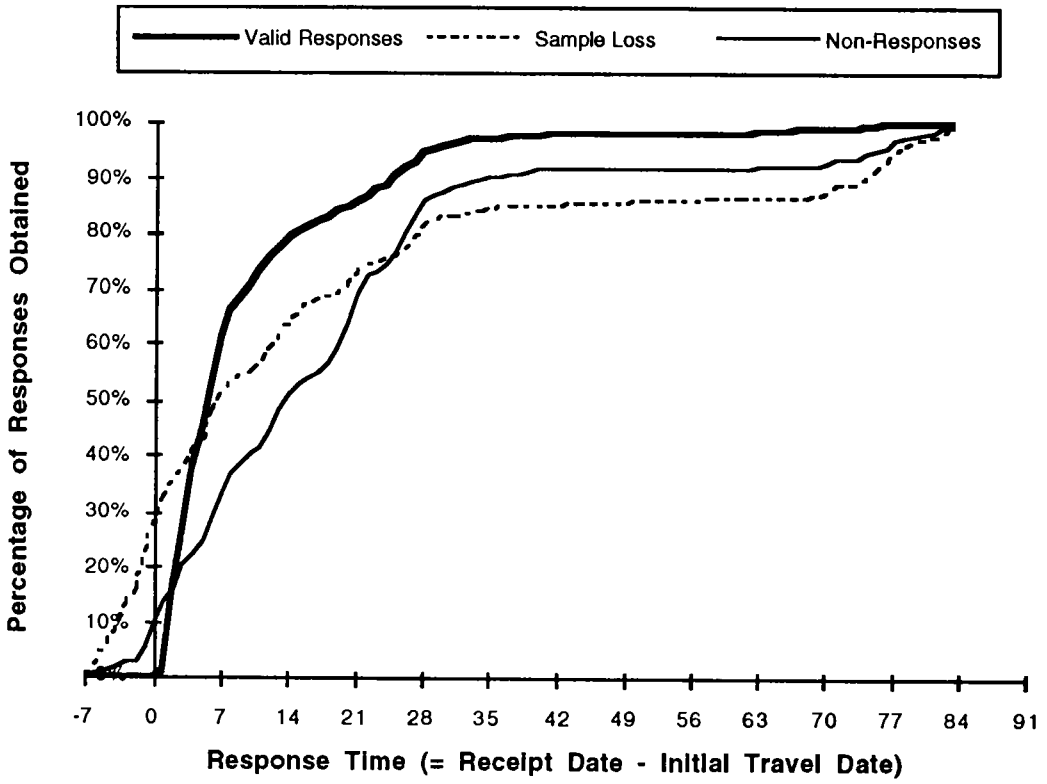

FIGURE 8 Speed of response by response type.

Whereas the reminder system is effective in increasing the response rate, it appears to be a lot of trouble and fairly costly. However, compared with simply increasing the original number of mail-outs to obtain the same total number of responses, the reminder system can be cheaper than the no-reminder system, as indicated in Table 1 for response conditions and marginal costs closely resembling the SEQHTS survey (*5*).

In this example, it is assumed that the overall response rate is 60 percent and that only 30 percent response is obtained from the mailing of the original questionnaire. To obtain the same number of responses, twice as many questionnaires would need to be mailed if no reminders are used as when reminders are used.

TABLE 1 Cost of Reminder and No-Reminder Survey Designs

	Pre-contact	First mailing	1st reminder	2nd reminder	3rd reminder	4th reminder	TOTAL
% Valid Responses	0%	30%	11%	6%	9%	4%	60%
% of Sample Outstanding	100%	97%	97%	53%	45%	35%	
Number of Items Sent Out	10000	9700	9700	5300	4500	3500	
Marginal Direct Cost (e.g. postage, printing)	$1.00	$7.00	$0.50	$0.60	$7.00	$0.50	
Marginal Labour Cost	$1.00	$2.00	$1.00	$1.20	$2.00	$1.00	
Total Marginal Cost	$2.00	$9.00	$1.50	$1.80	$9.00	$1.50	
Cost of Reminder Design	$20,000	$87,300	$14,550	$9,540	$40,500	$5,250	$177,140
Cost of No-Reminder Design	$40,000	$174,600	$0	$0	$0	$0	$214,600

For the survey with reminders, the percentage of the sample replying, with valid responses, to each component of the mailing process is shown in the top row. The second row shows the percentage of the original sample that receives each mailing. Thus 100 percent get the precontact letter, but because we find out about some sample loss before the questionnaires are mailed, only 97 percent get the first mailing of questionnaires. All of these get the first reminder, which is also a thank you letter for those who have responded already. As responses are received thereafter, their addresses are taken off the mailing list, thus requiring fewer items to be sent out in subsequent mailings, as shown in the third row. The fourth row shows the marginal direct costs of postage and printing for each of the stages. In the SEQHTS survey, the outbound and return postage for the questionnaire mailings was $2.00, and the cost of the questionnaire printing was about $3.00 per household (for a two-color print with shadings on high-quality paper). The letter, envelope, stamp, and color brochure for the precontact mailing cost about $1.00, whereas the reminder postcards or letter cost about 50 cents each. The marginal labor costs covered the preparation of the mailings (around 250 person days for preparing and sorting the 15,000 packages of questionnaires) and the monitoring of the incoming mail to update the mailing lists for reminders on a daily basis.

The total marginal cost of the survey design with reminders was about $177,000 (this does not include up-front costs such as the design and testing of the questionnaire, or follow-up costs associated with the coding, editing, and analysis of the data, all of which would be the same for both the reminder and the no-reminder survey design). By comparison, the survey without reminders would require that twice as many precontact letters and initial questionnaires be mailed to receive the same number of replies. The total marginal cost of the no-reminder design would therefore be about $215,000. It can therefore be seen that the survey without reminders is about $38,000 (or 20 percent) more expensive than the survey with reminders. The magnitude of this difference depends primarily on the cost of the questionnaire mailings; more expensive questionnaires make the cost differences larger. With less expensive questionnaires the differences are smaller, but for no reasonable cost level is the survey with reminders more expensive than the survey without reminders.

In addition to being less expensive, the survey with reminders reduces the nonresponse rate, thereby lessening the potential for survey bias. The reminders also provide information that can be used to correct for the biasing effect of the remaining nonresponse.

A number of other techniques have been used to improve response rates and the quality of the reported data in the SEQHTS and VATS surveys.

Phone Interviews

When the data from the returned forms are initially entered into the data base, missing data or apparent mistakes are "tagged" by the data enterers. They are then followed up by phone interviewers, who telephone these households to clarify any points of uncertainty. The phone numbers are provided by the respondents in response to a question on the survey form (in Australia, about 85 percent of respondents provide their phone numbers), and approximately 60 percent of all responding households are phoned. During phone interviews, a check is made of which person in the household completed each travel form to gain a measure of proxy reporting.

Validation Interviews

A sample of responding households was selected for a personal interview to check on the quality and completeness of the data provided in the self-completion phase of the survey. Each household member is asked to go through the information provided for his or her travel day. A variety of techniques have been used for this interview.

One method is to carry out a full personal interview (using the original self-completed form as a memory jogger). In this way, data on all travel are verified personally. Since respondents are also asked who filled in the original trip form, this is of particular value for measuring the effects of proxy reporting. In many cases a graphical summary of the travel and out-of-home

activities is used in these validation interviews. The representation is based on the time line concept (*13*) with a line for each of home, travel, and out-of-home activities (Figure 9).

This graphical representation was developed to assist interviewers and respondents to view the travel day at a glance. In the example shown in Figure 9, it would be easy to check whether the respondent left work for lunch by simply asking, "Did you stay in the same place between 9 a.m. and 5 p.m.?" Often, this simple probe question was enough for respondents to clarify that they indeed went out for lunch but did not report it in the survey because they did not think that such a trip was important enough to report.

The main purpose of these validation interviews was to obtain information on the underreporting of trips in the self-completion phase of the survey, thereby enabling the calculation of nonreporting weights, to be described later in this paper.

Nonresponse Interview Surveys

Finally, a sample of nonresponding households was selected for a personal interview to check on the reasons for their nonresponse. The reasons are essentially threefold. First, like many of us, respondents are simply procrastinators or forgetful; they meant to do the survey but never got around to it, or else they had completed the survey but forgot to send it back. Second, as mentioned earlier, many of the households from which no reply was received turned out, on inspection, to be sample loss. Third, there was a persistent group of nonrespondents who either refused outright or could not be contacted after several call-backs. As indicated in Table 2, in about half the cases in the Brisbane study area in the SEQHTS survey, the household agreed to complete a travel survey when contacted by the interviewer, and this information was used later in checking the calculation of nonresponse weights.

These nonresponse interviews have proven to be especially valuable in identifying households containing stubborn nonrespondents, those who were merely forgetful, and households that did not actually exist (i.e., sample loss)—important pieces of information for the calculation of the response rate and for nonreporting and nonresponse weighting factors.

Use of the range of techniques described in this section can result in a high response rate from mailback travel surveys. By using the preceding survey design and quality control procedures, a response rate of 73 percent was achieved in the Brisbane region of the SEQHTS study (*5*). In previous studies using similar techniques (*14,15*), response rates between 60 and 65 percent have been consistently achieved.

Despite use of these techniques, at least 30 percent of the population have not responded. If these 30 percent are a random sample of the population, estimates of the mean of various parameters will not be affected. If the nonrespondents are systematically different from the respondents, additional steps must be taken to correct for the biasing effects of nonresponse through the use of expansion factors and nonreporting and nonresponse weights.

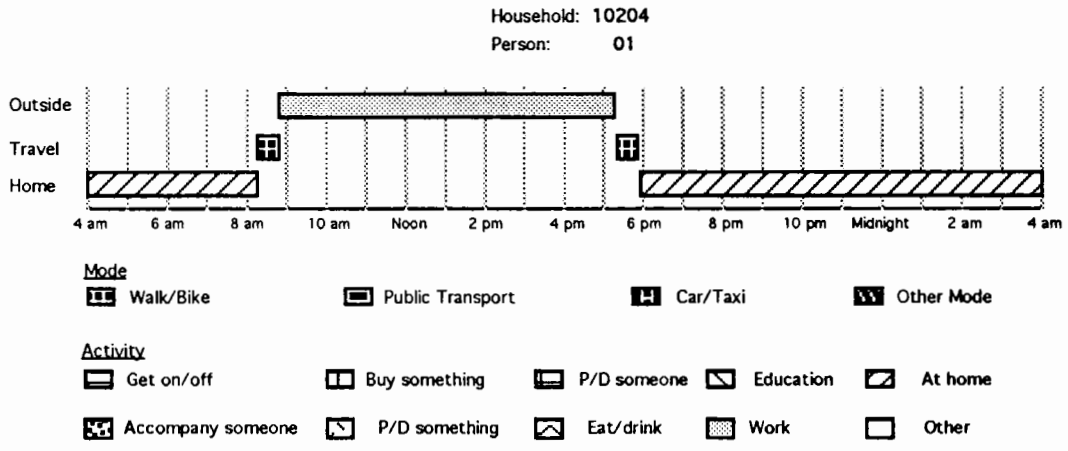

FIGURE 9 Graphical representation used in validation interviews.

TABLE 2 Response Behavior of Nonresponse Validation Households (*5*)

Final Response Type	No. of Households	% of Households
Valid Response	107	45%
Sample Loss		
No such address	2	1%
Vacant	29	12%
Other sample loss	38	16%
Other Loss		
Non-contact (after 5 visits)	16	7%
Refusal	46	19%
TOTAL	238	100%

Population Expansion Factors

As stated several times already, the eventual purpose of a sample survey is to draw conclusions about the characteristics and behavior of the population from which the sample was drawn. If the sample was selected according to the simple random sampling method, then theoretically the results of the sample survey can be expanded back up to the population by multiplying by the inverse of the sampling fraction. For example, if a sample of 100 people has been randomly selected from a population of 1,000, and if it has been found that this sample makes a total of 287 trips per day, then the total number of trips made by the population can be inferred to be 2,870. Whereas the concept of sample expansion is quite simple, the process is rarely as simple as just described, for the following reasons:

- Even with a simple random sample, there is no guarantee that the sample is truly representative of the population. Chance random errors will result in some groups within the population being overrepresented and others being underrepresented. If the variable in question (e.g., the number of trips per day) varies systematically across these groups, simple expansion of the sample results will not necessarily provide good population estimates.
- In many situations, we will have used a more complex sampling procedure, some of which (such as variable fraction stratified random sampling) will never produce a sample representative of the population, because we have deliberately under- and oversampled the strata. To obtain population parameter estimates, we need to take explicit account of the manner in which the sample was drawn and then work backwards to reconstruct the population estimates.
- Even if we have accounted for the manner in which the sample has been drawn from the population, and if a perfectly representative sample had been drawn, there is still no guarantee that what we obtain from respondents is what we expected to obtain. For example, not all people will respond to the survey; furthermore, this nonresponse is unlikely to be evenly distributed across the groups within the population. Thus the distribution of respondents across various characteristics is unlikely to be the same as the distribution of the total sample across those parameters.

For these reasons it is usually necessary to explicitly account for the composition of the respondents before expanding the results to represent the population to which the respondents belong. This explicit recognition is performed by means of population expansion factors, which relate the composition of the respondent group to a known composition of the population. To calculate these expansion factors, it is necessary to have a secondary source of data describing the population in terms that can also be related to the sample. The most common source of secondary data is a national census of population, which provides complete information about the population with respect to key socioeconomic variables. Provided that your survey asks these same questions of the respondents (in the same way and using the same response categories), you can calculate expansion factors to obtain population parameter estimates.

The simplest method of population expansion is to have a cross-tabulation of the control variables (e.g., age by sex by geographic region) from the secondary data, and to calculate the same cross-tabulation from the sample survey data. Division of the sample survey cell frequencies into the secondary data cell frequencies provides a matrix of expansion factors, with unique values for each combination of the control variables. These factors are then applied in a multiplicative fashion to each record in the sample survey data set.

This procedure would be used when the data in the secondary source are of a level of detail comparable with those obtained in the survey. However, this is often not the case, and frequently the secondary source data can only be obtained at a more aggregate level. Whereas we would like to know the number in the population in each of the cross-tabulation cells, often all we can get is the "marginals"; that is, the total number in each of the rows and columns. Thus in the preceding example, all we may be able to get is a breakdown by age and a separate breakdown by sex, but not a breakdown by age and sex together. In such cases, it is still possible to calculate population expansion factors, but since we are working with less information, the reliability of these expansion factors will depend on how much extra information is contained in the body of the cross-tabulation of the population values. To calculate expansion factors under these conditions, we need to adopt an iterative procedure until stable values of the expansion factors are obtained. When there are few control variables with little dependence between these variables, the iterative process may be quite short. In other situations, especially where there are a larger number of control variables on which the sample is being expanded, it may be necessary to iterate several times before a stable condition is achieved. Heathcote (*16*) and Stopher and Stecher (*17*) describe the expansion process in some detail.

In addition to the mathematical problems involved in using marginal totals for the estimation of expansion factors, a number of other practical issues need to be resolved. First, one has to find a good source of secondary data, which hopefully will provide the control variables in a cross-tabulated fashion (and not just in marginal total fashion). Second, the data in the secondary source should have been collected in a manner similar to that of the survey currently being conducted. In particular, the coding categories of the two data sets should be similar. Common definitions of items such as occupation, employment status, and housing type should be used (this may involve a compromise if the secondary data, such as the census, has already been collected). Third, there may be problems with the timeliness of the secondary data becoming available. For example, the census typically takes about 2 years from the time of data collection before the first results are available. Even then, these results are generally very aggregate in nature and may not be suitable for the purposes of calculating population expansion factors.

As a general rule, the design of the procedures for expansion of the data should be performed very early in the design process, since the availability of secondary data may often affect the choice and wording of questions on the survey.

Corrections for Nonreported Data

Nonreporting refers to the incompleteness of information in questionnaires that were returned. The incompleteness can refer to questions or parts of questions that were answered incorrectly or incompletely or to information that was not supplied at all. In the context of travel surveys, the nonreporting phenomenon is of particular importance in the nonreporting of trips and trip characteristics, since conclusions about trip rates (by mode) and general trip making behavior and characteristics are the focus of travel surveys.

A reason for nonreporting of trips and trip characteristics can be simple memory lapses, especially when the respondent is asked to recall trips made over a significant period in the past. But even in short-term recollection, trips are frequently forgotten or misrepresented. Another reason for nonreporting can lie in the conviction by the respondent that a trip was not "important," or it was too short, or it was performed on foot or by bicycle. Proper instructions about trip definitions and reporting requirements can reduce this source of nonreporting. It is

TABLE 3 Incomplete Information for Various Question Types

Characteristic	Incomplete Information	
	On Survey Form	After Corrections
Sex	3.0%	2.5%
Age	4.5%	4.5%
Marital Status	3.5%	3.0%
Education Level	9.4%	3.1%
Employment Status	7.0%	0.0%
Occupation	9.5%	2.0%
Drivers Licence	9.5%	4.5%
Trip Details:	4.3%	3.5%
Destination Address	15.0%	11.0%
Trip Purpose	10.0%	6.0%
Travel Mode	54.7%	51.3%
Travel Time	20.3%	12.3%

possible that a respondent is unwilling to disclose all trips because of an embarrassing trip purpose or destination. Very little can be done to overcome the latter problem.

The problem of incomplete information has been studied within the context of the KONTIV (*Kontinuerliche Erhebung des Verkehrsverhaltens—A Continuous Survey of Travel Behavior*) survey design in West Germany by Brög et al. (*18*) and Wermuth (*19*). The KONTIV design is a highly refined self-administered survey developed by Brög et al. (*20*). As such, the problem of incomplete information would be expected to be at a minimum compared with other, less well-designed, surveys. Nonetheless, the patterns of incomplete information are useful diagnostic information for the design of other surveys. Table 3 presents data on the percentage of responses for various questions for which there was incomplete information in the KONTIV survey. These results are presented in two ways: the raw percentage of incomplete information on the survey form and the percentage incomplete after the coder had made any possible corrections.

It can be seen that, initially, the extent of incomplete information on demographic and trip questions is in the range of 5 to 10 percent, but after coding and office editing this can be reduced to less than 5 percent. With respect to incomplete trip details, the major type of omission was travel mode. Wermuth (*19*) also shows that the extent of incomplete information for trip details varies with the trip purpose and travel mode, as indicated in Table 4. It can be seen that shopping and recreational trips are most likely to have incomplete information, both before and after coder corrections, whereas nonmotorized trips are more likely to be incompletely specified.

TABLE 4 Incomplete Information for Various Trip Characteristics (*19*)

	Incomplete Information	
	On Survey Form	After Corrections
Trip Purpose:		
Work	21.8%	9.8%
School	37.0%	6.8%
Shopping	60.3%	31.8%
Other Discretionary trips	30.8%	9.6%
Recreation	40.4%	13.7%
Return Home Trips	8.9%	0.7%
Travel Mode:		
Non-Motorised	28.6%	10.8%
Motorised	24.2%	9.6%
Public Transport	30.3%	7.9%

TABLE 5 Incomplete Information for Various Types of Respondents (*19*)

	Incomplete Information	
	On Survey Form	After Corrections
Age (years):		
10-15	31.9%	5.5%
16-25	22.4%	4.5%
26-45	25.1%	11.4%
46-64	26.3%	11.0%
>65	49.3%	22.3%
Education Level:		
Elementary School	31.5%	12.2%
High School	22.0%	10.1%
University	12.5%	4.6%

It is also possible to relate the extent of incomplete information to the type of respondent supplying the information, as can be seen in Table 5. Thus, the incomplete information increases as the respondent gets older and tends to decrease as the level of education of the respondent increases.

Whereas the problem of incomplete information is an inconvenience, especially to the coder who has to try to supply the missing information, a more serious problem is the nonreporting of trips (this may be seen as an extreme case of incomplete information). Brög et al. (*18*) and Wermuth (*19*) have shown that the extent of nonreported trips can be related to personal characteristics of the respondent and to various characteristics of the missing trips, as indicated in Table 6. With the exception of teenagers, who tend not to report many trips made by car (as a passenger), there is again a tendency for older people to have more nonreported trips. Whether this is a function of memory lapses or is a result of the types of trips they tend to make will be explored later. There appears to be no clear tendency for nonreporting of trips to be associated with any education level, but respondents without a driver's license tend to make more unreported trips.

In addition, the extent of nonreporting of trips appears to be a function of the characteristics of the trips themselves. As indicated in Table 7, nonreported trips tend to be shorter than average, by nonmotorized means of transportation, and of a more discretionary nature. As a result of the characteristics of the nonreported trips, the increase in mobility after accounting for these trips varies depending on the measure of mobility used. Thus the proportion of mobiles increases least, the trip rate per mobile increases more, and the trip rate across all people increases most as indicated in Table 8.

TABLE 6 Nonreported Trips for Various Types of Respondents (*19*)

Respondent Characteristic	% Non-Reported Trips
Age (years):	
10-15	27.4%
16-25	7.4%
26-45	15.5%
46-64	16.3%
>65	20.2%
Education Level:	
Elementary School	23.2%
High School	9.6%
University	17.8%
Licence Holding:	
Driver's Licence	11.6%
No Licence	21.0%

TABLE 7 Trip Characteristics of Nonreported Trips (*19*)

Trip Characteristic	% Non-Reported Trips
Trip length (km):	
0 - 0.5	26.5%
0.5 - 1.0	23.5%
1.0 - 3.0	13.8%
3.0 - 5.0	9.5%
5.0 - 10.0	7.5%
10.0 - 20.0	7.5%
>20.0	5.4%
Travel Mode:	
Moped, Motorcycle	25.0%
Walk	22.9%
Bicycle	14.4%
Car Passenger	12.3%
Car Driver	8.9%
Public Transport	6.7%
Train	0.0%
Trip Purpose:	
Shopping	18.4%
Recreation	17.2%
Other Discretionary Trips	14.5%
School	8.1%
Work	5.8%

The results reported in this section have been confirmed by other studies (*21,22*) and emphasize the need to at least be aware of, if not explicitly correct for, the effects of nonreported trips when presenting the findings of travel surveys.

Methodological research conducted as part of the (SEQHTS) (*5*) has offered further insights into the issue of nonreporting of trips and has suggested a way of correcting for this nonreporting in the expanded data.

In the SEQHTS survey, validation interviews were performed with a sample of the responding households. The information for the estimation of nonreporting correction factors was obtained by identifying all additions made to the stop data as a result of the validation interviews. These added stops were also classified as to whether they were expected or unexpected. Expected extra stops were those where, during data entry (before validation), it had been identified that it was likely that an extra stop should have been reported (e.g., a person went to a shop and did not return home). Unexpected stops were those that had not been identified in this way but that respondents reported during the validation interview checking.

As a result of experience gained in previous pilot surveys, it was decided to examine the characteristics of these added stops in terms of their mode, their purpose, and whether they were the last stop of the day. It was found that the added stops differed from the originally reported stops most significantly in their purpose and position in the day. The nonreporting correction factors were calculated by dividing the sum of the original stops, plus the expected added stops, plus the unexpected added stops by the original stops, that is,

$$\text{Nonreporting correction factor} = (\text{original stops} + \text{expected added stops} + \text{unexpected added stops})/\text{original stops}$$

TABLE 8 Increases in Mobility After Allowing for Nonreported Trips (*19*)

	% Increase in Mobility
Measure of Mobility:	
% Mobiles	4.8%
Trip Rate per Mobile	10.4%
Trip Rate per Person	14.2%

TABLE 9 Nonreporting Correction Factors for Expected Added Stops (*5*)

	Last Stop of Day?		
Destination Purpose	NO	YES	Total
Change Mode	1.015	1.000	1.015
Pick Someone Up	1.012	1.000	1.012
Drop Someone Off	1.000	1.000	1.000
Accompany Someone	1.022	1.000	1.022
Buy Something	1.000	1.000	1.000
Education	1.058	1.000	1.058
Work-Related	1.004	1.000	1.004
Go Home	1.021	1.071	1.052
Any Other	1.000	1.000	1.000
Personal Business	1.016	1.000	1.000
Social/Recreational	1.000	1.000	1.000
Social/Welfare	1.000	1.000	1.000
Medical/Dental	1.000	1.000	1.000
Childcare	1.000	1.000	1.000
Park/Unpark	1.200	1.000	1.200
Total	1.014	1.070	1.024

The resultant nonreporting correction factors for expected and unexpected stops are given in Tables 9 and 10. It can be seen from Table 9 that the major impact of the nonreported stop correction factors for expected additions will be on trips home at the end of the day, which are frequently forgotten but often easy to detect. From Table 10, it can be seen that the major impact of the nonreported stop correction factors for unexpected additions will be on "change-mode" stops made during the day and trips home at the end of the day. These trips are primarily by walk or public transport modes. The fact that stop purpose and mode are correlated means that the application of these nonreported stop correction factors based on stop purpose will also result in an (upward) adjustment for stops made by walk and public transport during the day.

The nonreported stop weights are then applied in the following manner:

- Any household/person/stop that was phoned or validation-interviewed does not need to have the expected or unexpected nonreported stop weights applied (because they would already have been found during the phone or validation interview).

TABLE 10 Nonreporting Correction Factors for Unexpected Added Stops (*5*)

	Last Stop of Day?		
Destination Purpose	NO	YES	Total
Change Mode	1.068	1.000	1.068
Pick Someone Up	1.037	1.000	1.037
Drop Someone Off	1.022	1.000	1.022
Accompany Someone	1.044	1.000	1.044
Buy Something	1.006	1.000	1.006
Education	1.029	1.000	1.029
Work-Related	1.012	1.000	1.012
Go Home	1.005	1.068	1.044
Any Other	1.000	1.000	1.000
Personal Business	1.016	1.000	1.016
Social/Recreational	1.025	1.000	1.024
Social/Welfare	1.000	1.000	1.000
Medical/Dental	1.000	1.000	1.000
Childcare	1.000	1.000	1.000
Park/Unpark	1.400	1.000	1.400
Total	1.027	1.067	1.034

- Any household for which the data were judged to be perfect, and hence would not have been phoned, needed to have unexpected nonreported stop weights applied (because had they been interviewed, an unexpected stop might have been found).
- Any household that had expected errors but that was not on the list to be validated and could not be phoned (because no number was given) would need to have both the expected and unexpected weights added.

The procedure, therefore, for application of the nonreported stop weights was as follows:

- If the household had been phone-edited or was a participant in the validation or nonresponse interviews, no nonreported stop weights were applied (this means a value of 1.00 was adopted).
- If the household had not been edited at all and if they stated that they did not have a phone or they did not say whether they had a phone (either way they definitely could not be phoned), then the expected and unexpected nonreported stop weights were applied to all stops made by that household.
- If the household had not been edited at all and if they stated that they did have a phone and they provided the phone number, then all stops made by members of that household received only the unexpected nonreported stop weights.

The final sets of nonreported stop weights for households with and without phone numbers are given in Tables 11 and 12.

As with the application of all correction weights, a major conceptual limitation must be acknowledged in the use of nonreporting correction factors. The reason for the application of the nonreporting weights is that some people did not tell us about some of the trips they made. By way of the validation interviews, we determine which are the most likely types of trips not to have been reported. We then multiply trips of this type that have been reported by a correction factor to compensate for the missing trips. In this way the total number of trips in the population should be more accurately estimated. However, from an individual person viewpoint, we are adding trips to those people who have already told us about their trips and not adding them to the people who have not told us about all their trips (because multiplying zero by any number still leaves us with zero trips). Therefore the total number of trips should be more accurately estimated, but the distribution of trips per person will be pushed further away from the real situation. Statistically, we have improved the estimation of the mean number of trips per person but artificially increased the variance of the number of trips per person. This occurs because of the use of multiplicative correction factors. To

TABLE 11 Nonreported Stop Weights (Phone Number Known) (*5*)

	Last Stop of Day?		
Destination Purpose	NO	YES	Total
Change Mode	1.072	1.000	1.072
Pick Someone Up	1.040	1.000	1.040
Drop Someone Off	1.022	1.000	1.022
Accompany Someone	1.049	1.000	1.049
Buy Something	1.006	1.000	1.006
Education	1.043	1.000	1.043
Work-Related	1.013	1.000	1.013
Go Home	1.011	1.086	1.057
Any Other	1.000	1.000	1.000
Personal Business	1.020	1.000	1.020
Social/Recreational	1.025	1.000	1.024
Social/Welfare	1.000	1.000	1.000
Medical/Dental	1.000	1.000	1.000
Childcare	1.000	1.000	1.000
Park/Unpark	1.449	1.000	1.449
Total	1.030	1.084	1.040

TABLE 12 Nonreported Stop Weights (No Phone Number) (*5*)

	Last Stop of Day?		
Destination Purpose	NO	YES	Total
Change Mode	1.083	1.000	1.083
Pick Someone Up	1.049	1.000	1.049
Drop Someone Off	1.022	1.000	1.022
Accompany Someone	1.066	1.000	1.066
Buy Something	1.006	1.000	1.006
Education	1.087	1.000	1.087
Work-Related	1.016	1.000	1.016
Go Home	1.027	1.139	1.097
Any Other	1.000	1.000	1.000
Personal Business	1.032	1.000	1.032
Social/Recreational	1.025	1.000	1.024
Social/Welfare	1.000	1.000	1.000
Medical/Dental	1.000	1.000	1.000
Childcare	1.000	1.000	1.000
Park/Unpark	1.600	1.000	1.600
Total	1.040	1.137	1.058

overcome this problem, we would need to develop additive correction factors that add the nonreported trips onto those people who have not told us about all their trips. However, this is logically difficult to implement. Therefore, multiplicative correction factors must be used in the realization that they improve estimates of the mean but worsen estimates of the variance. Since estimates of the mean are generally more important, it is better to use some form of multiplicative correction factor than not to use any at all.

