WORKSHOP ON MULTI-DAY AND MULTI-PERIOD DATA

Resource Paper

Multi-Day and Multi-Period Data for Travel Demand Analysis and Modeling

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ABSTRACT

Multi-day and multi-period surveys provide longitudinal data that facilitate the analysis, understanding, and modeling of changes in travel behavior over time. Since travel behavior is a dynamic phenomenon with both short- and long-term variability, the use of multi-day and multi-period data in transportation planning analysis and modeling is clearly worth consideration.

This paper focuses on issues related to the collection and use of multi-day and multi-period data in light of the considerable accumulated knowledge about the day-to-day and longer-term dynamics of travel behavior. Limitations associated with the use of one-day cross-sectional travel data are identified in the context of the benefits and economies that may be realized from multi-day and multi-period surveys. Survey design issues and methodological difficulties inherent in collecting multi-day and multi-period data are discussed together with possible solutions. Challenges for the workshop and future research needs are identified in the context of integrated multi-day, multi-period surveys that would offer extremely rich travel behavior information for transportation planning practice.

INTRODUCTION

The standard approach to household travel surveys is to collect data from a cross-section of the population of an urban area at one point in time (e.g., the spring of 1997), with each household being asked to report its travel behavior for a 24-hour period. While such single day, cross-sectional (single period) surveys are still the standard approach, a number of multi-day and/or multi-period household travel surveys have been undertaken over the past 20 years. The fundamental premise underlying the collection of multi-day and multi-period data is that people's activity and travel patterns depict considerable variability over time.

Society is in a constant state of transition. Both macroscopic and microscopic level changes in the urban environment, transportation system, and demographic or socio-economic structure drive temporal variations in travel patterns. Macroscopic level changes

include those that occur at a regional or sub-regional level and affect a large segment of the population of an area. On the other hand, microscopic level changes are those that occur at the household or individual level and generally tend to manifest themselves in the form of short-term activity and travel dynamics. In turn, these short-term adjustments may drive longer term variability in behavior. In addition, dynamics in behavior may arise from the randomness associated with the values, perceptions, attitudes, needs, preferences, and decision-making processes of travelers. Models that attempt to explain this random variability can be developed and refined only if measurements of such variability are available.

In this context, it is clear that multi-day and multi-period surveys can provide valuable data that allow the analysis, understanding, and modeling of variability in travel behavior over time (*1*). Indeed, the collection of multi-day and multi-period data has been receiving considerable attention, particularly in the recent past in the wake of legislative requirements that changed the course of transportation planning. The new planning context set forth by the Intermodal Surface Transportation Efficiency Act (ISTEA), 1991, and the Clean Air Act Amendments (CAAA), 1990, places greater emphasis on the planners' ability to accurately predict changes in travel behavior over time in response to changes in the transportation environment that may be brought about by new transport policies and technologies. However, with shrinking budgets and rising survey costs, transportation planners face several critical questions, issues, and challenges with regard to the collection of longitudinal travel behavior data.

The concept of integrated multi-day multi-period surveys is not new. Garrison and Worrall (*2*) and Worrall (*3*) recognized the value of longitudinal information at a time when the focus of transportation planning was primarily capacity expansion and highway alignment. The actual implementation of general purpose integrated multi-day multi-period surveys occurred only about two decades later when the Dutch panel survey (*4*) and the Puget Sound transportation panel survey (*5*) were conducted. However, it is noteworthy that multi-day travel diary surveys (typically conducted by urban areas around the world) may, in fact, be regarded as multi-period surveys where the spacing between "periods" is one day. Also, when two or more independent multi-day travel surveys conducted at different time points are combined, one obtains a multi-day multi-period data set. As such, multi-day and multi-period surveys have been in existence, in one form or another, for many years.

This resource paper aims to provide a framework that would guide and structure workshop discussions by raising questions, issues, and challenges that need to be addressed in designing and conducting multi-day and multi-period surveys. The paper deals only with the collection of data on personal travel behavior; freight and commercial movement data are beyond its scope.

The remainder of this paper is organized as follows. First, a brief discussion is provided on traditional methods of sampling over time for household travel surveys. Limitations associated with one-day cross-sectional surveys and the data they provide are identified. Then, the third section provides a review of the state-of-the-knowledge on the short- and longer-term variability in travel behavior. These sections point out the complexities associated with analyzing and understanding travel dynamics. In the fourth section, methodological issues and questions related to the design and conduct of repeated measurement surveys are raised. In addition, the economies (from a cost and efficiency perspective) that may be realized from longitudinal data are discussed within this section.

Finally, the paper closes with a fifth section that identifies the key questions and challenges for the workshop together with possible solutions and future research needs.

MOVING BEYOND TRADITIONAL ONE-DAY, CROSS-SECTIONAL SURVEYS

Since the early 1970s, travel behavior researchers have been paying increasing attention to the variability and dynamics of travel demand. Environmental, economic, and social considerations shifted the emphasis of planning from mere capacity expansion to the development of strategies and implementation of systems that would more effectively manage travel demand. It was recognized that greater accuracy and precision levels would be required of travel demand forecasts to address such planning requirements. Early examples of multi-day surveys include the 1971 household travel survey in Uppsala, Sweden that collected travel information for a 35-day period (*6*) and the 1973 activity survey conducted in Reading, England that collected activity information for a 7-day period (*7*). Since then, several other multi-day and multi-period surveys or combinations thereof have been conducted around the world. The Dutch national mobility panel (*4*) and the Puget Sound transportation panel (*5*) are two noteworthy examples that have yielded a large body of literature on the short- and long-term variability in travel behavior.

Multi-period surveys may be of several types. They include:

- *Repeated cross-sectional surveys*, where cross-sectional data are collected at several time points from independent samples of the population.
- *Time series surveys*, which involve the collection of aggregate level data at regular intervals for many years or time points. Census data that provide information at the block group or census tract level may be regarded as a time series.
- *Panel surveys*, where the same sample units are repeatedly observed at regular time points. Panel surveys may take several forms. For example, a rotating panel is one where a certain fraction of the panel members is intentionally dropped from the sample and an equivalent number of new members is recruited into the panel at each wave (time point).

While cross-sectional surveys (repeated or single-period) provide sufficient data for determining overall population characteristics or trends over time, they do not provide sufficient data for detailed behavioral analysis, cause-and-effect identification, and measurement of change at the disaggregate level. The following subsections discuss four primary considerations that warrant the use of repeated measurements in transportation planning.