Corrections for Nonresponse

Having corrected for nonreported trips of people who respond to the survey, it is now necessary to consider people in the sample who do not respond to the questionnaire at all. It is quite easy to think of a number of reasons why a nonresponse to a survey might occur. In this context we can only speak of a true or genuine nonresponse in a situation in which a response was indeed possible (e.g., the addressee simply did not want to respond). Quite a different situation exists where a response was not even possible (e.g., the addressee was deceased or the survey was sent to a nonexisting address). In this case we have what is often called "sample loss." Wermuth (*23*) provides data indicating the reasons for nonresponse to two self-administered mailback questionnaire surveys conducted in West Germany in 1981. He calls sample loss "nongenuine nonresponse" to distinguish it from "genuine nonresponse." Table 13 gives the results of these analyses of nonresponse.

The two basic concerns with respect to nonresponse are the importance of recognizing the existence of nonresponse and of the need to find ways of assessing its impact on the quality, representativeness, and reliability of the information derived from the survey. The analyst has to answer satisfactorily the question as to whether the results of the survey would have been the same even if a 100 percent response rate had been achieved. This question translates into the recommendation that the analyst establish information about the nonrespondents that will permit judgment about whether the information that could have been obtained from them would have been statistically different from that actually collected.

It would be desirable to have available a series of adjustment factors that could be applied for different surveys and population groups to account for the information lost through nonresponse. Unfortunately, these adjustment factors can only be obtained through significant survey research efforts into the characteristics of "typical" nonrespondents, which are generally costly and time-consuming. Since survey budgets tend to be very tight, it is virtually impossible to advance the state of the art of adjustments for nonresponse through regular survey activities. Separately funded and carefully staffed research efforts are necessary to achieve

TABLE 13 Reasons for Nonresponse in Self-Administered Surveys (*23*)

	Number of Households	
	Survey #1	Survey #2
GROSS SAMPLE	5039	7688
SAMPLE LOSS	370	603
Reasons:		
addressee deceased	*24*	*40*
household moved	*150*	*359*
addressee unknown	*172*	—
other	*24*	*204*
NET SAMPLE	4669	7085
Genuine non-response	1710	2677
Reasons (as far as known):		
Objective non-responses	147	279
- too old	*71*	—
- ill	*36*	*206*
- out of town	*40*	*73*
Subjective non-responses	249	437
- non-acceptance of questionnaire	*57*	—
- answer refused	*183*	*247*
- lack of time, other	*9*	*190*
Genuine non-responses (with known reasons)	396	716
Respondents	2959	4408
Household response rate	63.4%	62.2%

significant and analytically sound advances in this area. On the other hand, it has been shown through the limited research efforts that exist in this area (*5,10,23–26*) that an understanding of nonresponse effects can lead to significantly more accurate and representative survey results.

Moser and Kalton (*27*) identify five general sources of nonresponse:

- No longer at available address ("movers"),
- Physical (health-related) inability to respond,
- Refusals,
- Away from home during survey period, and
- Out at time of call.

Several strategies have been proposed to compensate for people whose addresses have changed since the sampling frame was prepared. One approach is to substitute for the moved household the new household that has moved to that address (if the sampling unit is the household address and not the specific residents). Another strategy could be to try to "pursue" the household to its new address and to obtain a response at that location (if the identity of the specific residents is important to maintain). A third strategy is to determine the number of households that have moved out of the survey area during the m months preceding the survey and to double the weight of an equal number of respondents who have moved into the area during that same time period. In this way the movers-in are included in the sample on their own behalf and also in place of the movers-out (*28*).

Only the last four reasons for nonresponse are of major interest to the analyst because the first reason could be considered as falling into the category of sample loss (i.e., they are out of the analyst's control once the survey sample has been drawn). It is the nonrespondents legitimately belonging in the sample who are of particular interest to the analyst because, under these conditions, carefully designed survey procedures can help reduce the problem. Very little, if anything, can be done about correcting for the nonresponse in the second category, neither in mailback self-administered surveys nor in home interview surveys. However, we ought to keep in mind with respect to the other reasons that nonresponse is a relative term. It depends very much on the surveyor's level of perseverance, quite aside from the quality of the overall survey design and administration. For example, in mailback surveys, it would be very unwise to omit follow-up reminders and to be satisfied with whatever is returned in the

first wave (i.e., after the questionnaire has first been distributed). The use of reminders can significantly increase the number of respondents, as shown in Figure 8.

Similar results are shown in Figure 10, which is based on surveys conducted in West Germany (*23*). It can be seen that in all three sets of survey data, the response rate increased significantly with the use of reminders. In the surveys carried out in three West German cities, a very extensive system of reminders was used, consisting of the following steps:

1. First announcement of survey by postcard,
2. First mailing of questionnaires (2 weeks later),
3. First reminder (postcard, 1 week later),
4. Second reminder (postcard, 1 week later),
5. Second mailing of questionnaires (1 week later),
6. Third reminder (postcard, 1 week later),
7. Third mailing of questionnaires (1 week later),
8. Fourth reminder (postcard, 1 week later), and
9. Fifth reminder (postcard, 1 week later).

In the survey covering nine cities, only Steps 1 through 5 were implemented, whereas in the Munich survey only Steps 1, 2, 3, and 5 were implemented. Several points arise from consideration of Figure 10. First, if each of the surveys had omitted all reminders, a response rate of only 30 to 35 percent would have been obtained. This, coincidentally, is the response rate often quoted for self-administered surveys. The use of the reminders, however, increased the response rates to more than 60 percent for all surveys. Second, it appears that only two mailings and reminders are needed. Whereas further reminders increase the response rate, they do so only marginally and are probably not very cost-effective. Third, the results are remarkably consistent over all of the surveys.

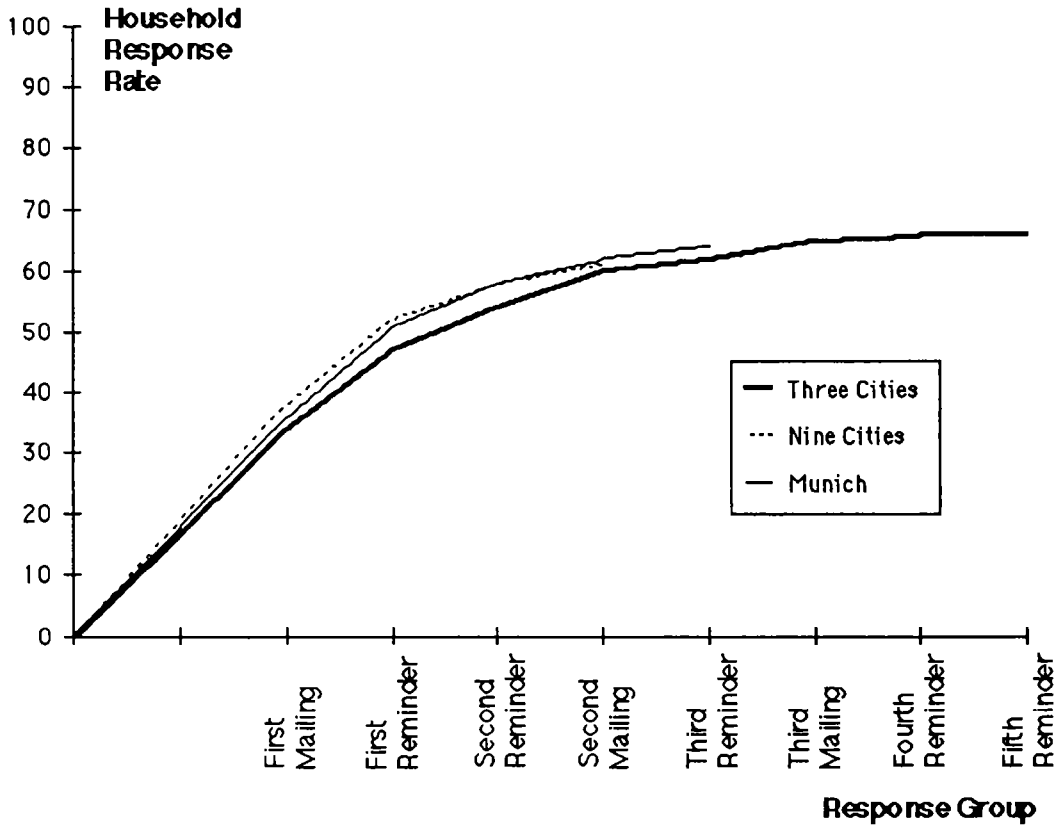

FIGURE 10 Effect of reminders on questionnaire response rates (*23*).

In addition to the responses being stimulated by the reminders, common sense alone tells us that the early respondents are likely to be different "from the rest of us" because they may have a particular interest in the topic of the survey or the time to respond to a survey very promptly. It is conceivable, for example, that a disproportionate percentage of retired people are among the respondents of the "first wave." Wermuth (*23*) investigated the socioeconomic status of respondents in the various response groups and found that, in both the Munich survey and the "three cities" surveys, larger households were more likely to respond and to respond earlier, probably because of the increased chance of finding someone in the household willing to complete the survey. Older people are more likely to respond, probably because of their greater free time. Employed people are more likely to respond, probably because of their greater extent of trip making and hence the greater perceived relevance of the travel survey. There appears to be no difference in response between males and females.

Similar results were found in the SEQHTS survey (*5*), as indicated in Tables 14 and 15.

Since household size, employment status, age, and time availability are likely to have an impact on trip-making characteristics, it is reasonable to assume that the travel characteristics and data for nonrespondents will be different from those for respondents. Brög and Meyburg (*24–26*) have demonstrated that trip-making characteristics change substantially as additional response waves due to reminders are recorded. For example, for the nine cities survey, Figure 11 shows that the trip frequency and the proportion of mobile persons in the population (i.e., people who make at least one trip) both decrease as the time to respond increases. Thus mailback questionnaire surveys that do not include follow-up reminders tend to overestimate trip making because of the higher mobility of the early respondents. This contrasts with home interview or telephone interview surveys, where the early respondents tend to be the "stay-at-homes" who generally have trip rates lower than average. Thus personal interview surveys without call-backs tend to underestimate trip rates.

The observation that trip rate declines with increasing time to respond to the survey has been interpreted as meaning that the trip-making characteristics of late respondents are different from those of earlier respondents. However, before this interpretation can be accepted, we need to account for two other possible explanations. First, it could be that late respondents simply belong to sociodemographic groups different from those of early respondents and that, whereas they make fewer trips, they make no fewer trips than early respondents in the same sociodemographic group. It has been shown above that the sociodemographic characteristics of early and late respondents are indeed different, and therefore sociodemographic expansion will tend to partially correct for the nonresponse problem.

Second, whereas the observed (i.e., reported) trip rates are lower for late respondents, it may be that they do not make fewer trips but simply report fewer trips (i.e., they have a higher nonreporting rate than early respondents). For the reasons given earlier, it is first necessary to correct reported trip rates in each response wave for sociodemographic and nonreporting differences as described in the preceding two sections of this paper.

In the SEQHTS survey responses were classified into six groups according to the time taken to respond. Those responding within 7 days (1 week) of their original travel day are classified as Wave 1 respondents. Those responding within 2 weeks of their original travel day are clas-

TABLE 14 Household Characteristics of SEQHTS Respondents by Wave (*5*)

	RESPONSE WAVE					
HOUSEHOLD SIZE	1	2	3	4	5	6
1	61%	17%	6%	10%	4%	2%
2	64%	17%	6%	9%	3%	2%
3	59%	20%	7%	7%	4%	2%
4	63%	18%	6%	8%	3%	1%
5	56%	21%	8%	10%	4%	2%
6	53%	24%	5%	12%	4%	2%
7	54%	21%	11%	11%	4%	0%
8	63%	25%	0%	0%	13%	0%

TABLE 15 Personal Characteristics of SEQHTS Respondents by Wave (*5*)

	RESPONSE WAVE					
	1	2	3	4	5	6
AGE GROUP						
0 -> 4	58%	19%	7%	10%	4%	2%
5 -> 9	60%	18%	6%	9%	4%	2%
10 -> 14	61%	19%	6%	9%	3%	1%
15 -> 19	60%	21%	7%	8%	3%	2%
20 -> 24	52%	22%	8%	10%	4%	3%
25 -> 29	54%	21%	9%	9%	5%	3%
30 -> 34	60%	19%	7%	9%	4%	2%
35 -> 39	61%	19%	6%	8%	4%	1%
40 -> 44	61%	18%	7%	8%	3%	2%
45 -> 49	64%	17%	6%	9%	2%	1%
50 -> 54	61%	21%	7%	8%	3%	1%
55 -> 59	71%	17%	5%	5%	1%	1%
60 -> 64	75%	14%	4%	5%	1%	1%
65 -> 69	76%	11%	4%	5%	2%	1%
70 -> 74	74%	14%	2%	7%	2%	1%
75+	70%	16%	6%	6%	1%	1%
SEX						
Male	60%	19%	7%	8%	3%	2%
Female	61%	18%	6%	9%	4%	2%
ACTIVITY STATUS						
Full-Time Employment	58%	21%	7%	9%	4%	2%
Part-Time Employment	62%	18%	6%	8%	3%	2%
Primary School	60%	18%	6%	9%	4%	2%
Secondary School	60%	20%	8%	8%	3%	1%
Tertiary College	59%	24%	6%	7%	2%	1%
Not yet at School	59%	19%	7%	10%	4%	2%
Pre-School	58%	20%	5%	8%	5%	3%
Childcare	53%	22%	6%	10%	7%	2%
Keeping House	63%	17%	7%	9%	3%	1%
Currently Unemployed	59%	19%	6%	9%	4%	3%
Retired or Pensioner	73%	14%	4%	6%	2%	1%
Other Pensioner	67%	12%	8%	6%	4%	3%
Other	77%	17%	2%	3%	2%	0%

sified as Wave 2 respondents, and similarly for Wave 3 and Wave 4 respondents. Those responding of their own volition after 4 weeks are classified as Wave 5 respondents. Those responding as a result of the nonresponse interviews are classified as Wave 6 respondents. Sociodemographic expansion factors were first applied to responses in each of these waves, followed by the calculation and application of nonreporting weights for each response wave.

Calculation of the average, and upper and lower percentiles, of the number of stops per person per day for respondents in each of the response waves, after application of the expansion factors and nonreporting weights, gave rise to the curve shown in Figure 12.

It can be seen from Figure 12 that the average number of stops per day decreases as the time taken to respond increases. Thus the respondents in the first wave have the highest stop rate, and those in the last waves have the lowest stop rates. This trend is consistent with that found in previous work (*23*).

A better picture of this trend can be obtained by considering the number of responding households in each of these waves and the cumulative percentage of responses. Thus in the SEQHTS survey 60 percent of the total respondents (weighted for demographic characteristics) responded within 1 week of the initial travel date, another 19 percent responded in the week after this, and so on. By the end of Week 2, a cumulative total of 79 percent of the total respondents had responded. The sixth response wave consists of respondents who were obtained from the nonresponse interviews. They represent more than themselves, however,

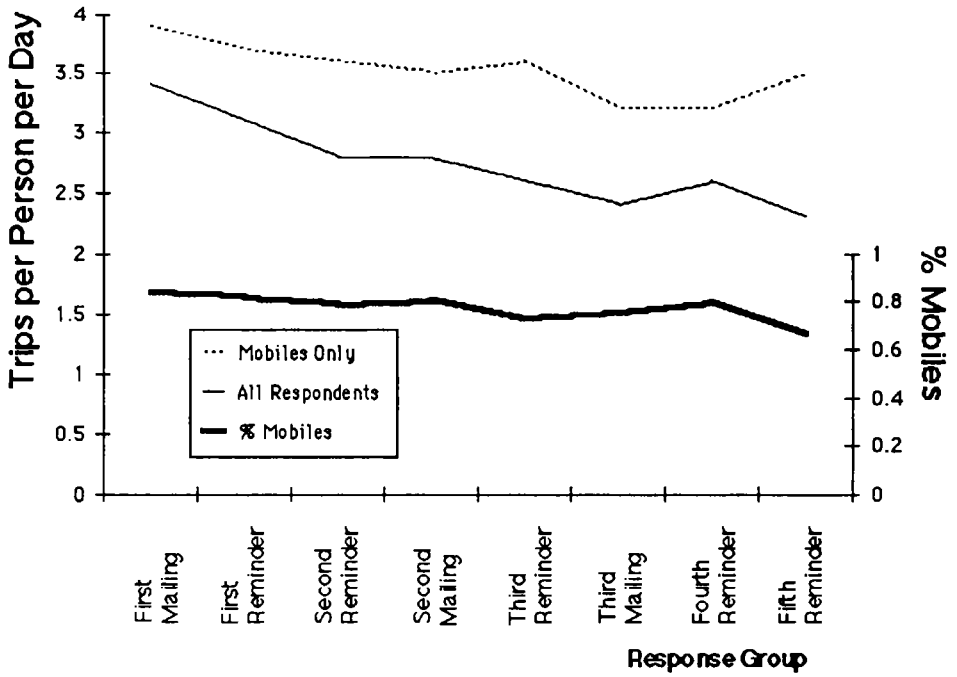

FIGURE 11 Travel characteristics as a function of response speed (*23*).

since only a sample of nonresponding households was included in the nonresponse interview sample. The nonresponse sample was found to consist of three subgroups: those who agreed to respond, those who refused to respond to the survey, and those who did not respond for other (perhaps travel-related) reasons. The second group have been referred to as "stubborn" nonrespondents; Wermuth (*23*) has noted that approximately 10 percent of the net sample are stubborn nonrespondents. The SEQHTS survey found that approximately 11 percent of the net Brisbane sample fell into this category. Therefore, it would never be possible to get more than 89 percent response from the net sample, and this value has been used as the up-

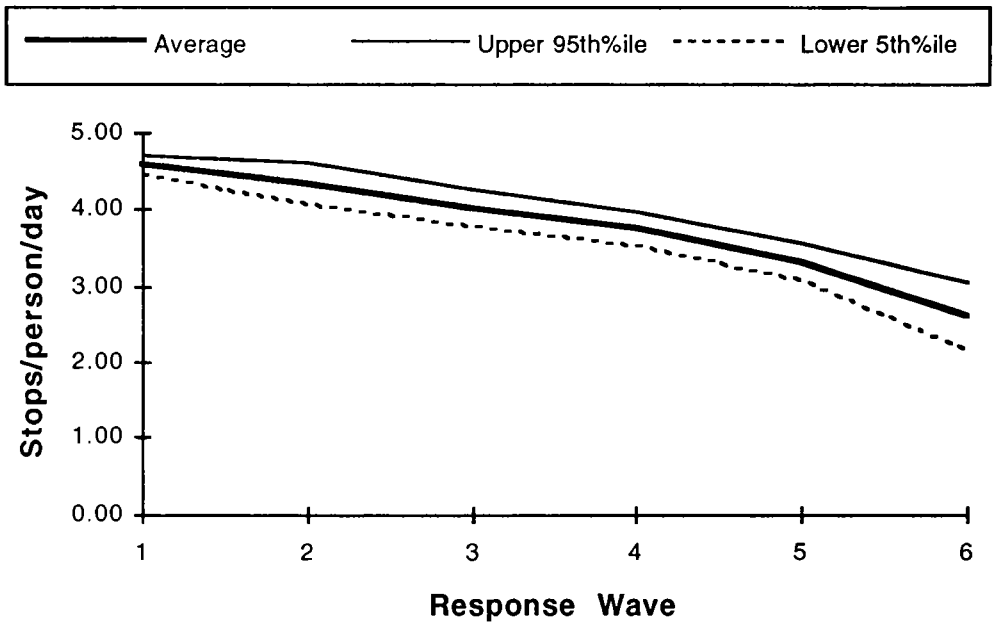

FIGURE 12 Average stop rate as a function of response wave (*5*).

per limit of cumulative response for Response Wave 6. The relationship between stop rate (stops/person/day) and cumulative percentage of net sample is shown in Figure 13.

This relationship (for the first five waves) is very similar to that obtained by Wermuth (*23*) in that the stop rate falls relatively uniformly after the second response wave. Using such a relationship, Brög and Meyburg (*26*) have postulated that the trip-making characteristics of nonrespondents are likely to be more similar to those who respond late to travel surveys than to those who respond early to travel surveys. They have assumed a linear decrease in stop rate after the second response wave up till the last respondents to the mailed questionnaire. They then project forward to estimate the likely stop rate of the nonrespondents.

In the case of Figure 13, a linear relationship is postulated as given by the dashed line overlaid on the response curve. This would give an estimate of approximately 2.65 stops/person/day for the nonrespondents. As it happens, in the SEQHTS survey, there was the unusual situation of actually having an empirical measurement of the stops/person/day for the nonrespondents from the nonresponse interviews. The actual value was 2.61 stops/person/day. This confirms the overall validity of the approach adopted by Brög and Meyburg (*26*) and Wermuth (*23*).

Given that these nonrespondents have a lower stop rate than the respondents, it is necessary to apply a correction factor to all observed stops to reduce the estimated population stop rate to account for the lower stop rate of the nonrespondents. Whereas it is possible that the reductions in stop rate apply nonuniformly to various types of stop, such differentiation has not yet been attempted; the nonresponse correction factor is applied equally to all stops. Later research should investigate variations in nonresponse correction factors by stop purpose, mode of travel, and so forth.

The nonresponse correction factor is calculated by considering the three major groups in the net sample and the stop rates associated with each group. The three groups are the respondents, the nonrespondents, and the stubborn nonrespondents. In the SEQHTS survey, these groups make up approximately 73 percent, 16 percent, and 11 percent of the net sample, respectively. The stop rates associated with the first two groups can be found from the data for the waves of respondents and the wave of nonrespondents. Thus the average stop rate for respondents in the first five waves is 4.38, and the average stop rate of nonrespondents is 2.61. The average stop rate for stubborn nonrespondents is assumed to be 4.38 (the same as the respondents, on the assumption that their unwillingness to participate in

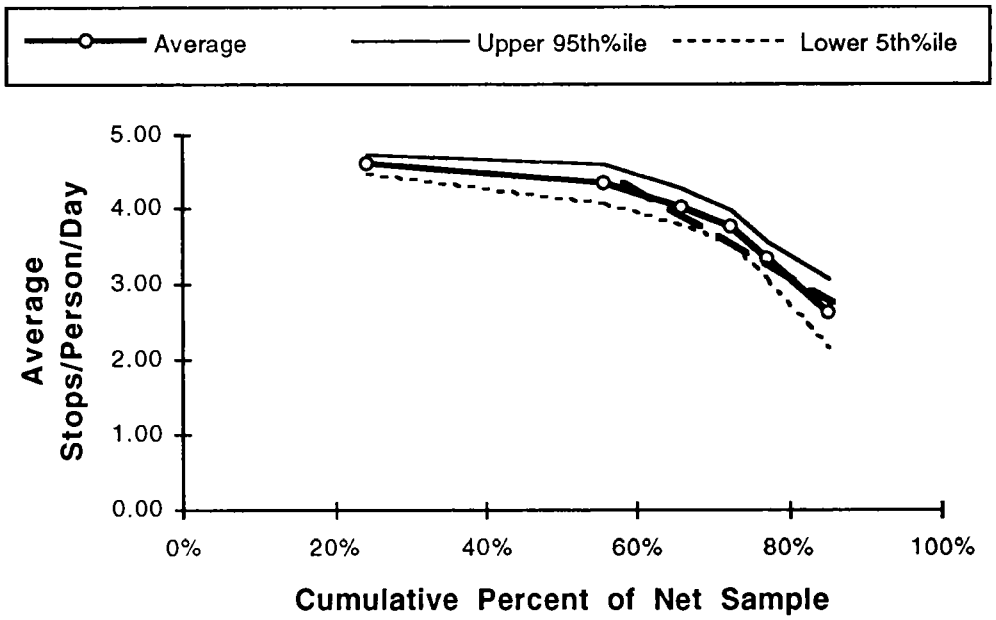

FIGURE 13 Stop rate as a function of cumulative response (*5*).

the survey has nothing to do with their travel behavior). Thus, the weighted average stop rate of the entire sample is $0.73 \times 4.38 + 0.16 \times 2.61 + 0.11 \times 4.38 = 4.10$. Since the average stop rate for the respondents would have been calculated as 4.38, a correction factor of 0.935 (equal to 4.10/4.38) was applied to all stops reported by respondents to obtain the correct stop rate for the entire net sample. This weighting factor was applied to all records in the stop file.

To minimize the effect of possible nonresponse bias, it is therefore good survey practice to send out at least one combination reminder/thank you postcard, followed 1 week later by another reminder postcard with a new survey form and, if funds and time permit, a third postcard after another week. This procedure will generate several response waves and will both reduce the nonresponse rate and increase the quality and representativeness of the survey results. It will also provide information on those respondents to the later reminders who might otherwise have been nonrespondents. This information can be used to investigate any trends in travel characteristics as a function of response speed, which can then be used to infer the travel characteristics of those who remain as nonrespondents.

For personal interview surveys the refusal rate is largely a function of the skill and experience of the interviewer. The subject matter of the survey also plays a significant role in the respondents' willingness to answer questions on a specific topic. Conflicting results have been reported on the desirability of making interview appointments by prior telephone call or by postcard announcement. Sudman (*29*) reported that the number of calls required to complete an interview was reduced from 2.3 to 1.7 per completed interview. On the other hand, Brunner and Carroll (*30*) found that prior telephone appointments had the undesirable effect of reducing the response rate. People will find it easier to refuse cooperation through the relative anonymity of a telephone contact than when confronted in a face-to-face situation at their home. Unfortunately, relatively little methodological detail for travel surveys has been reported in the literature. Rarely, for example, would one find enough information to construct empirical versions of the sampling and response process diagrams shown in Figures 5, 6, and 7. Until researchers begin to report the details of their survey methodology in as much detail as they report the results of the survey, we will not begin to develop a quantitative base upon which survey practice can be improved.

Finally, an "unrepaired" nonresponse bias may be serious enough to warrant selecting a smaller initial sample and placing more of the resources into a concentrated effort to obtain a higher response rate. Cochran (*31*) and Deming (*32*) have indeed taken this position. It is clear that ignoring the effect of nonresponse is a highly unprofessional and unscientific approach to survey sampling.

Conclusions

This paper has examined the issues of nonresponse in household travel surveys. The following points have been highlighted:

- The issues of nonresponse need to be considered within the framework of an overall systematic approach to the conduct of travel surveys. Nonresponse issues need to be planned for at the beginning of the survey process, not reacted to at the end of the process.
- In any survey, there is a trade-off between the quantity, quality, and cost of the data. Attention to nonresponse issues can improve the quality of the data (by removing biasing effects) and can also improve the cost-efficiency of data collection.
- There needs to be a clear recognition of the difference between sampling error (which is a function of the quantity of data collected) and survey bias (which is a function of the quality of the data collected). In the past, too much attention has been focused on increasing sample size, which increases the precision of population estimates, and not enough attention has been focused on the removal of biases, which increases the accuracy of the data.
- There are a number of different types of nonresponse, including failure of the household or person to respond at all, failure to provide details on entire trips, and failure to provide full information about variables describing trips.

- A number of different strategies exist to deal with nonresponse issues. Essentially these are to adopt design and administration procedures to reduce the extent of nonresponse and to use correction and weighting procedures to correct for the biasing effects of any remaining nonresponse.
- It is essential that all types of nonresponse be recognized in the various types of household travel survey and that consistent methods of calculation of response rate be used for the different types of household travel survey.
- The use of sociodemographic expansion factors, based on a source of accurate secondary data, is an essential component of any survey that purports to provide results describing the behavior of the population.
- In mailback travel surveys, the use of follow-up validation interviews can provide information allowing for the calculation of nonreported-trip weighting factors to correct for the underreporting of various types of trips in self-completion travel surveys.
- The use of a series of reminders in mailback surveys can dramatically increase the response rate and also provide information allowing for the calculation of nonresponse weighting factors that reduce the biasing effects of nonresponse.

Clearly, there will always be some nonresponse in all travel surveys. This paper attempts to raise the awareness of nonresponse and the bias it introduces into sample surveys. It has shown that the effects of nonresponse must be planned for at the very start of the survey process and procedures put in place to reduce both the extent of nonresponse and the effects of any remaining nonresponse. The paper has demonstrated how nonresponse might be reduced and how corrections might be applied to bring the final estimates of population parameters closer to their real values.

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Scope and Potential of Interactive Stated Response Data Collection Methods

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The scope of the growing number of interactive data collection methods directed at transport user response in future situations is reviewed. A brief introduction is given to the application of these methods under both the utility-maximization framework and a series of alternative assumptions about travel choice proposed by Gärling. It is suggested that the term most used in this domain of transport surveys, stated preference (SP), should be reserved for a particular subset of a diverse body of techniques that deserve a new nomenclature under the general term stated response (SR). A taxonomy of four classes of SR approaches according to whether constraints or behavioral outcomes (or both) are predefined rather than elicited in the survey designs is presented. In view of the considerable existing literature on conventional SP, the discussion focuses mostly on the other SR approaches. Examples of these approaches are given from travel survey research, as well as some broad guidelines for the selection of techniques and some directions for further research.

The label "stated preference" (SP) has been increasingly applied since the 1980s to various ways of surveying user response to hypothetical travel attributes and choices, thus distinguishing them from "revealed preference" (RP) surveys of actual travel patterns. Such techniques have generated considerable methodological debate in recent years, and this has spilled over to metropolitan planning organizations and others who must decide how to assign limited resources to new data collection, especially in the context of the requirements of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA).

Charged with anticipating change, many transportation planners are faced with a dilemma: whereas they may have a strong sense that it is not enough to observe current travel patterns, many are suspicious or unsure of what the SP tool kit may measure. The waters are further clouded by confusion over the word "preference," which has its roots in the early preoccupation of these methods with responses to alternatives, presented in surveys, in which the attributes of journeys (such as fare or travel time) were varied according to a predetermined design. In the SP workshop of the Third International Conference on Survey Methods in Transport, the comment was made that "stated response" (SR) might be a more accurate general term (*1*). I agree, and in the remainder of the paper, SR is used as the generic term, still referring to SP as it is used in the (largely econometric) literature on this subject.

In this discussion paper, it is suggested that (*a*) the notion of stated preference/response translates into many different data collection techniques and strategies, (*b*) the term SP should be reserved for a particular subset of techniques mainly used to estimate utility functions, and (*c*) SP data collection may or may not be necessary or sufficient, depending on which aspects of future choice are of interest and what time horizon is specified. The dimensions of transportation policy that are creating the demand for SR type data are examined, and an attempt is made to scope and classify these data collection techniques. Because much of the recent variety in SR is found in interactive data collection methods, these are the focus of the paper. Examples of the various classes of interactive stated response (ISR) are identified in such policy areas as congestion pricing, the potential use of electric vehicles, and energy contingency planning. Recommendations for considering ISR in data collection strategies are made, and some priorities for the research agenda are suggested.

The mandate for this discussion paper was to take a broad view of interactive SR methods. Current issues in SP experimental design and analysis techniques are discussed by Polak and Jones (*2*). The fact that most of the discussion in this paper goes beyond the "mainstream" of SP should not be interpreted as a dismissal of its usefulness.

Policy Planning Context for Stated Response Data Collection

Fundamentally, SR techniques are needed where information is sought about user responses to new situations. These may vary from highly specific situations, such as a change in a single supply characteristic (e.g., the frequency of a given bus service), to very comprehensive situations, such as the policy packages that might be used to improve air quality in a metropolitan area. The planner is, moreover, interested in alternatives, so the survey must provide the means of comparing different scenarios or versions of the potential change. Considering hypothetical alternatives is attractive from a sampling efficiency perspective. Each individual provides multiple sets of responses, each of which would require a different respondent if the survey were directed instead to "revealed" choices in a particular policy context.

Four dimensions of transportation planning policy in which SR may play a significant data collection role are discussed now, leaving methodological details for later sections of the paper.

Infrastructure Investment

Many of the well-developed SP techniques for collecting and analyzing data have addressed the benefits of infrastructure investments, notably through reducing travel time. An important objective has been to discover the monetary value of time for use in cost-benefit analyses of alternative investments. In the current investment climate, it is becoming increasingly important to discover the distribution of values of travel time and not just the mean values (*2*). However, the implicit idea is that the various components of travel time (walking access time, waiting time, in-vehicle travel time, etc.) have associated average levels of perceived satisfaction or utility, which the survey must measure. The planner may also want to know how the user trades off travel time against other transport supply attributes, such as the comfort and availability of seating or the reliability of information. Thus a major objective has been to develop models that predict choices in the presence of changed levels of attributes, under the assumption that individuals maximize their utility. Modeling utility functions for attributes is a major contribution to evaluating competing potential infrastructures or competing features of particular infrastructures.

Evaluating Novel Interventions

The introduction of a novel transport service or the building of an entirely new road are, of course, also investment decisions. But in common with regulatory innovations, such as con-

gestion pricing, they add another element to the difficulty of data collection: respondents are now being asked to consider situations that not only do not yet exist but of which they have little or no experience. Consider the case of proposals for a new river crossing that alters the time-map of a whole region, or for the provision of a driverless light rail system. Here the survey researcher faces the challenge of evaluating responses in the light of an image constructed partly from information supplied by the survey instrument and partly from the highly variable impressions respondents carry from other situations.

One of the problems of novel interventions is that adaptive responses by users may be very complex. This is particularly so in the case of unfamiliar technologies, such as intelligent transportation systems, telecommuting, or limited-range electric vehicles, the use of which may have implications for the linking of activities between travelers within or even between households. Responses to interventions affecting car use also tend to be complex because of the inherent flexibility of the mode. A further complexity is that transport innovations may be packaged with other products, such as hotel accommodations in the case of tourist travel.

Lowering the Risk of Strategic Planning

Here we must consider the data needs of planning with long time horizons to meet broad objectives such as sustainability, quality of life, or regional competitiveness. In fact, understanding the time horizon of anticipated changes is one of the most important steps in the specification of appropriate SR survey techniques. As noted in a recent overview of SP methods (2), longer-term horizons mean that structural changes can be contemplated by respondents. These changes may be in demography, life-style, or the economy, not just in the transport system. We may be very far from forecasting travel demand over long horizons, but nonetheless there is a need to imagine how travelers may respond to alternative futures envisaged by such planning policies as housing redensification, car restraint in historic city centers, demand restraint in nonattainment air quality districts, or the introduction of an open-skies policy in the regulation of the airline industry. A fundamental problem in the design of SR surveys is the instability of stated responses projected over a long period during which responses are likely to change as a result of accumulated experience. It is suggested later in this paper that such learning processes should themselves be one of the targets of data collection.

Emergency Planning

Transport planners are increasingly expected to help reduce the negative impacts of such temporary situations as the aftermath of natural and industrial disasters, public transport strikes, energy supply disruptions, and critical periods of air pollution. As in novel interventions, the survey researcher may face the double difficulty of assessing hypothetical responses under unfamiliar conditions, but the social and political contexts are very different. Emergency situations are sometimes the subject of contingency planning, a process to which SR surveys have contributed. In addition, actual emergencies may provide valuable opportunities for experimentation of a type that would normally be unthinkable, a point to be discussed later.

Scoping the Notion of Interactive Stated Response

Interactive methods are "generally taken to mean techniques which give explicit recognition to interaction between the interviewer and respondent(s) and attempt to use this positively" (3). In many cases, the interaction permits survey instruments to be modified or customized in the field on the basis of the characteristics, initial responses, or revealed behavior of respondents.

Predominant Uses of Interactive SR Methods in a Utility-Maximizing Framework

Most classifications of SP methods distinguish between surveys in which respondents rank or rate packages of attributes and those in which they are asked to choose between behavioral outcomes. Most of the SP literature takes for granted that these two main classes of data are to be specified and analyzed within a utility-maximizing framework. It is therefore to be expected that interactive SP methods are predominately proposed to improve the input to utility-based models. A detailed review of the relevant design issues is beyond the scope of this paper, but we should be aware of the growing contribution of interactive methods to answer three major concerns.

The first is that the quantification of preferences and choices will be invalid, or unreliable, if respondents are overburdened. Respondents cannot reasonably be expected to consider, without fatigue, all possible combinations of packages. Because full-factorial experimental designs are feasible only for very limited problems (i.e., those with few attributes and few levels to be presented), much attention is given to the specification of fractional and hierarchical designs. There are numerous examples in the literature of the advantages of relaxing completeness or orthogonality in the interests of package realism or to tailor boundary values (*4*). Thus, much emphasis is now placed on what is generally called "adaptive" designs, and in particular the development of interviews using portable computers. A very useful discussion of the principles of such designs is given by Bradley (*5*). These may be programmed to generate preference or choice packages relevant to a "revealed" base, usually the respondent's situation or the attributes of the current journey. It is also possible to include screening questions about key values in the process. There are, however, some risks, including nonorthogonal estimation data, problems with respondents with extreme preferences, and possible bias from correlations between the levels of design variables and the unmeasured components of utility (*2*).

A second concern is that respondents may vary in their willingness and ability to cooperate with SP tasks. Some trivialize the tasks presented. Even those who cooperate may, as Bates (*6*) puts it, "choose 'paths' through the task which do not correspond with the decision rules used by the analyst." It is also possible, in principle, to use computer-aided interactive interviews to detect poor cooperation and to use branching or interview termination in these cases. Obviously, we should then question how much sampling bias we are willing to introduce. However, it may be even more important, as Bates points out, to use another interactive technique—debriefing of respondents—to investigate how they interpreted the instructions for the task and how they viewed the exercise. Regardless of the degree to which respondents apparently complied with the instructions, it is particularly important to find out how much they may have temporarily changed the way they make decisions to complete the exercise.

A third major concern is the degree to which a respondent has an understanding of the contexts of stated preferences that is largely shared by all other respondents and correctly interpreted by the researcher. This is particularly troublesome in that context-dependence may underlie a number of observed discrepancies in the valuation of attributes, notably the "package effect" (*2,6*). In this effect, SP analyses typically suggest lower valuations of secondary attributes (such as comfort) when they are presented as part of a package including primary variables (such as fare) than when they are treated independently in an experimental design. There is a potential role for interactive methods to examine the perception of contexts explicitly in a pilot phase of an SP survey. This is an important example of a data-collection strategy involving more than one type of SR, a development illustrated later.

To summarize, these three concerns from SP, as practiced within the utility-maximizing framework, have served to introduce a number of key elements of interactive response techniques:

- The establishment of a revealed behavior base for an interview (this may involve travel or activity diaries administered and processed ahead of the interview);
- The "calibration" of SR instruments to the revealed behavior base, and possibly to initial assessments of boundary values;

- The elicitation of perceptions of contexts; and
- The debriefing of respondents about what they believed they were doing when responding to tasks and exercises as part of an SR survey.

We will now consider some alternatives to utility theory that require, among other things, extension of these elements.

Alternative Theoretical Frameworks for Travel Behavior

There has been a long debate in the travel behavior literature over the adequacy of the utility-maximizing framework as a description of how travel choices are made. The present purpose is not to take sides in this debate but to review the relevance of ISR methods to the data requirements of some alternative frameworks.

By the end of the 1970s, the part of the debate concerning measurement issues had benefited from a burgeoning of experimentation in transport survey and modeling methods. One consequence was a growing recognition that measurement should vary according to the complexity of the travel decision context. Heggie and Jones (*7*) organized decision contexts into four main domains with distinct empirical relationships and hence different possibilities for both modeling and measurement. The four domains were defined according to the degree of linkage or dependence between decisions along two dimensions: interpersonal and spatiotemporal. The four domains were identified as (*a*) independent, (*b*) spatiotemporally linked, (*c*) interpersonally linked, and (*d*) fully interdependent on both dimensions. The last two domains were subdivided according to whether the linkages functioned predominately within or between households. Of importance to the present discussion is that utility-maximization approaches are of limited applicability to the first domain, the domain of independent decisions, and that few utility-maximization solutions are known for the interdependent decision domains (the second, third, and fourth).

Three other illuminating reviews from this period, Brög and Erl (*8*), Dix (*9*), and Hanson and Burnett (*10*), lay out many of the measurement issues that are far from resolved a decade and a half later. Brög and Erl had long been concerned that planners may focus on monitoring trips without regard to the evolution of underlying human activities. They argue that only interactive measurement can adequately relate current and future household travel decisions to the "situational" context out of which comes the factors determining the degree of flexibility enjoyed by household members. They caution about expecting socioeconomic variables to account for the situational context and suggest that a chain of "objective circumstances—personal perception—subjective situation—individual decision—behavior" must be reenacted to understand behavior. Furthermore, this requires a comprehensive survey design using a variety of methods, some of which could observe the household members' efforts to reorganize their travel under hypothetical changes in transport supply and some of which should observe the household decision process in itself. Many emerging methods, such as gaming-simulation, offer worthwhile data, but no one method should be seen as "the" solution. They cite a number of applications of these ideas to understanding behavior without losing sight of the planner's need to estimate demand.

Dix contrasts the development of attribute-utility approaches and conjoint measurement (which was then emerging into utility-based SP) to other approaches such as attitude-based segmentation and activity-based interactive measures. He, too, draws attention to the notion of choice as a process rather than an event and lists the diversity of psychological concepts embraced by different travel behavior researchers during the 1970s: learning theory, habit formation, cognitive dissonance, satisficing, noncompensatory attribute-utility, arousal or curiosity seeking as a component of utility maximization, psychological response thresholds, and selective attention/information acquisition.

Hanson and Burnett focus on the measurement of travel as complex behavior in constrained situations, cover activity theory in much greater depth from a spatial perspective, and argue for "the flexible selection of methodological procedures for the problem at hand."

Both they and Dix elaborate on the critical insight that expressed choice is not the same thing as freedom to act, which gets to the heart of why the term "stated response" is more appropriate than "stated preference" for the class of survey methods that is the subject of this paper. If choice is a process, understanding behavioral outcomes under constraints requires dynamic measures of freedom to act. Hanson and Burnett thus emphasize that longitudinal panel data on activities are indispensable in the RP domain, whereas in the SR domain, both papers point to gaming-simulation as one promising new survey tool for exploring the dynamics of freedom to act under future conditions.

In the 14 years since the publication of these three papers, transport planning has continued, on the whole, to depend on surveys designed in the light of microeconomic theory and econometric methods. At the same time, there has been a certain amount of development of transport survey methods built around behavioral concepts other than utility maximization, as well as considerable research on activity-based methods and decision processes, much of it in fields such as time-use research, organizational psychology, and consumer behavior. Some of these developments are discussed later, but to understand data requirements, the variety of behavioral concepts and assumptions that may be included in travel choice models must be introduced. Gärling (*11*) provides a very useful review of alternative behavioral assumptions that places many of the concepts raised in the 1970s into the context of a wide range of recent behavioral research. In essence, these are the interdependency of "planned" decisions, information acquisition/representation/use and its relationship to planned behavior, the variety of heuristic and reason-based decision rules used by travelers, the potential for social factors to constrain egoism, and the process of implementing and maintaining choices.

Scope of Interactive SR Methods Under Alternative Theoretical Frameworks

At this point in the discussion, a transportation planner faced with writing a request for proposals to collect new data on potential changes in travel behavior might feel some despair over how to translate the plethora of behavioral concepts into methods applicable to policy analysis imperatives such as air quality and demand management. To the extent that travel choice is conceptualized as a dynamic and complex social-psychological process, much of the research needed to formalize the generalizability of our analyses may still be incomplete long after the current information requirements of the ISTEA and Clean Air Act regulations have been answered. After all, travel behavior modeling has made only limited progress in this direction in the past two decades.

Nevertheless, it would be a mistake to focus that part of new data collection concerning future behavior only on those attenuated problems compatible with current state-of-the-art, SP-based predictive models. Unless a foundation of data is built on which explanatory models of more complex behavior can be developed and that knowledge is used to validate the simplifying assumptions underlying most current SP, the credibility of all SR tools will be in doubt. Part of that validation will come from the simultaneous application of different instruments, and multi-instrument data collection strategies may offer more than the sum of the parts in travel behavior measurement. But criteria are needed for specifying a balance on the scales of specificity-comprehensiveness, prediction-explanation, and quantitativeness-qualitativeness to select the optimal set of survey methodologies in a particular policy environment. As a first step, in the next section of this paper, a schema for distinguishing four main types of SR survey is presented. However, the broad implications for survey methods of the major alternatives to the utility maximization framework must be examined. To do this, Gärling's five areas of alternative behavioral assumptions (*11*) are followed.

1. Interdependency of "planned" decisions: Gärling puts the emphasis on problem-solving theories of decision making and suggests in particular the use of production-system models of how people plan. Such models include metadecisions about how much to plan and under which guidelines. He argues that these metadecisions and external circumstances are more important than usually believed. In surveys of response to future contexts, this appears to require some sort of problem-solving exercise by respondents. Clearly, a key design pa-

rameter is the complexity of the interdependencies pertinent to the issue at hand. For this, a good point of departure is Heggie and Jones's domains of decision contexts (7). Such problem-solving exercises should also be interpreted in relation to previously used decision rules in contexts of comparable complexity (see Item 3).

2. Information acquisition/representation/use and its relationship to planned behavior: This area is mostly about the formation and imaging of choice sets. To explain choice, we need to know what kind of information respondents select and seek when a choice must be made and try to characterize the cognitive representation of that information. Part of this is "environmental" perception—of the location, nature, and usefulness of destinations. Another part is the perception of risks of various outcomes associated with a trip on a particular day, at a particular hour, and under a particular amount of time pressure, such as car accidents or arriving late for work.

Gärling points out that risk and uncertainty are mostly ignored in travel choice modeling. Part of our work at Université Laval on exposure to accident risk concerns how car drivers form, image, and test travel choice sets in the face of perceived risk, external constraints, and dysfunctional conditions. This follows up a proposed conceptual model of opportunity sets known as the operating envelope, which has guided a variety of SR survey methodology experiments with car drivers (*12–14*). According to this model, data collection should focus on the circumstances under which individuals seek information on options that are outside their day-to-day experience and on the learning brought about by both intended and unintended novel behavior.

The importance of the time horizon of anticipated travel changes in the specification of appropriate SR survey techniques was noted earlier. This issue is central to information and learning processes. For example, evaluating travel options following a commitment to a new home location should have different information requirements from coping with a 1-day strike at the day-care center, and it is to be expected that there is much more for an individual to learn, including about interdependencies, in the former case. Focusing on learning and information processes associated with long-term decisions is also one response to the concerns, such as those expressed by Polak and Jones (2), about the temporal stability of findings from SP methods.

3. The variety of heuristic and reason-based decision rules used by travelers: Gärling cites a number of theories supporting the use of different and perhaps multiple decision-making rules and suggests that the choice of rule may vary with demands such as time pressure, information overload, and desired precision. Examples include satisficing (conjunctive decision rule), choosing on the basis of a dominant attribute (lexicographic decision rule), elimination by aspects, frequency of good and bad features, expected utility, additive utility, and weighted additive utility. Utility maximization is thus a necessary but not sufficient source of rules. Decision theorists have categorized rules in a number of ways helpful to the design of data collection. For example, Payne et al. (*15*) distinguish between compensatory rules involving trade-offs (including trade-offs of utilities) and noncompensatory rules such as satisficing. Note that the term "rules" is also applied in a much more narrow sense to such decisions as, "If I anticipate having to carry heavy shopping, then I will take the car." These are also the type of rules that are captured in knowledge-based systems (KBS).

Even though the manifestation of noncompensatory rules (notably the lexicographic rule) is often noted in SP studies, it is not conventional to make the observation of selected decision rules an objective of data collection. The elicitation of rules presents substantial methodological challenges. However, the notion of plans (see Item 1) includes metadecisions about which decision rules are applied in given circumstances. This suggests that we should at least try to infer some "rules for the use of rules" from surveys that track and then characterize respondents' actions, both in recent "revealed" behavior and in simulations of new choices. In the case of relatively narrow decision contexts, it may be possible to build up an understanding after eliciting detailed if-then rules, perhaps using KBS methods.

A number of relevant survey methods based on simulation games collect data on revealed behavior over a reasonable period using travel-activity diaries and use these to tailor and calibrate a problem-solving exercise. "Calibration" in such methodologies refers not to model

calibration, but to establishing shared meaning between respondents and interviewers concerning the nature and quantity of resources available to solve problems, in some cases setting limits analogous to boundary values in the utility framework. A particularly promising variant involves such tracking and debriefing during a period of field experimentation, such as a trial high-occupancy vehicle lane or a "natural experiment" created by emergency conditions such as a transit strike or the aftermath of an earthquake. As suggested in Item 1, when interpreting simulated metadecisions in the light of rules observed from a period of revealed behavior, it is important to ensure not only that the calibration is realistic but also that the complexity (i.e., the degree of interdependence) of the decision domains is comparable.

4. The potential for social factors to constrain egoism: We need to take into account the possibility that people are influenced by the collective consequences, or the individual outcomes of the collective consequences, of their decisions. Gärling suggests that we explore social dilemmas in transport, and he has developed instruments to study the "commons dilemma" around the environmental impacts of personal car use (*16*).

It is particularly important in this area to use highly interactive methods to test the credibility of stated responses, because respondents may offer inaccurate views of their intentions when presented with hypothetical opportunities for altruism. For practical purposes, data are mostly collected from simulations of social dilemmas or situations in which a change in individual travel behavior would contribute to a common benefit such as reduced air pollution. Relevant examples include game-based surveys of potential voluntary responses to energy shortages (*17*) and the adoption of low-polluting vehicles (*18*).

5. The process of implementing and maintaining choices: The last of Gärling's categories of alternative behavioral assumptions concerns the propensity to act in accordance with decisions and to persist in that behavior. Here we are not concerned with expressed preferences versus freedom to act, but with the potential for a realistic choice to fail in its execution. The data we should seek here concern the limits of the context within which the individual considers a given behavioral response to be tolerable. This is the inverse of the pro forma question behind much of SR: How would you act in the following situation? Interviews are highly desirable for such explorations of the limits of contexts for carrying out intentions.

Maintaining a choice may involve other mechanisms. "Automatization" may explain why some behaviors persist without a deliberate decision to continue, or even beyond a time when the behavior has come into conflict with the individual's attitudes. Automatization implies that more advantageous alternatives are not evident or salient enough to be evaluated, and so the mechanisms for changing persistent habits are closely related to information acquisition, representation, and use. Data needs around persistence are thus substantially the same as those discussed in Item 2.

In concluding this rather cursory discussion of data needs for understanding travel choice under alternative conceptual frameworks, the following conclusions can be drawn:

- Interactive measures methods promise to play a dominant role in all of the areas of alternative behavioral assumptions.
- A broadly defined activity base is essential wherever the interdependence of decisions is high.
- The importance of processes rather than states implies the need for tracking, gaming-simulation, and experimentation.
- There is a need for some SR methods to elicit and not to simply hold constant many factors related to decisions.

The last point leads directly to the taxonomy presented in the following section.

Taxonomy of Stated Response Approaches

It is evident that the SR tool kit includes a wide range of existing and potential techniques. The selection of suitable SR methods in any given policy context is, of course, dependent on

many situational factors such as budget, political sensitivities, and desired levels of representativeness and accuracy. Nevertheless, transport planners must also make judgments about the pertinence of different approaches to measuring traveler responses to new situations, and it is time to adopt a nomenclature that is in pace with methodological developments. In particular, after barely a decade of its inclusion in the language of transport, there is much variation in what "stated preference" is assumed to encompass. A simple schema that assigns the term SP to only one of four classes of SR survey approaches is proposed here. This is a classification of the content of measures, not of method. Each approach can be implemented by a variety of methods, although there are prevalent methods associated with particular classes.

Defining the Basis for Classification: Degree of Open-Endedness of Behavioral Outcomes and Constraints

In developing SR techniques, a central design issue is the degree to which responses to predetermined choice vectors and packages are sought. There are two main groups of variables to consider: the behavioral outcomes and the constraints on behavior. The term "behavioral outcomes" refers to what travelers might do, such as changing departure times, modes, vehicles, destinations, and so forth. These can persist within a single trip for the short or long term. Constraints may be made up of many attributes, most of which are external or environmental, but some of which are internal or personal. The composition of external constraints includes transport supply attributes (such as price and level-of-service variables, which may vary by time of day and day of week), resources, temporal-spatial attributes of destinations, intra- and interhousehold schedule linkages, obligations, contracts, social and religious norms, traffic laws and regulations, and many others. Internal constraints include but are not limited to functional abilities, propensities to transient disorders, addictions, perceptions of risks, fundamental values, ethics, and adherence to taboos. Constraints can also be viewed as the components of decision contexts.

The classification of SR suggested here depends on whether behavioral outcomes or constraints, or both, are mostly elicited (i.e., measured in an open-ended manner) or mostly given in the course of data collection. Hanson and Burnett (*10*) argue for new techniques eliciting both at once. Elicitation may be undesirable (e.g., in factorial SP designs) or desirable (e.g., in gaming-simulation), but it results in very different types of measurement. Eliciting constraints is less familiar than eliciting behavioral outcomes in transport surveys, but it has a long history as a design choice in applications of simulation-gaming that are intended to explore processes. Also, in the main tradition of travel behavior modeling, outcomes are viewed as dependent variables and constraints as independent variables. From that perspective, eliciting constraints is more radical than eliciting outcomes, and eliciting both makes causal inferences more difficult to test.

Taxonomy

Figure 1 summarizes the four approaches. Although names have been given to each of the cells, elicitation is not a binary choice but a matter of degree, and therefore the categories are tendencies with areas of overlap on both dimensions. Also, it is expected that more than one of the four approaches will be used in some instrument packages, and this is desirable. In each cell the focus of measurement and a "template" or prototype question to clarify the type of information sought are shown. Of course, these are not the actual wordings of questions but rather the essence of the approaches.

The foci of measurement are believed to be best suited to the four quadrants, related to the increasing open-endedness of responses and constraints moving toward the bottom and the right. The number and variety of responses per respondent also increase in these directions, and thus smaller (but higher-quality) samples are appropriate. Nevertheless, as survey and analysis techniques develop, it is possible that some types of information will be found in

BEHAVIOURAL OUTCOMES	CONSTRAINTS (expressed as attributes: personal/household/social/spatial/supply, etc)	
	Mostly given	*Mostly elicited*
Mostly given	**STATED PREFERENCE** (focus = tradeoffs, utility) *"Given the levels of attributes in these alternatives, which would you prefer: [A].....? [B].....? etc ....."*	**STATED TOLERANCE** (focus = limits of acceptability, and thresholds for change) *"Under what circumstances could you imagine yourself doing: [r1].....? [r2].....? etc....."*
Mostly elicited	**STATED ADAPTATION** (focus = reactive and trial behaviour; problem-solving, rules) *"What would you do differently if you were faced with the following specific constraints: [.....detailed scenario]"*	**STATED PROSPECT** (focus = learning processes; information seeking; the imaging, formation and testing of choice-sets; metadecisions) *"Under what circumstances would you be likely to change your travel behaviour and how would you go about it [..broad context]*

FIGURE 1 A taxonomy of stated response survey approaches, showing "template" questions.

more than one quadrant. In the following discussion, existing examples of the four classes of SR are given, but this is as much a framework for developing new methodology as a way of cataloging available techniques.

Stated Preference

This term is reserved for approaches involving forced choices or trade-offs between predetermined options, whether those options are expressed in terms of packages of attributes or as behavioral alternatives in the face of given sets of constraints. Thus defined, SP surveys typically focus on a specific trip or on a repeated trip such as the journey to work. This use of the SP label is in keeping with most published definitions of SP (*19*) and is consistent with the predominant interpretation of the term. Stated preference surveys are the most important but not the exclusive source of future choice data for utility models. These approaches have made significant advances in the past decade and have gained increasing acceptance by policy makers. Current issues in this quadrant are discussed elsewhere (*2*).

Stated Tolerance

Moving to the right-hand column of Figure 1, respondents are no longer asked to respond to given levels or specifications of attributes, but rather to identify the nature and level of constraints comprising the limits of acceptability of behavioral outcomes. In this cell, the term "tolerance" is used to emphasize these limits for a set of particular, given outcomes.

Most applications of transfer prices, the forerunner of much SP work in transport (*20*), and of willingness to pay (WTP) belong in this quadrant. Transfer price data were also used in early applications of microsimulation to travel choice modeling, such as Bonsall's work (*21*) on organized car sharing.

Surveys limited to transfer prices or WTP are to the left of the stated tolerance (ST) quadrant, because it is possible to elicit many other types of constraint. Respondents may be asked to identify both the categories of constraint and the levels to which they are sensitive. In policy analysis terms, this is to suggest that ST can investigate a wide range of perceived barriers to and incentives for the adoption of specific behaviors. It is thus particularly relevant to the issues concerning the implementation of choices discussed earlier. The template question can also be phrased negatively, that is, "Under what circumstances could you imagine yourself no longer doing . . ." Whether approached positively or negatively, the purpose is to dis-

cover the ranges of constraints within which a particular behavior is likely to be tolerated, or threshold conditions for a shift to or from the behavior.

A related development with lessons for ST is the contingent valuation (CV) method. This has been used to assess preferences for environmental goods as well as to estimate—although not without controversy—appropriate compensation in the case of environmental disasters. In addition to its potential application to the environmental impacts of transport, an important disparity is revealed by CV studies. In general, the monetary compensation implied in a respondent's willingness to accept (WTA) a given loss in environmental quality is typically several times higher than the amount of the same respondent's WTP for an equivalent level of environmental improvement. Moreover, this difference, according to Payne et al. (*15*), "appears much larger than can be accounted for by wealth effects." These authors raise a number of broader questions, including the role played by the provision of information to respondents and indeed "the extent to which any assessment technique such as CV creates values as much as it reveals them." These lessons suggest that it is much more valuable to explore sets of constraints associated with particular behavioral responses than to reduce everything to monetary values, but in doing this we need a design for the consistent provision of information during the survey.

The potential of the ST quadrant to explore constraints other than price appears to have been neglected in transport surveys. Appropriate methods involve personal or telephoned interviews. Written instruments are feasible only for very limited constraint sets.

Stated Adaptation

In the bottom row, respondents are allowed to imagine for themselves how they would behave in the new situation of interest. Stated adaptation (SA) is the inverse of ST and uses the much more familiar "what if" type of question. In this quadrant, the constraints are laid out in sufficient detail that, it is hoped, the range of adaptations—the behavioral outcomes—that respondents would be able and willing to carry out in such circumstances can be understood. As in ST, the number of categories of constraints can vary.

The definition of this quadrant technically includes the open-ended version of what was generally known in the 1970s as a stated intentions survey, consisting of elicited reactions to given changes in supply attributes. However, this has never been a very credible basis for assessing choice in future contexts, and the term "adaptation" in this quadrant has been adopted to imply techniques that also bring about the imaginary or experimental validation of reactive behaviors. This requires simulated or actual trial behavior and the observation of the knock-on effects of behaviors—especially on established linkages. Ideally, data are collected on approaches to problem solving, the rules used, and the outcomes retained by the respondents. These are intensive techniques involving small, high-quality samples.

The best-known example of a simulation-based technique in this quadrant is HATS (*22*). For each participating household member, HATS uses a revealed travel-activity base from a 1-day diary, displayed on both a scheduling board and a map. New constraints such as a change in school hours are given, and household members attempt to accommodate this into their schedules. Any modifications are validated against each individual's set of other salient constraints, including linkages to other household members in the new situation.

Two recent surveys involving this type of simulated problem-solving concern the impact on household travel of limited-range battery electric vehicles (BEVs). Both of these surveys (*18,23*) used a survey package to observe the impacts of the range and charging requirements of BEVs on the way multivehicle households managed their cars over a simulated 7-day period under a variety of scenarios. The work was carried out in California and the Rhône-Alps region of France, respectively, using derivatives of the Car Use Patterns Interview Game (CUPIG) (discussed later). Once again, a gaming interview is built around displays summarizing recently revealed behavior, and simulated choices are debated by household members affected and carefully validated for feasibility. In the California case, the SA survey ($N = 51$) was backed up by other surveys: semistructured interviews of people after test driving a BEV, interviews of very early adopters of BEV technology, and a medium-sized mailed

questionnaire survey about car use patterns and desired attributes in new vehicles, which was designed using insights from the SR survey.