Behavioral Dynamics

Kitamura (*8*) and Goodwin, et al. (*9*) provide an excellent discussion on various theoretical aspects of behavioral dynamics in travel behavior that can not be adequately analyzed, understood, or modeled using one-day one-period data. They are as follows:

- *Response Lags*, where behavioral adjustments are made some time after the occurrence of an event (*10*)

- *Response Leads*, where behavioral adjustments are made in advance of an event (*11*)
- *Habit Persistence*, where people exhibit "routine behavior" characterized by repeated decisions of the same choices even after it is no longer optimal
- *Threshold or Cumulative Effect*, where the magnitude of change associated with an event may have to be greater or less than a certain threshold value to trigger a behavioral change
- *Behavioral Asymmetry*, or "hysteresis" (*12*) where people are found to make asymmetric adjustments in behavior in response to symmetrically opposite events (*13*, *14*)
- *Multiple Equilibria*, where behavior appears to be in a constant "disequilibrium" (*11*) with multiple possible states for any set of conditions (*14*)

The discussion above highlights some of the key behavioral considerations that form the basis for using multi-period, and in particular, panel data. Repeated measurements over time would be needed to explicitly capture such behavioral phenomena.

Policy Considerations

Why is the measurement and modeling of day-to-day variability of travel behavior important from a policy perspective? An excellent discussion in response to this question is provided by Jones and Clarke (*15*). They note that as the emphasis of transportation planning around the world has shifted from capacity expansion to the formulation of transportation policies aimed at effectively managing travel demand, some of the issues facing planners can not be addressed by one-day data (regardless of the sample size) because "by their nature, they are questions about variations in behavior over time".

They provide several key illustrations of the limitations of one-day data that can be overcome using multi-day data. For example, they found that a one-day survey conducted in 1981 in Hong Kong to study electronic road pricing feasibility was not able to answer the policy question: "how many car owners would not be affected by the road pricing scheme at all, if charges were imposed on Monday through Friday?". On the other hand, a study of car use conducted in Oxford that collected multi-day data was able to address such a question because the number of people who did not use their car during the entire week could be accurately determined.

In other words, multi-day data provides information about the distribution of frequency of participation, in addition to the mean participation rate. Information on the frequency of participation allows one to gauge the exposure of different demographic and travel segments to various policy scenarios. Similar arguments may be made with respect to the need for multi-period data. For example, panel data collected over a few years would allow the analysis of mode switching behavior, mode loyalty, residential relocation frequencies, carpool formations and dissolutions, and vehicle acquisition and disposal behavior. Policy implications of these aspects of behavior are clearly of great importance.

Modeling and Forecasting Considerations

From a modeling perspective, multi-period data, and in particular, panel data, greatly facilitate the identification of cause-and-effect relationships as they can account for

response lags, response leads, behavioral inertia, and habit persistence. Dynamic models of behavior that explicitly account for state dependence and heterogeneity can be estimated using such data (*16*). From a forecasting perspective, Kitamura (*8*) notes that the use of cross-sectional data for forecasting involves the assumption that changes in behavior over time may be predicted based on differences in behavior across individuals. He identifies three critical conditions for this assumption to be valid. They are:

- behavioral changes are instantaneous
- behavioral changes are symmetric or reversible
- behavioral relationships are stationary (constant over time)

The vast body of evidence (reviewed in the next section) clearly indicates that these conditions rarely, if ever, hold true. Panel data offer the only means of measuring the dynamics of travel behavior, especially over time periods longer than that captured in multi-day data, clearly establishing the basis for the collection of multi-period data from the same behavioral units.

Efficiency Considerations

Even if behavioral dynamics, policy questions, and modeling and forecasting considerations do not necessarily require the use of multi-day multi-period data, efficiency considerations may call for the collection of such data. Gains in efficiency of data collection are particularly substantial in the case of panel surveys where one can measure longitudinal variation in travel behavior while controlling for unobserved individual effects that are stationary over time. As such, panel data sets facilitate more precise measurements of behavioral changes and concomitantly reduce sampling errors and sample size requirements when compared with single-period data sets.

Pas (*7*) shows that substantial economies can be achieved with respect to survey cost and parameter efficiency if a multi-day sample, as opposed to a single-day sample, is employed in travel demand analysis. Similar economies can be realized through the adoption of a panel design as opposed to a repeated cross-sectional survey design. A detailed discussion of efficiency considerations in the collection of multi-day and multi-period data is provided later in this paper.

WHAT IS KNOWN ABOUT TRAVEL BEHAVIOR DYNAMICS?

This section reviews the body of knowledge on travel behavior dynamics. First, an examination of day-to-day variability in travel behavior is provided, and second, evidence on longer term dynamics is reviewed.

Day-to-Day Dynamics

There are two sources of day-to-day variability in travel behavior. First, day-to-day variability occurs because people's needs and desires vary from day-to-day. Thus, for example, the number of trips one takes varies from day-to-day because one need not do grocery shopping each day. Second, behavior varies from day-to-day because of feedback from the transportation system. Thus, one might choose a different route and/or departure

time for the work trip today if one encountered severe congestion yesterday on the usual route.

Hanson and Huff (*17*) and Huff and Hanson (*18*) present detailed discussions regarding the habitual and variable behavior of individuals over time. They analyzed a representative sample of 149 individuals who completed travel diaries for a 35-day period in Uppsala, Sweden, in 1971. They note that some behaviors, when examined in a disjointed framework (say, a work trip examined in isolation of the overall daily activity-travel pattern), are repeated on a day-to-day or week-to-week basis. However, when the overall daily activity-travel pattern is examined in its entirety, they find that a one-day pattern is not representative of a persons routine travel. For example, they note that relatively few activity stops occurred at regular intervals in an individuals longitudinal record. Instead, they tended to be distributed in a clustered fashion suggesting that little of the day-to-day variability present in an individuals travel-activity pattern is regularly systematic (*6*).

Huff and Hanson (*18*) examine for the existence of a typical travel day. They identified the most representative travel day for each person and compared it against all other days in a persons record; they found a very low sample-wide similarity index. Even when they considered the five most representative travel days, they found very little improvement. Hanson and Huff (*6*) present several further findings that challenge the existence of a typical travel day or set of days and strongly question the ability of a one-day travel diary survey to capture variability in travel behavior. Another interesting finding reported by Huff and Hanson (*18*) is that the no-travel day is a significant pattern that merits inclusion in modeling efforts. To do so, they argue, would require the collection of multi-day data to capture the travel and no-travel day behavior of individuals.

Much of the work reported by Pas and his colleagues in a series of papers (*7, 19-21*) utilizes seven-day activity data collected in 1973 in Reading, England. More recently, Pas and Sundar (*22*) extended the work using three-day travel diary data collected in 1989 in Seattle. Pas (*19*) formulated a paradigm for the representation of variability in behavior. The paradigm distinguishes between interpersonal variability and intrapersonal variability, each of which can be split into two components, a systematic or deterministic component and a stochastic or random component.

Pas (*19*) examined day-to-day variability in daily trip rates using the Reading data set. In this work, the variance in an individuals daily trip rate about his or her daily average was used as a measure of intrapersonal variability. Using this approach, Pas found that about 50 percent of the total variability in trip-making in the data set could be attributed to intrapersonal day-to-day variability in trip generation. In further extensions of his work, he found that the level of intrapersonal variability varies significantly across demographic segments. For example, it was found that females exhibit higher levels of intrapersonal variability than males, possibly due to the roles traditionally played by females in households. Pas and Sundar (*22*) extended the analysis to include trip chaining and daily travel time in addition to trip generation. Their findings showed considerable day-to-day variability in all of these characteristics.