Parallel SP/ST work in the United States to establish the utility or disutility of the BEV's range and charging requirements has suggested, in general, that cars would need to be sold at extremely discounted prices before people would buy them, even though a high percentage of the daily duty-cycles of automobiles fall within the currently feasible BEV range. It was hence assumed by some market analysts that only extremely "green" (ideologically ecological) market segments would be interested in changing their "second" car for a BEV. The SA surveys, however, provide clues to the manner in which adaptations to BEVs might be anticipated. It appears that in California the ideological green market is less significant than a market segment that would exploit the BEV as a complementary technology and not as a straight substitute for one of the household cars. The SA work in California also showed that the notion of a second car is not even a contemporary reality in most multicar households. Respondents in France, who were not facing California's regulation-driven market for low-emission vehicles, had their own views of how the BEV might fit into their future. The differences are interesting but beyond the scope of this discussion.

The key point is that the focus of SA on problem-solving provided important insights into how the market might develop on the basis of the uses imagined by respondents. It was not possible to quantify estimates of market penetration with this work, which is why SP/ST work on the attributes of BEVs was also undertaken. In California, the evidence from the SA work is different and more favorable to the eventual success of the BEV than the evidence from most of the SP work. The policy maker must weigh the evidence and avoid extreme interpretations that might arise from an ideological attachment to one approach or the other.

Another recent example of SA concerned hypothetical temporary citywide car-restraint scenarios, as well as permanent urban road pricing scenarios with and without the introduction of a new type of public transport service (*24*). This survey (N = 16) was in greater Lyon, France, and used some of the same visual aids to display the revealed base that the French BEV survey cited. Here the primary intention was to inform the design of a later SP survey on these two areas of policy. The interaction between the two policies was too complex for a one-stage SR design. The breadth of given contexts puts this study to the right of the SA quadrant, but its focus was clearly stated to be the observation of adaptations.

Some applications of Hoinville's priority evaluator (PE) technique (*25*) are SA approaches. In PE surveys, levels of predefined attributes are priced in a currency. Respondents are given an imaginary budget of this currency and asked to allocate it to the attributes and levels of their choice. Ideally, the budget is calibrated (scaled) to the value of existing choices on the same attributes, and then the respondent is asked to adapt to a different budget. Although originally used to study trade-offs between amenity investments, budget allocation principles can be used to elicit behavioral outcomes and to study the use of rules. For example, in the rationing stage of a game-based household interview about coping with a fuel shortage, Lee-Gosselin (*13*) used an accounting board to keep track of a fuel budget by activity category as actions were taken to reduce car use. In this case the budget was a percentage of the fuel actually used during a recent 7-day period for which activity patterns were recorded.

As mentioned in the discussion of alternative frameworks, actual trials of innovative supply constraints or various kinds of emergency may provide excellent opportunities to observe how travelers adapt to changes in constraints in situations that would otherwise only be feasible in simulations. An example of adaptation through telecommuting after an earthquake is described by Pratt (*26*).

Two more recent examples concern congestion pricing. An empirical SA approach was proposed in 1994 for a survey concerning the Bay Bridge (Oakland–San Francisco). The survey involved a trial visible only to respondents, who would be given scrip to pay for tolls under a variety of congestion-pricing schemes and whose choices would be tracked and then discussed in a series of telephone interviews (Applied Management and Planning Group, unpublished proposal to MTC for surveys in connection with the Bay Bridge Congestion Pricing Demonstration Program, 1994). Respondents would have to add some of their own money to maintain their previous levels of peak-hour crossings. A more sophisticated exam-

ple of this type of trial was implemented starting in late 1994 in Stuttgart, Germany (*27*). Using a prepaid debit card ("MobilPASS"), which is valid both for congestion pricing charges and for a combined transit and park-and-ride alternative, an automated record is kept of a user's choices and is subsequently analyzed relative to a peak-hour travel diary kept during a multimonth period. For the trial, the card is paid at the start of each month by the respondent in cash on the basis of the previous month's trip pattern. At the end of the month this amount is refunded, but any unused credits resulting from congestion avoidance accumulate and are paid out at the end of the trial. The payoff in the designs of both these pricing experiments is conducive to participation in the tracking survey.

The potential exists in all SR to validate simulated choices against actual choices on a disaggregate basis provided that it is possible to recontact respondents. This is particularly appropriate in SA simulations in view of the elicited outcomes and the recorded detail about how the adaptation came about. The interest is not just in the rate of adoption of the new behavior, but also the extent to which the observed relationship between activity patterns and the new behavior corresponds to that recorded in the simulation. Such validation is rare but can occur when a new transport service is introduced. For example, Bonnel (*28*) was able to compare respondents' simulated adaptations to a planned new tramway in Grenoble with their actual behavior 9 months after its introduction. On both occasions the use or nonuse of the tramway was examined in the light of data collected on activity patterns immediately preceding the interview day.

Finally, adaptive designs for SP may involve an SA stage. A well-known example is the Adelaide Travel-Activity Questioner (ATAQ), a computer-aided interview (*29*). The initial stage of ATAQ involved validating the feasibility of elicited behavioral outcomes against the activity patterns of the household. Outcomes that survived validation then became givens in an SP ranking exercise.

Before moving to the lower right quadrant, which is also the domain of much simulated and novel behavior, it is important to recognize that not all simulations of travel behavior have been conceived as SR surveys (i.e., the measurement of responses to future situations). As Mahmassani and Herman (*30*) point out, there is a hierarchy of strategies for the study of interactive dynamic systems, ranging from analytical models of idealized situations through simulation models, laboratory experiments, field surveys, and field experiments. Various kinds of simulation, including HATS, have been used to better understand decision rules under prevailing day-to-day conditions and to observe adaptive behavior under changed constraints. The former use of simulation serves to develop insights and theories that should be applied to SR data collection. Mahmassani et al. (*31*) provide an excellent example of this. To track commuters' adaptations to congestion, they used a two-stage survey designed around insights into the mechanisms governing day-to-day switching of route and departure time previously obtained in laboratory experiments where commuters interacted with a simulated traffic system (*30*). The objective of SR surveys is ultimately to generalize about the aspects of future choice to which the success of policies is sensitive—in the case of SA, methods of problem solving and coping, decision rules, and the elicited behavioral outcomes.

Stated Prospect

It is possible but not easy to devise measurement methods that record how respondents, in effect, invent future contexts for their travel behavior and explore alternative outcomes. Simulation gaming techniques are used here by necessity, although as Brög and Erl (*32*) point out, they must be embedded in a larger design. Neither the list of possible behavioral outcomes nor a detailed constraint scenario is predetermined. Nevertheless, approaches in this quadrant normally use a general scenario (such as an energy shortage) as the broad context, or possibly as a pretext, to initiate the process of learning about alternative outcomes. The term "stated prospect" (SPro) is used to symbolize not only the comprehensive future orientation of this quadrant, but also the centrality of information-seeking and the imaging, formation, and validation of choice sets. To understand these processes and to discover the metadecisions governing the selection and use of decision rules, it is inevitable that SPro involves ob-

serving how solutions are invented and by whom and relating this to previous efforts to reorganize activities and travel. It is also essential to debrief respondents about their operating assumptions during the game stage of the survey.

The template question shown in this quadrant is posed as the further development of the existing context, which itself is characterized from a household's revealed activity travel base. As in SA, SPro normally uses data from travel-activity diaries for a very recent period to prepare visual aids for use in an interview. However, the insights sought are more about classes of behavioral outcomes and constraints than about particular instances of either. For this reason, a revealed travel-activity base over a period of at least 7 days is highly desirable. For longer periods, it may be feasible only to use retrospective instruments. In the case of car use studies there are new possibilities thanks to recent developments in inexpensive electronic monitoring devices, which permit monitoring of useful samples of vehicles for weeks or months (*33*). Several Canadian studies use these devices, including the previously cited current project at Université Laval on choice set formation and the perception of accident risk.

One of the challenges of SR is to distinguish between the influence of tastes or attitudes and that of evolving constraints in the longer term. In the context of travel time, Polak and Jones (*2*) note evidence that travelers show greater sensitivity to losses than to gains in the short term, analogous to the WTA/WTP disparity noted earlier. However, they suggest that more symmetrical values of time might be expected in the longer term. Such asymmetries may not be confined to values of time. As noted earlier, if the evolving constraints take respondents into an unfamiliar future, the challenge is even greater. Faced with this, one strategy is to confine a sample to respondents with relevant experience. Polak and Jones cite the advice of Hensher to adopt such a strategy for SP work on traffic calming. A more compelling strategy is to find out about the learning processes involved, perhaps using previous experience as a segmentation variable.

The design of SPro surveys has much in common with that of "process-intensive" games, in which conditions of uncertainty and ambiguity are created to accelerate and observe the seeking of information, the imaging of options, and the discovery of interested parties. Such games are thus distinguished from "content-intensive" simulations, in which systems such as traffic or the urban land market are simulated explicitly under given rules and every effort is made to replicate the observable aspects of those systems in the real world.

There are important and growing implications from activity-scheduling experiments, such as those by Ettema et al. (*34*), for SR measurement in this quadrant. Their computerized simulation methods can be used to investigate decision making both under prevailing conditions and under hypothetical new situations. For the moment, this type of research is focused more on the former. However, these authors offer a conceptual framework for SPro (and SA) data collection under a production system model where long-term memory contains perceptions of activity attributes and short-term memory is the "scratch space" for processing decisions according to a rule base.

A largely manual SPro simulation method that has its roots in the 1970s was applied with promising results to federal and provincial energy contingency planning in Canadian surveys of 1984 and 1988. Canada was one of the few IEA member countries in the early 1980s willing to use policy instruments other than rationing to deal with the perturbations of market mechanisms in a supply shortfall, and no conventional survey technique had been identified to explore the advantages and pitfalls of voluntary restraint measures. The method selected, CUPIG, uses a revealed behavioral base from 7-day trip-activity diaries for each of the vehicles in a selected household (*13,17,35*). Visual presentation and tracking of prospective changes are achieved using a scheduling chart inspired by part of the HATS materials and a priority evaluator type of accounting grid for a fuel budget already described in the discussion of SA. A detailed interview log records the origin, timing, characteristics, validation, and a judgment of likelihood of each candidate decision to change travel behavior.

In the energy contingency planning application, this method was SPro in the voluntary demand restraint phase of an imaginary gasoline shortage but (as mentioned earlier) shifted to an SA approach for a subsequent rationing phase in the same interviews. This was because

the elicited constraints in the voluntary phase became givens for the rationing phase, at which time the budget reduction became explicit rather than ambiguous.

Of particular interest from the voluntary phase was the discovery of the levels of reductions in car use above which households ceased to seek information and to imagine new options for change. In terms of the "operating envelope" model, this amounted to a resetting of the perceived comfortable boundary around what would likely be "automatized" in day-to-day behavior. Moreover, for certain groups it was observed that the decision context was restructured after entering the mandatory phase, whereas for others it was "more of the same" heuristic process. All of these insights, although not immediately generalizable as quantitative estimates of user response, provided valuable input to the design of policies that would support voluntary demand restraint.

There is a key methodological finding from a number of the process-intensive simulation methods concerning the devices, such as scenarios or budgets, that are used to initiate the formulation of choices in novel situations. Even when these devices are seen by respondents as unrealistic or improbable, the gaming methods still function and the processes observed appear to be a plausible representation of how household and individual decisions evolve (*14,24*).

This completes the quick tour of the SR taxonomy. This was intended to provide a better nomenclature for SR techniques and to clarify design questions, not to provide watertight categories. Many emerging methods will use sequences of instruments coming from more than one quadrant. In addition, there are many possible variants of techniques that are otherwise low on elicitation but in which additional outcomes or constraints can be "written in" by respondents.

Recommended Principles for Selection of Interactive SR Techniques

We have seen that the interactive part of the SR tool kit is substantial. Using the definitions in Figure 1, all SPro, most ST and SA, and some SP approaches use interactive methods. Three principles addressed to those needing to go beyond SP (i.e., those whose problems cannot be expressed in terms of preferences for levels of a limited number of predefined attributes and behavioral outcomes) are offered. The principles summarize the selection process in terms of the direction of movement within the presented matrix, recalling that the axes are spectra and not dichotomies:

1. The more you need to know about enabling specific behaviors and testing their limits of acceptability, the more you must move right (toward ST and SPro).
2. The more complex the linkages between constraints, the more it is necessary to observe which behaviors are used to accommodate and adapt to changes in constraints and the more you move down (toward SA and SPro).
3. The longer the horizon, the more you need to know about learning processes and choice-set formation to distinguish between (*a*) the limits of taste and tolerance and (*b*) adaptation to constraints, and the more you need to move both right and down (to SPro).

Two other guidelines can be safely offered. First, it is wise to reduce the risk of misinterpretation of SR data by using coordinated multi-instrument strategies. For example, insights from small-sample SPro approaches should help in focusing SA, ST, or SP instruments for use with larger samples. Second, in sensitive "future" public policy areas such as road pricing, face-validity—using observations of real-world or laboratory trials if necessary—may be more compelling to policy makers than mathematical tractability.

It is inevitable that the further you move down or right, the more difficult it will be to use the data in elegant predictive models, and the more you must be prepared to construct complex explanatory models to generalize your findings. This is not to say that only qualitative analysis is appropriate, as useful as such techniques have proved in transport policy analysis. For example, research on activity scheduling (*34*) and knowledge-based systems for travel

choice (*36*) promise a wide range of new approaches to formalizing decision rules. These developments are much aided by recent advances in computing, but the direction of this work was anticipated much earlier, as in the decision domains of Heggie and Jones (*7*) and the situational groups of Brög and Erl (*32*). It is also to be expected that SR data will play an increasing role in microsimulation models.

Concluding Methodological Caveats

Approaches to SR data collection have been reviewed. It has not been possible to cover the design principles of the numerous methodologies applying these approaches. Some comment should, however, be made about methodological pitfalls common to most or all ISR approaches.

First, all the ISR surveys cited used small, purposive (quota) samples. Because this type of survey uses expensive techniques that have high respondent burdens, those who implement them will not be willing to waste resources on hostile or resistant respondents. It takes considerable courage and intellectual honesty to face the biases inherent in respondent selection and the effect of those biases on patterns of elicited responses. In essence, this amounts to understanding the difference between a representative sample and sample of representative variety. Also, Bradley (*5*) reminds us of the inherent biases in choice-based samples used, for example, to limit interviews to a relevant subpopulation, such as those who are current users of a transport service that is mooted for upgrading.

A related problem is that the linkages between household members are sufficiently central to most of ISR that whole households and not individuals are normally required as respondents, and many use group discussions. The scheduling of all mobile household members for a group interview is often a challenge in itself. Recruitment is very difficult without significant incentives. Compensation of $100 to $150 has been offered to households in California for multiple 7-day diaries and a 3-hr household discussion. The MobilPASS trial pays DM100, plus up to DM200 of accumulated payoffs from avoiding congestion, for a multimonth involvement. These payments do not appear excessive given that some focus group participations pay $50 to $100, but the jury is still out on the nature of any selection bias associated with such payments, especially if they are varied to provide an incentive for complete and accurate reporting of the activity base and for full participation in the interview tasks.

Second, all interactive techniques suffer from potential effects of observation on the respondent. There are important challenges to simulations that not only synthesize a revealed travel-activity base, thus providing more succinct "overview" information about interdependence than travelers may normally have at their disposal, but also accelerate the use of this information in a succession of future scenarios. Thus, the utmost care is needed in designing the consistent presentation of such feedback and successive unfolding of new information to the household. On top of this, interpersonal observer effects are potentially serious because the interviewer cannot avoid a central role in setting expectations about how to respond to such simulations. Very high-quality field staff are thus required.

A third point, related to the second, is that there are ethical considerations when mirroring back to respondents how they have made decisions in the past and indicating how they may make decisions in the future. The concern is not about affecting actual transport choices, but that in extreme cases relationships between household members could be affected by what is exposed in the interview: who really controls the use of the family's cars may sometimes be better ignored. Fortunately, problems of this kind are rare and can be minimized by sensible debriefing and adequate pilot testing of interviews on familiar ground.

Fourth, all these techniques are prone to framing effects. Payne et al. (*15*) point to the lack of theory in this area but cite some classic experiments in which identical outcomes in hypothetical situations are presented alternately as gains or as losses, leading to reversals in majority preferences. The WTA/WTP disparity is probably related to this phenomenon. One of the advantages of eliciting behavioral responses is that less framing of questions is necessary,

and there is robustness in the validation of actions that is part of SA and SPro, but these approaches can also suffer from framing bias in the presentation of scenarios.

Finally, more can be said about data preparation and analysis techniques, although these are necessarily varied. With SPro and SA, interview data reduction can often be accelerated by building inventories of simulated decisions, which are defined here as choices to act, or rejecting a potential action, after discussion. Structured interview logs, which may be manual or computer assisted, are designed, from which sequences of problem solving and analyses of behavioral outcomes can be reconstructed. A wide range of attributes of decisions (such as who initiated them, who is affected and how, what would make them tolerable, and so forth) can be precoded to speed up the work of an observer, who is generally not the interviewer. Decision inventories are particularly useful for developing classifications of respondents and adaptation strategies. Other summary data from interviews and analyses of preinterview activity patterns are, of course, critical additional inputs to such classifications.

Conclusion: Recommendations for Research

Much of what has been presented is an appeal to balance out methodological research on stated response. Most effort has thus far been invested in the upper left-hand quadrant. There is a constant theme of building SR around a better theoretical understanding of the revealed activity base. It is assumed that predictive and explanatory models will continue to exist side by side, but they need to be linked more fully. The observation and categorization of decision rules appears to be a common thread in many of the recent interactive approaches discussed, a development anticipated 7 years ago by Bradley (*5*). In particular, it is desirable to fund survey methods research that applies those approaches to situations in which travel behavior is in the process of rapid change, including those created by congestion, regulation, new technologies, or crisis.

Interactive stated response survey approaches have begun to make an important contribution to transport policy analysis. To a greater or lesser extent, they allow people to invent their own future. Therefore, they should help us avoid characterizing the future only in terms of what we can easily measure or building policy on an overly literal interpretation of the attenuated models of behavior that have driven much previous data collection about future choices in transport.

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Resource Paper for Survey Methodologies Workshop

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The total methodological design of interrelated surveys to provide data for analysis, understanding, and modeling of household and personal activity, time use, and travel behavior is addressed. Evolving trends in models in response to current and emerging planning and policy issues are discussed to set the stage for developing data collection needs. Survey design issues are discussed, and the needs for the cross-sectional, single-day household survey of revealed behavior (revealed preference) are discussed in the context of the availability of other, often more appropriate, methods, namely stated preference/stated choice experiments and multiday, panel surveys. Sampling and sample design are discussed, first with regard to a single-day survey, then as affected by multiday design and the economies and other benefits introduced by the use of stated preference surveys and longitudinal panels. A brief description of recent and ongoing surveys in the United States is given.

Metropolitan transportation planning and policy analysis in the United States is undergoing a major revival in the 1990s. The renewed interest in urban transportation planning and policy analysis comes in the wake of the requirements contained in the recently enacted Intermodal Surface Transportation Efficiency Act (ISTEA) and Clean Air Act Amendments (CAAA). The rule-making based on these two pieces of legislation also sets forth considerable challenges for transportation planners and policy analysts. It is becoming clear that new analytical capabilities and related data are needed to support current and emerging planning and policy analysis in the nation's metropolitan areas, particularly in areas that do not meet National Ambient Air Quality Standards ("non-attainment areas").

The professional transportation community has started grappling with the technical issues raised by the recent legislation and rule-making, but the resolution of many of the issues will take substantial research and development effort. As part of this process, data collection needs are being scrutinized. One of the prime sources of data used historically in metropolitan transportation planning is what has been termed the "home interview survey" and what is now commonly called the "household travel survey" (see discussion in the following section). As a result of the new needs, as well as the advances in technology and a variety of sciences, there are challenges and opportunities in developing household travel survey methodologies for the future. The renewed interest in regional transportation planning studies has resulted in recent efforts to collect metropolitanwide data sets despite the prediction

just a few years ago that travel surveys in the 1990s would be very small scale, both in terms of the sample size and the geographic coverage (*1*).

The purpose of this paper is to provide a framework to guide and structure the discussion at the Survey Methodologies Workshop at the conference on Household Travel Surveys: New Concepts and Research Needs. The paper raises and frames the many methodological questions that need to be addressed in designing household travel surveys that meet current and emerging transportation planning and policy analysis needs. This paper deals only with the collection of data about personal travel behavior. Freight and commercial movements are not considered here, although these trips are coming to be recognized as important in metropolitan transportation planning.

The charge to the Survey Methodologies Workshop focuses attention on sampling in the design of a household travel survey. We have, however, interpreted our responsibility (and, implicitly, that of the workshop) more broadly, since sampling design and many of the other decisions to be made in designing a household travel survey are interdependent. For example, the sample size needed to estimate a population parameter describing daily travel with a specified level of precision depends on whether the respondents are asked to report their travel for a 1-day or a multiday period. In any event, we have interpreted our charge more broadly for another, related reason. None of the other workshops at the conference is concerned with the total design of household travel surveys, so we have taken that responsibility upon ourselves, although we do not deal with many aspects in detail.

Household Travel Surveys in Perspective

We consider a household travel survey to be a survey in which data are gathered on the personal travel behavior of the members of a sample of households. What distinguishes a household travel survey from other travel-related surveys is that in a household travel survey the household is the sampling unit, and the personal travel behavior of the members of the sampled households is the subject of the inquiry. Conventionally, travel behavior is requested only of those more than 5 years old. However, some recent surveys include all members in the sample households (e.g., the survey conducted in 1994 in western Oregon and southwest Washington).

The earliest household travel surveys in the United States were carried out during the mid-1940s. The earliest household travel surveys were of a special type known as a home interview survey, in which an interviewer visits the home of each selected household, typically on the day following the day for which the household members were asked to report their travel. We note here that in some fields the term household survey implies that the survey is conducted in the household (*2*). But we believe it is important to think of the home interview survey as a special case of a household travel survey, with the latter being conducted by telephone, mail, personal interview, or some combination of these methods of contact and retrieval.

The earliest household travel surveys had a number of other characteristics. They were retrospective surveys in that the respondents were asked to recall their behavior on a previous day, typically the day immediately preceding the interview day. Earlier surveys had no prespecified interview day (there was usually a mailed introductory letter, close to the target day); later surveys sometimes included both an introductory letter and a phone call to set up the interview day. This reliance on respondents' ability to recall their travel on the previous day was probably mitigated by the advantages of a face-to-face interview and the interviewer's ability to probe for "missing" trips.

The earliest household travel surveys were conducted on very large samples, ranging from 4 percent in the largest urban areas to 20 percent in small urban areas. Large samples were needed in the early surveys because of the aggregate nature of the models in use at that time (based on aggregated zonal attributes) and because of the lack of any prior information on the phenomena being studied. In any case, large sample sizes were needed to provide data to estimate the zone-to-zone origin-destination matrix. Usually simple random sampling was

used for these early surveys, with the sample frame being a street address directory or utility billing list.

Over the years, the conduct of household travel surveys has changed considerably. First, beginning in the mid to late 1970s, urban areas conducting household travel surveys started making do with a much smaller sample size. This trend was made possible by the introduction of disaggregate models, which make far more efficient use of the data than do aggregate models. Specifically, the use of disaggregate choice models for the mode choice phase of the four-step modeling framework led to the use of a relatively small household travel survey, generally supplemented by an on-board survey to provide additional information on the public transit modes of travel (since in many cities a random sample would give too few transit cases). The use of such enriched, choice-based samples in model estimation was greatly facilitated by the work of Lerman and Manski (*3*), which showed how one should weight the observations from such a sample to obtain unbiased parameter estimates in a multinomial logit choice model.

To our knowledge, the last home interview surveys in major U.S. metropolitan areas were those undertaken in Portland and Baltimore in 1977 and the survey in Dallas in 1984. The Portland survey was a simple random sample of 1,000 households taken from a street directory base. The Baltimore survey also used a sample of 1,000 households. Half were sampled by an area probability sample, and the other half were chosen by oversampling in areas where transit usage was high (*4*). In the early 1980s, household travel surveys started to use other methods for contacting sample households and retrieving the travel and related data. In 1980, for example, Caltrans conducted a household travel survey of 2,000 households in the San Francisco Bay Area using a telephone survey. Reinke (*5*) reports that this survey was deemed successful because it was conducted at a much lower cost than a home interview survey and the response rate was more than 50 percent. In 1981 MTC conducted a similar telephone-based travel survey of 7,200 households in the Bay Area to update its 1965 data base.

Telephone surveys have a number of potential drawbacks, but the disadvantages can be mitigated by careful survey design. As discussed in the section on sampling, a case can be made for the use of address-based sample frames, in which case nontelephone households could be physically contacted with either in-home or mailback retrieval, in essence a hybrid approach. There is some controversy over the use of multiple reminders and mailbacks versus telephone retrieval (or in-home surveys). Stopher (*6*) made the case, on the basis of a small sample pilot of the 1991 Boston survey, that there was a poorer response from mailback than with telephone retrieval but that the response from larger households was better with mailback.

The information we attempt to collect in household travel surveys has increased in quantity and complexity in recent years, and the trend is toward the collection of even more data of a more complex nature. As a result, perhaps, the charge to the methodologies workshop suggests that the workshop consider the possibility of returning to the use of in-home interviews for conducting household travel surveys. Of course, a major issue in the use of in-home surveys is the cost of conducting such surveys. Purvis (*7*) recently estimated that the 1965 Bay Area Transportation Survey of approximately 30,000 households would cost more than $200 per household in today's dollars. This is more than twice the cost of the 1990 Bay Area Transportation Survey (a telephone-based survey). However, if there are substantial potential advantages to be gained from home interview surveys, their reintroduction should be carefully considered.

The reality of neighborhoods suffering from high levels of personal violence (usually coincident with low income) raises a question concerning the ability to motivate poorly paid survey staff to aggressively recruit and interview households under these circumstances. The emergence of gated enclaves of the wealthy along with their private protective services raises the question of accessibility to recruit and interview these households. We might thus end up with even more nonresponse bias than with a telephone survey. Stecher et al., in another resource paper for this conference, note that it is not clear that the in-home survey will give improved response rates.

The household travel survey is only one approach for obtaining personal travel information, the other common ones being on-board surveys, employer-based surveys, and roadside origin-destination surveys. As noted earlier, on-board surveys of transit riders are used to supplement the information obtained in household travel surveys by providing information on "rare behaviors," especially concerning infrequently used modes. To our knowledge, choice-based sample enrichment for bicycle and walk travel has not been attempted in the United States—the difficulty of getting a random sample intercept for these modes may be insurmountable, and self-selected samples are not useful for model estimation. Employer-based surveys are also useful sources of information on personal travel, particularly for the journey to and from work, and might be very useful as we examine the effectiveness of employer-based TDM measures. Roadside origin-destination surveys, however, have become rare, being replaced by license plate intercepts followed by mailed out or telephone contact travel surveys. The Dallas-Fort Worth area recently fielded a direct roadside interview survey with good success, which may lead to a resurgence of this method. Of course, new possibilities for collecting personal travel data are becoming available through the use of advanced technologies (the subject of another workshop at this conference).

Current and Emerging Household Travel Data Needs

Data collected in household travel surveys can serve a number of purposes, although the conventional use of household travel survey data is for the estimation and calibration of travel forecasting models to be used in predicting network flows under a variety of alternative transportation plans and policies. In this paper we focus on the collection of household survey data for the development of travel forecasting models, but we recognize that such data can be useful for a number of different purposes. First, models that are not incorporated in the conventional travel forecasting model set can be developed. For example, as suggested by Harvey and Deakin (*8*), household travel survey data could be used to develop models of car use that describe the likelihood of a cold start being made. Second, household travel survey data can be used to monitor trends in personal travel and to assess the extent to which planning and policy objectives are being met. Third, household travel survey data can of course be used to conduct fundamental studies of travel behavior, although such studies sometimes require data that would not normally be collected in a "routine" household travel survey.

The data that are mandated for vehicle miles traveled tracking and emissions inventories do not come from household travel surveys but are mandated to be taken from the Highway Performance and Management System (HPMS) count program. This source, however, does not account for cold starts and the cold start mode of travel, which are the primary determinants of emissions and hence air quality. As Harvey and Deakin (*8*) point out, there is a danger that because some data are mandated, nonmandated data needs, such as household travel surveys, might be overlooked.

The effect of travel demand management measures (congestion pricing, parking pricing, improved transit service and bicycle facilities, as well as employer-based actions) must be evaluated. These measures can have effects anywhere in the individual decision structure—the decision where to locate home and workplace, to travel, or to change route, mode, activity or trip pattern, or time of day for activity and travel.

The CAAA essentially requires consideration of the effect of transportation infrastructure investment on the location of jobs and housing development (as the law was written, the rules or federal regulations are less prescriptive). This leads to the need for integration of the land use-transportation analysis and forecasting paradigm.

The CAAA requires much more realistic simulation of emissions than is currently included in the modeling structure, namely vehicle use by type by time of day by road segment. When this requirement is combined with TDM actions, the postprocessing approach often practiced is inappropriate. Furthermore, the Congestion Management System (CMS) requires responsiveness to the effects of the operational and vehicle priority changes envisaged. In particular,

Intelligent Transportation System (ITS) implementation can affect travel demand in all of its dimensions. The ITS component of CMS will be heavily dependent on real-time data acquisition, which is not addressed here.