Several other studies have examined the variability in travel characteristics on a day-to-day basis. Kitamura and van der Hoorn (*23*) examine the timing with which an individual repeats a certain behavior. They found that about 70 percent of the male workers and 59 percent of the female workers in the Dutch panel data set (*4*) had identical daily patterns of shopping participation on five or more of the days of each of two weeks

(six months part). A study by Hirsh, et al. (*24*) regarding time allocation indicated that daily and weekly variation accounted for most of the variation in time allocation for home and travel activities, while seasonal variations contributed little. Departure time and route choice dynamics have been analyzed by Mahmassani and his colleagues (e.g., *10, 25*). It was found that, departure time switching is more frequent than route switching for the journey-to-work. However, the authors recognize that their results are dependent on the measures of variability used and the criterion used to define a switch in behavior.

In summary, a vast body of knowledge and evidence supports the notion that there is considerable day-to-day variability in travel behavior. The evidence challenges the existence of a typical travel day representative of the daily or weekly activity-travel patterns exhibited by individuals. While some variations in the extent of day-to-day variability have been found depending on the specific measures of variability used, travel characteristics examined, and data sets employed, it is clear that day-to-day variability in travel behavior exists and is substantial.

Longer Term Dynamics

A vast majority of the literature on the longer term dynamics of travel behavior is based on several noteworthy panel surveys conducted within the last 15 years. One such panel, the Dutch National Mobility Panel, was conducted from 1984 through 1989 with 10 waves of data collected approximately six months apart (*4*). In each wave, respondents were asked to maintain seven-day trip diaries in addition to reporting demographic and socioeconomic characteristics at the person and household level. Thus, the panel provided extremely rich multi-day and multi-period information on evolving demographic and travel behavior trends in the population and researchers have exploited the availability of this information for modeling various aspects of travel demand dynamics.

Transitions in mode choice, changes in trip rates and lagged responses in mobility to changes in income and car ownership (*26-28*) have been studied to identify intertemporal relations among travel characteristics. Golob (*29*) finds that there is significant state-dependence and heterogeneity in travel behavior over time. Meurs (*30*) and Kitamura and Bunch (*31*) developed dynamic models of travel demand to account for such effects under various error covariance structures. Goodwin (*11*) and Pendyala, et al. (*14*) estimate dynamic elasticities of transport demand and find that they are very different from cross-sectional elasticities. Kitamura and van der Hoorn (*23*) used multi-day data across waves (e.g., pattern of week 1 vs. pattern of week 2 six months later) to analyze weekly activity patterns and travel expenditures.

The Puget Sound transportation panel was initiated in 1989 (and is ongoing) with two-day trip diary data collected approximately one year apart (*5, 32*). A choice-based panel sample that provided a large transit user segment was employed so that detailed analysis of transit usage could be undertaken. Examples of applications include Kitamura, et al. (*33*) and Pendyala, et al. (*34*) who examine mode choice transitions between the first two waves of the panel and develop weights to account for biases arising from endogenous sampling and attrition. Researchers have converted the trip diary information into activity information to model temporal variability in activity participation (*35, 36*). Models of activity choice and home-stay duration were found to be temporally unstable across waves (years); however, the extent to which day-to-day variability contributed to this temporal instability could not be isolated. Chung and Goulias (*37*) account for sample selectivity

biases arising from residential relocation and attrition and analyze the effect of these two discrete choice phenomena on activity engagement behavior.

Panel surveys have been extensively used in conjunction with the evaluation of a transportation policy or improvement project. These panels usually take the form of before-and-studies and include a control group to capture changes in behavior in response to the policy or improvement. Examples include studies on carpool lane impacts in San Diego (*38*), employer-based trip reduction measures in Southern California (*39*), and telecommuting impacts in California (*40*).

A variety of other panel studies are also noteworthy as they clearly capture and reveal the significant levels of behavioral dynamics in human activity and travel engagement. Hardwick and Wilmot (*41*) describe the National Black Panel conducted in South Africa and report changes in travel characteristics over time. Wrigley and Dunn (*42*) use the Cardiff consumer panel to analyze dynamics of grocery shopping behavior. Hensher and Smith (*43*) use the Sydney automobile panel to study the dynamics of car ownership, car utilization, and fuel consumption. Lee-Gosselin (*44*) models the dynamics of car use patterns using a gaming approach to investigate how households would respond in the event of a fuel shortage. Lyon (*45*) is a rather unique study of behavioral dynamics in that it examines the effects of attitudinal variables on travel choices. Mannering and Winston (*46*) use the energy panel to analyze household vehicle ownership and utilization over time. Van Wissen and Golob (*47*) develop a dynamic structural equations model of car fuel-type choice and mobility.

As expected, the numerous studies cited above differ with regard to the degree of behavioral dynamics observed depending on the data set and modeling methodology employed. However, they all demonstrate the presence of multiyear behavioral dynamics that is extremely important in the context of short- and long-term travel forecasting and transportation policy assessment.

COLLECTION OF REPEATED MEASUREMENT DATA

The previous discussion clearly showed that there is substantial evidence on the short- and long-term variability of activity and travel behavior. If one wishes to analyze, understand, and model this variability in behavior, then one would need to use multi-day multi-period data. This section offers a detailed discussion on the issues associated with the collection of such data.

Survey Design

Lawton and Pas (*48*) introduce the concept of a total survey design. For example, what is the optimal combination of number of days per wave, days-of-the-week in each wave, number of waves, wave-spacing, panel duration, sample size by wave, survey instrument design, and survey administration method for the conduct of a multi-day panel survey? How can this total optimal design be determined, for a given budget level? This section furnishes a discussion of issues on various components of the total design.

Measures

Jones and Clarke (*15*) point out, “the question of the measurement of variability is really a question about how we measure behavior”. What are the travel or activity indicators that

are of interest to the planner? What are the criterion levels for defining a change in behavior? For example, is a three minute shift in departure time choice considered a change in behavior from one day to the next? If one examines certain aspects of travel behavior such as the commute trip or total trip generation on a daily basis, very little variability is likely to be found. On the other hand, if one examines the complex nuances of personal activity and travel engagement, then one is likely to measure large degrees of variability in behavior.

Should one collect activity or trip information? Stopher (*49*) discusses the merits of using activity diaries over traditional trip diaries to collect travel information. On the other hand, Golob and Meurs (*28*) argue that diaries requiring a greater effort on the part of the respondent (such as activity diaries) may result in greater biases towards non-reporting of entire days because of increased respondent fatigue.

Overall, multi-day panel surveys can offer dynamic data on travel, land use, demographic, and socio-economic characteristics. Changes in travel behavior can be directly related to changes in exogenous or endogenous characteristics. In addition, they offer the opportunity to ask retrospective questions, i.e., questions about past behavior or characteristics that may be accurately recalled by respondents (*50*).