It is clear that new travel forecasting models are required and that the current "four-step" paradigm is not well suited for use as a policy analysis and planning tool in the era of CAAA and ISTEA. In fact, the limitations of the conventional paradigm have been well known for a long time, but they have been highlighted by the needs of the current planning and policy analysis environment. The development of a new paradigm for travel demand forecasting in response to CAAA and ISTEA began in earnest in the United States when the Federal Highway Administration (FHWA) issued an RFP in August 1992 asking proposers to develop such a framework. Four teams were selected to undertake this task, and their reports were submitted to FHWA by the middle of 1993. Subsequently, a synthesis of the recommended approaches was prepared by the Volpe Transportation Systems Center. During this period the Travel Model Improvement Program (TMIP) was established, funded by the U.S. Department of Transportation (FHWA, FTA, and OST), the Environmental Protection Agency, and the Department of Energy. The latter program is also sponsoring the development of TRANSIMS, an urban transportation microsimulation tool, by the Los Alamos National Laboratory.

Naturally, the four reports to FHWA differed in the recommended directions for a travel forecasting framework, yet a number of common threads can be found in these reports. More important, in the past year a consensus has emerged concerning the characteristics of a framework for travel forecasting to meet current and emerging policy analysis and planning needs. The characteristics include microanalytic simulation of travel demand and network flows, with travel demand being modeled over the course of a 24-hr day or longer period, not as a set of independent trips (as is the case in the current framework), taking into account the dependencies in the travel patterns of members of a given household. Furthermore, in the emerging paradigm, travel is modeled as a dynamic phenomenon that derives explicitly from the need or desire to participate in activities that are spatially separated from one another.

The derived demand nature of travel has been recognized for more than 30 years, but the existing framework for travel forecasting (which is essentially the same as that developed for the earliest urban transportation planning studies nearly 40 years ago) does not really treat travel as a derived demand. (Similarly, until recently, our data collection procedures also focused on trips rather than activities.) This approach to travel demand modeling is generally referred to as the activity-based approach.

Cross-sectional, revealed preference data focused on trips, rather than activities, is extremely limited for addressing many of the current policy questions and for use in the emerging approach to travel forecasting. To answer many of these policy questions there is a need for both stated choice/stated preference data for hypothetical questions and longitudinal data describing revealed responses to endogenous (e.g., family structure) and exogenous (e.g., change in supply of land and transportation infrastructure, travel cost, and parking supply) stimuli. Data on linked household decisions, including the use of time for household activities and travel, are needed for a sufficient description of behavior. The latter is included in the more recent surveys, as described later, and is covered by another workshop at this conference.

The development of stated choice experiments that clearly deal with response to change stimuli in a multidimensional and holistic fashion is challenging and will also be discussed at another workshop at the conference. The use of stated choice and stated preference for travel model development is becoming common in Europe and Australia. Models built from such data can be used for policy analysis and can be incorporated, using either joint or sequential estimation with revealed preference data, to develop regional predictive models. Stated preference is essential to estimate the direction and size of likely response to many of the TDM actions proposed—actions that either fall completely outside current experience or are far outside the range of current experience (e.g., congestion pricing of roads or gasoline selling at $4.00 per gallon). Again, this topic is covered by another conference workshop.

Methodological Issues in Household Travel Surveys

In designing a household travel survey, many factors have to be considered and a multitude of decisions need to be made. The decisions range from the size of the sample down to the detail of the type of paper on which the recruitment letter will be printed (if one is used).

The charge for the Survey Methodologies Workshop clearly focuses on sampling issues. However, as noted earlier, we have chosen to include a number of related issues in our discussion. We first discuss survey design issues that are not generally considered sampling issues but that we believe must be considered in conjunction with sampling design questions in designing a contemporary household travel survey. We then discuss sampling design, and we conclude this section by considering how sampling design and other aspects of survey design are interrelated.

Survey Design Issues

In designing a household travel survey, there are important methodological questions concerning (*a*) the completeness of the activity reporting (i.e., only activities requiring travel versus all activities), (*b*) the period for which respondents are asked to report their travel and related behavior, (*c*) whether the survey is cross-sectional or longitudinal, and (*d*) whether the survey is to include only data on existing travel behavior [so-called revealed preference (RP) data] or information about respondents' preferences for hypothetical alternatives is also to be included in the survey [so-called stated preference (SP) data]. These four issues, the last three of which are closely related to sampling design questions, are discussed below. In any case, one could argue that the length of the period for which respondents are asked to report their behavior, and whether the survey is a cross-sectional or longitudinal one, are really sampling issues. In fact, Hautzinger (*9*) points out that when we conduct a travel survey we are really sampling from a space of people and days. That is, when we prepare a sampling plan for a travel survey, we select whom we will survey and for which days we will ask them to report their travel.

Trip-Based, Activity-Based, and Time Use Surveys

Traditionally, household travel surveys have focused on travel, and the typical question in such surveys had the form "Where did you go?" followed by other questions about the trip. In some recent surveys the format has been modified to focus on activities by asking questions such as "What did you do?" Stopher (*6*) refers to the latter type of survey as an activity survey, but the survey to which he refers (Boston, 1990) collected information only on out-of-home activities. To make the distinction clear, Pas and Kitamura (*10*) refer to surveys in which both in- and out-of-home activity information are obtained as time use surveys. A discussion of the field of time use research and its relationship to travel modeling is given by Pas and Harvey (*11*).

There are a number of reasons for collecting activity or time use data. First, if we wish to understand and model travel as a derived demand, we need to focus on the activities that are linked by the trips. Second, the activity or time use approach to travel surveys, particularly the latter, places the travel in the context of the respondent's day and hence facilitates recall of short, infrequent trips. Finally, to examine in-home activity substitution under constrained transportation supply or increased costs, information on in-home activities is important. In addition, multiple activity stops away from the home might be an important response to situational change.

The other matter of importance is the evaluation of the transport system under constrained supply, or "What is an acceptable level of service?" There is evidence of a time trade-off of discretionary activities where travel times for the work activity are high (*12*). It could be that many of these discretionary activities are what constitute "quality of life" and that the impact of congestion may be better measured as activities forgone rather than V/C ratios (*13*).

If this is true, the use of time is an important concept, and a full accounting of activities is needed. This is also consistent with the utility theory that is the basis for current models—the disutility of travel is offset against the utilities of activities.

Experience in Portland, where a full activity (or time use) survey was conducted recently, does not suggest that the respondent burden or response rates were significantly affected. For those who were recruited, the response rate (completions) was 63 percent, using a strict definition of completeness—an activity diary for all members of the household, no partials accepted. This is not out of line with experience with recent travel activity (only) surveys, especially considering that the Portland survey was a 2-day survey. The biggest problem is to explain to respondents why nontravel activity is important in a travel survey.

Traditional trip-based surveys can be used to infer the activities associated with the trip. However, the number of trip purposes is usually very limited in travel surveys, making it difficult to clearly define discretionary activities in any meaningful way. The trip purpose definition is also not consistent with the activity definitions in the richer set of data obtained in traditional time-use surveys, a possible source of secondary information on time use. In the Portland study, 28 activity codes under 5 groupings (household sustaining, social, personal enrichment, recreation and other diversions, and other) were used. The intent is to let the data reveal what is and is not discretionary, rather than using ad hoc assumptions.

Length of Reporting Period

Historically, respondents in household travel surveys were asked to report their travel behavior for a 24-hr period (generally the previous day), although it is well recognized that travel patterns vary from day to day. For example, one generally does not go shopping and do banking each day, although such activities need to be done from time to time. This conventional approach is presumably based on the belief that if a random sample of households is drawn and samples of households are random across the days of the week, the behavior of households of a given type on different days of the week will be observed. (Only weekdays were sampled in the early studies.) In this way, a sample representative of the population of households and days of the week is obtained, and the average behavior of the households, or the behavior of households on the average weekday, can be modeled. Whereas the conventional approach might make sense if the only interest is in modeling average behavior, it might not be the most cost-effective way to collect data. Furthermore, it does not provide information that might be important in modeling response to TCMs, for example.

If there is day-to-day variation in personal travel behavior, additional information is obtained by asking respondents to report their travel for more than a single day. How much more information is obtained from a multiday survey, of course, depends on how much day-to-day variation there is in personal travel behavior. Furthermore, each additional day in a multiday survey presumably provides less information than the previous one, on the average, increases the possibility that some trips are not reported due to respondent fatigue, and affects respondents' willingness to participate in the survey because of the additional burden. In any event, the cost of each additional survey day needs to be traded off against the increased information obtained.

Research undertaken quite some time ago showed that a substantial proportion, on the order of 50 percent, of the variation in personal trip generation rates was attributable to within-person, day-to-day variation when data for 5 consecutive weekdays was examined (*14*). Pas (*15*) also showed that for a relatively wide range of assumptions about the marginal cost of collecting data for additional days, the optimal number of days for a multiday survey was approximately 2 (from the point of view of parameter estimation in a linear trip generation model). This analysis did not, however, take into account respondent fatigue and a possible increase in nonresponse rate.

The research just mentioned was conducted with data collected in Reading, England, in 1973. A recent study, using 3-day survey data collected in Seattle, showed that similar levels of day-to-day variation in trip generation rates and daily time used for travel exist in the United States (*16*). Furthermore, it may well be that in the context of activity/trip chaining

models, the level of day-to-day variation is even larger, thus making multiday surveys more cost-effective in this case. Results recently reported by Ma and Goulias (*17*), using data from the Puget Sound (Seattle) Transportation Panel, suggest greater day-to-day variability in activity patterns than in travel patterns.

Whereas there is some indication that respondents report fewer trips toward the end of a 7-day survey (*18*), it is unlikely that respondents in a 2-day survey would underreport travel on the second day. In fact, Pas and Sundar (*16*) found no evidence of decreased levels of reporting in subsequent days in the 3-day survey conducted in Seattle.

Beyond the question of cost-effectiveness for model estimation, a multiday survey provides information that cannot be obtained in a traditional single-day survey. For example, from a 1-day survey one cannot learn about what has been referred to as "part-time carpooling," where commuters carpool 2 or 3 days per week but not on all days. In addition, multiday information is needed to understand and model the possible multiday effects of TDM/TCM actions. The other opportunity with multiday diaries is the possible inclusion of weekend as well as weekday data, further adding to the understanding of weekly activity patterns, as opposed to daily patterns.

Longitudinal Data

Traditionally, household travel surveys were cross-sectional. Data were gathered that essentially took a snapshot at one point in time. More than 10 years ago researchers started emphasizing the need to collect, analyze, and model longitudinal data to understand behavioral responses to situational change [an early assessment of longitudinal surveys in transportation is given by Hensher (*19*)]. However, the first suggestion for the use of panel data in transportation modeling seems to be that by Worrall (*20*), who suggests that longitudinal data are needed for proper modeling of urban travel and location decisions as well as for monitoring purposes. (This idea emerged from an NCHRP project on monitoring urban travel conducted by Garrison and Worrall in 1966, but the report was never published—probably because the researchers' ideas were far ahead of their time.) Worrall's paper suggests the use of a "permanent response panel—analogous to the consumer panels employed in market research" to collect longitudinal information on location preferences, daily activity sets, and daily travel patterns of urban households. Interestingly, not only did research by Garrison and Worrall point to the idea of panels for collecting urban travel and related data, it also raised the idea of the other form of longitudinal data discussed here, namely, multiday data. In fact, Worrall's paper suggests the possibility of using smaller samples for 2-, 5-, or 7-day surveys as opposed to larger samples for a single day.

Longitudinal household travel surveys can take a number of forms:

- Repeated cross-sectional surveys,
- Before-and-after surveys, and
- Panel surveys.

The panel, which is the most commonly used longitudinal survey method in transport planning, is a repeated survey (wave) of the same sample of respondents. The period between waves depends on the behavior being analyzed. It could be a before-and-after survey—weeks to months, an analysis of automobile ownership transactions (6 months or triggered by an action), travel behavior changes, or a housing transaction analysis (perhaps annual). A multiday survey, in fact, can be thought of as a very high frequency panel of short duration. In this type of survey the sociodemographic characteristics of respondents remain constant and the external environment, including the transportation level of service, is generally treated as constant except for cases in which day-to-day changes in departure time or route have been examined specifically as a function of the respondent's experience on previous days (*21*).

Longitudinal data and models have a number of advantages relative to cross-sectional data and static models (*22*). Most important, the use in forecasting of a model based on cross-sectional data from one point in time represents the "longitudinal extrapolation of

cross-sectional variations" (*22*). That is, in forecasting with a model based on cross-sectional data, we essentially apply cross-sectional elasticities derived from differences across different observational units as if they represented the longitudinal elasticities that reflect the change in behavior, for each observational unit, that is brought about by a change in an explanatory factor. Goodwin et al. (*23*) show that this approach is valid only under the following very restrictive assumptions: (*a*) the behavioral response is immediate (i.e., no time lag or lead), (*b*) the magnitude of the behavioral response is the same regardless of the direction of change (i.e., symmetrical response to change), and (*c*) the behavioral response is independent of the past history of behavior.

Of course, the validity of these assumptions cannot be examined without longitudinal data. As the recent summary of transportation-related panels provided by Hensher and Raimond (*24*) shows, there have been a number of such studies, primarily in Europe, over the past 10 years. The first major panel for transportation studies was the Dutch National Mobility Panel, which began in 1984 and ran through 1989 (*25*). The first general-purpose transportation panel in the United States is the ongoing panel in Seattle (*26,27*). Empirical evidence from panel studies is accumulating and indicates that the foregoing conditions under which one can use models based on cross-sectional data to make forecasts are not valid in the context of travel and related behaviors (*28,29*).

As noted by Kitamura et al. (*30*), dynamic models based on longitudinal data allow for the "explicit incorporation of behavioral dynamics including lags and leads in response time, asymmetry in response, behavioral inertia and habitual response patterns (e.g., brand loyalty)." Such models are therefore able to provide more realistic descriptions of behavior in which present decisions affect future behavior and are affected by past decisions.

A panel survey provides information that simply cannot be obtained from a repeated cross-sections design. For example, if one used the repeated cross-sections design to study changes in car ownership, one could estimate the overall change in car ownership but could not identify the fact that some households increased their level of car ownership while others decreased or maintained the same level of ownership. Goodwin (*29*) reports a variety of examples of the rich interpretations that can be made from panel surveys that would be masked by repeated cross-sections designs.

Issues with the use of panels include sample maintenance and replacement, panel attrition and conditioning, weighting and use of panel data, and the introduction of the dimension of change in response over time (it is not clear that we have the tools to develop models of choice under this last condition). The problems of attrition and conditioning and techniques to deal with these problems have been extensively examined in the context of the Dutch National Mobility Panel (*31–33*). Attrition was particularly severe in the Dutch National Mobility Panel, and only 33 percent of those in the first wave completed all 10 waves (the waves were 6 months apart). In the Puget Sound Transportation Panel, particular care was taken to reduce attrition by maintaining contact with the sampled households beyond the needs for data collection. In the case of this survey, 81 percent of the Wave 1 sample completed Wave 2, whereas 63 and 55 percent of the Wave 1 sample completed Waves 3 and 4, respectively. Interestingly, both the Dutch National Panel and the Puget Sound Panel were multiday surveys in addition to being panel surveys. The Dutch survey used a 7-day diary, whereas the Puget Sound survey used a 2-day diary. As noted earlier, analysis of the data collected in the Netherlands indicated a systematic decrease in trip reporting over the course of the week.

An important continuing issue in panel surveys is the need for good information on the frequency of occurrence or base shares of interesting behaviors that may be rare or sparse, particularly for a panel sample that would probably be smaller than a cross-sectional sample. However, it is possible that cross-sectional surveys could be replaced by carefully conducted panel surveys.

Stated Choice/Preference

SP surveys and derived models are the subject of another workshop (and resource paper) at this conference. However, this subject must be introduced here because the incorporation

of an SP survey can have a large effect on the sample needed in the revealed preference household survey.

This approach to data collection is very efficient in parameter estimation because of the use of a factorial design of the sample, maintaining orthogonality, and much information can be obtained from each respondent with the use of multiple scenarios per respondent. The use of this technique can also reduce the need for complexity in the RP portion of the household travel survey. SP is particularly useful for transit modeling, where there is a need to ensure a full range of attribute variables for parameter estimation. If SP is fully utilized, a much smaller RP sample is needed. The RP survey becomes essential for providing estimates of base shares, which are important for scaling or calibrating SP models. SP can also include nonobservable (in RP) variables (e.g., the value of a guaranteed seat or personal security), providing parameter values for these attributes. It may be the most useful source of information for nonvehicular modes of travel. It is the only conceivable source for models and policy analysis of new situations and speculative hypotheticals (e.g., congestion pricing and telecommunications effects). The major limitation in the use of SP is the difficulty of a design that includes the added complexity of activity pattern or trip chain changes as a part of the response to situational change.

Design of the RP sample is simplified under this strategy. The main requirement for the RP sample is the provision of information on behavioral shares—the size for "unambitious" model estimation. That is, the recommended strategy is to make use of the strengths of each of these techniques, while mitigating their weaknesses by using combined data to estimate our models. There has been a flurry of activity on this front (*34–42*).

Sampling and Related Issues

Sampling Frame

The sample for household activity and travel behavior should clearly be a random sample of households that is as representative as possible. The most commonly used selection approach is random digit dialing of household telephone numbers. There is a strong case to be made for the use of street address directories or electric/gas utility lists. The telephone universe clearly omits the poorest households, and upwards of 50 percent of households in large urban areas are unlisted, leading to telephone recruitment in a "cold call" situation. Combined with telemarketing saturation, this leads to a large number of refusals to participate (the recruitment rate was only 52 percent in the Portland market in 1994–1995). Another strong argument for an address-based sample frame is in the use of urban design stratification schemes. The random digit dialing of unlisted numbers makes prestratification very difficult. As a practical recruitment matter this would also mean the ability to send an introductory mailer before the recruitment telephone contact. Unlisted numbers would have to be visited for recruitment, an added cost, and households without phones would also be included.

Sample Size

For simplicity we only discuss the RP home interview survey at this stage, assuming a 1-day diary and a cross-sectional survey. The effects on sample size of multiday and longitudinal designs as well as SP enrichment are discussed in the next section.

As a general statement, we tend to deal with responses with sparse representation of behaviors of interest and to look at behaviors that may be redefined during model specification (e.g., number of modes to be considered by the number of trip purposes to be considered, trip or activity chain classification). We do not think that there is any a priori way of determining the sample size, especially when we are dependent on the survey to determine the behavior frequency (there is rarely an independent estimate). In any case, when we intend to use the data to estimate a number of different models, it is hard to determine the sample size needed

to meet the needs of all the models, and it certainly becomes very difficult to try to optimize the sample with respect to a variety of models. As Axhausen (*43*) notes, we use the same survey to provide data for models working at "quite different time horizons and levels of social complexity. For example, there are short term models, such as mode choice and departure time choice, long term models, such as car ownership or work place choice, models with simple social contexts, such as destination choice of individuals, and models of high social complexity such as the allocation of the household vehicle." Furthermore, the models operate at varying levels of spatial complexity.

There has been research on sample size for transportation modeling, especially in the late 1970s and early 1980s. However, it has primarily been aimed at trip generation for a predetermined set of purposes using cross-classification models (*44,45*) or at multinomial logit models primarily of mode choice (*46–48*). The modeling demands are now much more rigorous. For example, we do not know of any work dealing with sample size needs for nested logit models or the best sampling plans for such models.

There is an accepted rule of thumb among disaggregate modeling practitioners that at least 30 cases of a behavior classification to be modeled must be present in the data. We have heard of the desire for 100 observations, but it is doubtful that this is a practical goal. It is clear that this leads to questions of sample stratification or choice-based sampling, or both, to obtain enough observations of desired rare behaviors without drawing an immense random sample that might be financially impractical. [The number of households for recent and current household travel surveys in the United States ranges between 400 (Pittsburgh) and 16,000 (Los Angeles) for a 1-day survey.]

An example might be to estimate the number of households required to adequately sample bicycle users for work trips, where an independent estimate of share is available (Census). Assume the average share for a region is 1 percent and that there are 1.2 workers per household, who travel to work 85 percent of the time (allowing for vacation, sick days, etc.). To get 30 bicycle journeys we would have to sample 2,941 households. This is derived as follows: (no. of occurrences required)/(expected frequency of occurrence) = 30/(.01*1.2*0.85). This is an absolute minimum, allowing no room for error. There is reason to believe that bicycle trips are forgotten or discounted by the respondent in a trip-based survey and are therefore underreported. This was certainly the case in the 1985 Portland survey, where 4,900 households did not yield enough bicycle trips for modeling the mode choice for this mode of travel.

The situation becomes more complex when we expect many attribute parameters to be needed (e.g., walk time, wait time, in-vehicle time and cost, automobile ownership, and household size, to delineate the decision space for transit choice). Where transit ridership is low (typically 3 to 10 percent for the western United States for work and 1 to 3 percent for other purposes) and there is a desire to separate by mode of access (walk, transit, car), we may be looking for 300 to 400 cases at a minimum to be able to estimate a model. The problem is exacerbated by the lack of good a priori knowledge of the frequency distribution of a desired modeled behavior (transit percentage for a nonhome trip with a work end, for example). When we consider the possibility of estimating models on the basis of trip chains or journeys from home and back, it is clear that no definitive answer can be given at present.

There is usually a practical sense of how much money is available for a household travel survey, and the sample size is often dictated by the budget. This being said, the recommendation of the authors is to get as many samples as can be afforded and to maximize the information given by the sample by stratification and other techniques. It is our opinion, on the basis of experience of one of the authors, that at least 4,000 household survey days are required to estimate a fairly unambitious, traditional model (six trip purposes and five modes), which would not include bicycle use, if the sample is a simple random one (Portland, Oregon). With the development of models directed toward activity-based modeling (see earlier discussion), with the explicit consideration of time use, it is likely that a very large purely random sample would be needed in some cities if revealed preference models were to be the only accepted techniques for collecting travel-related data, as is the current U.S. practice. A dis-

cussion of the interrelationships among sampling and other survey design issues (the use of longitudinal panels and stated choice experiments) is given later.

Sampling Technique

Random Sample

By definition the sample must be randomly drawn for unbiased model estimation. It is not necessary, however, to have an unstratified (regionwide) random sample, since this would produce a wasteful abundance of information about the most common behaviors and insufficient information on less common behaviors of interest. Of course, this is a very inefficient strategy.

Cluster Sample

The main reason for cluster sampling is to minimize costs in fielding in-home surveys. Should the data from the census long form no longer be available, it is probable that all or a portion of the activity and travel behavior survey will have to be collected at the home (see later discussion under Survey Weighting and Expansion). In this case, cluster sampling should be considered—the clusters would still have to be randomly drawn.

Choice-Based Sample

This approach has historically been used for trip-based modeling, where on-board transit survey data (supposedly randomly drawn) have been used to enrich the household sample data. In the context of models of activity patterns or trip chains, a survey of trips (e.g., on-board) would not be useful. However, an on-board intercept of transit users to identify a subset of households with transit use is appropriate, and these households would then be included in the sample for the household travel survey. This technique was used for a sample of automobile access to transit travelers in the 1994 Portland survey and for transit riders in the Raleigh-Durham survey (1994–1995). When used as an on-board intercept for a choice-based sample of households in Eugene, Oregon (1994), where 25 percent of the transit riders are children, problems with randomness became obvious. The question of asking children for their phone number or where they live is difficult, and children cannot commit their household to be a survey respondent. For a choice-based sample to be useful, an independent estimate of base shares for nonwork activities is needed, which is not usually available in the United States. Designing an intercept technique for pedestrian and bicycle use and for telecommunications effects may prove impossible.

Stratified Sample

This strategy makes sense if the strata are used to maximize the chance of getting the desired samples of rare behaviors. On the other hand, this approach is counterproductive when the sample is politically or arbitrarily stratified, which is common practice in the United States, for example, to provide representative data at the county or city level. There is a direct compromise when there is confusion between collecting descriptive data for member jurisdictions (or modeling data that are jurisdiction specific) and collecting data for model estimation. The rule of thumb in collecting 30 to 100 unbiased cases of rare behavior to be modeled still holds—if there are five counties a 500 percent increase in the sample size is needed for local model estimation. With normal budget constraints, the compromise often results in no models for rare behavior and more data than needed for modeling common behaviors, a very inefficient approach.

Geographic stratification to maximize efficiency has great promise. This technique was used in the Oregon-Southwest Washington 1994 household activity and travel survey and in the Triangle Transit Authority's 1994–1995 activity and travel survey. The approach used in

these recent surveys entails stratifying by urban design character—"oversampling" areas where mixed use and a good pedestrian and bicycle environment exist increases the probability of observing pedestrians, bicyclists, and transit riders. Similarly, oversampling the exurban and rural locations to get better information on household location choice characteristics and travel patterns for households with poor urban accessibility is useful. First returns from the Portland part of the Oregon-Southwest Washington survey suggest reasonable success with very rich data. This approach was used in the 1977 Baltimore survey mentioned earlier in this paper.

Survey Weighting and Expansion

The following discussion is in the context of the United States and U.S. sources of independent data, since that is the experience of the authors.

The primary reason for expansion weights is for the production of descriptive statistics, trend tracking, mandated measurement of goal attainment, estimation of base shares for calibration of stated choice models, and the use of choice-based samples. They are not often needed in disaggregate model estimation from random or random stratified sample data. Similar techniques are needed to prepare an estimate of households for base year aggregate model calibration and application.

The first stage is the estimation of stratum weights to develop a simple expansion to the universe of households. This is dependent on the stratum definition. In the case of a geography by urban design stratification, a classification of all households by stratum is required (a GIS overlay approach is practical here). Each stratum can then be proportionally expanded. This obviously requires the availability of a data base of households by location for the survey year. The second stage is to determine the factors needed to carry out a socioeconomic weighting to account for nonresponse bias and nonrepresentativeness of the survey respondents. This can be carried out using a combination of the Public Use Microdata Sample of individual households of the Bureau of the Census and the data tabulations at the tract and block group level.

Similar methods are being explored by the Los Alamos National Laboratory and researchers at the National Institute of Statistical Sciences to develop "synthetic" household populations for use in urban microsimulation models [Beckman (*49*) describes one such approach].

Loss of Census Long Form

There is currently a move to collect only those census data needed for population enumeration for representative voting purposes as laid down in the Constitution. The long form data on household socioeconomics and structure would be lost. There is also a move to go to "continuous measurement"—collection of a smaller sample annually that could yield added information on a timely basis, with 3- to 5-year aggregation used to create a larger sample similar to the current decennial cross section. The latter approach would not lose much and would be very useful for modeling endeavors such as household location.

Complete loss of the long form sample would lead to the need for a much tighter fielding of household surveys—probably of larger size. These surveys would need to provide good estimates of the base distributions directly. The use of a sample frame similar to the census enumeration technique (master address file), probably with some telephone pickup and in-home interviews for nontelephone households, would be required. Nonresponse in travel surveys would become a major issue, with the need to push for in-home surveys of telephone nonrespondents. Careful stratification can minimize the problem, but overall control would have to be much tighter. This could possibly double the per household costs for a survey. The household survey would become important for the underlying distributions of household structure currently available intermittently from the census. An alternative would be to conduct a "census style" survey of a larger set of households, with a subset being subject to the activity and travel survey.

Interrelationships Among Sampling and Other Survey Design Issues

Multiday and Longitudinal Panels

Multiday

Previous research (*15*) has examined the relationship between the number of days in the survey period and the sample size for a given level of precision in the estimated parameters in a linear regression trip generation model of person travel. One can achieve a given level of precision in the estimated parameters with either a 1-day sample or with a smaller multiday sample because additional survey days yield increased information. The size of the multiday sample, relative to the size of the 1-day sample, depends on the level of day-to-day variability in the travel phenomenon being modeled. However, because of the economies inherent in conducting a multiday survey (design, sampling design, sample recruitment, and so forth are essentially the same for a 1-day survey as for a multiday survey), one might be able to achieve a given level of precision for less cost with a multiday survey, or one might be able to increase the precision of the parameter estimates for a given survey cost. Using the data collected in Reading (see the section Survey Design Issues), Pas shows, for example, that a 2-day sample would yield about a 20 percent reduction in cost, for the same precision in the parameter estimates, under the assumption that the variable cost (or cost per day) of the survey is 25 percent of the fixed cost. In this case, it turned out that the sample size for the 2-day survey would need to be approximately 67 percent of that for the 1-day survey to yield the same level of precision in the parameter estimates. However, even if the cost savings were lower, the additional information provided by the 2-day survey would make this the more desirable approach.

Longitudinal Panel

We do not know comparable efficiencies to be obtained from a panel survey in terms of the precision of the parameters in an estimated model. However, the relationship between the sample size needed for a two-wave panel survey (N_p) and the sample size for a repeated cross-sections survey (N_c), to yield the same precision in the estimate of the change in some variable between two points in time, is given by Smart (*50*) on the basis of results of Kish (*51*), as follows:

$$N_p = N_c/(1/1 - R)1/2 \quad (1)$$

where

N_p = sample size for the panel survey,
N_c = sample size for the repeated cross-sections survey, and
R = correlation between the two surveys (for the variable of interest).

Smart reports an example, based on data in Kish, of estimating changes in car ownership on an annual basis. In this case, R was found to be approximately 0.8, so that the sample size for a panel survey would be less than 0.50 (about 0.45 to be more accurate) of that needed for a repeated cross-sections survey to yield the same precision in the estimate of the annual change in car ownership.

Of course, the lower the correlation in the variable of interest across the two time periods, the smaller the sample size reduction brought about by the use of a panel survey. However, even if the correlation were only 0.5 (thus indicating a high level of change over time in the variable of interest), the sample size for the panel survey could be about 0.7 of that for a repeated cross-sections survey. Even in this case, the use of a panel survey would lead to substantial cost savings. For example, in the case where R = 0.5, if a repeated cross-sections survey of 1,000 observations yielded a precise enough estimate of the change in the variable

of interest, then a panel survey with about 700 observations would yield the same level of precision in the estimate of the change. Allowing for attrition, and taking account of the cost per unit in the case of a panel survey versus that in repeated cross-sections, the cost of a panel survey would be about 60 to 70 percent of that of a repeated cross-sections survey.