Duration and Timing

The overall survey duration and the spacing or time interval between survey contacts are important dimensions of repeated measurement surveys. In general, both of these dimensions depend on the phenomenon under investigation and the budgetary resources available (*6, 8, 51*). For instance, if one were studying phenomena that change slowly (say, residential location, workplace location, car ownership, etc.), then longer survey durations and a larger wave spacing may be warranted. If one were interested in capturing short term variability in travel behavior, Hanson and Huff (*6*) indicate that reporting periods several weeks long and wave spacings of one day (i.e., a multi-day survey) may be called for. In their study, they conclude that a seven-day record of travel does not capture most of the separate behaviors exhibited by an individual over a five-week period. With respect to budgetary resources, Cantor (*51*) notes that one needs to determine the overall duration for which the population of interest will be observed and then strike a balance between wave spacing and survey costs. While frequent contacts may increase respondent burden and fatigue, they may also facilitate better respondent tracing and memory of survey procedures.

With respect to the number of survey contacts or waves, Kitamura (*8*), Bradley (*16*), and Hensher and Smith (*43*) suggest that it is preferable to have more than two waves of data so that the first wave data may be treated as initial conditions in analyzing subsequent waves of data. A related issue is that of capturing the timing of change in behavior. Panel surveys provide information on behavioral units at discrete time points thus offering little information on the exact timing of a behavioral change or the duration for which a certain behavior is exhibited. Raimond and Hensher (*52*) discuss the concept of a “continuous time panel” in this context.

Finally, on what days of the week should travel information be collected? Conventional wisdom suggests that Tuesdays through Thursdays are preferrable because they constitute “typical” days. Hanson and Huff (*17*) challenge this notion by showing that individuals are evenly distributed across all days of the week with respect to their most

representative travel day. They do note, however, that weekend-days are less representative than weekdays.

Sample Design

The third topical area to be addressed in this section is concerned with sample size selection, precision of model parameter estimates, and the resulting cost implications. Koppelman and Pas (*21*) and Pas (*7*) provide extensive evidence on the gains in efficiency in trip generation model parameter estimates as a result of using multi-day data. They show that these gains in efficiency diminish as the number of days of data collection increases. This is because, beyond a certain point, additional days of data offer little unique information. Pas (*7*) shows that the preferred duration of data collection increases as the extent of intrapersonal variability present in the data set increases.

Smart (*53*) provides a relationship between the sample size required for a two-wave panel survey and that required for a two-period repeated cross sectional survey to obtain the same precision in estimates of change over time. The relationship is:

$$N_p = N_c\sqrt{(1-R)}$$

where N_p = sample size for the panel survey
N_c = sample size for the repeated cross-section survey
R = correlation between the two surveys for the variable of interest.

It is seen that, as the variable of interest exhibits a greater degree of state-dependence (higher value of R), the sample size required in a panel survey design decreases. When R=0, i.e., the variable of interest is not correlated over time, then no savings in sample size result from the use of a panel design.

Lawton and Pas (*48*) provide several examples of the cost savings that may be derived from the sampling efficiency of a panel design. They note that, while the cost of each additional respondent in a cross-sectional survey is about $75 to $85 per unit, the corresponding cost for a multiwave panel survey is only about $55 to $75 per unit. However, they note that potential cost savings in panel designs are tempered by panel attrition and the need to refresh the sample. As an illustration, consider a four-wave panel survey where the sample size at each wave is 2,000 and panel attrition between waves is 20 percent.

Let cost of collecting one household-day of information (including refreshments) = $100
Let cost of collecting one household-day of information in each repeat wave = $50
Total sample in each wave = 2,000
Stayers in each wave = 1,600
Refreshments added in each wave = 400
Total cost of panel survey = 2,000 x $100 + $50 x (1,600 + 1,600 + 1,600)
+ $100 x (400 + 400 + 400) = $560,000
Total number of household-days of information = 2,000 x 4 = 8,000
Cost per household-day of information = $560,000 ÷ 8,000 = $70

On the other hand, a pure cross-sectional survey design would be 30 percent less efficient as one would spend $800,000 to obtain 8,000 household-days of information or would get only 5,600 household-days of information for $560,000. Cost savings in the panel design are realized while simultaneously gaining increased information on temporal changes in behavior. The numerical example above can be easily extended to incorporate multi-day techniques.

Panel designs can offer economies in several contexts. For example, a panel sample can be enriched with a choice based sample (*54*) that would facilitate the analysis of change in rare behaviors. Such a scheme was adopted in the Puget Sound transportation panel and weights were developed to account for both choice-based sampling biases and attrition biases (*34, 55*).

Administration

An examination of the trends in household travel data collection show that surveys are becoming increasingly multi-stage efforts. Mailout/mailback techniques are being combined with computer-aided telephone interviews in a series of stages to collect the maximum amount of data in the most efficient manner possible. The availability of alternative survey administration techniques and their potential multi-stage combinations raises the question as to whether certain modes of administration (or combinations thereof) are more favorable in the context of a repeated measurements survey. At this time, it appears that very little is known about the effects of alternative survey administration techniques on response rates, attrition, fatigue, and conditioning in multi-day panel surveys. Garrison and Worrall (*2*), reporting on a 28-day diary survey study conducted in Skokie, Illinois, indicate that careful survey administration with incentives and constant reminders helps reduce respondent fatigue and forgetfulness.

Problems and Potential Mitigation Strategies

The benefits associated with multi-day panel surveys are certainly tempered by the inherent difficulties and issues associated with multi-day and panel data collection. As issues related to multi-day surveys get combined with issues related to the conduct of panel surveys, the level of inherent difficulty may be amplified when one considers an integrated multi-day panel survey. The discussion in this section provides an overview of the challenges involved in collecting data on dynamics of travel behavior.

The authors recognize that, in addition to data collection issues discussed here, there are several statistical and econometric issues involved in the modeling of repeated measurement data that are beyond the scope of this paper. Detailed discussions of such issues can be found in Kitamura (*8*), Meurs (*30*), Chamberlain (*56*), and Hsiao (*57*).

Nonresponse

The first issue addressed here is that of initial nonresponse, where an individual either refuses to participate in the survey or provides no information at all even after agreeing to participate. It is conjectured that initial nonresponse is higher for panels due to the higher level of commitment required on the part of the respondents. Initial nonresponse may pose a problem if it is selective in nature. For example, Purvis (*58*) found that, in recruiting

households for the San Francisco Bay Area panel survey, households with fewer workers, drivers, autos, and lower household income were more prone to refuse participation.

Table 1 provides a comparison of initial nonresponse rates across different surveys conducted in the recent past. The first two columns pertain to panel surveys while the latter three are cross-sectional surveys. Increased levels of initial nonresponse due to the adoption of a panel survey design are not evident in the comparison depicted in Table 1. The percent of contacts who expressed a willingness to participate as well as the percent of those recruited who actually responded are quite similar between the panel and cross-sectional surveys included in this table. It is to be noted that the comparison in Table 1 is purely qualitative and non-scientific as it considers a very small number of surveys and more importantly, does not control for survey instrument design and administration effects (*59*). A more rigorous scientific comparison of surveys, while controlling for survey instrument design and administration effects, should be conducted (*48*).

TABLE 1 A Comparison of Initial Nonresponse between Panel and Cross-Sectional Surveys

Response Characteristic	Panel Surveys		Cross-Sectional Surveys		
	Dutch Panel (1984)	Puget Sound Panel (1989)	Portland (1994)	San Francisco (1990)	Washington, D.C. (1994)
Number Contacted	6,128	5,175	13,140	20,068	2,664
Number Willing to Participate	2,886	2,944	7,090	10,903	1,283
As % of Contacts	47.1%	57.0%	54.0%	54.3%	48.0%
Number Actually Recruited	2,185	2,944	7,090	9,835	1,003
Number Responded	1,764	1,713	4,451	9,439	656
As % of Contacts	28.8%	33.0%	34.0%	47.0%	24.6%
As % of Willing	61.1%	58.0%	63.0%	86.6%	51.1%
As % of Recruits	80.7%	58.0%	63.0%	96.0%	65.0%

In addition to initial nonresponse, one may also have to deal with item nonresponse where a respondent does not give information on specific items or variables in the survey. The extent of item nonresponse may increase from one wave to the next as the effects of panel fatigue (see next section) become more pronounced over time. Item nonresponse (missing data) can pose a serious problem for dynamic modeling efforts. Richardson, et al. (*60*) provide excellent overviews of *a priori* strategies to reduce nonresponse such as obtaining official sponsorship of the survey, use of a cover letter, customizing the survey instrument and mode of administration to the population under study, using incentives, furnishing postage-paid reply envelopes (in case of a mail-back survey), providing free telephone assistance, and the use of reminders and follow-up schemes. Murakami and

Watterson (*5, 32*) found that incentives reduced nonresponse and that a pre-paid incentive of $1 per individual was superior to a post-paid incentive of $10 per household. Another *a priori* strategy that may reduce item nonresponse in the context of a panel design is that of instrument updating (*50*) where instruments used in subsequent waves can be made more user-friendly than those used in previous waves.

Techniques are also available to deal with initial and item nonresponse on an *a posteriori* basis. These techniques are primarily weighting methods that adjust the respondent sample according to known population distributions. Chung and Goulias (*37*) estimate weights using a model of self-selectivity that can be used to account for initial nonresponse. In the context of item nonresponse, Hensher (*61*) and Little and Su (*62*) discuss various imputation procedures.

Fatigue

A major issue in the design and administration of repeated measurement surveys is that of fatigue. For how many periods should respondents be asked to report their activities or trips? While each additional survey day or period offers rich additional information, this must be traded off against the possibility that the quality of information obtained may deteriorate with increasing levels of respondent fatigue. Two primary types of respondent fatigue are noteworthy, namely, diary fatigue and panel fatigue.

Diary fatigue has been extensively studied by Golob and Meurs (*28*) using seven-day travel data from the first wave of the Dutch Panel survey, Goulias, et al. (*50*) using two-day travel data from the California Telecommuting Panel survey, and Pas and Sundar (*22*) using three-day travel data from the Seattle region. Among these studies, Golob and Meurs (*28*) find statistically and behaviorally significant reductions in trip reporting over the seven-day diary period. These reductions are primarily attributed to an increase in the number of respondents reporting no travel and a decrease in the number of reported walking trips. All of the other studies did not find significant reductions in trip reporting. However, it should be noted that these studies analyzed data from considerably shorter diary periods than the seven-day period analyzed by Golob and Meurs (*28*).

Panel fatigue has been investigated by van Wissen and Meurs (*4*) and Meurs, et al. (*63*) in the context of the Dutch panel and by Murakami and Watterson (*32*) in the context of the Puget Sound panel. Meurs, et al. (*63*) find increasing levels of trip under-reporting with each subsequent wave of the survey. In the first wave, trip under-reporting amounted to 2.27 trips per week per person. This figure increased with each subsequent wave and reached a high of 8.35 non-reported trips by the seventh wave. van Wissen and Meurs (*4*) show that between-wave reporting biases can be corrected using refreshment samples; after correcting for biases, they find that the adjusted trip rates show an increase of 11 percent in trip making over the seven-wave period. Murakami and Watterson (*32*) found that, between the first two waves of the Puget Sound panel, home-based work trip rates were stable. Reductions in overall trip rates could be attributed to under-reporting of home-based other and non home-based trips; presumably, these trips suffer from greater under-reporting as they are not as routine and fixed as the work trip.

In the context of an integrated multi-day panel survey, one can expect fatigue to occur both within-waves and between-waves. Meurs, et al. (*63*) provide a means by which within-wave and between-wave biases due to trip under-reporting may be corrected *a posteriori* in a multi-day panel survey. However, care ought to be taken *a priori* in the

design and administration of a multi-day panel survey so as to minimize not only within- and between-wave fatigue effects, but also within- and between-wave attrition (see next section). This is because the increased duration associated with collecting multiple days of information within each wave may not only contribute to fatigue, but also to increased attrition due to the burdensome time-consuming nature of the survey. Incentives, panel instrument updating, and appropriate administration techniques are *a priori* methods that may help alleviate these effects.

Attrition

Attrition occurs when respondents leave the panel over time. If attrition occurs for legitimate reasons, e.g., moving out of the study area and death, or if attrition is purely random, then there is not likely to be any problem other than a reduction in overall sample size. Empirical evidence, however, indicates that attrition is usually selective. As a result, changes in sample composition from wave to wave will exhibit systematic tendencies. The problem is exacerbated if attrition is selective with respect to unknown characteristics of the respondents, and these unknown characteristics are correlated with mobility or other variables of interest. This is because attrition effects due to unobserved characteristics can not be controlled for in modeling efforts. Sample statistics and model coefficients estimated based on the resulting "stayer" sample can no longer be used to infer population statistics.

Attrition was found to be substantial in the Dutch panel survey. Attrition was especially pronounced between the first and second waves (*8*) and selective in nature (*13*). Low-income households, smaller households, households without cars, households with lower mobility levels, and those with lower education left the panel at higher rates than other households. Attrition rates were found to progressively decrease with subsequent waves of the survey (*4*). This indicates that the conditional probability of participation in a survey wave, given that the respondent has participated in previous survey waves, increases as the survey progresses through time. In the Puget Sound panel (*32*), attrition rates between consecutive waves have found to be rather steady at 20 percent. As one would expect, slightly higher attrition rates were observed between wave pairs spaced further apart in time.

In the conduct of an integrated multi-day panel survey, attrition may occur both within-waves and between-waves. Within a wave (i.e., between days in a wave), distinguishing between those who truly made zero trips on subsequent days versus those who dropped out of subsequent day trip reporting is a considerable challenge. With respect to between-wave attrition, Abdel-Aty (*64*) found that only 7 percent of leavers in a Los Angeles commuter panel left intentionally. The remaining 93 percent of leavers could not be contacted or traced. This is a very encouraging result, because problems related to telephone non-contact can be substantially reduced by better panel maintenance and contact methods.