Another example follows, using 1990 to 1994 costs: Whereas a household survey costs about $100 for a single day and $130 for a 2-day survey when all costs are allocated (survey and sample design cost are added to the cost of sampling, recruiting, and retrieving and validation of responses), the marginal cost of sampling, recruiting, and retrieving is about $75 to $85 per respondent. In a multiple wave, the design and sample are in place, and recruitment of previous respondents tends to be successful. Because of more successful recruitment, estimates of the cost for successive waves (after the first) are $55 to $75 per household, and perhaps lower. It has been estimated that the repeat waves cost about $45 per household in Seattle (discussion with E. Murakami).

The trade-offs in sample size here are less clear. Whereas the per household costs in subsequent waves are about half the initial wave cost, and each wave adds considerable information, the ability to capture rare behaviors is reduced by the smaller base sample size. Assuming the latter issue could be dealt with in other ways, the cost-effectiveness of a longitudinal design can be explored as follows. A base of 2,000 sample households could (assuming attrition rates similar to those in Seattle) drop to 1,400 households by Wave 4, giving 6,800 household-days at the same cost (assuming a subsequent wave cost rate at 50 percent of the initial wave) as 4,400 household days in a 1-day cross section. [Initial cost = x, total cost = 2,000*x + x/2*(1,800 + 1,600 + 1,400): 6,800 household-days at $4,400x; the $4,400x would obviously buy 4,400 household-days as a single nonrepeated cross section.] Thus, a longitudinal design could provide about a 50 percent increase in household days for the same price as a single cross section. The major benefit of a panel design, however, is the increased availability of temporal change information. This data source is of particular benefit to undertaking transactions modeling of automobile ownership and dwellings.

A base longitudinal survey of, say, 1,500 households, with continuing replacement of attrition and a rotation of new households in each 5-year period, carried for 10 years, could give 15,000 household days for about $1,000,000. [Start with 1,500 at $150,000 ($100 each), rotate/replace 300 households per year ($30,000 per year), resurvey 1,100 households at $50 each ($55,000 per year); total cost = $150,000 + 9 * $30,000 + 9 * $55,000 = $915,000, with an ongoing annual cost of $85,000 per year.] The same number of household-days with a 1-day survey would cost about $1,500,000, on the basis of recent U.S. costs. Alternatively, 10,000 household-days could be obtained at the same cost. The longitudinal survey, however, carries much more valuable information.

Multiday and Longitudinal Panel Interaction

It is clear that a combination of longitudinal and multiday techniques can be used to reduce the total cost per unit of information. In the preceding case an approximation would be to reduce the sample size from 1,500 to 1,000 households for 2 days each, yielding the same information at about a 20 percent savings in cost. Another reason to combine panels with multiple days is that when one tries to estimate change in travel behavior from, say, two waves of a panel survey, one is better off with multiday data. Otherwise, the change is confounded by day-to-day variability. Therefore, one may infer change where none has taken place, or one may infer stability where change has taken place. In a recent study, Mannering et al. (*52*) reported that activity models estimated with the 2-day diary data from two waves of the Seattle panel appeared to be unstable over time, but they acknowledge that day-to-day variability (which is only partially captured by a 2-day diary) may have partially confounded their results.

It is not known by the authors whether any statistical work on the problem of optimal sample design for a multiday panel survey has been attempted or completed. This is an area for future cooperative research with statistical scientists.

Stated Choice/Preference

With the need to consider the many complex TDM/TCM strategies, urban design effects, and nonmotorized travel, the question of the appropriateness of revealed preference techniques can and should be argued. The household survey soon begins to take on the attributes of the White Knight in Lewis Carroll's *Through the Looking Glass*, becoming impractically top-heavy. Attempts to answer all possible questions are, perhaps, doomed.

A method considered in detail at another workshop at this conference, stated preference, is relatively inexpensive on a per survey basis. In Portland an extremely complex pricing survey cost less than $50,000 (road pricing, congestion pricing, parking pricing, and fuel pricing for commuters). This was for a design with 15 choices, 15 attributes, and 400 respondents each giving 8 responses. Simpler surveys (new mode effects on existing corridor travel patterns, for example) can be in the range of $20,000 to $30,000. The use of this technique to investigate currently rare behaviors (e.g., bicycling) can significantly reduce the demands on the size and complexity of the revealed preference surveys (household surveys). The inclusion in the SP survey of alternatives that are used and have revealed behavior to scale the stated choice models is important. The availability of known underlying shares is also important. The need for large samples of rare behaviors in revealed preference (household) surveys to get a rich range in needed explanatory variables is reduced or removed.

Recent Experiences and Current Plans for Household Travel Surveys in the United States

Most metropolitan areas in the United States entered the 1990s with travel demand models that had been developed using data that were woefully out of date. In some areas the last household travel survey had been conducted in the 1960s, but given the changes that had taken place through the 1980s in household structure, employment location, and travel patterns, even data sets that were only 10 years old were inadequate for modeling current travel behavior.

A number of metropolitan areas in the United States undertook a household travel survey to coincide with the 1990 census of population. More important, a large number of metropolitan areas have either very recently completed a household travel survey, are in the midst of undertaking such a survey, or plan to undertake such a survey this year. These studies have generally been motivated by the recognition that current data are needed to update existing travel demand models. Furthermore, there is increasing awareness of the need to collect the data that are needed to develop the next generation of travel forecasting models.

An examination of household travel surveys undertaken in 1994 or planned for 1995 shows a trend toward collecting household travel data that can be used both for existing travel forecasting models and the emerging model framework. The current wave of household travel surveys can be characterized by the following features:

- The focus is on activities rather than trips (at a minimum, an "activity format" is used for asking the questions, although in-home activities are not always included).
- Information is collected on in-home activities in a number of cases.
- There are variations in the level of detail and the approach for collecting in-home activity information (we are still learning how to best obtain such information).
- A multiday reporting period is used in some of these surveys.
- The surveys are stated preference surveys, which sometimes follow a revealed preference survey.
- Some are the first wave of a planned or proposed panel survey.
- Sampling is generally by telephone number, although some efforts have been made to sample households that do not own telephones.
- Geographic or other stratification is used to obtain information on rare behaviors.

• A multiphase approach, using telephone (CATI) and mail-out, is emerging as the standard approach for recruitment and retrieval. The phases can be summarized as follows: (*a*) recruitment letter mailed to sampled households; (*b*) recruitment telephone call made (with key sociodemographics obtained early in the call); (*c*) memory jogger or diary, or both, mailed to respondents; (*d*) reminder call made on the night before the travel days; and (*e*) retrieval telephone calls made—usually multiple calls used (or mailback) to get information from all intended household members.

Important Issues

It could be hypothesized that a combined multiday panel integrated with stated preference surveys (possibly at each wave of the panel survey) is the most efficient design. Some might consider this to be a radical suggestion, but it should be kept in mind that Worrall suggested almost 30 years ago that multiday panel surveys be considered for urban transportation studies. Whereas there is a long wait for the first data, much more information is obtained in the long run. A continuing annual expense, for a panel survey, may be more easily institutionalized in a public agency budget. The stated preference instruments could first be used to estimate the basic time and cost elasticities for specific market segments. Subsequent SP surveys would address the burning policy questions of the day.

Rather than recommending a direction for household travel surveys, we would prefer to think that this resource paper has raised many of the important issues for discussion, clarification, and then, it is hoped, the development of new directions in the collection of data for policy sensitive models of household activity and travel behavior. We list a series of issues to guide the discussion at the workshop.

To make the best use of funds to be spent on data collection requires that we spend some money now on research and development for household travel survey methods. We need to be creative and not be constrained by past practices if we are to develop sound procedures for the household travel surveys of the future.

1. Should we set the highest-priority research topic as the issue of developing the "best" combined methodology mix—also known as total design?

2. What is the optimal allocation of a (fixed) data collection budget for a period of N_Y years, in terms of the number of households N_H, the number of days N_D, and the number of waves N_W?

3. The issue of designing the sample to get a reasonable estimate of base shares from revealed preference surveys (especially a smaller panel) is a challenging one. Success here also makes the stated choice approach much more utilitarian. Do we know the right stratification scheme? How does this affect the choice of sample frame?

4. The integration of stated preference means that we need to know more about the optimal design of the common attributes for joint estimation and the techniques to create an efficient combined design. What do we know about this? How much formal research has there been?

5. Is the possibly greater nonresponse bias of multiday surveys a real and quantifiable disincentive to the use of such surveys? Another workshop at this conference will address this issue.

6. Could a lower frequency (say 2-year intervals) provide useful information from a panel survey? How much information would be lost? Of course, a lower frequency would enable the use of a larger panel (and hence allow for better estimates of the base shares) or reduce the annual survey cost.

7. Is a national panel used to develop the response to change metric useful and combinable with occasional household surveys and stated choice surveys at the local level? Do we need panels in every major metropolitan area in the country?

8. Travel surveys seem to be getting harder and more demanding, whereas the public is subjected to telemarketing and surveys to the point of distraction. Is this an argument for smaller coverage panels and the use of the frugal stated preference? Or is this an argu-

ment for passive surveys of travel behavior (to be discussed also at the workshop on new technologies)?

9. Is there evidence that differences in response rates between multiday and single-day surveys in the United States are so great as to suggest not using a multiday approach?

10. Similarly, what are the differences in the response rates for cross-sectional versus panel surveys in the United States? Are they different enough to make one preferable to the other?

11. How much is known about panel attrition and conditioning, especially in the United States? Do we need more research here or do we have enough?

12. Is it time to use address-based sample frames, given the difficulties raised by unlisted and no-phone households?

13. Should we use in-home retrieval for no-phone households?

14. Which is better, mailback or telephone retrieval?

15. Consistency (surveys monitoring change) versus new surveys for information on changing behavior and response to new policy concerns should be considered.

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The authors have also gained considerable insight and information from meetings of peer review panels on model specification and survey needs for several studies in the United States. These include Portland (panel on models, 1992; panel on survey methods, 1994), Raleigh-Durham-Chapel Hill (Triangle Transit Authority, panel on models, 1992; panel on survey methods, 1993), Honolulu (1993, 1994), Dallas-Fort Worth (1994), and New York (1994). It is impossible to disentangle the sources of ideas, since these meetings included a wide range of academics and practitioners, among them Carlos Arce, Bill Allen, Jim Benson, Dan Brand, Patrick De Corla-Souza, George Dresser, Tom Golob, Dave Hartgen, Greig Harvey, Ron Jensen-Fisher, Ryuichi Kitamura, Arnim Meyburg, Michael Morris, Elaine Murakami, Chuck Purvis, David Reinke, Jim Ryan, Will Schroeer, Gordon Schultz, Gordon Shunk, Frank Spielberg, Cheryl Stecher, Peter Stopher, and Johanna Zmud.

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The authors are solely responsible for the contents of this paper.

Travel Behavior Survey Data Collection Instruments

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There exists a tremendous variety in the structure and form of instruments to collect household travel data. The basis for most instruments was the in-home interview used in the 1950s and 1960s. Current instruments reflect changes in data collection methods, from in-home to mailback or telephone retrieval. The amount and type of information desired to be collected have also changed with the requirements of new legislation and the underlying transportation planning and forecasting models. Current issues in household travel survey instrumentation are discussed, including the pros and cons of various approaches, and recommendations for future practice are presented.

Current views of what is essentially an art form—the design of instruments for travel behavior surveys—are presented. These instruments are designed to maximize the likelihood of obtaining objective, valid, and reliable data. This requires the acknowledgment that respondents do not necessarily interpret questions in the same way as the question designers. The "art" comes in translating the information needs of the transportation planner into the everyday language and meaning of respondents.

Research Objectives

In the United States, federal legislation such as the Intermodal Surface Transportation Efficiency Act of 1991 and the Clean Air Act Amendments of 1990 have placed new requirements on travel demand forecasters. The new demands include greater specificity of time, location, and duration of various operating conditions for all types of motor vehicles; information about choices in vehicle use; analysis of trip chaining; greater information about parking and parking costs for use in transportation demand management; and information about respondents' previous home and job locations and tenure for use in jobs-housing balance analyses.

There also appears to be the beginnings of a paradigm shift in travel demand forecasting away from the traditional four-step process toward an approach that explicitly incorporates household life cycle and travel decision-making characteristics into models. To build new models on this basis, household surveys are starting to collect more and different types of per-

sonal activity data. Despite warnings to the contrary (*1*), it does not appear that large, regionwide household surveys are being phased out in favor of small, targeted surveys. In fact, on the basis of current surveys under way for Portland Metro (*2*), the North Central Texas Council of Governments (*3*), and the New York Metropolitan Transportation Council (*4*), household surveys appear to be growing larger and more complex.

Even in this time of change with regard to research objectives, the same general categories of data persist:

- Household information,
- Person information, and
- Activity or travel information.

On the basis of these three categories, the traditional data elements included on household survey instruments are discussed.

Household Information

Household data elements include information about the physical household, the household's vehicles, and the household's occupants. Table 1 summarizes the typical household data elements collected and gives a column of comments on the source and usage of selected data elements.

Income

Household income may be collected as either a metric or a categorical variable. In the former case, respondents are asked to name a dollar amount. Whereas some surveys have successfully used this technique, most ask respondents to place themselves in an income category.

There are several approaches to income categorization. The most direct involves presenting respondents with a series of ranges and asking them to select the one that is reflective of their circumstances. This method is appropriate for written, face-to-face, and telephone instruments. Another technique that may be used in telephone surveys involves asking respondents whether their household income is greater or less than a benchmark amount, such as $40,000. Depending on the response, the interviewer proceeds to a second question that narrows the range further. This approach has the benefit of being somewhat more discreet. It also offers the opportunity to at least grossly categorize respondents, since many will answer the first such question in such a series even if they refuse to reveal their household income within narrower ranges.

With the multiple instruments commonly used for household surveys, asking about income more than once (during the recruitment and the retrieval phases) has also proven effective in achieving response rates to this item in excess of 90 percent. When household income levels reported are different at the two collection points, retrieval data have been used for analysis, because they were presumably based on a written record (i.e., the household information form) instead of a telephone recruitment call.

Unrelated Persons

Dwelling units occupied by unrelated individuals present challenges in understanding household travel behavior. For instance, the combined household income and vehicle ownership of two apartment mates may be misleading since apartment mates do not generally share financial resources or vehicles. There has thus been interest in gathering personal income information and personal vehicle ownership for each household member in addition to or in lieu of household information to gain an understanding of the travel decision making of unrelated individuals within households.

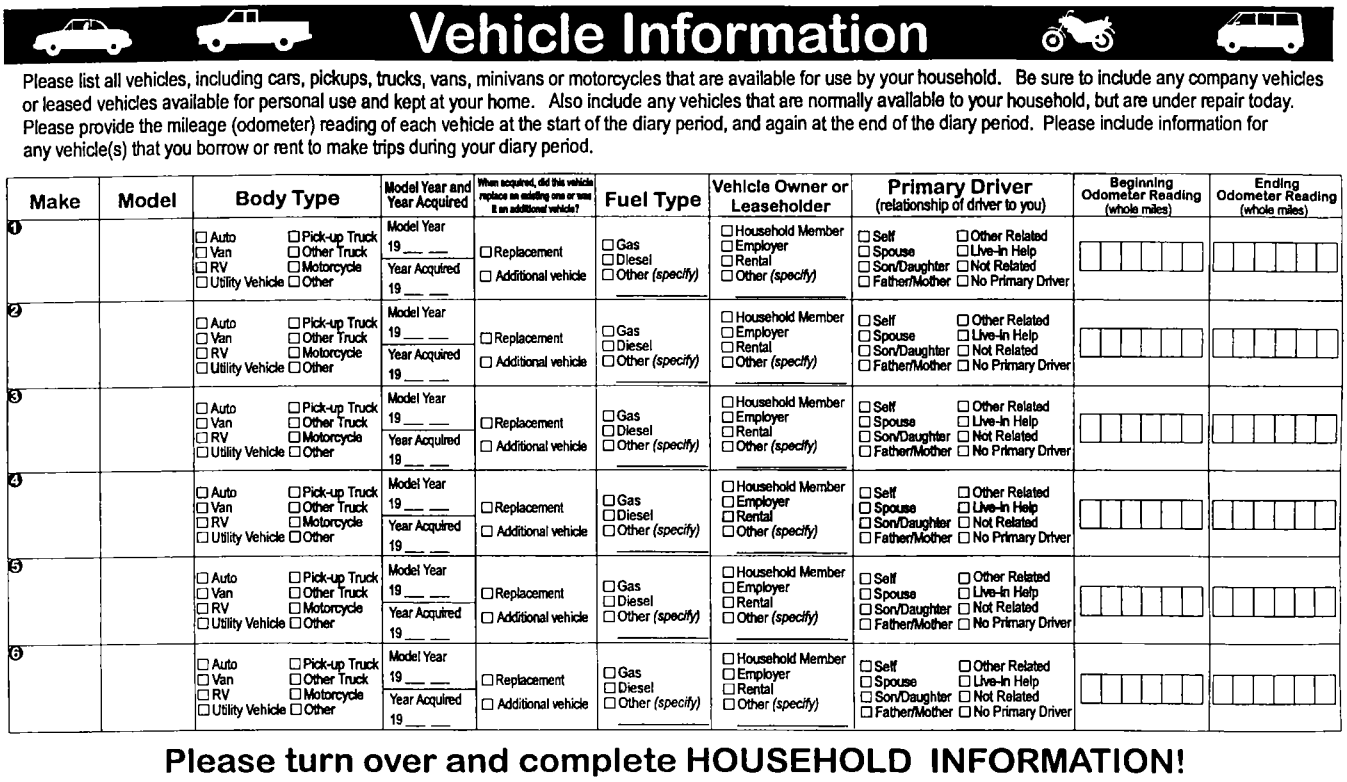
TABLE 1 Household Data Elements

Category	Data Element	Comment
Physical Household	Location of residence	Street address and city.
	Type of dwelling unit	Derive from U.S. Census categories.
	Tenure (own or rent)	Derive from U.S. Census categories.
	Length of residence	Derive from U.S. Census categories.
	Location of previous residence	Harder to get full address as length at current residence increases. Collect city at a minimum.
	Reason for moving	
	Number of telephone lines - In the household - Shared with other households - Devoted to fax/modem	Data on telephone lines is used to correct sample weights. Data on fax/modem may be useful for analysis of relationships between telecommunications and travel.
Household Vehicles	Number of vehicles available to the household	Collect as a continuous variable and categorize during analysis.
	Primary driver of the vehicle	
	Make of the vehicle	Collect as open-ended on instrument.
	Model of the vehicle	Collect as open-ended on instrument.
	Body type of the vehicle	NPTS includes 8 categories.
	Fuel used by the vehicle	Common categories are gas, diesel and other.
	Model year of the vehicle	
	Year vehicle was acquired	
	Was vehicle a replacement or addition	
	Vehicle owner/leaseholder	Response options should include household member, employer, rental agency and other.
	Odometer reading	Odometer readings at the beginning and end of the diary period may be collected.
Household Occupants	Number of persons living in the household	Collect as a continuous variable and categorize during analysis.
	Number of workers in the household	Can be used for lifestyle and/or non-response analyses.
	Annual household income	Use same categories as U.S. Census or other source suitable for expansion.
	Language(s) spoken in the home	

Vehicles

Because of the increasing desire to use household transportation surveys to estimate air quality impacts, more complete vehicle information questions are being included on household survey instruments.

However, defining the household vehicle data element is not as obvious as it may seem. Households (or members of households) may own, lease, or borrow vehicles, may use employer-supplied vehicles, or may otherwise have vehicles available for use. Whereas the number of vehicles available to a household is often used as a sampling variable and as a basis for data weighting relative to U.S. Census figures, the Census's question is phrased to focus on vehicles "kept at home for use by members of your household," which is slightly different from all vehicles available for household use. As shown in Figure 1, household survey in-



Vehicle Information

Please list all vehicles, including cars, pickups, trucks, vans, minivans or motorcycles that are available for use by your household. Be sure to include any company vehicles or leased vehicles available for personal use and kept at your home. Also include any vehicles that are normally available to your household, but are under repair today. Please provide the mileage (odometer) reading of each vehicle at the start of the diary period, and again at the end of the diary period. Please include information for any vehicle(s) that you borrow or rent to make trips during your diary period.

Make	Model	Body Type	Model Year and Year Acquired	When acquired, did this vehicle replace an existing one or was it an additional vehicle?	Fuel Type	Vehicle Owner or Leaseholder	Primary Driver (relationship of driver to you)	Beginning Odometer Reading (whole miles)	Ending Odometer Reading (whole miles)
❶		☐ Auto ☐ Pick-up Truck ☐ Van ☐ Other Truck ☐ RV ☐ Motorcycle ☐ Utility Vehicle ☐ Other	Model Year 19__ __ Year Acquired 19__ __	☐ Replacement ☐ Additional vehicle	☐ Gas ☐ Diesel ☐ Other (specify)	☐ Household Member ☐ Employer ☐ Rental ☐ Other (specify)	☐ Self ☐ Other Related ☐ Spouse ☐ Live-in Help ☐ Son/Daughter ☐ Not Related ☐ Father/Mother ☐ No Primary Driver		
❷		☐ Auto ☐ Pick-up Truck ☐ Van ☐ Other Truck ☐ RV ☐ Motorcycle ☐ Utility Vehicle ☐ Other	Model Year 19__ __ Year Acquired 19__ __	☐ Replacement ☐ Additional vehicle	☐ Gas ☐ Diesel ☐ Other (specify)	☐ Household Member ☐ Employer ☐ Rental ☐ Other (specify)	☐ Self ☐ Other Related ☐ Spouse ☐ Live-in Help ☐ Son/Daughter ☐ Not Related ☐ Father/Mother ☐ No Primary Driver		
❸		☐ Auto ☐ Pick-up Truck ☐ Van ☐ Other Truck ☐ RV ☐ Motorcycle ☐ Utility Vehicle ☐ Other	Model Year 19__ __ Year Acquired 19__ __	☐ Replacement ☐ Additional vehicle	☐ Gas ☐ Diesel ☐ Other (specify)	☐ Household Member ☐ Employer ☐ Rental ☐ Other (specify)	☐ Self ☐ Other Related ☐ Spouse ☐ Live-in Help ☐ Son/Daughter ☐ Not Related ☐ Father/Mother ☐ No Primary Driver		
❹		☐ Auto ☐ Pick-up Truck ☐ Van ☐ Other Truck ☐ RV ☐ Motorcycle ☐ Utility Vehicle ☐ Other	Model Year 19__ __ Year Acquired 19__ __	☐ Replacement ☐ Additional vehicle	☐ Gas ☐ Diesel ☐ Other (specify)	☐ Household Member ☐ Employer ☐ Rental ☐ Other (specify)	☐ Self ☐ Other Related ☐ Spouse ☐ Live-in Help ☐ Son/Daughter ☐ Not Related ☐ Father/Mother ☐ No Primary Driver		
❺		☐ Auto ☐ Pick-up Truck ☐ Van ☐ Other Truck ☐ RV ☐ Motorcycle ☐ Utility Vehicle ☐ Other	Model Year 19__ __ Year Acquired 19__ __	☐ Replacement ☐ Additional vehicle	☐ Gas ☐ Diesel ☐ Other (specify)	☐ Household Member ☐ Employer ☐ Rental ☐ Other (specify)	☐ Self ☐ Other Related ☐ Spouse ☐ Live-in Help ☐ Son/Daughter ☐ Not Related ☐ Father/Mother ☐ No Primary Driver		
❻		☐ Auto ☐ Pick-up Truck ☐ Van ☐ Other Truck ☐ RV ☐ Motorcycle ☐ Utility Vehicle ☐ Other	Model Year 19__ __ Year Acquired 19__ __	☐ Replacement ☐ Additional vehicle	☐ Gas ☐ Diesel ☐ Other (specify)	☐ Household Member ☐ Employer ☐ Rental ☐ Other (specify)	☐ Self ☐ Other Related ☐ Spouse ☐ Live-in Help ☐ Son/Daughter ☐ Not Related ☐ Father/Mother ☐ No Primary Driver		

Please turn over and complete HOUSEHOLD INFORMATION!

FIGURE 1 Example of a vehicle information form.

struments often contain considerable language clarifying what is meant by "vehicles available to your household."

Person Information

Personal data elements include information about each household member's socioeconomic and personal characteristics, employment, and schooling. In recent surveys a number of questions regarding trip patterns associated with work and school have also been included. Table 2 summarizes the types of person data gathered in the most recent household surveys. The discussion that follows touches on several instrumentation issues associated with person information.

Household Relationships

Greater interest in life-style-based transportation research increases the importance of data on household relationships (*5*). The U.S. Census approach is commonly used in constructing this data element. Under this conceptualization, the person (in whose name the dwelling is rented or owned, or an adult) filling out the form provides information on the relationship of every other member of the household to him or herself. Categories such as spouse, son or daughter, brother or sister, father or mother, roommate, live-in domestic help, and so forth are used to facilitate reporting. Whereas this method leaves some ambiguity regarding the relationship among members of the household other than the person completing the form, it is relatively straightforward.

Race/Ethnicity

Race/ethnicity usually has not been included in travel surveys, since it has not been an element in most; however, it could be used as a check for systematic nonresponse among ethnic

TABLE 2 Person Data Elements

Category	Data Element	Comment
Socio-Economic and Personal	Relationship within the household	Based on relationship of each household member to the person completing the household form.
	Gender	
	Ethnicity	
	Year of birth/age	Year of birth generally results in lower item non-response than age.
	Disability status	Disability categories may include both sensory and mobility impairments.
	For unrelated individuals - Personal income - Vehicle ownership	
Employment	Employment status	This data element includes categories such as full-time, part-time, retired, unemployed and looking for work, unemployed and not looking for work and full-time homemaker.
	Occupation of primary job	The categories for this data element are generally collapsed from U.S. Census categories.
	Industry of primary job	Same as above.
	Address of primary workplace	The name of the company/establishment, the street address, and the city are generally collected.
	Years at primary job	
	Days per week at primary job	
	Days per week work at home for primary job instead of workplace	Care must be taken in phrasing this question to capture the information desired.
	Primary job - usual start and end times	
	Primary job - ability to flex start/end times	
	Primary job - shift rotations, if any	
	Cost of parking at primary job	
	Employer-subsidized transit passes	
	Transportation mode to primary job	May be a complex data element to collect for respondents who use multiple modes, or different modes on different days.
	Secondary job, same elements as above	
	Previous job location	
School	Level of school	
	Name of school	
	Address of school	
	Days per week at school	
	Transportation mode to school	May be a complex data element to collect for respondents who use multiple modes, or different modes on different days.
	Second school, same elements as above	

groups. When used for this purpose, care should be exercised to construct the question in such a way that comparisons may be drawn with census categories.

Work at Home

Questions regarding work done at home have begun to be introduced in the person information section of household surveys through questions ascertaining the frequency of this behavior. Activity recording also captures this if it occurs during the diary period.

In asking about working at home, definitions are crucial. Framing the question in terms of working at home instead of going to the usual workplace is specific and nonambiguous, capturing those people who practice classical telecommuting. Asking simply about the number

of days the respondent works at home may be expected to capture both telecommuters and those who bring home work to do in the evenings; without specification, it may also trigger reporting of gardening, home improvements, cleaning, or other household work.

Activity Information

The heart of the travel behavior survey is the detailed record of activities or trips made by the respondent during the recorded period. "Trip" does not have the same connotation among the general public as among transportation professionals. People think about their behavior in terms of activities rather than trips. They are therefore more likely to accurately recollect what they did and where they did it (the main activity-based survey questions) than how they got there (the main trip-based survey question).

There is evidence from the 1991 Boston area survey that an activity focus yields higher per person trip rates than does a trip focus (*6*). Both formats yield the same data on trips; the difference is in how the question is asked. For example, assume a sequence in which a person starts at home, leaves at 7:00 a.m., drives alone to work, arrives at work at 7:30 a.m., and stays at work until 12:30 p.m. In a trip-focused diary, the respondent would be asked about the characteristics of the trip made between 7:00 and 7:30 a.m. In an activity-focused diary, the respondent would be asked about the two activities in this sequence: at home (usually 3:00 a.m. to—in this case—7:00 a.m.) and at work (7:30 a.m. to 12:30 p.m.). The trip information is obtained in terms of how the respondent got from one activity to the other.

Activity Data Elements

Table 3 summarizes the data elements collected on recent household surveys using an activity-based approach. The basic activity categories indicated are derived from traditional trip purpose types.

As interest has grown in understanding more about the substitutability between in- and out-of-home activities, greater detail has been introduced into these categories. The recent survey in Portland, for example, has collected information on all in-home (as well as out-of-home) activities that last 30 min or more. Figure 2 shows the list of activities proposed for the New York study. More moderate innovations have also been made in the activity categories (such as making "buying gas" and "medical/dental" their own categories).

Even with an activity-based approach, however, concerns remain about the accuracy of inferring travel (trip) characteristics between activities. This is especially an issue in considering wait times for transit trips. One alternative, which brings the approach full circle, is to treat travel directly as an activity.

Location Information for Geocoding

It is critical to collect sufficient information to ultimately geocode the addresses. Ideally, one would like to collect the street number, street direction prefix, street name, street suffix, city, and ZIP code, plus the place or business establishment name for each location. If computer-assisted retrieval techniques are used, preprogrammed lists of city and street names and major malls or business districts can facilitate the accurate recording of address information.

Parking Costs

In addition to asking questions concerning actual parking costs, recent practice includes asking respondents who use alternative modes that do not require parking what the cost would have been if they had driven.