Several studies have examined *a posteriori* methods for addressing attrition. To account for biases arising from selective attrition, several researchers have developed attrition models to develop appropriate adjustment weights for the stayer sample. For example, Kitamura and Bovy (*13*) develop weights based on the probability of participation estimated using a binary probit model. Kitamura, et al. (*33*) and Pendyala, et al. (*34*) extend the work to account for choice-based sampling biases, while Goulias and

Ma (*65*) develop attrition weights in a multiwave context using an ordered probit model. Meurs and Ridder (*66*) also examine attrition and response effects in the Dutch mobility panel using refreshment samples and estimate a random effects model to estimate the size of the attrition bias and its effect on trip reporting.

Hensher (*61, 67*) discusses weighting and imputation methods in the context of initial nonresponse and attrition in a multiwave panel of households intended to track changes in automobile ownership and usage in Sydney, Australia. In addition, he emphasizes the importance of *a priori* methods of respondent tracing and survey administration to minimize selectivity biases arising from initial nonresponse and attrition. He notes that the success of a tracing operation is dependent on the nature of the search rather than the sample characteristics. Highly trained and motivated survey staff and effective tracing mechanisms (postcards, thank you letters, and obtaining contact information for a relative or friend) are helpful in reducing selectivity. The effects of incentives and panel instrument updating are still unknown and merit further investigation.

Refreshments

Quite often, multi-period panel samples are replenished with new households or behavioral units from one period to the next. These new households or behavioral units are called refreshments and serve several purposes. First, they help maintain the overall sample size of the panel survey, especially when attrition effects may be resulting in substantial reductions in sample size over time. Second, refreshments may be used to keep the panel sample representative of the population at each point in time. Refreshment households reflecting changing demographic trends in the population and compensating for selective attrition help keep the sample representative.

Even though refreshments play an important role in panel maintenance and representativeness, there has been very little research into the recruitment, sampling, and weighting of refreshment households. Pendyala and Kitamura (*55*) describe various exogenous and endogenous sampling schemes for drawing refreshments to account for population dynamics and selective attrition. They derive weights for refreshment samples assuming a random sampling process. Hensher (*61*) discusses sample refreshment strategies based on the type of panel design and the degree of representativeness desired in the panel sample. He indicates that “the critical element is a replacement mechanism that enables individuals and households to join the panel with known selection probabilities”. Goulias and Ma (*65*) develop a weighting scheme for refreshment households using census data to adjust the refreshment sample to be representative of the population. Despite these noteworthy efforts, issues related to the recruitment, sampling, and treatment of refreshment samples still remain largely unanswered, thus calling for further research in this important area of study.

Conditioning

Silberstein and Jacobs (*68*) and Waterton and Lievesley (*69*) discuss the issue of panel conditioning, where behavior and responses in later contacts of a panel are influenced by participation in the panel and by the responses provided in earlier waves of the survey. These effects become larger as the individual stays in the survey for a longer period of time. Silberstein and Jacobs (*68*) note the inherent difficulty in isolating conditioning

effects from attrition effects and real changes in the population over time. As such, their analyses, though showing some evidence of conditioning, could not provide conclusive evidence on the actual magnitude of biases due to conditioning effects. Similarly, Waterton and Lievesley (*69*), though using a controlled experimental design, provided only an exploratory analysis of conditioning due to the inherent difficulty in developing quantitative measures of conditioning. They do, however, report that repeated interviewing affects responses by raising consciousness, making respondents less fearful, and improving respondent understanding of the interview process. On the other hand, they found no evidence of freezes in behavior (i.e., the suppression of changes in behavior due to participation in the panel) or increased motivation to participate in subsequent waves of the survey. The overall message from these papers is that even if conditioning effects exist, they are small and pale in comparison to recall effects, which are a much more serious influence on data quality.

It is likely that respondent conditioning effects will depend on whether or not the same respondent is filling the questionnaire at every wave. If different respondents are filling the questionnaire at different waves, then differential conditioning effects may distort responses. As such, efforts should be made to ensure that the same respondent is participating in each wave of the survey. On the other hand, the magnitude of conditioning effects increases as the frequency of participation in the survey increases. The use of a rotating panel design may help alleviate this problem to a certain degree.

CHALLENGES FOR THE WORKSHOP

Multi-day multi-period surveys provide a wealth of information on short- and/or long-term dynamics in traveler behavior and values that would not be available if single-day, single-period cross-sectional surveys were conducted instead. Recent attempts at using multi-day and multi-period data to analyze short- and longer-term dynamics in travel choices in an integrated framework have been very encouraging. Mannering, et al. (*35*) and Ma and Goulias (*70*) are excellent examples of such attempts. In examining temporal stability across waves, Mannering, et al. (*35*) indicate that diary durations in excess of two days may be required to truly isolate between-wave changes from day-to-day variability effects. If only single-day data were available at each time point, one may infer change where none has taken place, or infer stability where change has taken place (*48*).

While most modeling efforts using panel survey data have focused on the modeling of specific travel behavior phenomena, there are two noteworthy efforts that attempt to build more comprehensive long-range travel demand forecasting systems using panel data. Goulias and Kitamura (*71*) present a dynamic microsimulation model of regional travel demand forecasting, called MIDAS, that was estimated using the Dutch panel data. The second noteworthy effort is that of Mackett (*72*), who develops a microsimulation model system called MASTER and applies it to the City of Leeds in England. Both of the studies yielded promising results indicating that panel survey data offer a viable means of developing comprehensive travel demand forecasting systems based on sound theories of behavioral dynamics.

Undoubtedly, the value of longitudinal data has been realized in many fields of study (e.g., *73, 74*); but so have the inherent difficulties (*8*). Issues that need to be addressed and clarified through further research efforts abound. This section highlights the main issues

for consideration and discussion at the workshop. It should be noted that some of the issues listed below are relevant only in the context of an integrated multi-day panel survey.

Survey Design

- *Type of Repeated Measurement*: What type of repeated measurement survey design is suitable for different transportation planning applications? Deaton (*75*) shows how repeated cross-sectional surveys can be used to track trends using cohort analysis techniques. When is one longitudinal survey design preferrable to another?
- *Instrument or Information Type*: What type of instrument should be used for data collection? What types of information should be requested from respondents?
- *Panel Duration*: For how many years should a panel survey be conducted, especially in the context of a general purpose travel survey? At what point do response quality and attrition become serious issues?
- *Wave Spacing*: What would be an appropriate interval between wave pairs, particularly in the context of general purpose travel surveys? What are the effects of wave spacing on respondent burden, fatigue, and panel member retention?
- *Day-of-Week Effects*: On what days of the week should multi-day data be collected within- and between-waves?
- *Level of Variability*: What level of intrapersonal variability (e.g., day-to-day vs. week-to-week) should be captured in a longitudinal survey?
- *Sampling Scheme and Sample Size*: What types of sampling schemes and sample sizes are most efficient from modeling and cost standpoints in a multi-day panel design?
- *Mode of Administration*: What are the effects of alternative administration techniques on response rates, fatigue, attrition, conditioning, nonresponse, and sampling?