TABLE 3 Activity Data Elements

Category	Data Element	Comment
Activity	Type of activity	The level of detailed categories has been proliferating. The collection of all activities lasting 30 minutes or more is another trend.
	Start and end time of activity	In an activity-based approach, start and end time are the appropriate elements (as versus arrive and leave). Travel time is calculated as the time between the end of one activity and the start of the next.
	Name of place where activity took place	Important for geocoding, especially when precise address information is not recorded.
	Address where activity took place	Cross-streets are often all that respondents can report.
	Frequency activity takes place	This can be an awkward data element to collect, particularly for routine activities.
Mode	Mode	Include walk /bicycle prominently in presenting options.
Personal Vehicle	Use of household vehicle or other vehicle	Linking the vehicle used for trips to the detailed information collected about each household vehicle permits valuable air quality analyses.
	Driver or passenger	
	Vehicle occupancy	
	Type of parking	Refers to parking in a lot, on the street, etc.
	Parking cost	Collects the amount and the interval (i.e. $2.00 per hour)
	Parking payment method	Captures parking costs paid for by validation, by the employer, or out of pocket.
Transit	Transit fare	
	Transit payment method	
	Location of access/egress	May be captured in several ways.
	Mode of access/egress	May be captured in several ways.
	Wait time	
	Number of transfers/other transfer data	
	Availability of personal vehicle	Must define "availability."
Walk	Distance	Can be captured in blocks or miles
	Availability of personal vehicle	Must define "availability."
Bicycle	Use of bicycle lanes or bicycle paths	
	Means of securing bicycle at destination	
Shopping	Mall or shopping center	Captures if shopping took place in a mall or shopping center.
	If in a mall or shopping center, number of stores visited	
	If in a mall or shopping center, did respondent eat	
Commercial Trips	Commercial vehicles stopping at the household.	Captures trip attractions to the household.

Recruitment Instruments

The recruitment instrument is used primarily to gain a household informant's consent to participate in the diary survey. In practice, the content of the recruitment instrument has varied depending on whether the household has been previously contacted by letter or how much of the household and person data are to be collected during recruitment.

Impact of Recruitment Script on Participation

The recruitment interview is a social interaction in which the interviewer and the respondent are intertwined by the script. The initial challenge is to differentiate the survey from a "junk call." Refusals are much more likely to occur at the very beginning of interviewer contact rather than after a respondent has been selected, after the questionnaire has started, or after the diary has been mailed. Thus, the first 30 to 60 sec of contact are crucial, particularly from the standpoint of minimizing nonresponse.

The skill of the interviewers does much to determine the success of the recruitment call, along with the wording and phrasing of the recruitment appeal. Opinions differ among survey professionals concerning how much information should be given in the appeal, and the

At Home Activities
Sleep/napping
Meals
Personal care
Dependent care
In-home amusements
Household business
Household maintenance
School/school-related
Working at home
At home exercise
Telephone
Computer

At Work Activities
Work
Meals

Outside of Home/Outside of Work Activities
Drop off or pick up someone
Meals
School/school-related
Shopping (general)
Shopping (major purchases)
Medical care
Household business
Culture/entertainment
Formal entertaining
Religious
Civic
Spectator sports
Exercise/athletics
Personal care
Household care
Visiting
Work related/outside work
Professional services
Buying gasoline

FIGURE 2 Detailed activity categories.

research literature does not provide a definitive answer (*7*). In general, the appeal should be reasonably brief and contain enough information to reduce potential respondent nervousness. The longer potential respondents must listen without active involvement, the greater the chance they will lose interest before the questioning even begins.

The following should be considered for inclusion:

1. Identification of the interviewer, the interviewer's affiliation, and the survey sponsor;
2. Brief explanation of the purpose of the survey and the study area;
3. Brief explanation of the household commitment;
4. Positively worded phrase to encourage cooperation; and
5. Statement about the use of the findings.

Not everything in the study must be explained in the introduction. In particular, explanations about individual questions or sections should be deferred until the appropriate place in recruitment questionnaire, follow-up questionnaires, or diaries. Also, fallback statements should be devised for interviewers for use with respondents who may want additional information about the study. The fallback statements should be honest, standardized explanations that the interviewers can read or paraphrase.

Incentives

Surveys depend on respondents' cooperation for their success. It is widely believed, however, that response rates have been declining and that respondent resistance is increasing. Thus, there has been an increasing interest in using monetary or other incentives to motivate respondent participation. Any evaluation of incentives must recognize that they are only one feature of a comprehensive survey design that may increase participation. It may be possible to achieve appropriate response rates through careful sample management, experienced interviewers, and prenotification and follow-up calls (*8*).

Current literature suggests that "prepayment of the incentive had significant positive effects on response rates" (*9*). It signals to the respondent that the research is "sufficiently important to justify a rather bold and unusual gesture" (*9*). Others suggest that by including an incentive in advance, "the researcher extends a token of trust to the survey participant

and initiates a social exchange relationship which invokes an obligation for the participant to reciprocate in kind" (*10*).

The amount of the incentive varies according to the group under study. Arbitron Radio Market studies use higher incentives for harder-to-reach populations. Berry and Kanouse suggest that "the size of the incentive payment may be one of several cues that respondents can use to judge a survey's importance" (*9*). However, when public money is being used to fund a household travel study, incentives may not be considered appropriate use of taxpayers' money by the public at large.

Incentives may also be more effective when used with populations that have been "oversurveyed." Survey Sampling, Inc., publishes a list of the most frequently surveyed metropolitan areas. The list includes, not surprisingly, most of the major urban areas of the country, as well as many mid-country areas considered by market researchers to be representative of the nation.

Incentives used for travel surveys have included state lottery tickets, cash, and gifts (pens). A direct comparison of monetary incentives was conducted as part of the first wave of the Puget Sound Transportation Panel (*11*). It was found that an incentive of $1 per household sent out with the diary materials yielded slightly better participation rates than $10 per household that returned completed diaries (64 versus 60 percent). Both monetary incentives increased the participation rate over no incentive (49 percent). At this juncture, however, there is no clear consensus among practitioners as to whether, or when, incentives should be considered for travel behavior surveys.

Respondent Materials

There has been general agreement that better data are obtained when respondents are provided instruction and data recording materials in advance. Respondent materials have included diaries, memory joggers, household forms, vehicle forms, cover letters, reminder cards, and fact sheets. These and other materials issues are discussed in this section.

Diaries

Two forms of travel diaries appear to be prevalent in travel surveys: a single-page form, which is often printed double sided on legal size paper, and a multipage booklet. The one-page form may be less intimidating to respondents and costs less to print and mail. However, the space available for respondents to actually write location and other open-ended information is usually tiny, which can lead respondents to simply omit a response when there is no space for them to write it out. This is an important consideration should the addresses need to be geocoded.

A multipage booklet offers more space for respondents to record address and other information and provides room for more detailed instructions. The multipage booklets may be more intimidating to potential respondents, and they cost more to produce and mail.

The increase in the amount of data to be collected has raised concerns that the forms have become so massive and complex that they deter potential respondents and contribute to a lower response rate. One option has been to print fewer questions on the forms but to use telephone retrieval to ask respondents the full set of questions. This reduces the size of the forms, which should be less intimidating to respondents. However, there are two potential disadvantages: First, reliable data are more likely to obtained when respondents are cued in advance that they are going to be asked about something and that they should write it down or remember it. Second, taking items off the printed forms limits the ability of "proxies" or spokespersons to adequately relay the data from other household members. Most surveys permit someone other than the person actually doing the activities to relay information to the telephone interviewer during the retrieval phase. If key information items are

not written down, proxies will be unable to assist—which negatively affects overall completion rates.

Time Period (24 or 48 hr)

Whether 24- or 48-hr diaries should be used to collect activity and/or travel information is the subject of considerable debate. One issue is the perception that 48-hr data collection places too great a burden on respondents. Another is whether there are significant differences in activities and travel across 2 consecutive days to warrant the additional collection of data.

Respondent burden is an issue that should not be treated lightly. The ability to gain and keep a household's participation in the travel survey will largely depend on the perceived burden of responding. Having a respondent track activities and travel for 24 hr is definitely less of a burden than tracking for 48 hr. In addition, a lengthened reporting period for respondents not only increases the burden during the activity days but also makes for a longer retrieval interview to collect the activity and travel data. However, the additional burden created when requesting 48 hr of information may be somewhat mitigated through the diary design. Taking into account the literacy level of the target population and the ease of recording information can reduce the respondents' perceived burden and any negative impact on response rates.

An analysis by Golob and Meurs (*12*) of a 7-day diary used by the 1984 Dutch National Mobility Panel found that total trips per person declined 1.0 percent per day because of response bias. The principal cause appeared to be an increasing tendency of respondents to report no travel at all on a given day and a day-to-day increase in the underreporting of walk trips. Both of these tendencies may be corrected by careful prompting in telephone retrieval.

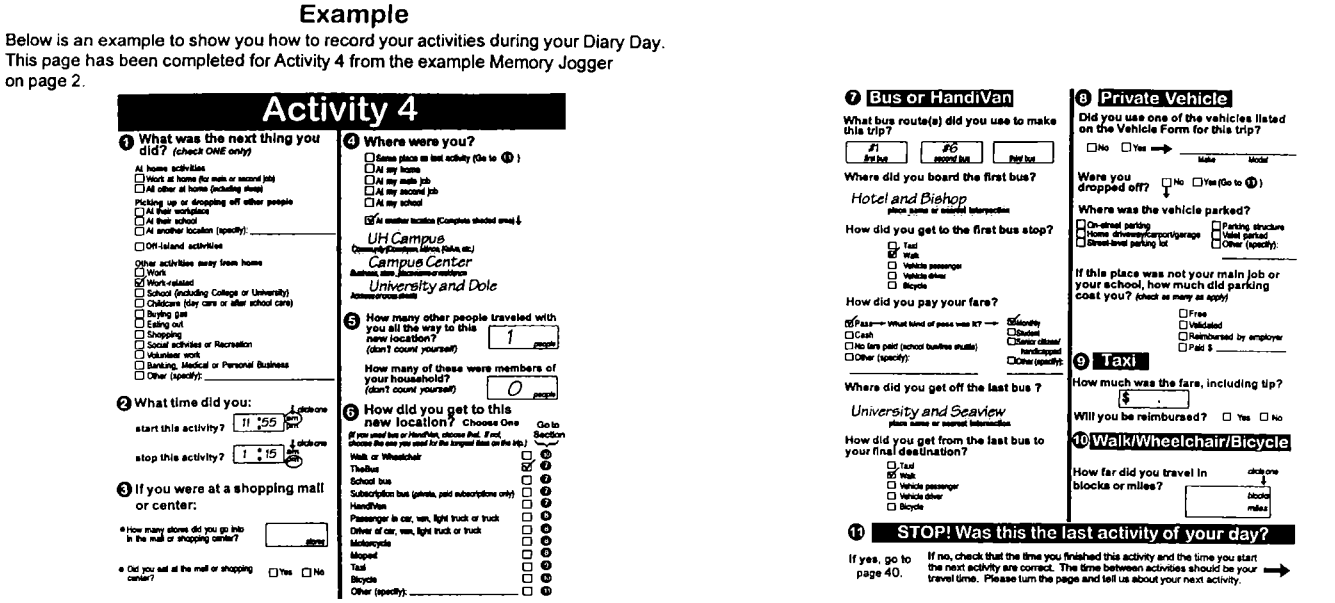
The second issue is the extent to which the activities and travel on the second day mirror those from the first day. One theory is that the data from the 2 days will be strikingly similar. Therefore, it follows that it may not be necessary to collect data for both days. However, studies have shown that the ability to capture part-time use of travel modes and trip-chaining greatly increases with the use of a multiday diary. A recent study on the variability of route and trip scheduling for the evening commute indicates that only 16 percent of stops made on the work-to-home trip were "routine" (*13*). Another study, which examined 2 days of travel from respondents to Wave 1 and Wave 2 of the Puget Sound Transportation Panel, concluded that the day-to-day variation in activities was substantial enough to warrant the use of 2-day diaries (*14*).

Examples

A common means of illustrating for the potential respondent exactly what information is desired is to provide an example—either of a completed activity or trip—directly in the diary instrument. Example pages from a recent travel survey are shown in Figure 3.

Although diaries are designed to collect activity or trip data as the travel is undertaken, it is suspected that many respondents fill out diaries retrospectively. The memory jogger encourages the recording of key data as the travel is undertaken. Memory joggers have come in two forms: as a specially designed two-sided pocket card, which household members can easily carry around with them during the assigned travel/activity days, and as a separate page bound in with a booklet travel diary. Whatever the form, the memory jogger provides space to record notes on at least the what, how long, and where of a specific number of activities or trips. Respondents are asked to record notes in the memory joggers throughout the day, then transfer their notes to their activity and travel diaries at the end of the day. An example of a memory jogger is shown in Figure 4.

Memory joggers are designed to facilitate recollection of specific elements relating to activities and travel. Particularly in studies where the diaries are somewhat bulky and difficult to carry, the memory jogger provides a convenient forum to aid respondent recall. With the use of more compact diaries, the utility of memory joggers may diminish.



❶ The person went to a lunch meeting, so the activity is work-related.
❷ The person was at the meeting from 11:55 a.m. until 1:15 p.m.
❸ The activity was not at a shopping mall or shopping center, so the person skipped this question.
❹ The activity was at a new location, so the person filled out the address.
❺ One other person went to the meeting. This other person was not a member of the same household.
❻ Both people took TheBus to the meeting.
❼ They first rode the #1 bus and then transferred to the #6 bus to get to the meeting.
They got on the #1 bus at the corner of Hotel and Bishop Streets.
They walked to that bus stop.
The person paid the bus fare with a monthly pass.
Both people got off the #6 bus at the corner of University and Seaview.
They walked from the bus stop to the meeting at Campus Center.

FIGURE 3 Example pages from an activity diary.

Household and Vehicle Forms

Each decision to include a particular data element in a household travel study must be followed by an equally important decision of when to collect that information. Data collection takes place during recruitment, reminder, and retrieval.

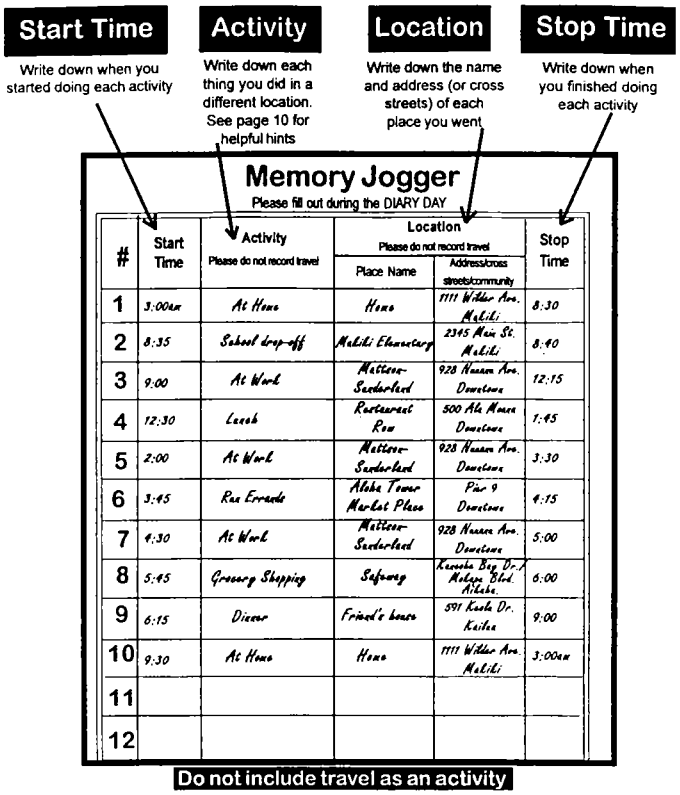
As discussed previously, a telephone recruitment interview is frequently used to obtain participation of the household and to collect demographic information about the household. If the recruitment interview is too long (i.e., more than 15 min), there is a higher probability that the household will not participate in the study.

To reduce respondent burden and ensure household participation, some agencies have opted to minimize the recruitment contact and include household or vehicle forms, or both, in the materials packet. The data collected on these forms are retrieved during the reminder or retrieval call, or the respondent is asked to mail back the completed forms. As a result, the respondent burden is not actually reduced, but shifted to a later stage in the data collection process. The reasoning is that the household has already made an investment in the study and will not be as likely to refuse to participate.

However, it is equally important to remain sensitive to the amount of information included in the materials packet sent to the recruited household. If it appears to be too much work, the household may refuse to participate. A refusal to participate at this stage is more costly, because time and funds were expended during the recruitment call and the mailing of the survey package.

Household Form

The household form typically is used to collect detailed employment and school information from household members. The data elements (discussed earlier) usually fit on one page. Depending on household size, the removal of these items from the recruitment interview may shorten that call by 3 to 5 min. This reduces respondent fatigue during the recruitment call but may result in loss of data if some households decide in the interim that they do not wish to participate.



#	Start Time	Activity (Please do not record travel)	Location (Please do not record travel)		Stop Time
			Place Name	Address/cross streets/community	
1	8:00am	At Home	Home	1111 Wilder Ave. Waikiki	8:30
2	8:35	School drop-off	Waikiki Elementary	2345 Main St. Waikiki	8:40
3	9:00	At Work	Matson-Sunderland	928 Nuuanu Ave. Downtown	12:15
4	12:30	Lunch	Restaurant Row	500 Ala Moana Downtown	1:45
5	2:00	At Work	Matson-Sunderland	928 Nuuanu Ave. Downtown	3:30
6	3:45	Run Errands	Aloha Tower Market Place	Pier 9 Downtown	4:15
7	4:30	At Work	Matson-Sunderland	928 Nuuanu Ave. Downtown	5:00
8	5:45	Grocery Shopping	Safeway	Kaneohe Bay Dr./ Kalaniana'ole Blvd. Kailua	6:00
9	6:15	Dinner	Friend's house	591 Kuulei Dr. Kailua	9:00
10	9:30	At Home	Home	1111 Wilder Ave. Waikiki	3:00am
11					
12					

FIGURE 4 Example of a memory jogger.

Vehicle Form

Like the household form, vehicle forms are often included in the packet of materials sent to participating households. If space permits, the vehicle information may be printed on the reverse side of the household form. (See Figure 1 for an example of a recent vehicle form.)

Other Materials

Several other respondent materials may be used in conducting a household travel survey: cover letter, fact sheet, reminder cards, and incentives.

Cover Letter

The cover letter is an important part of the materials packet. In fact, the packet should be assembled so that the cover letter is on top when the respondent opens the packet. The cover letter adds validity to the survey process and should be written with respondent literacy in mind. The contents should convey the relevance of the project to the household (i.e., Do traffic conditions in your area concern you?). It should provide a contact person and telephone number in case the household has questions, and it should confirm the steps of the process. Finally, the letter should be signed by a prominent local official.

Reminder Card

Reminder cards, with assigned travel and activity days prominently displayed, may also be included in the materials packet. To be effective, they should be designed for a specific display location (i.e., posted on the refrigerator).

Fact Sheet

A fact sheet has been included in some household surveys to provide respondents more detailed information about the purpose of the household survey than can be communicated in the cover letter. The intent is to motivate higher response rates. Structuring the fact sheet in a question and answer format has proven to be an effective way of addressing most of the points commonly raised by survey respondents. Fact sheets can be designed to fit on two-sided letterhead or as tri-fold brochures.

Literacy Level

According to the *National Adult Literacy Survey* (*15*), 23 percent of the nation's adults read below an eighth grade level. This has strong implications for the design of complex survey instruments. Literacy levels were an issue in the recent household survey conducted in the Detroit region, particularly with lower-income participants, who are already harder to recruit and more difficult to retain. One possible solution is to have all sets of instruments checked for reading level and to have appropriate changes in wording made wherever possible to simplify the instruments.

Foreign Language Materials

In regions where there are concentrations of monolingual, non-English-speaking populations, the issue of translating the travel behavior surveys and instruments into other languages emerges. Not only does translation permit the inclusion of non-English-speaking individuals in the sample, it also facilitates data retrieval from persons whose English is limited and who may feel more comfortable in their first language.

Household interview instruments are most frequently translated into Spanish; however, in many areas of the country, Asian languages are increasingly being considered for instrument translation. For example, the 1991 Southern California Association of Governments survey was translated into Chinese (Cantonese), Korean, Vietnamese, and Cambodian, in addition to Spanish.

Translating materials into another language introduces additional costs. Besides hiring interviewers who are bilingual (English plus the desired other language), the instruments should be "back-translated" to ensure that the full meaning and intent of the questions is retained. Back-translating involves translating materials from English to the other language and then translating the same set of materials back into English. Care must also be taken with producing materials in languages that involve a different typeface system (Chinese, etc.).

In general, unless the incidence of monolingual, non-English-speaking households exceeds 5 percent of the total population in the area to be surveyed, the cost to translate the materials into a given language exceeds the benefits from a strict survey design point of view. At this point, the decision to translate becomes a political one.

Retrieval Instruments

To date, all travel surveys conducted in the United States have relied on respondents to record their travel. There are, however, many different methods of retrieving the recorded information. In the 1960s and to some extent in the 1970s, interviewers were often sent to the households to physically review and retrieve travel information. Many surveys requested the respondents to return the completed survey forms by mail (mailback). Some surveys collected the information by telephone. As computer capabilities were enhanced, recorded travel behavior information began to be retrieved using computer-assisted telephone interviewing (CATI) systems.

The choice of retrieval mode affects the survey cost, forms used, and response rates. The three main retrieval approaches (in-home, mailback, and telephone) are discussed in this section.

In-Home Interview

In-home interviews usually involve an initial in-home visit to recruit households to participate in the survey and a second visit to retrieve completed surveys. The advantages of this approach are that the interviewers can check the activity information directly with the respondents, the sampling frame can be controlled to the Census block level, and households without telephones are (relatively) easily included. There are conflicting views on whether the in-home approach enhances response rate. Response rates to the in-home surveys conducted in the 1960s were higher than those obtained in more recent telephone surveys. However, response rates to all types of surveys have declined in the 1990s, making it difficult to determine the extent to which the retrieval method was the causal factor.

In-home interviews have the disadvantage of being more costly on a per household basis. The challenges faced by interviewers in recruiting households in-home has been exacerbated by the increase in "gated communities" and other residential areas with controlled access.

Mailback

The least costly method of household travel survey data collection involves a multimode method. Households are recruited by way of a brief qualifying telephone interview. After it agrees to participate, the household is mailed a packet of survey instructions and travel diaries to be completed and mailed back to the survey management team. This method has been used by the Chicago Area Transportation Study (*16*) and by researchers in Europe and Australia (*17*).

There have been concerns about the extent to which respondents may underreport trips using a self-administered mailback method. A travel behavior study in San Antonio, Texas (*18*), found just the opposite. In that survey, participating households were asked to mail their completed diaries back in addition to having the data retrieved by telephone. When the data from the mailback were compared with the data collected from the phone interview, statistically significant undercounting of trips was uncovered in the mailback. Overall, the phone data collection generated 9.75 trips per household, compared with 9.12 trips for the mailback. The "within-case" difference was 0.63 trips per household.

Under the mailback method, the researchers must budget time to telephone or otherwise recontact households to clarify incomplete, illegible, or missing data. Completed data must also be entered into computer files for analysis.

In general, response rates are 10 to 15 percent lower for mailback than for telephone retrieval. For sample sizes exceeding 4,000, the mailback method presents challenges in the management of paper data. On the positive side, mailback may be more cost-efficient than telephone retrieval, especially for smaller samples.

Telephone Retrieval

Travel information has been retrieved by telephone since the 1970s. Early methods had interviewers writing the information into survey forms on the basis of their conversation with the respondent. The information was subsequently key entered for checking and analysis. As computer systems became more sophisticated, programs were developed for interviewers to key information directly into a data base. Later enhancements permitted the programming of the exact question being asked, as well as skip patterns based on specific responses. Systems that include the exact "script" on a computer screen, into which the interviewer directly inputs the responses, are CATI systems.

CATI systems have become increasingly capable of complex checking and programming. The ability of the CATI system to accommodate complexity is dependent on the skill of the programmer and the CATI software being used. Many survey firms use commercially available software (e.g., Ci3 software for PCs and Survent software for mainframes). Other sur-

vey firms have developed their own proprietary software for data collection. For example, a "trip-rostering" routine has been built into the interviewing software for the 1995 NPTS. This routine was established to reduce the interview time and the redundancy of trip reporting, particularly when household members travel with each other. As each person is interviewed, trips that are taken with other household members are tracked. When subsequent members mention these same trips, the information is copied over. This and other enhancements to telephone retrieval procedures point out the real differences in the ability of CATI systems to program in desired logic checks as real time, on-line checks, while keeping screen refreshment time minimal.

There has been concern that telephone retrieval methods may yield fewer trips. The concern has been that "telephone fatigue" sets in as the number of trips to be reported increases and that households simply underreport trips to finish what can be a very lengthy telephone call. Even when the CATI system permits respondents to skip over information that was already provided by other family members and the screen refreshment time is kept to less than 1 sec, retrieval of travel information from all family members can last 45 min or more. This period is rarely one telephone call—retrieval of a complete household usually requires several telephone calls to the same household.

CONCLUSIONS

The amount of information desired from household surveys by transportation planners has increased tremendously over the past few years. Accompanying the increase in data elements has been a decline in response rates. Current practice, as outlined in this paper, has evolved from attempts to reduce nonreponse.

User-Friendly Forms

Careful attention to the wording and layout of questions should help in the design of user-friendly forms. Wording of questions can be checked by professionals for grade reading level. Professional graphics designers may be used to review layout and design. The importance of the visual aspects of travel diaries and related materials cannot be overemphasized. Unfortunately, there is often a direct trade-off between visual simplicity and the amount of data desired.

There are a number of unresolved issues regarding materials, including single-page compared with booklet travel diaries, the need for memory joggers, and when to use incentives.

Potential Enhancements to Household Travel Surveys

Several enhancements could improve the collection of household travel data.

Linking CATI to a Geographic Information System

One enhancement to current telephone retrieval methods would be to directly link the CATI system on-line with a geographic information system (GIS). As respondents described the location of their trip origins or destinations, the interviewers could follow the trip on a GIS display and simply point and click on the reported locations. The geocode for each address could thus be directly input into the data base.

Use of Passive Data Collection Instruments

As the amount of information desired increases, the use of passive data collection devices needs further exploration. Such devices might include the use of global positioning systems

to track vehicles or even persons, or other forms of in-vehicle monitoring. The spread of "smart card" technology for payment of transit and toll fares may provide another source of travel information.

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New Technologies for Household Travel Surveys

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The advent of new technologies and recent advances in travel survey techniques have marked a new era in household travel surveys. Computer-assisted interviewing (CAI) technology has been available for more than 20 years; however, its widespread use in household travel surveys is a more recent trend. The reasons for this trend include advancements in personal computers, the introduction of graphical user interfaces, and the sophistication of CAI software. Some of today's CAI software includes built-in logic that can identify inconsistencies in a survey as it is being completed. Technologies designed specifically for use with spatially referenced data (e.g., geographic information systems and the Global Positioning System) also benefit travel surveys. These technologies can result in more efficient data collection, improved data quality, reduced survey costs, and more flexible output products. This paper discusses current and potential uses of new technologies in household travel surveys. The advantages of these technologies are identified along with potential biases and errors that they may introduce into travel survey data. A discussion on possible research areas that focus on taking full advantage of new technologies is also presented.

At a recent conference on the use of data in transportation planning, it was observed that "because the effectiveness of planning depends so strongly on the existence of a good database, designing a data collection and management plan for an urban area becomes an important task in transportation planning" (*1*). Key elements of such a plan are to determine which data will be collected, which types of techniques will be used, and the reasons for collecting the data. Although data needs vary from one urban area to another, information that can be obtained from household travel surveys will continue to be critical to successful planning. Such information allows one to relate daily travel patterns and trip-making behavior to household and individual characteristics—a relationship that is the foundation for understanding network flows. Time-of-day trip making, mode choice, trip chaining, and other information obtained from surveys will continue to be vital to planning transportation systems and in formulating traffic management schemes.

Such data can be collected with a variety of techniques. Roadside interviews, postcard surveys, license plate surveys, phone surveys, and travel diaries have been used in the past to collect personal travel information for transportation planning purposes. Computer-assisted interviewing (CAI) techniques, such as computer-assisted telephone interviewing (CATI) and

computer-assisted personnel interviewing (CAPI), have greatly improved the efficiency and effectiveness of travel surveys. Travel diaries combined with in-vehicle dataloggers can provide information on vehicle speed distribution by road class by time of day and length of trip. Such a combination has been used in Atlanta as part of a research project that monitors vehicle activity for air quality modeling. In addition, simple dataloggers have been used to monitor vehicle activity for 100 vehicles during a 2-week period (*2,3*). However, this experience has shown that this combination of data collection techniques is often unwieldy and makes results difficult to interpret.

One of the key challenges facing today's transportation planner is to develop a cost-effective way of collecting and managing travel data, particularly with the spatial and temporal disaggregation capability that is critical to providing the varying scales of analysis that characterize effective planning in the 1990s. Two emerging technologies—geographic information systems (GISs) and the Global Positioning System (GPS)—could have a significant impact on the effectiveness and usefulness of survey data.

The purpose of this paper is to examine the use of new technologies, including advances in CATI and CAPI technologies, GIS, and GPS in household travel surveys. The following section (*a*) describes the basic characteristics of these technologies, (*b*) the advantages of using them in concert with travel surveys, and (*c*) the potential biases and errors they may introduce into data bases. The remaining sections of the paper discuss possible research areas that focus on taking full advantage of new technologies.

Computer-Assisted Telephone Interviewing

The telephone, in conjunction with computers, has been used in household travel surveys since the 1970s. Early CATI packages were designed primarily to simply "computerize" traditional paper and pencil procedures to collect survey data more efficiently. The advent of personal computers and the introduction of graphical user interface technology has brought about significant changes in today's CATI systems. New CATI systems incorporate capabilities that support nearly every phase of the overall survey process and can greatly reduce post-processing. The 1990 Nationwide Personal Transportation Study (NPTS) used CATI technology with great success; more innovative CATI tools are planned for the 1995 NPTS. For example, a "trip-rostering" routine has been built into the interviewing software to reduce interview time and the redundancy of trip reporting, particularly when household members travel with each other.

There are many other examples of how CATI has been enhanced to improve the interview process. While some survey firms are using existing CATI software (e.g., Ci3 software for personal computers and Survent software for mainframes), others have developed their own proprietary software for data collection. Shanks describes a computer-assisted execution system developed by the University of California, Berkeley, with extensive survey data checking capabilities that can greatly reduce survey errors and minimize postprocessing or follow-up contacts with survey respondents (*4*). Ng and Sargent describe a specialized CATI system used in Canada that uses extensive look-up tables to assist the interviewer (*5*). On-line detailed tables of helpful information on the different working screens is key to the smooth operation of this CATI system. This feature reduces keystrokes while enhancing data quality by minimizing spelling errors.

Telephone retrieval has several benefits because interviewers can interact with responding households and can obtain clarification of data that have omissions or are not logically consistent with other answers in the survey. The sophistication of the CATI software make it possible to flag logically inconsistent responses automatically for clarification. Further, telephone interviewers can clarify confusing questions when interviewees seem confused or resistant. Doing this tends to increase the response rate. A number of Canadian urban travel surveys have demonstrated that with sufficient interviewer training, a relatively high survey response rate can be achieved (*5*). In mail-back surveys, for example, the respondent burden is high, especially on detailed travel survey questionnaires. Therefore, mail-back surveys can under-

represent groups that are not accustomed to filling out complex forms or are not fully literate in English (e.g., senior citizens and recent immigrants).

There are a number of disadvantages in using CATI. First, biases may be introduced in the survey sample. For example, the portion of the population without a telephone will be underrepresented if other methods of interviewing are not used. Second, there is concern that telephone retrieval methods may yield fewer trips. As the number of trips to be reported increases, the tendency to underreport trips becomes more apparent. This occurs because to offset the great deal of time respondents spend on the phone, they may not report short trips. Hassounah, Cheah, and Steuart (*6*) describe a CATI survey of 61,000 households in Toronto in which trip underreporting was the rule for short discretionary trips and trips made during off-peak periods, and they describe procedures to correct for trip underreporting. Other CATI limitations can be attributed to the increased use of answering machines, the advent of caller ID to screen calls, and the tendency of people to avoid unsolicited phone calls.

Computer-Assisted Personal Interviewing

Computer-assisted personal interviewing (CAPI), similar to CATI, relies on a computing device to directly input survey information. CAPI systems are used by interviewers in the field to interview survey respondents directly, either at home or at another location, such as a roadside. CAPI systems also make use of sophisticated software to make the interviewing process more efficient and to minimize postprocessing. Notebook and palm computers are the most common hardware used in CAPI systems. The interface can be enhanced if pen-based or touch-screen technology is used.

The advantages of CAPI are similar to those of CATI, and results from previous surveys show that personal interviews provide the best response rate of any survey methodology currently used. One advantage that CAPI has over CATI is that it encourages the respondent to answer more fully and honestly. Facial expressions can make it evident whether a respondent is confused or insincere. Personal interviews also allow the interviewer to use other survey aids in an interactive manner, such as showing the interviewee hard copy or digital maps to help clarify trip origins, destinations, or both.

The major disadvantage of CAPI is cost. The National Travel Survey conducted in the United Kingdom ruled out the use of CAPI because of the cost of hardware (*7*). Even though hardware costs have come down considerably, the cost of face-to-face interviews is still a major consideration. Another disadvantage of CAPI is that interviewers are at risk for becoming victims of crime. In some instances, two interviewers and even a uniformed police officer have been used in the survey; however, this adds to the survey cost. The challenges faced by interviewers in recruiting households is magnified by the increase in controlled access communities (e.g., country club communities). This can result in survey bias.

Geographic Information Systems

GISs are designed to handle spatially referenced data, such as cartographic data. Such systems facilitate the storage, retrieval, manipulation, analysis, and display of large amounts of spatial data. General coverage of the topic of GIS technology can be found in Huxhold (*8*) and Antenucci et al. (*9*). Aronoff (*10*) presents a management perspective of GIS. An in-depth treatment of GIS can be found in Maguire, Goodchild, and Rhind (*11*).

For purposes of this paper, a GIS is defined as a spatial display and analysis tool for decision making that allows the user to overlay attribute data of each referenced location to produce information related to different combinations of these data. A GIS consists of a data base containing spatially referenced, land-related data as well as procedures for systemati-

cally collecting, updating, processing, and distributing these data. The fundamental base of a GIS is a uniform referencing scheme that enables data within a system to be readily linked with related data. A true GIS can be distinguished from other systems through its capacity to conduct special searches and to generate overlays that actually produce new information. This is in contrast to a large number of systems that are limited simply to graphics reproduction, such as computer-aided design and drafting (CADD) and data selection and reports, such as traditional data-base management systems (DBMSs). Even when CADD and a DBMS are linked together through a common interface, they only constitute a sophisticated computer mapping system, not a GIS. A true GIS integrates modern principles of software engineering, data-base management, and mapping theory. It provides the user a wide range of automated tools for the capture, manipulation, storage, analysis, query, and display of map and other land-related data.

A GIS comprises five basic elements:

1. Selected data about geographic locations;
2. Software to manipulate and manage these data;
3. Hardware on which the data and software are stored, input, and displayed;
4. People responsible for overseeing GIS operations; and
5. Procedures for using and maintaining the GIS.

Each of these five elements plays an essential role in the functioning of a GIS and must be fully understood before a system can be designed and implemented.

Characteristics of GIS Spatial Entities

The primary purpose of a GIS is to organize extensive and varied data into a common spatial framework. There are two common methods, or data structures, that are used to organize spatial data. These are the raster, or grid, data structure and the vector, or polygon, data structure. Figure 1 contains a raster map and a vector map. The raster map, which shows part of Thailand, has a 0.5-km cell size. The vector map shows a downtown area for a small town in central Georgia. These maps illustrate the differences between raster and vector data maps. A raster data structure is not appropriate for use in travel surveys because it is difficult to link attribute data such as census information to a spatial object (e.g. census tract).

Vector-based GISs store spatial data as points, lines or arcs, and polygons. Descriptive attribute information can be associated with each of these basic spatial entities. Thus, it is possible to query a road segment stored as an arc to identify an associated attribute such as vehicle miles traveled (VMT). More sophisticated GISs have an additional data structure, known as paths, for storing spatial information. Paths are simply a collection of arcs that are grouped into a single entity. Attributes can be associated with a path as a whole or can be linked to individual lines or arcs that make up the path. An example of a path might be a public transit bus route. A bus route in this case is a single entity (GIS path) that has attributes associated with it such as bus route ID, patronage, and schedule information. The GIS path representing a bus route consists of several roadway links, each with their own set of attributes (e.g., number of lanes and posted speed limit). A travel route from an origin to a destination is another example of a GIS path.

Fundamental GIS Capabilities

The strength of a GIS is its capability of manipulating and aggregating spatial data. With its robust set of spatial analysis tools, a GIS can be used to count the number of trip origins that fall within a traffic analysis zone (TAZ) (a point-in-polygon operation). In addition, a GIS can be used to proportion a census block group's attribute information to a TAZ (polygon-overlay operation) and to calculate total VMT within a grid cell (line-through-polygon

FIGURE 1 Sample raster map (*above*) and vector map (*below*).

operation). A GIS relies on the topology of its vector data structures to perform spatial analysis efficiently. Topology refers to the explicit definition of spatial relationships between entities. Thus, a roadway link "knows" what links it connects to. The importance of topology is illustrated in Figure 2, which shows how well-defined spatial relationships make it possible to efficiently calculate accurate distances through a network, perform logically consistent buffer analysis, and capture useful information about bordering or connecting spatial objects.

In addition to its spatial analysis capabilities, another fundamental GIS capability is geocoding—the assigning of coordinates to a spatial object. Address matching is one example of a geocoding operation in which the GIS is able to assign coordinates to a point entity by matching its address to an address range that is stored with street information already in the GIS data base. Through address matching, it is possible to perform a batch operation to geocode thousands of data records in a short period of time.

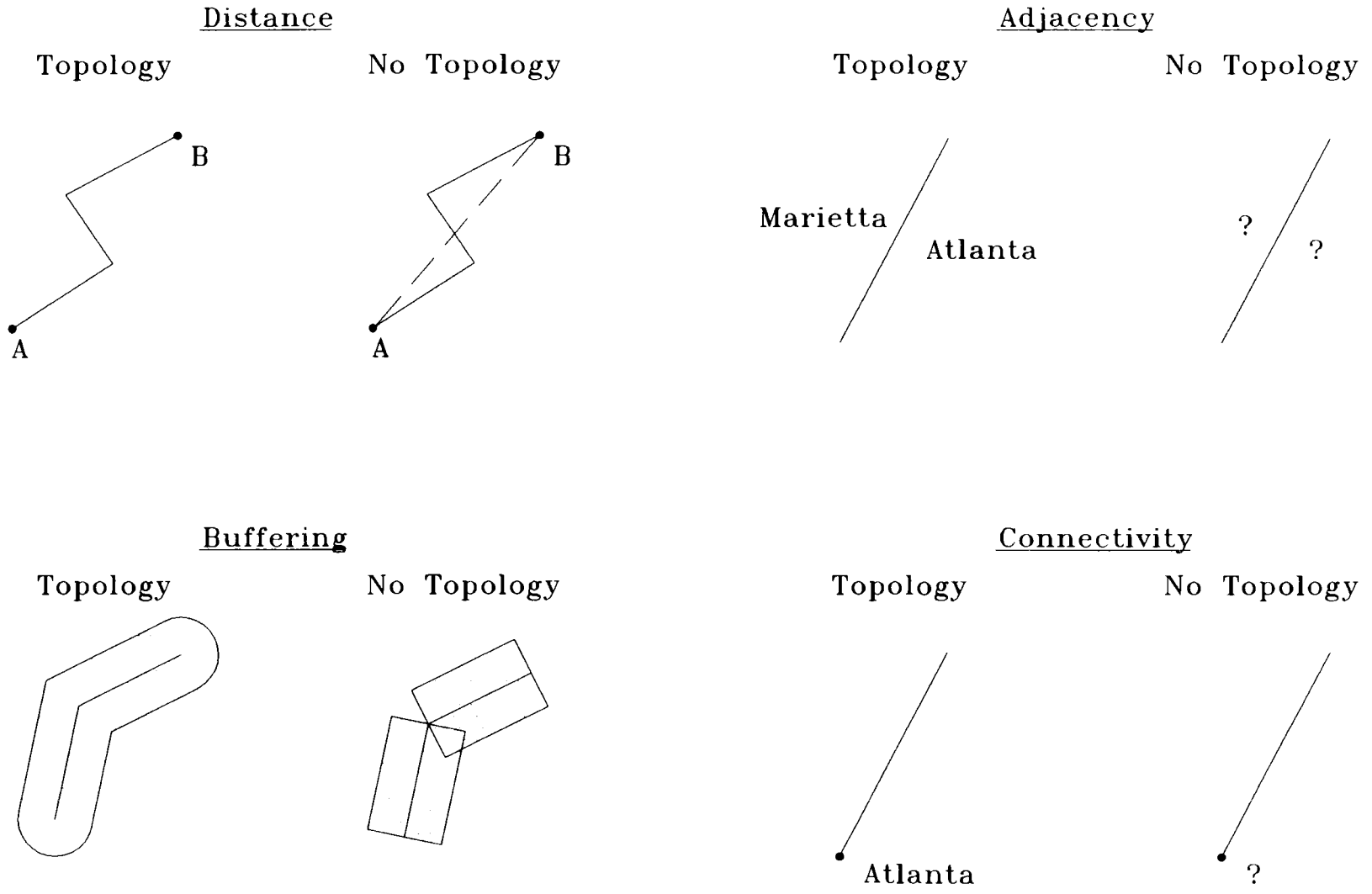

FIGURE 2 Importance of topology.

Use of GIS Technology in Travel Surveys

GIS technology has not been used extensively as an element of travel survey methodology. Hsiao and Sterling (*12*) describe how the use of GIS technology enhanced the accuracy and efficiency of origin-destination (O-D) survey data analysis and provided detailed spatial analysis results for evaluation of a new intercounty commuter rail service. Abdel-Aty et al. (*13*) describe how the geocoding and routing capabilities of a GIS proved useful in a survey conducted in Southern California. One of the objectives of this project was to compare actual route data with GIS shortest paths and conduct follow-up interviews with survey respondents to determine why their routes deviated from the shortest path. Shurbajji (*14*) showed how a GIS could be used to identify transit usage trends in the Atlanta metropolitan area based on the results of a geocoded transit origin-destination survey. As noted in this study, "GIS technology can provide effective means of analyzing service areas of potential transit services ... this technology can be combined with survey information which can be used in service analysis to enhance transit users and their behavior." By using the geocoded locations of the origins and destinations of respondents, the GIS was able to quickly and efficiently produce trip table information and socioeconomic variables by zone, which was extremely valuable to the planning process. The GIS thus provided a much easier and more effective platform to analyze survey data than previous approaches.

The following discussion is based on current literature and the authors' own experiences with using GIS technology for travel surveys. The benefits of using a GIS in travel surveys can be divided into several areas: input, processing and analysis, spatial display and query, and output.

Input

A GIS has a variety of methods for entering both spatial and attribute data. Spatial data either can be transferred from an existing digital format that includes positional information or can be geocoded. Because origin and destination data are usually locationally referenced by their addresses, a GIS's address matching geocoding tools make the system ideally suited for use in processing travel survey data. A drawback of address matching is that errors in the digital road network, such as missing address range information, misspelled road names, and, in some instances, missing roads, can lead to unsuccessful matches. To compensate for this, alternative methods for geocoding can be used. One possibility is to visibly locate spatial data, such as a trip's destination, on a digital road map. Using a GIS's graphical editing capabilities, the destination can be added to the data base simply by "picking" the approximate location on the display. This process is commonly referred to as "heads-up" digitizing.

Another limitation of address matching is that an origin or destination (e.g., identical street names that exist in two different cities) can be incorrectly geocoded. This problem can be alleviated somewhat by considering more attributes than just an address in the address matching procedure. In addition to the address ranges associated with road segments stored in the data base, other attributes such as city, county, and ZIP code can be used to ensure that the match is accurate. In addition to origins and destinations, trip routes can be geocoded as well. Routes that are stored in a spatial format (e.g., route data collected using GPS) can be transferred into a GIS directly.

The positional accuracy of point data and route data that are geocoded into a GIS depends on the quality of the underlying digital road network. A road network that is based on the Census Bureau's TIGER line file can be off by 100 ft or more at any one location. The impact of this error on travel survey data is not likely to be substantial.

Processing and Analysis

The process of translating travel survey data to final analysis format is generally recognized as labor-intensive and time-consuming. The ability of a GIS to manipulate spatial information and actually create new information can be valuable for processing travel survey data. Some especially useful capabilities are aggregation and overlay, routing, and statistical analysis.

Aggregation and Overlay

The Atlanta Regional Commission is currently conducting an O-D study for use with its 1990 Travel Demand Forecasting Model. The mail-in surveys include origin and destination addresses that are geocoded by a GIS. Once geocoded, the origin and destination data are overlaid with a TAZ polygon layer using GIS point-in-polygon operations. This process eliminates errors associated with manually placing origins and destinations with TAZs through visual inspection. Once aggregated into TAZs, attribute data can be summed and the results can be reported at a TAZ level.

Routing

A significant use of O-D data is in the development of friction factors used in travel demand forecasting models. The development of friction factors requires an accurate estimation of the distribution of travel duration by purpose. Using routing algorithms, a GIS can calculate the time of travel from an origin and a destination at different times of day. However, the accuracy of these data depend on the quality of average and free-flow speed data included in the GIS data base. Comparison of GIS-generated shortest paths with actual survey data can be instrumental in understanding travel behavior (*13*).

Statistical Analysis

Most sophisticated GISs have the ability to perform statistical analysis. At a minimum, statistical summaries of TAZ data can be developed. This capability can be invaluable in developing trip generation models either through cross classification or multiple regression. In addition, the statistical analysis capability can identify important socioeconomic relationships that help planners better understand the travel phenomenon. For example, the transit service planning case described by Shurbajji used the statistical analysis capabilities of a GIS to define the household income, gender, ethnicity, and age distribution of those arriving at transit stations. Because such data were available by household location (through GIS geocoding), trip length distributions also were produced as part of the analysis.

Spatial Query and Display

GISs include a robust set of visual display capabilities that allow spatial data to be described in a format more powerful than tabular reports. TAZ maps that are color-coded by various attributes such as total number of home-based work trip origins can be developed. These visual displays can be easily understood by decision makers. Visual inspection of travel survey data also may make trends more apparent. Spatial query is another powerful GIS feature. For example, a spatial query can be done, even with insufficient travel data, to identify TAZs, even though population for the zones suggest otherwise. This capability may be beneficial in identifying random sampling errors that may bias data.

Output

A GIS has a variety of output capabilities. In addition to being able to produce a wide variety of hard-copy maps, a GIS can produce tabular results. These results can be formatted to be compatible with other transportation tools, such as travel demand forecasting models.

GIS Disadvantages

The primary disadvantage of GISs is cost. A GIS's costs go beyond the cost of the hardware and software that support the system. A GIS is data driven, and data (especially highly accurate data) can be expensive. In addition to travel survey data, a great deal of spatial information is needed to support GIS use. Roadway centerline information is required to serve as a base map and provide geocoding capabilities. Other needed spatial information may in-

clude TAZ boundaries, census tract boundaries, and land use information. Spatial accuracy, completeness, and currentness of these data add to the cost of creating and maintaining this map information. Ideally, this information would already be available because of the existence of a GIS used for other applications. It could be cost prohibitive if new spatial data (besides the travel survey information) must be developed. Another potential difficulty with using a GIS is lack of domain expertise. GISs are highly specialized and require a great deal of proficiency to be used effectively.

The Global Positioning System

GPS provides a means to obtain accurate positional information anywhere in the world, 24 hours a day. GPS is based on a constellation of 24 satellites orbiting the earth, and identifying a specific location is accomplished through satellite ranging. By measuring the distance from an object's location to the known position of GPS satellites, the object's location can be calculated through triangulation. GPS receivers, which communicate with the satellites, can perform these calculations automatically. Distances are determined by measuring the time difference between a clock internal to the receiver and signals received from the satellites. Typical GPS receivers can provide positional accuracies to within 100 m of actual locations. More advanced systems can provide accuracies within 2 cm.

There are two types of GPS surveys: static and kinematic. A static GPS survey is done solely for collecting the point positions of spatial features, such as a bus stop. Static point positions can be very accurate because averaging can be used to adjust multiple readings taken at the same location over a period of time (usually at least 180 sec). As the GPS receiver collects point information at a particular location, the user can enter attribute information about the point being collected into a datalogger or notebook computer linked to the receiver. A kinematic survey is performed when linear information, such as a travel route between a particular origin and destination, must be collected. The positional accuracy of kinematic GPS survey data is not as good as data from static surveys because averaging is not possible.

GPS Use in Travel Diary Surveys

GPS has been used successfully in a number of intelligent transportation systems (ITS) projects, including the Orlando TravTek project (*15*) and the Chicago ADVANCE and California Pathfinder projects (*16*). GPS also has been a key component in automatic vehicle location public transit projects (*17,18*). One of the areas in which GPS remains underutilized is travel surveys.

Transportation professionals and other users of travel survey data surmise that people often underreport very short trips when self-reporting methods are used. Other problems with self-reporting include the tendency to round travel times to 5- or 10-minute intervals. Similar tendencies to round may occur in reporting trip distances as well. Vehicle instrumentation with a GPS receiver can alleviate some of the problems associated with self-reporting. A GPS receiver can precisely monitor the time a vehicle leaves a location, the route the vehicle takes to get to a destination, any intermediate stops, the speed and acceleration characteristics of the vehicle while making the trip, and accurate distance information.

There are a number of advantages for using GPS technology in travel surveys. A GPS receiver keeps accurate clock time and can monitor a vehicle's movement without reliance on rough estimates that are common in self-kept travel diaries. Furthermore, all trips regardless of distance can be monitored. By downloading the GPS information to a GIS, specific route and other network attribute information can be linked to the monitored trip. This information can be verified with self-kept information that could be logged into an electronic device such as a notebook computer linked to the GPS receiver. A benefit of such a system is that all data can be directly downloaded, bypassing intermediate transfer through error-prone manual methods. Figure 3 illustrates a series of trips that were logged in a GPS receiver and dis-

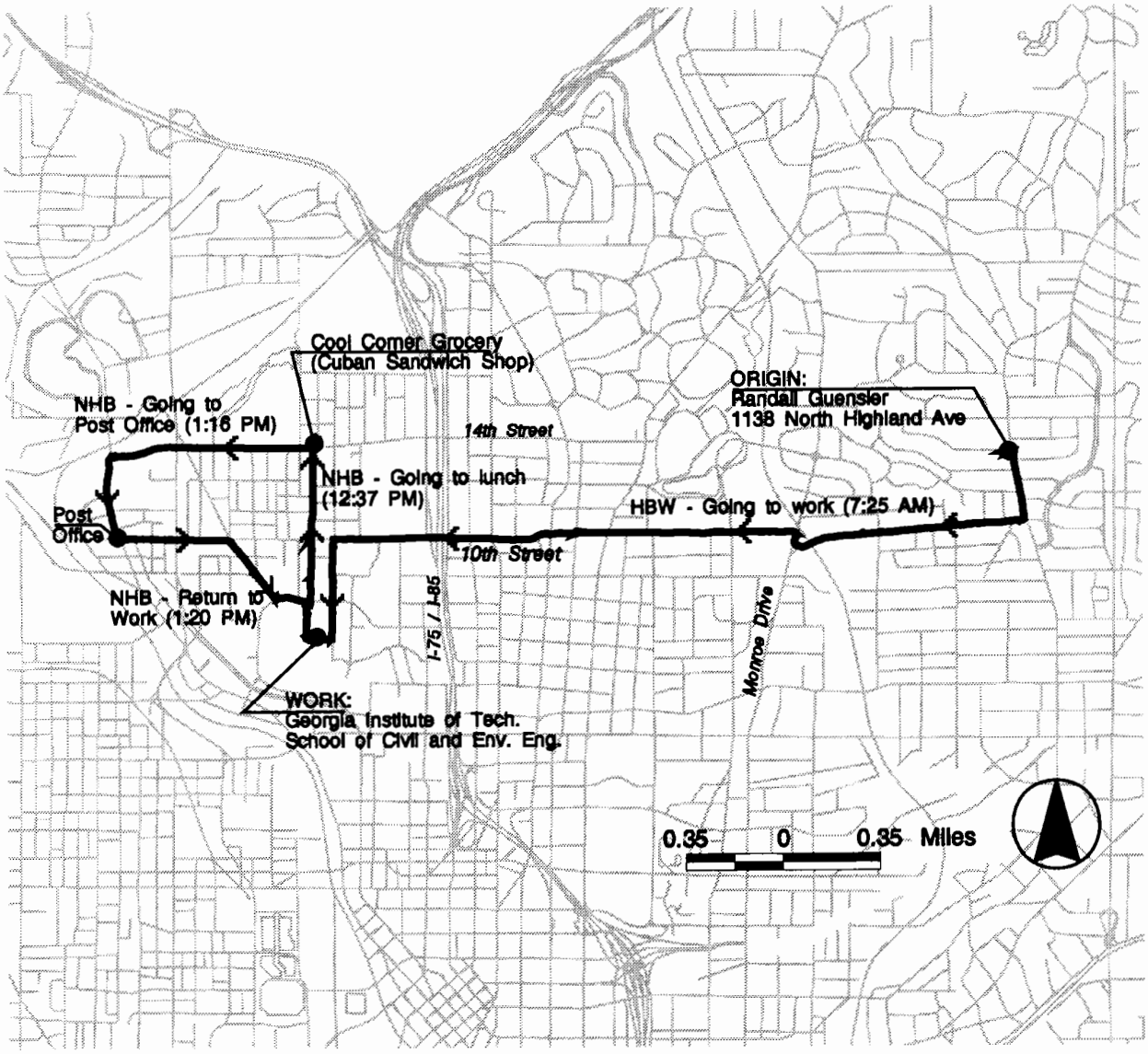

FIGURE 3 GPS travel diary data displayed in a GIS.

played in a GIS with selected attribute information. The trip has not been modified from its original raw data except through differential correction to improve positional accuracy.

Georgia Institute of Technology is currently working on developing the next-generation mobile emissions model, which considers critical information that is not used in current emissions models. A vital component of this project is determining the travel patterns of a representative sample of drivers. By using GPS, it is possible to track a vehicle that is used by a study participant. Using a customized user interface on a notebook computer that is linked to the GPS receiver, the driver can enter critical trip attributes such as origin, destination, and purpose. The positional information collected by the GPS receiver is dynamically linked to speed and emissions monitoring equipment installed in the car. Once the survey is completed, the travel diary data can be imported into a GIS for processing and analysis.

GPS Disadvantages

Several disadvantages associated with the use of a GPS include cost, technological limitations, vehicle instrumentation, and lack of acceptance or misuse by study participants. The cost of

the instrumentation can range from between $5,000 to $15,000 per vehicle. This cost includes a GPS receiver, a portable computing device such as a notebook computer, and associated software. Postprocessing equipment can add significant costs. These costs are decreasing and will continue to decrease with advances in technology and as the use of GPS becomes more popular.

Technical limitations primarily stem from errors associated with the positional inaccuracies of a GPS receiver. These errors are relatively small, especially if postprocessing is used to differentially correct positional information. The most significant disadvantage of using GPS occurs when satellite availability precludes the possibility of taking positional readings. A GPS receiver must be able to track four satellites at once to be able to pinpoint a location, otherwise no position will be recorded. Several factors can limit the number of satellites that can be tracked. The most notable is the blockage of a GPS signal. Buildings, overpasses, trees, and the earth's topography can block the relatively weak signal from a GPS satellite. Because GPS can provide positions every second, the loss of a few seconds of data while passing under an overpass is unlikely to be a problem. The major difficulty arises when a study participant drives for an extended period of time in a location where satellite tracking is difficult or impossible. One example would be driving through a downtown area of a city.

The lack of acceptance or misuse of equipment is another disadvantage of using GPS. Requiring a driver to use instrumentation that is alien to the vehicle may influence the driver's decision to travel. Furthermore, not using the equipment properly will undoubtedly lead to systematic errors. These problems can be alleviated somewhat by designing the instrumentation in such a way that user interaction is kept to a minimum.

Research Areas

This section addresses the research areas identified in the Household Travel Surveys Workshop. Once identified, these areas were prioritized based on urgency, timeliness, and cost. The high-priority research items are

- Using GIS technology for sampling, including developing typology of urban form. The spatial aggregation and analytical capabilities of a GIS may prove invaluable in the stratification of demographic characteristics for travel survey purposes. GIS technology also can be used to analyze demographic and socioeconomic data to help create standards for classifying urban form.
- Improving accuracy of travel behavior information by using GPS to track individual trips. By using GPS in household travel surveys, all trips regardless of distance can be monitored. The improved accuracy resulting from the use of GPS may help transportation professionals better understand travel behavior.
- Integrating GIS into a CATI system for on-line geocoding of origins and destinations. It is hypothesized that using on-line geocoding as opposed to postcollection geocoding can reduce respondent burden, increase the reliability of the coded trip end, and increase the "hit" rate in geocoding because nonhits can be clarified with the interviewee immediately.

The medium-priority items are

- Using CAPI for state preference research. This research proposes that a CAPI study be conducted either at households identified through a household survey or in focus groups to elicit results on interviewees' perceptions of the interview environment.
- Using CAPI for multimedia-assisted interviewing. The proposed research will investigate the value of including multimedia presentations on the CAPI hardware to help the interviewer obtain more accurate answers from respondents.
- Conduct a research synthesis on using GIS technology in household travel surveys. GISs offer many potential benefits in the conduct of household travel surveys. The purpose of this research is to develop a comprehensive synthesis on the use of a GIS as a tool for household travel surveys.

The medium-low priority and low-priority items in order are

- Route coding using a GIS in personal interviews;
- Using multimedia instruction as part of household travel surveys; and
- Monitoring personal travel with GPS body-pack units.

Conclusion

Transportation planning by its very nature is data-dependent. For decades transportation planners have developed regional data bases that continue to serve as the basis for transportation planning. The effectiveness of this planning process is directly related to the quality of the data. As we head into the 21st century and as the profession assesses the types of modeling approaches it needs for the future, a close examination of cost-effective data collection strategies is needed.

The use of CATI, CAPI, GIS technology, and GPS as an aid in conducting travel surveys offers many potential benefits. These benefits include more efficient data collection, improved data quality, and more flexible output products. CATI and CAPI can provide real-time logical consistency checks that can help improve the accuracy of respondent answers. GISs provide spatial data manipulation capabilities to automate data processing tasks that historically have required a great deal of manual effort. The aggregation of travel survey data to TAZs is an example of a processing task that can be greatly simplified by using a GIS. The major benefit of GPS is in conducting travel diary surveys. GPS can alleviate some of the biases associated with conventional self-reported travel diary surveys because all trips including intermediate stops are monitored.

Perhaps the greatest potential for CATI, CAPI, GIS technology, and GPS is if they are used with each other in travel surveys. There are certain instances in which CAPI may be more appropriate then CATI (e.g., in cases where respondents do not have telephones). Likewise, in restricted access communities, CAPI may not be practical. Both CATI and CAPI could benefit from the geocoding capabilities of a GIS. In addition, the combination of socioeconomic data and perceived travel characteristics (obtained from surveys) with real-time vehicle monitoring and location (obtained from GISs and GPS) can provide a powerful tool for transportation analysis. Of course, such a use presupposes that those subject to the surveys and vehicle monitoring activities will, in fact, participate. This human element of the analysis approach will be one of the real challenges in taking advantage of the potential of these technologies. Even with this, however, recent advances in CATI and CAPI along with the spatial handling capabilities provided by GISs and GPS offer tremendous advances in the collection and analysis of travel survey data. These capabilities will go a long way toward enhancing the quality of transportation analysis in the years to come.

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AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
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