Problems

- *Initial Nonresponse*: How do different longitudinal and cross-sectional survey designs compare with respect to initial nonresponse while controlling for survey design and administration effects?
- *Item Nonresponse*: What types of survey designs, questions, and instruments lead to greater item nonresponse? What are the effects of alternative data imputation techniques on sample statistics and model parameter estimates?
- *Fatigue Effects*: How do different survey designs compare with respect to fatigue? What are the factors that contribute to within-wave and between-wave fatigue? What are the inter-relationships between attrition effects, conditioning effects, and fatigue effects?
- *Attrition*: What is the cost- and retention-effectiveness of different attrition-reducing strategies? What are the effects of alternative survey designs, instruments, administration techniques, and questions on attrition?
- *Refreshments*: How can refreshments be recruited and weighted appropriately to preserve the overall representativeness of the sample?
- *Conditioning Effects*: How can panel conditioning be measured? If panel participation results in behavioral alterations, then is the survey capturing true population behavior?

- *Database Management*: Panel data bases are more complex to manage, store, retrieve, and analyze than traditional cross-sectional data sets. How can they be best organized?

Potential Mitigation Strategies

- *Weighting*: Are weighting methods available for accounting for all possible sources of bias in a multi-day panel survey? How do sequential and joint weighting procedures compare (*65*)?
- *Incentives*: What are the effects of incentives on various aspects of survey response including nonresponse, attrition, fatigue, and conditioning?
- *Respondent Tracing*: What are the effects of various respondent tracing strategies in the context of a panel design?
- *Instrument Updating*: To what extent can a survey instrument be modified in a subsequent wave, without compromising the analyst's ability to compare behavior across waves?

It is envisaged that discussions at the workshop will help refine the list of issues identified above, adding new ones and/or deleting existing ones, thereby setting the research agenda for the next several years.

ACKNOWLEDGMENTS

The first author appreciates financial support provided by the conference organizers and the University of South Florida while the second author gratefully acknowledges that provided by Duke University and the National Institute of Statistical Sciences. The authors thank Dr. Henk Meurs and Elaine Murakami for their insightful comments and suggestions on earlier drafts of this paper.

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Workshop Summary

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ORGANIZATION AND SCHEDULE

After introductions, the group established its schedule for the nine hours it had been allocated for its deliberations. The first three hours were spent reviewing the resource paper and discussant presentation that had been made in the plenary session, allowing for expanded detail; hearing and discussing an additional paper describing the experience with the German Mobility Panel; and followed by a general discussion of issues in the field and any other topics of interest to the group. The second three-hour grouping centered on the what, why and how of using multi-day and multi-period surveying approaches. The last three-hour period focussed on identifying future issues of concern, structuring the nature of needed research, and in summarizing the previous discussion. This general structure was adhered to through the deliberations of the highly knowledgeable and effective workshop group.

What Is Multi-Day–Multi-Period Surveying?

Multi-day–Multi-period surveys are concerned with capturing the dynamics of the travel process and recording variations and stabilities in travel behaviour over time and in response to a number of features of transportation:

- Changes in policy and/or provision of services,
- Overall trends/natural evolution in travel behavior,
- Intra-personal transitions (e.g., life-cycles), and
- Net and gross effects of travel activity change.

For instance, a multi-day survey will capture variations in work travel behavior or in shopping trips. A multi-period survey might monitor changes in behavior related to changes in fuel costs or transit prices; it might establish how household travel changes with increasing incomes or addition of children to the household or, simply, changes produced as a subject ages.

The group recognized the following separation between multi-day and multi-period surveys:

- **Multi-Day** - *same person; multiple days (e.g., 7-day travel diary).* Offers a continuous measurement of intra-personal transport behaviour taking account of day-to-day variability in trip patterns. It was noted that

  – Multi-day can be considered as a form of multi-period data.
  – Multi-day can be seen to complement multi-period surveys in that it provides a baseline measurement of variability in individual travel behaviour that can be used to separate these trends from year to year variation.

- **Multi-Period** - this can be seen as having two distinct types:

  – **Repeated Cross-Section** - *same survey at intervals in time, carried out on different individuals*. This approach records generalized trends over time. Further exploration of this method was not considered part of the assignment of the workshop. It was, however, used as a contrasting approach for some discussions.

  – **Panel** - *same survey at intervals in time, but carried out on same individuals*. This approach looks at the dynamic processes of intra-personal and inter-personal travel behaviour over a longer period of time and usually involves discrete measurement.

The group saw that there are real benefits to complementary arrangements between multi-day and multi-period surveying, one of which is the ability to differentiate between daily cycles and longer-term trends. Similarly, multi-instrument approaches between cross-sectional surveying and panels can provide significant rewards, notably in improved assessment of trend identification.

It was felt that some clarification of definitions was needed for the benefit of the workshop and the following definitions were adopted:

- *Attrition/Mortality* - drop outs between waves (there are varied meanings of these words in some countries);
- *Fatigue* - under-reporting due to extensive exposure to continued surveying questions;
- *Continuous* - on-going from day-to-day;
- *Discrete* - one snapshot in time;
- *Rotation* - intentional partial replacement of panel in each wave;
- *Refreshment* - replacement of drop-outs with new recruitments in a wave of a panel.

WHY DO SUCH SURVEYS? WHAT SPECIAL BENEFITS DO THEY PRODUCE?

A Fundamental Observation

It was the sense of the group that travel behaviour can be seen as a series of interacting cycles, the daily, diurnal cycle that we study most, but then the weekly cycle, and the monthly and seasonal cycles. For long recreation trips an annual cycle must be examined. For instance, no judgments about long-distance travel rates can be determined from a one-week or one-month survey. Separating these cycles, understanding their dynamics, and explaining their impacts on travel behaviour is the real justification of multi-day and multi-period surveys. An important example from Poland was given when shopping patterns sharply shifted from daily to weekly patterns as the result of structural economic shifts in the society related to opening to the West and will shift again as a result of European Union mandates.

Based on this premise the group explored the rationale behind the use of multi-day and multi-period surveys:

Multi-Day

An extensive discussion of the role of multi-day surveying was held. A summary listing of the conclusions of the group would include

- To separate day-to-day effect from wider trends (individual variations account for 40% of
- total variability in travel behavior);
- To explore variability within a week;
- To explore specific journey types, e.g., journey to work, shopping, weekend travel;
- To separate usual/average and "rare" travel behaviour;
- To explore the travel behaviour in low-mobility households
- To more precisely investigate mobility budgets and activity scheduling; and
- To benefit from budget gains as a result of parameter efficiency.

Multi-Period: Panel

A similar discussion of the role of multi-period surveys with the same respondent, or panels, developed the following list of conclusions:

- To monitor adjustments to changes in policy provision (unless adjustment processes are very rapid, cross-section models will be inadequate to record adaption and anticipation effects);
- To allow more reliable statistics and models;
- To explore inter-relational effects;
- To explore net versus cell effects;
- To identify transition points and time paths;
- To explore the diffusion effects of new technology into the market;
- To better understand "chicken and egg" situations;
- To have independent efficiency consideration of contextual quality when compared to cross-sectional surveys;
- To achieve more efficiency in monitoring when changes take place, compared to retrospective questions in cross-sectional surveys because of memory effects; and
- To have lower cost than repeated cross-section approaches because of smaller sample sizes to collect more precise and contextual information and diminished sampling costs in second and subsequent waves.

There was a view held by many that multi-day/multi-period panels could be justified on cost grounds alone independent of their ability to provide greater insight into cycles of travel behavior.

An important example of the utility of panel data analysis was demonstrated in the paper on the German Mobility Panel, in which distinct travel differences were revealed for persons within a given vehicle ownership group when stratified by their vehicle ownership levels in previous panels, indicating that changes in travel activity cause changes in auto ownership rather than auto ownership causing travel.

Other examples of applications considered were the identification and analysis of occasional versus regular transit users and the ability to establish whether public policies, such as a change in fares, may generate more or less effect than intended because of unexpected internal dynamics such as lagging or leading effects. Lagging effects might be the slow response to a new facility that slowly wins users; leading effects might involve actions of users before an impending event such as moving to an area because it soon will have superior transit service. Another area of useful application was in private sector transportation investment analyses where short-term shifts need to be more precisely anticipated. Understanding responses to new toll roads was given as an example. Panels were seen as a rapid way to be responsive to the short-term needs of private operators.

HOW ARE THE SURVEYS DONE?

It was recognized that panel surveys may present some specific problems in terms of survey design and data analysis, and that we should look for ways to mitigate the effect of these on the various elements of data quality.

Initial Nonresponse

This may be higher than with cross-sectional survey designs because of the longer-term commitment involved, but data collected are more likely to be reliable, and omitted variables and reporting errors can be avoided or better understood.

Representativeness of Sample

It was believed that it was better to collect data on the whole household, but it was noted that, if the household is the base unit in a panel, individuals leaving the household, via marriage, divorce or moving away, would not be traced. The problems of local and national surveys were different here given the difficulties in tracing households or household members who move between local areas, although it was recognized that most moves are intra-regional.

It was recognized that we may need to stratify sampling for “rare populations,” particularly where sample sizes may be smaller.

It was believed that not enough is known about the initial nonresponse effect on representativeness in panel surveys. One way to explore this could be a single question on average mobility on refusal, as demonstrated successfully in the Netherlands. If it is known that trends in representation are similar to those in cross-sectional surveys, then the usual weighting methods can be used at the analysis stage.

There was considerable discussion of representativeness of panels after repeated cycles, and the various methods of replenishment. One view was that there are cases where representativeness may not be critical if the goal is to look at dynamic effects over time of certain groups rather than the general population. This raised the topic of the role of using complementary cross-sectional surveys with a panel.

The use of housing registers to construct a sampling frame was raised and discussed, in which the unit of observation is the housing unit rather than the household. In this approach whoever is in the unit is surveyed and the previous respondents are not traced.

Respondent Burden

It has been suggested that travel diaries can be particularly burdensome in panels. The possible advantage of two-day diaries over the frequently used seven-day diaries was discussed, and there was a recognition that there may need to be a trade off between coverage and fatigue.

It was suggested that researchers are aware not to over-burden panels with additional questions but should rather run complementary panels and/or cross-section surveys to gather additional information.

Panel Effect

A long-serving panel may suffer from a conditioning/"good citizen" effect resulting from participation, in that they begin to learn the kinds of answers associated with positive connotations. Rotating samples can be used to control for this effect.

Attrition

The problems of adjusting for attrition may be less than those involved with adjusting for nonresponse in a cross-sectional survey. We know much more about the attritors. We usually have extensive socio-economic characteristics information for those leaving a panel.

It was believed that incentives for continuation need not necessarily be large; they were most effective when appropriate and well timed, as proven by the conference sponsors. Evidence appears to indicate that they should be offered before completion of each wave. Other thoughts were

- Recontacts should be made with all household members in household panels.
- Postcards for completion on moving can help in tracing drop-outs.
- Binding respondents to panel with a "contract" can mean increased problems in initial recruiting but usually leads to more accurate reporting and less attrition. The effect on representativeness is not known.
- It was thought that respondents should receive survey results between waves as an added incentive but this must cause caution because of its conditioning panel effect.

Different Reporting Effects Between Waves

There was a discussion of the appropriate spacing between waves of a panel. Among the key observations were the following:

- Spacing between waves should take account of seasonal effects, national holidays, and other temporal cycles, e.g., days of the week.
- Spacing should take account of respondent burden, length of survey versus frequency of waves.
- The group noted the importance of controlling for this as part of the analysis.

NEW TECHNOLOGIES

Among the new CASM (Computer Assisted Survey Methods) techniques are those referred to as CAPI, CATI, and CASI (Computer Assisted Personal Inverview, -

Telephone Interview, -Self Interview). Many of these are particularly suited to panel approaches.

CASM may be more efficient in panels conducted with a self-completion computer in one's own home, because it is only necessary to train the respondent once, yet there is the potential to collect data over several years.

It was also noted that the smaller typical size of panels made the use of automated means more feasible in terms of interviewer training control and total costs because there were typically fewer interviewers to be trained and equipped with expensive tools.

FUTURE RESEARCH NEEDS

It was noted that survey design and analysis of multi-period data are still at the experimental stage. Therefore it was felt that we needed to take a laboratory approach to future needs. A laboratory could be established to research and disseminate experience on panel surveys. One goal is to continue structuring the problems, recognizing that there were the general issues of panel surveying to be addressed as well as the special issues raised by transportation. The research should involve further exploration of the following issues:

- Differences between transportation panels and other panels outside the transportation sphere;
- Sampling - nonresponse and recruitment processes, and
- defining the sample schemes for transition populations based on a dynamic set of criteria rather than cross-sectional criteria;
- Stratification for segments of the population;
- Instrument suitability;
- The possibilities for linkages between cross-sections and panels and multi-approach data collection;
- Study of "rare events";
- Incentives - examining their role and effectiveness;
- Comparative cost analyses between cross-sectional surveys and panels;
- Analysis - more formal analysis of existing data,
- development of multi-period-specific methods and display techniques,
- systematic meta-analysis on survey designs to see how this affects data quality
- cross-survey analyses, and mechanisms at international level for collaboration on experimentation.

CONCLUDING OBSERVATIONS

The group agreed that there was a rich area here for further research and discussion. The discussions held were very stimulating and developed a broad array of topics for further consideration which this summary only briefly captures. The members of the workshop were substantially assisted by the excellent papers and the prepared discussion provided.